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Global Cardiac Surgery Capacity Development in Low and Middle Income Countries

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Global Cardiac Surgery Capacity Development in Low and Middle Income Countries

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ISSN 2523-3084 ISSN 2523-3092 (electronic)
Sustainable Development Goals Series
ISBN 978-3-030-83863-8 ISBN 978-3-030-83864-5 (eBook)
https://doi.org/10.1007/978-3-030-83864-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword I: Duke Cameron

The current COVID-19 pandemic and its economic consequences, as well as worldwide events that have highlighted disparities in justice and health care among the disadvantaged, have brought global health into sharp focus. In the discussions and debates that have en-sued, we have become more aware of both the moral imperative and the shared dividends of caring for everyone, even those well beyond our borders. As surgeons, we sometimes forget the value we bring to a wide range of medical problems, from cataracts to abscess, fractures, hernias, bowel obstructions, penetrating trauma and curable solid neoplasms. Cardiac sur-gery is often dismissed as too expensive for the developing world, but cardiac disease re-mains a major cause of death in nearly every country, even among its youngest and most productive citizens, and models exist for judicious surgical treatment that is respectful of lim-ited resources. Frequently cited is cardiac surgery's ability to "raise all boats" in hospitals by improving the quality of care in respiratory support, critical care, support for renal insufficien-cy, blood banking and infection, to name a few.

In this book, Kpodonu and colleagues have assembled a remarkable collection of chapters covering global cardiac surgery, from its history to its role in healthcare systems, the role of professional societies in education and its deployment, sustainability and the opportunities for digital healthcare technologies. Finally, "case histories" of cardiac surgery development in individual countries are presented, teeming with lessons for other surgeons with similar hopes and ambitions.

I began reading this book anticipating themes of altruism and humanitarianism. I was not dis-appointed, but I was also impressed by how much thoughtfulness, experience, practical guidelines and collective wisdom are shared within these pages. Herein is a blueprint for sharing the remarkable tools cardiac surgeons hold. The foundations have been laid. It's time for all of us to lend a hand.

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Foreword II: Thiery Folliguet

While humans began to exhibit behavioral modernity around 100,000 years ago, it is only within the last 300 years that surgery was discovered, developed and adopted around much of the world. Initially developed as a result of the many injured on the battlefields during the frequent wars, the methodology of surgery was adopted mostly during the Napoleonic Wars where intervention was required to avoid exsanguination by cauterizing the blood vessels. The introduction of safe cardiopulmonary bypass in the 1960s gave the surgeon the accuracy to operate on the heart, and today, in most of the modern countries, a full team of cardiologists, surgeons, perfusionists, anesthesiologists, ICU specialists and nurses come together to perform cardiac surgery.

The evolution over the many years within specialized medical and paramedical units has allowed these teams to perform an invasive act on the heart with given results, which for most part of the time is predictable and low. Additionally, reviewing the cases where complications and death occurred amongst peers during mortality and morbidity reviews allows the identification of problems and to correct if necessary by establishing rigorous protocols. This constant learning and evaluation generates high-quality surgeries and positive results, which is necessary in this field. The research and the development of new approaches and tools are aimed to simplify procedures and to transform traditional techniques toward surgery that is mini or non-invasive. Unfortunately, what is happening today in the developed world is not applied to developing countries.

The need to develop cardiac surgery in emerging countries is real since cardiovascular disease is the leading cause of death worldwide, responsible for 17.5 million deaths every year, of which 80% occur in low- and middle-income countries. 75% of the world does not have access to cardiac surgery. In most countries, healthcare expenditure parallels the GDP with an average of 12% on health compared with 5% of GDP in low- and middle-income countries. The COVID-19 pandemic unmasked this enormous difference, with some countries unable to provide oxygen for simple face mask treatments, whereas other countries were able to implement mobile medical units allowing patients to have extracorporeal support (ECMOS) placed in any hospital and then transferred to a tertiary hospital for ICU treatment.

Kpodonu and colleagues have published this book with the purpose of transferring the knowledge, techniques and technology used today in the developed countries to emerging countries, in order to practice cardiac surgery in a safe and reproducible way. Thanks to advances in information technology, patient in need of cardiac surgery can be reviewed and selected by video-conferencing, allowing teams to decrease cost and improve selection of patients. Training new surgeons with simulators and by video-conferencing can also be implemented to speed up the learning process. The entire book is organized into easy-to-read chapters so as to provide the reader with possible solutions to address challenges that are commonly faced in the emerging countries with respect to cardiovascular diseases. The technologies described should help lower the barrier and cost to populations in need of cardiac expertise while achieving excellent cardiovascular outcomes in low- and middle-income countries.

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Preface

Global cardiac surgery can be defined as a platform “that places a priority on improving health outcomes and achieving health equity for all people worldwide who are affected by cardiac surgical conditions or have the need for cardiac surgical care”. Surprisingly, of all the surgical subspecialties included in the discourse surrounding the global burden of disease, global cardiac surgery is the one subspecialty that is most often omitted. Much of the disregard, however, is believed to be a result of the perceived difficulty of introducing cardiac surgery in low-resource settings given its complex follow-up, its demand for intensive human resource training, and the required capital funding necessary to establish widely available and sustainable cardiovascular services. Unfortunately, this disregard undermines the parallel attempts to ameliorate the global burden of cardiovascular disease (CVD), a known cause of significant morbidity and mortality of all non-communicable diseases worldwide.

To date, 93% of people living in low- and middle-income countries (LMICs)—nearly 6 billion people worldwide—are estimated to lack access to cardiac surgical care when needed. It is estimated that 4,000 cardiac centers perform open heart surgery around the world, but only a fraction are in LMICs. The latter are commonly located in countries without existing national health insurance schemes, and annual surgical volume is often low due to workforce and resource constraints. In light of the growing burden of CVD around the world, including the epidemiologic transition from communicable to non-communicable diseases in LMICs, recognition thereof is vital to move toward the Sustainable Development Goals and Universal Health Coverage. Establishing cardiac centers requires substantial physical, financial, and human resources, and political commitment. This textbook *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries* is published with the purpose of transferring the knowledge, techniques, and technology used today in the developed countries to emerging countries, in order to practice cardiac surgery in a safe and reproducible way providing a practically applicable resource on how to treat cardiac patients with limited resources and at the same time presenting strategies on how these can be managed, therefore making it a critical tool for those involved in this field. Understanding approaches taken by existing centers may thus inform and optimize the establishment of new centers to expand comprehensive cardiovascular services worldwide, particularly in LMICs.

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Acknowledgment

Jacques Kpodonu (JK) would like to show his profound appreciation to the numerous outstanding contributors for their contribution in putting this textbook together. Special thanks to Duke Cameron, 98th President of the American Association for Thoracic Surgery, Robert S. D.Higgins, 55th President of the Society of Thoracic Surgeons and President of Brigham and Women's Hospital (Boston), David Tom Cook, MD and colleague members Diversity and Inclusion (D&I) workforce of the Society of Thoracic Surgeons, Dr. John Meara, Director Program in Global Surgery and Social Change Harvard Medical School, and Dr. A. Tom Pezzella for their tireless advocacy and support for global surgery that led to this work. Special recognition to my cardiac surgery colleagues at Beth Israel Deaconess Medical Center/Harvard Medical School for their support, Grant Weston (Springer), Karthikeyan Durairaj, and Ritu Chandwani (Scientific Publishing Services) for their editorial support in making this work possible and completing on time. Finally, I want to thank my wife Tiffany, children Nathalie and Henri, and parents Prof. John Kpodonu and Mrs. Jacqueline Kpodonu for their unwavering support in getting this work to completion.

About the Book

The series Sustainable Development Goals Series focuses on how to provide suitable care to cardiac patients with limited resources reinforcing the SDGs contains detailed guidance for physicians practicing in emerging countries and covers how cardiac surgical care can be used as a tool to strengthen health systems. This book provides a focused resource on the development of cardiac surgery capacity and its role in in the sustainable development and strengthening of associated health systems. A background is provided on the extent of the problems that are experienced in many nations with suggestions for how suitable frameworks can be developed to improve cardiac healthcare provision. Relevant aspects of governance, financial modelling and disease surveillance are all covered. Guidance is also given on how to found and nurture cardiac surgery curriculum and residency programs. *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries* provides a practically applicable resource on how to treat cardiac patients with limited resources. It identifies the key challenges and presents strategies on how these can be managed, therefore making it a critical tool for those involved in this field.

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Part I

Global Surgery as the Neglected Stepchild of Global Health

1 History of Global Surgery

Alexis N. Bowder, Barnabas Alayande, and Zachary Fowler

The neglected stepchild of global health.

Drs. Jim Kim and Paul Farmer

Abstract

Over time the field of "global surgery" has evolved and emerged as a clear and necessary component of global health. This chapter attempts to document the history of this evolution. In the early years of global surgery, we saw the proliferation of faith-based initiatives, non-governmental organizations, and various individual institutional efforts. More recently, over the last thirty years, we have seen an increase in academic partnerships and a focus on ethics in global surgery. Since 2015, key policy milestones including the Lancet Commission on Global Surgery, the World Health Assembly Resolution 68.15, and Disease Control Priorities *Essential Surgery* have helped place an emphasis on the importance of developing regional and national strategies to increase access to surgical care worldwide.

Keywords

History · Global surgery · Global health

1.1 Introduction

The history of "modern" surgery itself is a relatively recent one, given that anesthesia in any form did not emerge until the mid-nineteenth century. As described below, the history of international efforts to improve surgical care goes back to this early time. That high-income countries required at least half a century to progress to a reasonably safe surgical environment within their own borders, though, means that the history of surgical care in the global context begins in earnest quite recently. The last half of the twentieth century saw the proliferation of faith-based initiatives, non-governmental organizations, and various individual efforts, bringing some degree of surgical care to areas of the globe in which health systems, as they were, did not include the vast proportion of health care requiring surgical

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_1

expertise. An intentional look at disparities in access to surgical care around the world did not come until 1980, when Dr. Halfdan Mahler, Director General (DG) of the World Health Organization (WHO), addressed the 12th biennial World Congress of the International College of Surgeons. He stated "The vast majority of the world's population has no access whatsoever to skilled surgical care and little is being done to find a solution…. I beg of you to give serious consideration to this most serious manifestation of social inequity in health care" [1].

In spite of Dr. Mahler's plea, the field stayed within the realm of the ad hoc efforts and vertical programs of the faith-based groups, non-governmental organizations (NGOs), and occasional individuals, which by this time included some educational institutions. However, it was almost thirty years after the acknowledgement by the WHO DG that lack of surgical care was a "most serious manifestation of social inequity in health care" that the oft-quoted epithet "neglected stepchild of global health" was used by Drs. Paul Farmer and Jim Kim in 2008 [2]. In 2015 the Lancet Commission on Global Surgery (LCoGS) estimated that 5 billion people were without access to surgical care worldwide and determined that investing in surgical care was a cost-effective public health intervention [3]. That same year saw the 68th World Health Assembly (WHA) adopt the resolution declaring strengthening surgery and anesthesia services an integral part of universal health coverage. Completing a trifecta, 2015 also saw the third edition of the Disease Control Priorities include a separate volume dedicated to surgical care with a global perspective. The events in 2015 confirmed that global surgery had become a part of the global health family, but the question remained, what does the term global surgery entail?

Just as the term global health has been known to carry a number of different definitions or connotations, the term global surgery is still being defined. In 2014, a lengthy definition of global surgery was provided by many of the same authors who wrote the LCoGS. Here it was defined as an "area for study, research, practice, and advocacy that places priority on improving health outcomes and achieving health equity for all people worldwide who are affected by surgical conditions or have a need for surgical care," stating that this definition applies to a wide group of specialties including all surgical specialties (including obstetrics and gynecology), anesthesia, perioperative care, emergency medicine, nursing and more. The definition goes on to describe the populations, solutions, and issues addressed by global surgery [4]. More recently a shorter definition was provided by Fitzgerald et al. who define global surgery as "a term used to describe a multidisciplinary field, concerning the improved and equitable surgical care across international health systems with an explicit focus on Low- and Middle-Income Countries (LMICs)" [5].

Perhaps more important than having one standard definition of the field is understanding its beginnings and progression over the last 40 years. This chapter describes the history of the field of global surgery encompassing the foundations of medical missions, institutional efforts, academic global surgery, key policy shifts in the field, and the evolution of national surgical, obstetric and anesthesia plans.

1.2 The Foundations of Medical Missions

The history of global surgery is incomplete without an understanding of the contribution of medical missions. Some of the first medical missions started as early as 1838 and continue to hold a place in global surgery today [6]. This term specifically refers to temporary surgical platforms including short-term surgical trips and self-contained surgical platforms, and specialty surgical hospitals which may or may not be faith-based [7, 8]. Despite the critical tilt away from short term, non-development related surgical work, the roots of global surgery run deep into these efforts. Humanitarian efforts (missions that operate under the setting of acute emergencies), and work by charitable organizations (those that, at least in part, are funded by private donations) have contributed immensely to surgical efforts worldwide [7]. Resulting from the observation that these contributions were initially individual and later institutional, the history of surgery in medical missions is hydra-headed.

1.2.1 Faith-Based Missions

A prominent pioneering figure of faith-based surgical missions was the Framingham born Peter Parker, who was said to have "opened China to the gospel at the point of a lancet" [6]. Armed with skill in general surgery and ophthalmology, he sailed to Guangzhou, China under the cover of the American Board of Commissioners for Foreign Missions. His success in treating more than 50,000 Chinese patients, coupled with his connections with British and American businessmen and missionaries positioned him as a leading figure in developing the idea of medical missions. He was involved in the founding of the Medical Missionary Society in China in 1838 and when forced out of China by the First Opium War, he travelled extensively through Europe and the United States successfully popularizing an agenda of faith-based medical missions' advocacy with a surgical bent [6].

In the 1950s, a juxtaposition of medical missions and early academic global surgery can be seen in the work of pioneers like Dennis Burkitt, a surgeon who served during World War II in Africa and Sri Lanka, eventually settling at Mulago hospital, Kampala Uganda [9]. He identified a facial tumor of young children and, beginning with a grant of 25-pound sterling, surveyed hospitals by mail and identified an ecological effect on distribution of a cancer. Through a 'global collaboration', Burkitt and his overseas partner, Tony Epstein, identified the role of the Epstein Barr virus. He eventually travelled over 10,000 miles by vehicle to properly map the geographical extent of the tumor's occurrence [9].

In the following years, a number of organizations would partake in surgical missions, and Shrime et al. have attempted to classify international surgical endeavors for ease of evaluation. They classify these efforts as follows; short-term reconstructive missions, self-contained surgical platforms and specialty mission hospitals [7]. The history of these different thrusts are distinct and detailed below.

1.2.2 Short-Term Reconstructive Missions

Historically, short-term surgical trips have been dominated by those for plastic surgery, including cleft lip and palate care, post burn contracture management, general reconstructive surgery. There have been numerous organizations that have used this model; many have evolved, at least to some extent, into broader models. The first of these was Interplast (now known as Resurge International), which developed out of the plastic surgery department at Stanford University in 1969. Several others grew out of Interplast, including Operation Smile in 1982, which is by far the largest [10]. This model has served to introduce many High-Income Country (HIC) medical professionals to LMIC surgical needs, but as global economies have improved and the importance of health systems development has become apparent, it has fallen increasingly into disfavor.

Another NGO, The SmileTrain, was created by founders who had previously worked with Operation Smile [11]. It introduced the model of paying surgeons in LMICs directly to provide cleft care, rather than sending foreigners to do the surgery. This was a major modification emerging out of the short-term trip model, and one that has had a major influence on the provision and availability of cleft care.

1.2.3 Self-Contained Surgical Platforms

Self-contained surgical platforms like Mercy Ships, an international maritime surgical charity founded in 1978, The Orbis Flying Eye Hospital, an international eye surgery charity started in the mid-1970s, and Cinterandes Mobile Surgery Unit which launched in 1990, are examples in the history of stand-alone missions that enter into communities with capacity to provide surgical care without relying on local resources [12–14]. Inspired by the work of an international hospital ship SS Hope, the size and number of port cities, and their faith, the founders of Mercy Ships purchased and refurbished an Italian cruise ship in 1978. They converted it to a 400-bed surgical facility and moved from port to port in the South Pacific, Central America, Caribbean, and Africa using volunteers to deliver surgical services. In 24 years, 18,800 surgeries had been performed on the first ship and other vessels were added to their fleet. Surgical equipment and operating conditions on the ships were similar to those available in HICs, however, the clinical presentation of pathologies encountered in LMICs was commonly at more advanced stages [12]. Several land, sea and air models of these self-contained platforms have been deployed. The convenience and efficiency of these historical intermediate models for surgical delivery must be weighed against cost effectiveness, sustainability and opportunities for training [7].

1.2.4 Specialty Surgical Hospital Missions: The Barsky Model

Specialty surgical hospital missions like those focused on vesico-vaginal fistulae, cataract surgery and post burn reconstruction were largely a focus in the 1990s and modeled a more long-term, sustainable, effective and efficient model [7]. A pioneer of this concept was Aurthur J. Barsky, professor of Plastic Surgery at Albert Einstein College of Medicine, New York. He established a children's Plastic Surgery program in post war Vietnam after a 1967 survey trip that established the need for children's plastic surgical care, a full-time training program, and a modern facility that would be handed over to locally trained surgeons [15, 16]. Funding was sourced by a novel charity—Children's Medical Relief Fund. Starting with a temporary unit and transiting to permanent structures in 1969, the unit was run by volunteers who trained indigenous staff [15]. By 1970, over 50 surgeries were being done every week by qualified plastic surgeons [16]. Current examples of these specialty hospital mission models include the CURE International, Neuro and Clubfoot Hospitals which focuses on pediatric orthopedic care in 14 countries, Aravind Eye Hospitals, Tamilnadu, India, the Danja Fistula Center, Danja, Niger, Babbar Ruga Hospital, Katsina, Nigeria and the Adayar Cancer Hospital, Chennai, India [7].

Criticism of these historical models has contributed to the trajectory of global surgery as we know it today. Evidence provided by research on short term surgical missions operative outcomes is limited and of low quality, supervisory regulatory systems are limited [17–19]. The rich history of surgical missions has cast doubt on the aptitude of local health care systems, disrupted local health facility functions, diverted resources from regular patient care pathways, and in some cases has promoted the 'savior mentality' and power imbalances [7]. Safety may also be overestimated as follow up reporting in these surgical missions is also generally of poor quality [7, 17, 18]. Though these criticisms are valid, medical missions are likely to continue to play a role in global surgery for years to come. Moving forward it is imperative to evaluate the ethical, clinical, and societal implications of these efforts.

1.3 Early Institutional Global Surgery Efforts

An appreciation of early institutional efforts in the field of global surgery is imperative to understanding the current global surgery movement. Here we describe the history of two institutions the International Committee of the Red Cross and *Médicine Sans Frontieres.*

1.3.1 The International Committee of the Red Cross

The International Committee of the Red Cross (ICRC), is the oldest existing humanitarian organization, with over a century and a half of experience [20, 21]. As part of a larger movement consisting of the ICRC, International Federation of Red Cross and Red Crescent Societies, and numerous national societies, the ICRC focuses on victims of armed conflict based on fundamental principles of neutrality and impartiality among combatants [20, 22]. The ICRC works under the mandate of the Geneva Conventions, which also includes access to essential preventive and curative health care with standards that are universally acceptable. By legal status and mandate, it is distinct from an intergovernmental agency or a non-governmental organization [21].

The surgical interventions of the ICRC in arenas of war can be considered as part of the foundations of global surgery. The origin of the ICRC is traced to the battle of Solferino during the Second Italian War of Independence in 1859. The sight of over 40,000 dead and wounded men abandoned after the battle inspired a Swiss businessman, Henri Dunant, to take action that led to the founding of the ICRC [21]. He led an effort in impartial care of wounded soldiers by appealing to locals to tend the wounded while insisting on equal treatment of both Austrian and French soldiers. He subsequently published *A Memory of Solferino* with two solid appeals: the formation of relief societies in peacetime including nurses who would care for the war-wounded, and the protection of these recognized volunteers through an international agreement [21, 23]. A charitable association called the Geneva Society for Public Welfare pursued the realization of these ideals in 1863 [20, 21] This work led to the founding of the International Committee for Relief to the Wounded, which later morphed into the ICRC. On October 26th 1863, 16 nations and 4 philanthropist groups met and adopted the distinctive emblem still used by the ICRC today. Since then, four Geneva Conventions (adopted in 1949) and three Additional Protocols (adopted in 1977 and 2005) have been adopted by member states [22]. These are centered on protection and care for the war wounded, prisoners of war and other victims, and protection of civilians in wartime [21].

The ICRC was seen initially as essentially a reactive association until the first world war [21]. With resurgence of international violence and wars, it has since consolidated and restructured to be anticipatory and proactive while expanding field operations. It has been a major player in both historic and modern war surgery and has had large-scale surgical operations in civil wars (Nigeria, Angola, Mozambique, Nicaragua and El Salvador) and decolonization and national liberation wars (Eritrea, Rhodesia, East Timor, Namibia etc.) [21, 22]. Continuing warfare worldwide has widened the scope of ICRC activities to include support of existing health systems in addition to attending to the more urgent war surgery needs. This has included orthopedic rehabilitation activities added to emergency relief and training of expatriate medical staff and local doctors [21] The flagship Health Emergencies in Large Populations (H.E.L.P.) courses, publication of war surgery annuals, and contributions to professional journals are part of the international surgery education thrust [22].

1.3.2 *Médecine Sans Frontieres*—The Beginnings

Another early organized institutional surgical model is that of the *Médicine Sans Frontieres* (MSF) [24, 25]. The 1967 secession of Biafra, Nigeria's eastern region, prompted the gruesome Nigerian Civil war. Pictures from the war travelled near and far, and France was particularly sympathetic to the Biafran cause. Bernard Kouchner, a French Gastroenterologist, and Max Recamier visited the region in 1968 with a 50-person team as part of the International Red Cross [24–26] This team was forced to provide war surgery in hospitals regularly targeted by the Nigerian military. Reaction to the war and famine led to the founding of the *Groupe d'Intervention Medical et Chirurgical d'Urgence* [24]. These doctors began to lay the foundation for a novel and non-conforming brand of humanitarianism that would prioritize the welfare of suffering individuals and ignore political, economic and religious boundaries. Their focus was on victims' rights over neutrality. In 1970, a disastrous cyclone and floods in Eastern Pakistan led to the demise of at least 625,000 people. A parallel response to this disaster by French medical journalist, Raymond Borel, led to the formation of *Secours Médical Français*. Both efforts were combined on 22 December 1971 by 13 founding doctors and journalists to form *Médicine Sans Frontiers* (MSF), known internationally as Doctors Without Borders [24]. Missions to Nicaragua, Honduras, Thailand and Cambodia followed in the 1970s [24–26]. MSF surgical activities have historically covered a range of general to specialized surgical care including obstetrics, fistula, trauma, orthopedics, and burn care in resource-poor, conflict, and post-conflict settings. The organization reorganized and expanded to 19 national offices and five operational sections. It now represents an international, humanitarian, non-governmental organization which conducts emergency medical activities in over 90 countries [27].

The beginnings of the movement were an attempt to emphasize equity and this has percolated to the mainstream global surgery movement. Prominent MSF interventions have occurred in situations of war and violence in Sudan, Liberia, Somalia, Bosnia, Rwanda, Sierra Leone, Kosovo, Chechnya, Haiti, India, Uganda, Congo, Cambodia, Libya and Yemen. Some organizations (such as Doctors of the World) have historically modified the MSF model within the humanitarian surgical space.

1.4 Early Policy Milestones

Around the time early institutional efforts in international surgery were taking hold, the Declaration of Alma Ata was adopted in 1978, representing a major milestone in public health. Sponsored by the WHO and the United Nations Children's Fund, it convened 134 countries to reaffirm health as a fundamental human right and called for global action to address inequities through primary care [28]. As mentioned in the beginning of this chapter, in 1980 an address to the World Congress of the International College of Surgeons, WHO Director-General Halfdan Mahler stated that surgery must play a vital role in primary care, and the widespread lack of access to skilled surgical care was a symptom of deep social inequity [1]. However, despite the elevation of surgery and healthcare for all as priorities on these global platforms, policy-directed actions to improve surgical care were slow to develop. The WHO Global Initiative for Emergency and Essential Surgical Care was developed by the WHO Programme for Emergency and Essential Surgical Care in 2005 to serve as a forum for broad, interdisciplinary stakeholder engagement to share information and strengthen policy and education. More than 140 Member States have collaborated in this initiative and used various avenues to address surgical system gaps [29].

1.5 The Evolution of Academic Global Surgery

In comparison to the longstanding history of medical missions and institutional efforts dating back to the 1840s and 1940s respectively, the entry of academic institutions into the field of global surgery has been relatively recent. The history of academic global surgery correlates in time with the Declaration of Alma Ata in the late 1970s. Twinning programs, or partnerships between HIC institutions and LMIC institutions, were some of the earliest global surgery academic endeavors dating back almost 30 years ago [30].

In the 1980s Memorial Sloan Kettering Cancer Center (MSKCC) began a funded fellowship in which surgeons from LMICs came to MSKCC for a 3 month stay [31]. The University of Washington in Seattle and Kwame Nkrumah University of Science and Technology in Kumasi, Ghana have also had a 25-year collaboration focused on capacity building for research on injury prevention, trauma care, and surgical care. Another example of an academic partnership is the Vanderbilt University partnership with AIC Kijabe Hospital and BethanyKids at Kijabe in Kenya. Unlike the aforementioned partnerships, this 10-year partnership has demonstrated how universities and faith-based organizations (FBO) in Africa can work together to improve access to surgical care. In addition, Operation Giving Back (OGB), the volunteer arm of the American College of Surgeons, developed guidelines for the formation of a consortium of Global Surgery programs whose focus is on development of the surgical workforce in Sub-Saharan Africa [31]. More recent than the establishment of twinning programs in global surgery has been the development of academic global surgery electives.

In 2010, a survey by OGB and Association of Program Directors in Surgery found a broad range of international activities among U.S surgical residencies, including 7 formal international rotations of the 55 programs that responded [30]. In 2011, the American Board of Surgery and Accreditation Council for Graduate Medical Education (ACGME) approved global surgery electives to count towards graduation requirements and the number of general surgery programs in the United States that offered global surgery electives increased from 13.3 to 34% of surveyed institutions [32]. In addition to global surgery electives, a number of surgical programs both in the United States and abroad have developed global surgery fellowships or global surgery tracts. These programs allow residents to dedicate one or two years to global surgery research, policy, and/or advocacy and often involve participants spending a significant amount of time working with surgeons in LMICs as part of the fellowship [33–35]. Finally, two medical student organizations have recently been formed in the academic global surgery space—the Global Surgery Student Association and InciSion—with a focus on supporting medical students interested in global surgery and global surgery advocacy, research and education worldwide.

As the interest in global surgery continues to rise in academic settings, a number of issues regarding ethics and sustainability will need to be addressed. This will ensure that academic partnerships are equitable, sustainable, and focused on what is needed by partners in LMICs rather than on the needs of HICs. For example, a majority of the U.S. global surgery electives consist of U.S. trainees traveling and working in LMIC surgical settings, but very few have any reciprocal option for trainees from LMICs to spend time in the U.S. In addition, when trainees or surgeons do visit the U.S, many U.S institutions and laws prohibit them from operating on or touching a patient. This is just one of the many ethical issues that presents itself in academic global surgery. Discussing ethics both in academic and global surgery as a whole has been a recent development in the field.

1.6 History of Early Ethics in Global Surgery

Prior to 2015, global surgery literature was largely dominated by HIC authors. Most publications contained reflections on individual or institutional experiences during short- and long-term surgical missions. A large proportion of the organizational reflections were in the domain of plastic and reconstructive surgery reflecting the work of Operation Smile, Smile Train, InterPlast and other plastic surgery charities [36–38] Many cost effectiveness studies were published which strengthened funding rationale for short term missions, again with a cleft deformity surgery tilt [39–43]. However, published global surgery organizational audits found that complications rates were higher when patients were operated on by surgeons participating in surgical missions [44–46]. Evaluation of the academic benefits of surgical missions to HIC surgeons, residents and medical students uniformly suggested benefit to these participants, but whether these missions provided academic benefits to the local teams was not explored [47, 47–50]. Some of the literature gave advice on adequate preparation for missions and on possible improvisations (like alternative anesthesia) that may be needed during working trips to LICs [51, 52].

However, early lone voices began to challenge the status of ethics in surgical missions and suggest ways to correct power imbalances going forward [15, 53–55]. Several ethical issues, such as informed consent on short term medical missions and the use of photographic images from international programs, have been raised [56]. On the side of surgical safety, Patel and colleagues challenged the lip service paid to surgical safety and variability in the use of the WHO surgical safety checklist during international outreach cleft missions [57].

Solutions to perceived ethical issues gave rise to the proposal of a diagonal care surgical delivery model as an alternative to the long-term horizontal approaches developed by the WHO or World Bank and the trending vertical models used by much of the global surgery community. In these vertical models, HIC surgeons would arrive, operate and leave the follow up to local surgeons, who may be more experienced than the foreigners and could be better served with more resources rather than more postoperative patients [57]. Horizontal inputs of faculty, financial support, research training, equipment and surgical care were to give way to residency programs, self-sustaining revenue, academic culture, infrastructure and local surgical capacity [57]. The Rwandan model of public sector, non-governmental organization and academic partnership for global surgery training was also described during this period [58]. Published calls for coordination and formation of networks within global surgery were made, noting fragmented international volunteerism. In particular, the need for a global pediatric surgery network was raised [59].

Prophetic voices heralding the birth of global surgery as a distinct discipline closed this 'pre-Lancet Committee of Global Surgery era' [60]. As global surgery approached its watershed; surveys of infrastructure and global surgical workforce were done by a few authors with a view to mapping international need in the buildup to work of the Lancet Commission on Global Surgery [61]. Some of this work confirmed a shortage of doctors and inadequacy of data [62]. Calling attention to the need for larger policy shifts aimed at addressing the lack of access to safe, timely, and affordable care worldwide.

1.7 Recent Global Surgery Policy Shifts

The most recent policy formation to improve surgical care was catalyzed in 2015 by several key events. The LCoGS published its seminal report, *Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development*. This report emphasized the need for research and data in global surgery and outlined major gaps in surgical care using a health-system approach. A framework was also presented for countries to overcome these gaps through strategic plans embedded in a broader strategy to improve health systems [3]. In keeping with this aim to improve surgical care through horizontal, interdisciplinary strategies, Resolution 68.15 was passed by the World Health Assembly, providing a mandate to WHO and Member States to strengthen surgical care and anesthesia as an essential component of universal health coverage (UHC). WHA 68.15 called for an intersectoral approach led by Ministries of Health that integrated data collection, education and training, infrastructure, finance, and quality of care. It also requested that the WHO Director-General promote sharing of information, technology, and skills among Member States, support policy development, and set aside resources from the approved WHO budget to assist Member States in achieving the objectives of the resolution [63]. Additionally in 2015, the third edition of *Disease Control Priorities* (DCP-3) published a volume dedicated entirely to surgical care. *Essential Surgery* provided a characterization of the global burden of conditions requiring surgical management, an assessment of the most cost-effective procedures, and characterization of surgical care delivery platforms. This exercise led to the development, by author consensus, of a package of essential surgical procedures. The package included 44 procedures, of which 28 are provided on an emergent basis, that should be available in all health systems and are designated to primary health centers, first level hospitals, and second or third level hospitals. In 2019, Pakistan became the first country to develop plans to implement a surgical package based on the DCP-3 [64]. Of note, the LCoGS, WHA 68.15, and DCP-3 all placed an emphasis on building capacity of primary health centers and first-referral hospitals with the aim to increase population access by decentralizing services.

1.8 National Surgical, Obstetric, and Anesthesia Plans

Since 2015, National Surgical, Obstetric, and Anesthesia Plans (NSOAPs) have been used by a growing number of countries as a method to comprehensively improve surgical care. The NSOAP process is based on an adaptation of the WHO health system building blocks and uses the domains of infrastructure, workforce, information management, service delivery, finance, and governance [65, 66]. The development of a NSOAP is carried out using a framework applied in a context-specific manner, typically consisting of the following stages: Ministry of Health ownership, situational analysis, stakeholder engagement and priority setting, drafting, monitoring and evaluation system development, costing, governance, and implementation [67]. NSOAPs have been recognized as an important strategy to achieve widely accepted agendas, such as the Sustainable Development Goals and Universal Health Coverage (UHC) [68, 69]. To date, NSOAPs have been developed in several countries, including Ethiopia, Madagascar, Nigeria, Rwanda, Senegal, Tanzania, and Zambia, and dozens of other countries have begun the NSOAP process or have expressed a commitment to developing a plan [66].

1.9 Regionalization of Surgical Strategy

With the recent prioritization of surgical care by countries around the world, several areas have taken a regional approach to the planning process. The Southern African Development Community passed a resolution in 2018 recognizing surgical care as a critical component of primary care and UHC. This regional agreement extends to 16 Member States and provides additional political leverage to embark on the NSOAP process [70]. Several regional political bodies in the Western Pacific have also endorsed a commitment to improving surgical care. The 2019 Pacific Health Ministers Meeting led to a commitment to NSOAPs as part of regional efforts to achieve UHC [71]. An initial group of 5 countries are collaborating to fulfill this commitment and develop a model for strategic planning in the region [72]. These efforts are aligned with a resolution passed by the WHO Western Pacific Regional Committee Meeting in 2020 to endorse an Action Framework for Safe and Affordable Surgery (2021–2030). This framework provides a guide for Member States and the WHO Western Pacific Regional Office to use a region-specific approach to strengthening surgical care while achieving UHC and previously set regional priorities for 37 countries and areas [73, 74].

1.9.1 Standardization of Metrics and Data Collection

To date, a lack of reliable data on surgical care access and outcomes has led to the development and adoption of standardized metrics. The Lancet Commission on Global Surgery proposed six core surgical indicators and targets to evaluate surgical systems [3]. These include proportion of a population able to reach a facility providing the Bellwether procedures (laparotomy, cesarean delivery, and open fracture repair) within two hours, surgical specialists per 100,000 population, surgical procedures per 100,000 population, perioperative mortality rate, risk of impoverishing expenditure, and risk of catastrophic expenditure. Four of these indicators (surgical workforce, procedure volume, and risk of impoverishing and catastrophic expenditure) have been adopted by the World Bank as World Development Indicators (WDI). At the time of incorporation into the WDI dataset in 2016, more than 170 countries had data available for each indicator [75]. Another system for collecting and monitoring population health data is the Demographic and Health Surveys (DHS) Program, which analyzes and disseminates health information from more than 90 countries [76]. In 2018 Zambia became the first country to include surgical data in its DHS and used the LCoGS indicators as a basis for this decision [77]. Five questions were added to the survey to assess surgical volume and timely access to surgery, and the results of this assessment were reported in 2020.

1.10 Conclusion

In the year 2020 global surgery has emerged as a clear component of global health.

- Medical missions and early institutional efforts still play a role in addressing the need for safe, affordable and timely surgical care.
  - It is important to evaluate the ethical, clinical, and societal implications of these efforts
- Recently a rise in interest in global surgery and academic partnerships has emerged.
  - We need to ensure that these are equitable and sustainable in the years to come.
- Secondary to significant global policy shifts surrounding global surgery, national and regional plans are being developed that aim to improve access to surgical care on a country level the worldover.
  - The development, implementation, and evaluation of the effectiveness of these plans will be a large part of the future of global surgery.

Acknowledgements We would like to acknowledge the efforts of Dr. Scott Corlew for their assistance in the compilation of data and editing of this document.

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2 Global Surgery: From Grassroots Movement to Global Momentum

Manon Pigeolet, Tarinee Kucchal, and Rennie Qin

Abstract

2015 marked a year to set new goals, and as the Sustainable Development Goals were launched, global momentum for the surgical patient had arrived. Academia, non-governmental organizations, student organizations and many other organizations and partnerships joined forces to attract the necessary attention to global surgery and to advocate for better care for patients without access to timely, affordable and safe surgical care. Many advocacy efforts in global surgery focus on systems strengthening as a way to increase access. In line with this idea The Lancet Commission on Global Surgery recommended the formulation of National Surgical, Obstetrics and Anesthesia Plans (NSOAPs) as a coordinated and strategic roadmap to improving surgical care around the world. NSOAPs are only the first step towards surgical system strengthening, and with every NSOAP that is implemented, the long-term impact of these plans will eventually come into scrutiny. NSOAPs must therefore contain robust data collection and reporting systems that will be will crucial for the monitoring and evaluation of NSOAPs, and also guide evidence-based policy making, research priority setting, and the attraction of more funding in the future. Ongoing global partnership will also be required to address other complex issues that arise as a part of the surgical planning process.

Keywords

Surgery · Global health partnerships · Systems strengthening · Health policy

2.1 Introduction

During the era of the Millennium Development Goals (MDGs) in the 1990s and 2000s, surgery was a largely absent topic at many international development conferences and meetings. However, 2015 marked a year to set new goals, and as the Sustainable Development Goals were launched, global momentum for global surgery was also reached.

This momentum was reached due to the collective efforts of the entire field of global surgery. Academia, non-governmental organizations, student organizations and many others joined forces to attract the necessary attention to global surgery and to advocate for better care for the patients without access to timely, affordable and safe surgical care. They advocated in their own local communities and hospitals, met with Ministries of Health to discuss policy amendments and

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_2

changes to the health systems, and spoke at high-level meetings in Geneva and New York to get the most powerful political leaders convinced about the absolute necessity of surgical care for all. However, one group remained missing from this joint effort. Unlike other fields of global health such as Infectious diseases, non-communicable diseases, HIV and malaria, global surgery currently lacks the presence of organized patient groups and their representatives in advocacy efforts.

In this chapter we will give a short overview of all major players that contributed to the recent success of global surgery in global health and the partnerships that formed to consolidate efforts and delivery results. We will discuss the various platforms used to advocate for global surgery. Last but not least, we will also touch upon the development of "National Surgical, Obstetric and Anaesthesia Plans" by Ministries of Health to set comprehensive and coordinated roadmaps towards surgical systems strengthening.

2.2 Partnerships and Advocacy Organizations in Global Surgery

Academic, clinical, and research partnerships in global surgery have existed for decades before the term "global surgery" came into the global health discourse. Further sustained progress and development in global surgical standards requires a consistent effort by actors in the field. Partnerships have helped create grassroot movements and build momentum for more significant players to step in to advocate for the inclusion of global surgery at high level discussions among international and government organisations, the integration of sound surgical policies into health systems globally, and an investment into establishing or strengthen programs and services that enable access to safe, affordable surgical, obstetric and anaesthetic care. This has been achieved through both independent and strong multi-actor collaborations and partnerships that include academic institutions, international organisations, professional associations and student societies.

2.2.1 The WHO Global Initiative for Emergency and Essential Surgical Care (GIEESC)[1]

One cannot discuss global advocacy efforts without considering engagements from the World Health Organisation. Former Secretary General of the WHO, Halfdan Mahler, recognised early that surgery has an important role to play in primary health care and in the services supporting it. In an address at the World Congress of the International College of Surgeons in 1980, he called on the international surgical community to advance the surgical agenda in global health, to prioritise the training of health workers in surgery, and develop training programs equipping first line service providers with essential surgical skills. Since then, the WHO has risen to the occasion and increased its participation in global surgery efforts. These are primarily fulfilled by the Global Initiative for Emergency and Essential Surgical Care (GIEESC), a program dedicated to leading efforts to reduce the global burden of surgery-related diseases resulting from injuries, pregnancy-related complications, communicable and noncommunicable diseases, disasters and humanitarian crises.

GIEESC is a global forum that fosters the exchange of knowledge between multidisciplinary stakeholders including health professionals, public health experts, health authorities and local and international organizations. This forum has been fundamental in sharing knowledge between countries to advise policy formation and develop educational resources to reduce the burden of death and disability from surgically amenable. GIEESC was also fundamental in establishing the Essential Surgical Care Programme (EESC), a sub-program specifically focused on strengthening health systems by improving access to safe, timely and affordable surgical, obstetric and anaesthesia care, to optimize health outcomes.

[1] WHO Global Initiative for Emergency and Essential Surgical Care (GIEESC), https://www.who.int/surgery/globalinitiative/en/.

This program has a multitude of successes, most significantly their role in adding more surgical targets as components of universal health coverage for the Sustainable Development Goals (SDGs). They ultimately facilitated passage of WHA resolution 68.15. In May 2015 at the 68th World Health Assembly where WHO member states unanimously adopted Resolution WHA68.15: Strengthening emergency and essential surgical care and anaesthesia as a component of universal health coverage. This decision was later supported at the 2017 70th World Health Assembly, with the passage of Decision Point 70(22), requiring WHO Secretariat to report on the progress of surgical indicators every two years until 2030. These changes came to be through the advocacy efforts of both those within the WHO and actors later mentioned in this chapter. The EESC has been instrumental in implementing these commitments. Not only have they developed tools for monitoring and evaluating surgical care systems and provide guidance in development of national surgical obstetric and anaesthesia plans (NSOAPs), but with their relationships within ministries of health in Member States, the WHO/EESC possess reasonable influence to advocate for the inclusion of global surgery in the health priorities of the countries.

2.2.2 The Lancet Commission on Global Surgery[2]

The Lancet Commission in Global Surgery (LCoGS) is one of the best-known scientific partnerships in global surgery. An interdisciplinary group of 25 researchers, doctors and academics brought together advisors spanning six continents and over 110 countries. Their hallmark publication: "Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development" ultimately set the stage to attract global attention for surgery in 2015.

[2] Meara et al. [1].

This publication did more than set a common vision and mission, it also laid out knowledge gaps and put forward research goals for the next 15 years. It was the first to link surgery to its economic effects, put concrete numbers on the unmet need for surgery in LMICs and propose a roadmap to tackle this unmet need (and its economic implication) by 2030. It is the LCoGS report that, even today, drives many research groups in their endeavours and stimulates academics to establish new research partnerships to fill these knowledge gaps. The commissioners also put forward clear policy targets and indicators for LMICs to reach by 2030. These policy suggestions range from upscaling surgical care, to human resources for health and the economic and financial investments required of surgical care delivery.

2.2.3 The G4 Alliance[3]

The Alliance for Surgery, Obstetric, Trauma and Anaesthesia care, also known as the G4 alliance, was founded in 2015 as a surgical homologue for the NCD alliance. The G4 alliance is an international alliance that brings together professional organizations, academic institutions, surgical colleges, student groups, research groups and non-governmental organizations working on the terrain in both surgery and anaesthesia. The main focus of this partnership to deliver a unified voice in advocacy on the international stage.

The G4 are in regular attendance at major international events including the United Nations General Assembly in New York City and the World Health Organization's World Health Assembly in Geneva, advocating for the inclusion of global surgery at the discussion table. They lead the 2015 campaign at the 68^{th} WHA to promoted surgery's importance in health systems and helped pass resolution 68.15. In the wake of this movement, other organisations such as the WFSA and a list of prominent influencers-including Atul Gawande, Jim Kim and even

[3] The Alliance for Surgery, Obstetrics, Trauma and Anesthesia care, http://www.theg4alliance.org/.

Madonna- have championed the cause. This undoubtably influenced many countries to begin developing national surgical plans as a part of official government policy, and private industry such as GE and Johnson & Johnson began committing tens of millions of dollars toward safe surgery programs. The G4 continues to lead the way in advocacy efforts today, developing a purpose-built advocacy tool kit to empower others in taking charge of their advocacy efforts, bringing together individuals and organisations across the globe and continuing to garner support from policymakers and influences to bring global surgery to the global health fore.

2.2.4 World Federation of Societies of Anaesthesiologist (WFSA)[4]

Since its founding in 1966, the WFSA represents the major advocacy group for the anaesthesia limb of global surgery and have actively promoted and advocated for the patient safety in anaesthesia. As the only global federation of anaesthesiologists, they are well placed to influence decision-makers within the World Health Organisation and consultative to with United Nations Economic and Social Council (ECOSOC).

The WFSA worked closely with both the commissioners of the 2015 Lancet Commission on Global Surgery and the Disease Control Priorities 3 (DCP-3) report on Essential Surgery, ensuring that safe access to anaesthesia was given appropriate and due regard. The WFSA is also an official liaison with the WHO, making for official statements at high-level meetings at the 68th WHA, that ultimately resulted in the passage of Resolution 68.15. Following the passage of the World Patient Safety Day Resolution (Resolution WHA 72.6) at the 72nd WHA, the WFSA uses this opportunity to highlight and support the provision of safe and high-quality anaesthesia globally. This is in additional to their already existing collaboration with the WHO in establishing and revising the WHO-WFSA International Standards for a Safe Practice of Anaesthesia.

2.2.5 South-South Partnerships[5]

"South-South partnerships" are partnerships in which organizations from different LMICs work together, without a high-income country partner. This type of partnership was developed during the Cold War-era as a way for LMICs to take charge of their own development pathways without external interference. Recently these partnerships have received renewed attention as a means to achieve the Sustainable Development Goals.

In global surgery two well-known examples are the West African College of Surgeons (WACS) founded in 1960 and the College of Surgeons of East, Central and Southern Africa (COSECSA) founded in 1999. Both organizations heavily invest in creating transnational opportunities for surgical training, research and quality improvement in the field of medical education.

2.2.5.1 The West African College of Surgeons (WACS)[6]

The West African College of Surgeons (WACS) is an independent organization which has as an objective to promote and organize postgraduate education and training in surgery. The term surgery is interpreted broadly and includes anesthesiology, dental surgery, obstetrics and gynecology, ophthalmology, oto-rhino-laryngology, radiology and general surgery and its related subspecialties. The college predominantly operates in the countries that are a member of the Economic Community of West African States, however fellows from outside of this region are also welcome to join the WACS community.

[4] World Federation of Societies of Anaesthesiologist, https://wfsahq.org/.

[5] United Nations Department of Economic and Social Affairs, https://www.un.org/development/desa/en/news/intergovernmental-coordination/south-south-cooperation-2019.html.

[6] West African College of Surgeons (WACS), https://www.wacscoac.org/.

The college works together with other surgical organizations like COSECSA to support the implementation of the WHA68.15 resolution and to increase future opportunities for collaboration. Additionally, WACS supports the rollout of National Surgical, Obstetrics and Anesthesia Plans (NSOAPs) throughout the West African region.[7]

2.2.5.2 The College of Surgeons of East, Central, and Southern Africa (COSECSA)[8]

The College of Surgeons of East, Central, and Southern Africa (COSECSA) is an independent body that fosters that provides post-graduate education in surgery and surgical training throughout the region of East, Central and Southern Africa. It is a non-profit organisation operating in Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia and Zimbabwe.

COSECSA's primary objective is to advance education, training, standards, research & practice in surgical care in this region. As such, they have been leading advocates of access to safe surgical services in the African region, by establishing and maintaining standards of care delivery through a locally developed but internationally recognised surgical training programme.

2.2.6 Educational and Grassroots Partnerships in Global Surgery

Partnerships between universities, hospitals and non-governmental organizations have existed for a long time and have had different approaches throughout history. Some have focused specifically on surgical care delivery in a "surgical mission" model or by organizing surgical care in high-income setting for a very select group of patients. Others focus on health system strengthening and implementation science at the hospital level, where hospital management and organizational processes are evaluated and adapted according to the possibilities. Yet another type of organizations has instead maintained an educational or research-oriented focus; organising medical exchange opportunities or establish research partnerships between institutions from high income and lower- or middle-income countries. Different models of engagement aside, all these collaborations and partnerships have contributed to the field of global surgery in their own way. This is why these grassroot partnerships can be seen as a complimentary structure to the larger high-level organizations.

2.2.6.1 Harvard Medical School's Program in Global Surgery and Social Change (PGSSC)[9]

Harvard Medical School's Program in Global Surgery and Social Change (PGSSC) lead global surgery academia through the Lancet Commission for Global Surgery. Chaired by the director of the program, Dr John G Meara, and including numerous faculty and fellows as commissioners, the PGSSC lead the way in global surgery academia, quantifying the challenges and working with country partners to establish the global surgical indicators we work towards today. Since then, through in engagements with partners in Asia, Africa and Latin America, the PGSSC continues to drive research that informs their policy development and advocacy efforts at local, national and international forums.

2.2.6.2 Other U.S.-Based Educational Partnerships

Global surgery initiatives have also been a strong focus for many other academic institutions,

[7] King-David Terna Yawe. West African College of Surgeons and its role in global surgery. FACS Bull [Internet]. 2018 May 1 [cited 2021 Feb 25]; Available from: https://bulletin.facs.org/2018/05/west-african-college-of-surgeons-and-its-role-in-global-surgery/.

[8] The College of Surgeons of East, Central, and Southern Africa, http://www.cosecsa.org/.

[9] Harvard Medical School's Program in Global Surgery and Social Change (PGSSC), www.pgssc.org.

including McGill's Centre for Global Surgery,[10] University of Utah's Centre for Global Surgery[11] and the Duke Institute for Global Health.[12] McGill's Centre for Global Surgery serves several regions in Africa, Latin America and the Middle East, while University of Utah's largest programs take place in Mongolia and Ghana, and Duke collaborates with the National University of Singapore to strengthen advocacy and capacity building programs in Myanmar, Papua New Guinea, Vietnam, Sri Lanka, Thailand.

2.2.6.3 Student Organisations

Student bodies have mobilised globally and have a prominent role in raising the profile of surgery in the global health agenda, most notably the International Student Surgical Network (InciSioN)[13] and the International Federation of Medical Students Associations (IFMSA).[14]

The IMFSA, working in close collaboration with InciSioN, have been present and participated in discussions with the WHO, non-governmental organisations, academia and other student groups. The IFMSA was founded in 1951 aiming to bring medical students closer together in post-war Europe. Over time it grew to be one of the strongest and largest student organizations worldwide, with member organizations representing over 125 countries and 1.3 million medical students worldwide. They promote partnerships and facilitate ethical electives where students may engage in sustainable capacity building activities related to safe surgery and anaesthesia. InciSioN is an international non-profit organization for medical and public health students, residents, and young doctors in the field of global surgery. Advocacy remains a vital pillar of activity for the student lead group and they actively engage on several platforms including a dominate social media presence to raise awareness and improve capabilities and policies globally. Initiatives range from those targeting the medical students, trainees, surgeons, and other healthcare providers, to the general public, other non-profit organizations, to stakeholders and government officials.

Following passage of WHA resolution 68.15, IMFSA and InciSioN collaboratively started Global Surgery Day on May, 25th as a global awareness day on Global Surgery. InciSioN went on to later play a pivotal role in co-organising numerous WHA side events in 2017 in conjunction with with Lifebox Foundation, the WFSA, the G4 Alliance, and Operation Smile to advocate of global surgery on the international public health platform and in 2018 established their own independent international conference, the InciSioN Global Surgery Symposium (IGSS), dedicated to exploring the challenges global surgery faces in low- and middle-income countries. Finally, InciSioN continues to support and equipping students with the skills necessary to engage in advocacy by established and piloted a formal standardized three-day global surgery advocacy workshop, Training Global Surgery Advocates (TGSA), in order to create a global legion of effective and knowledgeable advocates and future leaders. Since its establishment, InciSioN has expanded to over 80 countries and 45 fully established National Working Groups (NWGs) across all world regions. In their partnerships with major public health bodies, professional organisations and NWGs, InciSioN continues to lead advocacy campaigns for better health outcomes and health equity through timely access to affordable safe surgical, anaesthesia and obstetric care throughout the world.

2.2.7 Ethical Considerations in Global Surgery Partnerships

The decolonization of global health has received quite some attention in the last few years and the discussions have not left the global surgery community untouched. Many organizations are in the process of analysing how to position

[10] McGill's Center for Global Surgery, https://www.cglobalsurgery.com/.

[11] University of Utah Center for Global Surgery, https://medicine.utah.edu/globalsurgery/.

[12] Duke Global Health Institute, https://globalhealth.duke.edu/.

[13] InciSioN, https://incisionetwork.org/.

[14] The International Federation of Medical Students Associations, https://ifmsa.org.

themselves as anti-colonial and anti-racist. This process will need a lot of introspection, uncomfortable conversations and self-realizations. However, it will also be a vital and necessary process for the global surgery community to go through in order to survive and continue to meaningfully contribute to global health in the long-term.

Power politics and the current distribution of wealth and political power across nations and within nations are an inherent consequence of our world's history. Many partnerships are unconsciously affected by these power imbalances which may influence decision making regarding targets, indicators and deliverable outcomes. Long-term relationships and partnerships with sufficient room to build trust between partners, and development of a mutual understanding of each other's history, context, opinions, and priorities should be chosen over short-term, fragmenting, unsustainable projects.

A strong focus on health systems strengthening instead of vertical disease-oriented programs will be the future of global health. It is the development of NSOAPs within the surgical community that ties in perfectly with this shifting focus towards health systems strengthening.

2.3 National Surgical, Obstetric, and Anaesthesia Plans

A systematic review of surgery in national health plans of African countries found that 82% of national health plans had fewer than five mentions of surgery.[15] The lack of prioritization of surgery in health strategic plans reflect the gap in surgical care highlighted by the LCoGS. The LCoGS recommended the formulation of national surgical plans as a coordinated and strategic roadmap to improving surgical care.[16]

[15] Citron et al. [2].

[16] Meara et al. [1].

2.3.1 Framework and Process

The LCoGS proposed a framework for national surgical planning adapted from the World Health Organization Health Systems Building Blocks Framework comprising of six domains—infrastructure, workforce, service delivery, information system, finance, and governance (Fig. 2.1). This framework recognizes the complexity and cross-cutting nature of surgical systems and its role in overall health system strengthening. The terminology gradually evolved to the more all-encompassing one of National Surgical, Obstetric, and Anaesthesia Plans (NSOAP).

The development of NSOAPs follows an eight-step process (Fig. 2.2). The first and most crucial step is ministerial ownership to ensure that NSOAPs are locally driven, tailored, and contextualised. Following this, a multi-stakeholder approach is undertaken with stakeholder consultation as a part of the situational analysis followed by stakeholder discussion in priority-setting workshops. This combines top-down leadership of the ministry with bottom-up mobilization of front-line providers and bestows ownership across the spectrum. Broad stakeholder involvement also aims to improve the accountability, transparency, and feasibility of NSOAPs. After over-arching goals and priorities are set, the ministry steers through the remaining stages of drafting, monitoring and evaluation, costing, governance, and implementation.

2.3.2 Principles and Purpose

NSOAPs aim to create change by improving the visibility of surgical care and setting a precedence for its inclusion in all future health planning. Through strategic planning, it seeks to improve coordination between governmental, private, and civil sectors, and promote efficiency in resource allocation. Taking a horizontal and sustainable health systems approach, NSOAPs closely integrate surgery within existing national health and development strategies. By including a data collection and costing framework, it argues a business case and aims to attract funders

Fig. 2.1 A Framework for National Surgical, Obstetric, and Anaesthesia Plans. Reprinted from "Globalization of national surgical, obstetric and anaesthesia plans: the critical link between health policy and action in global surgery"[17]

Fig. 2.2 The NSOAP Development Process

to invest in surgical care. Most importantly, in building a global movement towards surgical planning, NSOAPs are not one-size-fit-all scalable solutions; they focus on grassroot, locally-driven initiatives and solutions.

2.3.3 Global Momentum

Zambia was the first country to develop an NSOAP modelled on the LCoGS framework. Its NSOAP was launched in 2017 and fully integrated into the Zambian National Health Strategic Plan 2017–2021. Funding was allocated to double the number of training positions for surgery and obstetrics and to create additional training centers for operating room nurses and nurse anesthetists.[18] To date, seven countries have developed NSOAP including Zambia,

[17] Truché et al. [3].
[18] Peters et al. [4].

Tanzania, Rwanda, Nigeria, Pakistan, Ethiopia, and Senegal. Whilst the majority of the countries underwent a centralized process driven by the Ministry of Health, Pakistan. followed a decentralized model with shared authority and responsibility between federal and provincial governments reflective of its political structure.[19]

As well as the early successes from the Zambia NSOAP, the Ethiopian NSOAP attracted external funding from the GE foundation to build 80 new operating rooms. The Rwanda NSOAP incorporated the LCoGS indicators into Rwanda's health management information: system.[20]

Building on this momentum, the Harvard Medical School Center for Global Health Delivery Dubai hosted an NSOAP workshop for High-Level Global, Regional, and Country Authorities and Funders in March 2019. Strong global partnerships were forged among national experts and champions, academic institutions, development banks, professional associations, and the representatives from the World Health Organization in attendance. In September 2020, an NSOAP manual was launched by the Program in Global Surgery and Social Change (PGSSC) at Harvard Medical School, the United Nations Institute for Training and Research (UNITAR), and the Global Surgery Foundation.[21] Although foreign partners may assist the process, they do not define the outcomes. NSOAPs represent a model of equitable anti-colonial global health partnership—they are run by local leaders for local constituents.

2.3.4 Regional Momentum Towards a Global Movement

Following the Dubai meeting, 22 countries are currently in the process of developing NSOAPs (Fig. 2.3). There is a growing trend towards regionalization of surgical planning. Health Ministers on the Southern African Health Community (SADC) and the Pacific Community (SPC) both adopted regional resolutions committing towards developing NSOAPs as a part of universal health coverage.[22] Regional collaboration offers a platform for experience sharing on common challenges and solutions. The Pacific Island Countries, for example, face a set of unique and common problems to surgical care delivery including small size, geographic isolation, rural population, natural disasters, and the effects of climate change. It also facilitates the coordination and harmonization in efforts around training, data collection, and research.

In 2015, 13 countries in the Pacific region collaborated to collect the LCoGS indicators.[23] In the SADC region, countries plan to use a common template to collect national surgical data as a part of their NSOAPs to generate regionally comparable results.

Moreover, regionalization also builds regional momentum. At the Dubai meeting, a key challenge expressed by national surgical champions is the lack of institutionalization of surgical, obstetric, and anesthesia care within ministries of health despite strong support from professional organizations and academia.[24] Following strong advocacy by national ministry champions in the Asia–Pacific region, Member States officially endorsed the World Health Organization Western Pacific Regional Action Framework for Safe and Affordable Surgery 2021–2030 at the 71st Regional Committee Meeting in October 2020. This marks a milestone in the institutionalization of surgical planning within regional and national health ministry agenda.

[19] Fatima et al. [5].

[20] Sonderman et al. [6].

[21] (2019) National Surgical, Obstetric and Anesthesia Planning for High-Level Global, Regional, and Country Authorities and Funders. Harvard Medical School Center for Global Health Delivery–Dubai, Dubai, United Arab Emirates.

[22] WHO (2019) Outcomes of the Thirteenth Pacific Health Ministers Meeting. World Health Organization, Tahiti, French Polynesia.

[23] Guest et al. [7].

[24] (2019) National Surgical, Obstetric and Anesthesia Planning for High-Level Global, Regional, and Country Authorities and Funders. Harvard Medical School Center for Global Health Delivery–Dubai, Dubai, United Arab Emirates.

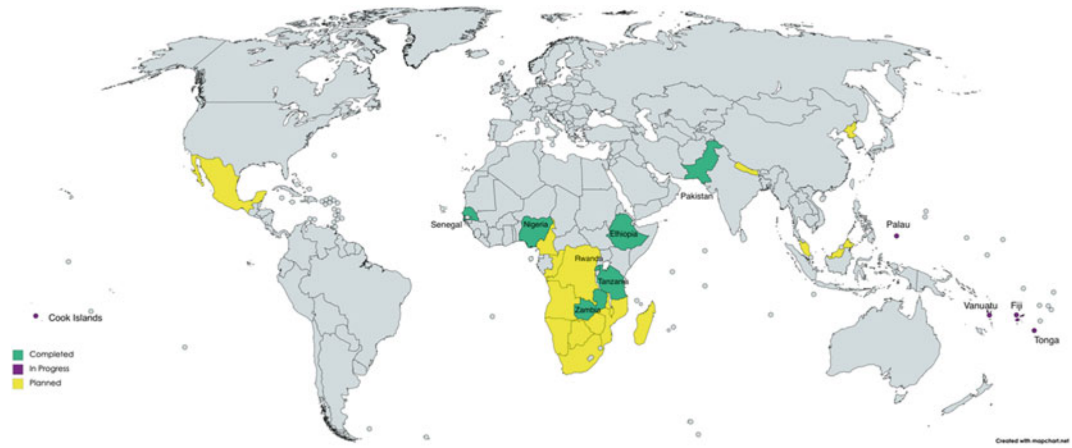

Fig. 2.3 Global momentum towards NSOAP development

2.4 Conclusion

In the last decade, the field of global surgery has grown exponentially and is continuing to do so. This could not have happened without the engagements of the diverse players or the partnerships we have discussed thus far. However, while global surgery has come a long way, there is still a long road ahead.

NSOAPs are only the first step towards surgical system strengthening, and with every NSOAPs that is implemented, the long-term impact of these plans will eventually come into scrutiny. NSOAPs must therefore contain robust data collection and reporting systems that will be will crucial for the monitoring and evaluation of NSOAPs, and also guide evidence-based policy making, research priority setting, and the attraction of more funding in the future. Ongoing global partnership will also be required to address other complex issues that arise as a part of the surgical planning process, particularly the cost and availability of consumables highlighted by many participants of the Dubai meeting.

Although surgical care is cost-effective, the mobilisation of capital investment for NSOAPs and surgical systems strengthening will be critical to global surgery's success and must be prioritised. Strategies to mobilise funds include aligning global surgery with universal health coverage, integrating with other health priorities, regionalisation, and ongoing advocacy to create demand for surgical systems strengthening through policy development and implementation. Research efforts have already successfully aligned NSOAPs with UHC, sustainable development goals, and disaster preparedness. Ongoing efforts are required to align surgery with other priorities such as pandemic preparedness, climate change, trauma, and cancer care to ensure integrated implementation of NSOAPs and surgical systems strengthening within existing government priorities, and to attract funding.

Finally, the importance of equity and decolonisation in the practiced of global health and surgery cannot be understated. The current momentum of high-income countries exploring their own colonial pasts should be seen as an opportunity to re-evaluate current views and practices in global health. Embracing this shift in principles and values, we need to see an increased presence of low- and middle-income country players at all levels of global health engagements, with specific attention to the high-level discussion tables. In addition, we require greater investments in grassroot mobilisation, including advocacy capacity building, development of strong professional organizations and increased support for locally owned and driven research efforts to ensure that LMIC voices are heard at all levels of global surgery. South-south collaborations are a promising approach to achieve equity and support and develop (trans)-national grassroot movements.

The collective voices of global surgery have had considerable success in elevating the status global surgery from neglected stepchild to the poor cousin of public health. However, the journey has required a substantial investment of time and effort to reach this far. As the field continues to grow and as our advocacy, research and policy efforts strengthen, we now look forward to bring global surgery to the fore of public health with the spirit of equity, justice, anti-racism and anti-colonialism.

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3 UHC Surgery and Anesthesia as Essential Components of Universal Health Coverage (WHA 68.15)

Hiba Ghandour and Paul Truche

Abstract

Universal health coverage (UHC) is the ideal that "all people have access to needed promotive, preventive, curative, and rehabilitative health services, of sufficient quality to be effective, while also ensuring that people do not suffer financial hardship when paying for these services." Achieving UHC has become a global goal set forth under the United Nations Sustainable development goals. Achieving UHC is not possible without also ensuring the five billion people who lack access to safe, affordable surgical care. Strategies to ensure universal surgical care involve a range of economic and political strategies designed to increase financial risk protection with respect to surgical services and ensure that populations can receive surgical care without facing financial hardship.

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Keywords

Universal health coverage · Universal surgical coverage · Global surgery · NSOAP · Financial risk protection · UHC 2030

3.1 Introduction

Access to safe, affordable, and high-quality surgical care is a key component of any mature health system. Although traditionally approached as a niche aspect of healthcare reform, the past decade has seen a dramatic increase of interest in the delivery of surgical care in low resource settings. This interest has been fueled, in part, by United Nations (UN) member states' commitment to achieve universal health coverage by the year 2030 [1].

Universal health coverage (UHC) refers to the ideal that "all people have access to needed promotive, preventive, curative, and rehabilitative health services, of sufficient quality to be effective, while also ensuring that people do not suffer financial hardship when paying for these services." In December 2012, the United Nations formally endorsed a resolution on Global Health and Foreign Policy urging countries to focus on delivering universal health coverage especially for the poor and marginalized populations. In 2015, the landmark resolution *Transforming Our World: the 2030 Agenda for Sustainable Development* outlined the adoption of universal health

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_3

coverage as a target for the year 2030. These resolutions emphasized financial risk protection and access to quality essential health-care services, medications and vaccines for all. Although surgical care was not specifically referenced, that same year the World Health Organization (WHO) and the Member States officially recognized surgical and anesthesia care as an essential component of universal health coverage through resolution 68.15. Although there is no doubt that the presence of accessible, high quality, and affordable surgical care is necessary to ensure the goals set forth by the concept of UHC, developing the complex infrastructure, specialist workforce, and triage systems required for robust surgical care has remained challenging. Emerging policy through National Surgical, Anesthesia and Obstetric Plans combined with growing investment interest has provided the groundwork for a better understanding of surgical system scale up; nevertheless, considerable effort is needed to continue this endeavor [2].

3.2 Universal Health Coverage

3.2.1 *History of UHC: A Transition from MDGs to SDGs and the Expansion of IHP +*

Universal health coverage has developed as a result of several internationally driven transitions in the approach to achieving adequate health coverage globally. In the year 2000, the WHO adopted the millennium development goals (MDGs) which included 8 broad targets for the year 2015. The health related millennium development goals included eradicating extreme poverty and hunger, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases, ensuring environmental sustainability and developing a global partnership pertinent for the development of essential medications and vaccines. These goals represent broad, ambitious efforts to improve access to and ameliorate the quality of health globally in an effort to reduce mortality and advance wellbeing. The MDGs were broadly considered a success: over a billion people were lifted out of poverty, child mortality dropped to more than half, and the rate of HIV/AIDS infection fell nearly 40%. Nevertheless, over 1.5 Billion people living in poverty remained without adequate health coverage. To aid in achieving the ambitious MDGs, the International Health Partnership (IHP +) was launched in 2007 and aimed to strengthen coordination in the healthcare sector by providing support to government led national health plans.

In 2015, with the adoption of the Sustainable Development Goals (SDGs), a shift towards a larger set of more trackable, universal and sustainable goals was made. The 17 goals are intended to be reached by 2030 and represent 17 broad and interdependent commitments to the attainment of a better future. The third SDG, good health and well-being demonstrates a renewed commitment to health globally. SDG 3 contains 13 targets and 28 indicators and aims to ensure healthy lives and promote well-being for all. The renewed holistic commitment to health improvement contained in SDG 3 is underpinned by Target 3.8 “achieve universal health coverage, including financial risk protection.” This target presents an opportunity for comprehensive and coherent health with a focus on Health Systems Strengthening (HSS) and highlights a change in focus away from vertical disease-specific programs towards a systems-based approach that takes into account the complex interplay of different health interventions in the attainment of better health. In addition to SDG 3, improved access to surgical care can be linked to multiple other SDGs including 1, 5, 8, 9, 10, 16 and 17. With the shift from MDGs to SDGs, and the underpinning of UHC under target 3.8, the IHP + expanded its mandate after a series of consultations with the World Health Organization, the World Bank, civil society and others to cover HSS and UHC, becoming the UHC 2030 movement by December 2016.

3.2.2 UHC as a Means to an End

The WHO listed health as a fundamental human right in its constitution in 1948 and reinforces this concept in 1978 in Health for All. This is reinforced in multiple covenants such as the Covenant on Economic, Social and Cultural Rights. As a fast emerging goal since 2015, UHC is a human rights issue as well as a health financing and economic development issue. With the expansion of the IHP + into the International Health Partnership for UHC2030, otherwise known as UHC2030, a global compact was adopted on September 4th, 2018 at the United Nations General Assembly (UNGA) by 22 countries and territories. The global compact embodied a renewed and accelerated commitment to UHC with a focus on sustainable, resilient and equitable health systems. The next milestone for UHC was during the 74th UNGA in 2019, where the first high-level meeting on UHC (HLM-UHC) was convened. The HLM-UHC was a historic moment as world leaders got together to champion the vital role that primary health care has for the attainment of health for all by 2030. A political declaration was the result of the HLM, with world leaders committing to strengthening trauma and emergency care systems, given that essential surgical capacity is part and parcel of an integrated healthcare system. This was the first time surgery was included as one of the essential components for UHC in a comprehensive political declaration.

Despite its importance, UHC as a standalone goal is insufficient to achieve health for all. Challenges with distribution and poor quality of services remain, noted in multiple countries, such as Mexico's *Seguro Popular* system. The system has been effective but not evenly distributed in the country, leaving many patients behind. Additionally, even if access to preventive services as well as treatment is ensured uniformly, the challenge of ensuring quality throughout arises. These challenges pose a risk on the human rights standards of 'accessibility, affordability, acceptability and quality' enforced by the International Covenant of Economic, Social and Cultural Rights. This reinforces that UHC is a means to an end rather than an end in itself.

Longer term goals such as ensuring healthy lives and protecting the right to health need to be broken down to smaller, more achievable goals. UHC is a tactical objective on the path to realizing health for all, given it is a process-related target and potentially achievable in a smaller time frame of one to two decades. It may take generations to realize long term goals such as changes in life expectancy and an elevation in population health standards, making smaller goals vital. Therefore, UHC and complementary measures to UHC are needed, namely a focus on social determinants of health as well as ensuring legal and social protection.

Lastly, UHC is largely political, and cannot be achieved without recognition of its dependence and consequences on governance and politics. Achieving UHC requires domestic as well as international political support, which via coalitions, can aid in garnering advocates and enablers, to ensure adequate implementation. This is especially important for surgical care which remains unrecognized from a political standpoint. Continued efforts to establish surgical care as a public health priority are critical to ensure that political priorities align with the unmet surgical need.

3.3 Surgery as Part of UHC

Inadequate access to surgical care was recognized as early as 1980 when Hafden Mahler, then director general of the WHO, recognized broad disparities in surgical care. In 2008, Dr. Paul Farmer and Dr. Jim Kim published Surgery and Global Health: A view beyond the OR, remarking that surgery was the "neglected stepchild of global health." However, it was not until 2015 that surgical care was formally recognized as an essential component of UHC.

In 2015, adoption of the World Health Assembly (WHA) Resolution WHA 68.15 "Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage" cemented a commitment by countries to include surgical care as a component of their UHC efforts. This was a significant milestone for the inclusion of surgical care within the UHC agenda. However, targets for monitoring achievement of surgical system scale up were not outlined and strategies to ensure that surgical care would be scaled up remained poorly undefined. The question of how to ensure that all populations have access to surgical care remains unanswered, but considerable advancement has been made through the efforts of a number of international partners.

Three primary objectives to ensure robust surgical care incorporated within UHC have been outlined. The first is to increase the level and distribution of health through the provision of safe and timely surgical care to all that need it. The second to protect individuals from financial risk and impoverishment as a result of receiving surgical services and the third is to ensure that the quality surgical services provided are commensurate with need. The key to achieving these objectives lies in a context-based approach to scale up of surgical services. Each country, and each heath system has unique needs. Ensuring surgical care is not possible with a one size fits all approach, and instead must rely on careful consideration of local needs.

Monitoring progress towards achieving surgical UHC has remained difficult. In 2015, the same year that surgical care was added to the UHC agenda, The Lancet Commission on Global Surgery published Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. In it, six core surgical indicators with targets for 2030 were established to align surgical services with the sustainable development goals. These six targets may be useful to monitor progress towards UHC and include metrics of access (two-hour geographic access), service delivery (Surgical volume, surgical workforce), quality (perioperative mortality) and financial risk protection (impoverishing and catastrophic expenditure). Four of the six targets were adopted as World Development Indicators (WDIs) which are a set of over 1400 internationally comparable annual statistics compiled by the World Bank. Evaluation of these targets has remained limited as data collection to the six surgical indicators has remained sparse in the past five years, however they remain the cornerstone for tracking global progress towards universal surgical coverage.

In 2019, as mentioned previously, surgery was again listed as an essential component of UHC during the HLM-UHC, under article 35, which aimed to renew commitment to strengthening trauma and emergency healthcare systems. This was followed by additional advocacy efforts by the Harvard Program in Global Surgery and Social Change (PGSSC) during the 10th Inter-Agency Expert Group on the SDG Indicators (IAEG-SDGs). The IAEG-SDGs was created by the UN statistical commission to develop and implement a framework for the goals and targets of the 2030 agenda, with Target 3.8, the UHC target, being one of them. Given that national statistical offices from most UN member states report to the expert group and that the framework designed by the IAEG-SDGs lacks data collection on access to surgery, Harvard PGSSC advocated for amendment of the current framework, an effort in progress.

3.4 Strategies to Achieve Universal Surgical Coverage

Achieving the goals of universal health coverage with respect for UHC requires ensuring that there is adequate availability of surgical services coupled with the ability for patients to afford it. Numerous studies have evaluated the cost effectiveness of surgical services in low- and middle-income countries and demonstrated that surgical care results in a large reduction of lost GDP growth economic burden of disease. The body of literature from low- and middle-income countries supports the notion that most LMICs are far below the surgical targets set forth by the LCOGs. Furthermore, even high-income countries such as the United States, do not have adequate financial risk protection despite proportionally higher healthcare spending. This reinforces the notion that there is no one size fits all approach to improving access to surgical care and that context specific approaches are key.

Ensuring that surgical needs align with UHC, it is important to consider which surgical services are available and which must be covered to ensure financial risk protection. In an ideal world, all surgical services would be available for free, however with finite resources from both an infrastructure and workforce standpoint, the choice of which operations must be available and at what cost requires careful consideration by each country. A set of essential surgical services was outlined by the publication Disease Priorities 3 (DCP3): essential surgery. It provided a core set of cost-effective, essential surgical interventions that could act as an essential package for surgical scaleup [3].

National Surgical, Obstetric and Anesthesia Plans (NSOAPs) have emerged as the dominant health policy strategy to address surgical UHC. These plans are designed to be context specific national strategies to scale up surgical services while also ensuring financial risk protection. To date 8 countries have published these plans, but none have begun the implementation phase. Additional strategies involving regional compacts have also been adopted. The Southern African Development Community (SADC) passed an intergovernmental resolution that recognized surgical care as part of member countries efforts to achieve UHC. This regional approach harnesses the collective ability of the region to secure funding for surgical scale up and creates a multinational level of accountability for improving surgical UHC. A similar regional approach is being undertaken in the South Pacific region with NSOAP workshops scheduled for 2021.

3.5 Health Financing and Surgery Under the Umbrella of UHC

Universal health coverage is designed to provide the full spectrum of essential health services, from health promotion to prevention, treatment, rehabilitation, and palliative care while ensuring that access to these services remains equitable and that patients are protected from undergoing financial hardship as a result of accessing needed health services. It is important to recognize that UHC does not mean free health coverage. The three dimensions of financing surgical UHC, adapted from the World Health Organization Three Dimensions Framework include three coverage domains: population coverage, service coverage, and financial coverage. Ensuring surgical universal health coverage similarly involves policy decisions across the three dimensions including choosing what populations have access to surgical care coverage, what services (operations) are covered, and how out of pocket costs are reduced (financial risk protection) (Fig. 3.1).

Although a number of countries have adopted national health systems that provide free point of care services to citizens, not all countries can sustainably provide free healthcare. The importance of financial risk protection lies in the prevention of financial hardship especially for the poorest populations and a commitment that poverty should not exclude access to necessary health services. UHC is also not defined as a specific package of services, but rather a commitment for continual expansion of sustainable health services.

While ensuring financial risk protection for patients undergoing surgical care remains key, it has also been one of the most challenging aspects of surgical health policy. The cost of surgical scale up combined with the necessary policy to achieve financial risk protection require considerable investment. For example, Tanzania's National Surgical, Obstetric and Anesthesia plan will add an additional 3% to national health expenditure. Health financing plays an important role in ensuring that surgical scale meets the goals of universal health coverage.

Achieving these goals requires comprehensive health financing that supports surgical aid. One of the fundamentals of health financing is a health system that is capable of maintaining and improving human welfare. This is done via raising sufficient funds to employ healthcare services—such as medical doctors, nurses, purchase medications and medical equipment—needed for both the safety of the individual patient and for society as a whole. Protecting patients from financial impoverishment is the other mainstay of health financing. Core indicators used to achieve health systems strengthening and financial risk protection include total health expenditure per capita, government health expenditure as a proportion of total government expenditure and ratios of household out-of-pocket payments for health to total health expenditure.

3.5.1 Micro Health Insurance Systems

The predominant method of healthcare financing in developing countries is out-of-pocket payments, which often lead to financial catastrophe. In order to afford direct payments, many are forced to utilize their savings, borrow money or sell productive assets such as livestock which have downstream economic effects on populations, especially those living in rural poverty.

One method suggested to curtail the latter is the utilization of micro health insurance (MHI). MHI is a strategy, also called mutual health insurance or community-based health insurance, in which small scale, targeted schemes are developed to pool financial resources in specific communities or among specific populations. MHI is often more complex than traditional life insurance, as it provides services towards specific risks or illnesses and involves the health care provider, whether independent of or in partnership with the MHI strategy. MHI has been used in low- and middle-income countries to offer financial risk protection by means of risk pooling and decreasing out-of-pocket expenditure. It has been studied extensively and implemented in multiple settings, with positive outcomes. It has been proven that MHI decreases total health expenditure, household borrowings, catastrophic health expenditure and poverty. MHI is an important tool, protective against impoverishment, whose impact is to be studied further and utilized in additional settings to aid in achieving sustainable health financing and health systems strengthening.

3.5.2 Innovative Financing

Innovative financing is a mechanism in resource mobilization which aims to raise funds and design mechanisms which aim to improve the use of funds. Some funding mechanisms are joint public–private ventures or non-traditional applications of Official Development Assistance. Organizations such as the Global Fund and the GAVI alliance have deemed innovative financing a vital mechanism. One of the main innovative financing mechanisms used by the Global Fund is its Debt2Health initiative, where donor countries forgo a proportion of the money owed to them, provided the debtor agrees to invest half of the forgiven debt in agreed upon programs. Another mechanism applied by the Global Fund is the ProductRED initiative, where a share of companies' profit on goods branded with ProductRED are donated to support the Fund.

3.5.3 Universal Surgical Coverage and Financial Risk Protection

Taking this one step further, financial risk protection and innovative financing are important for universal surgical coverage, as part of achieving UHC. Nearly half the world's population, 3.7 billion people, are at risk for catastrophic expenditure due to potential surgical expenses. Additionally, 33 million and 48 million are driven to financial catastrophe secondary to surgical costs and non-medical costs respectively. One example of a non-medical cost associated with access to essential, quality and affordable surgical care includes having adequate infrastructure, or a mode of transportation to enable timely arrival to healthcare centers. In Myanmar, a modeling study revealed that 44% of the population is at risk of catastrophic health expenditures should they seek access to pediatric surgery and that 90% of that risk is attributable to non-medical costs. This highlights the vitality of mobilizing innovative financing mechanisms as well as enabling financial risk protection plans to ensure access to not only essential health, but essential surgical coverage as well. Given the high risk of patient expenditure due to surgical care, achieving UHC without addressing financing structures for surgical care is not possible.

3.6 The Role of Academia in Achieving Universal Surgical Coverage

Academic surgery has taken a new role in the advancement of universal surgical coverage. A dramatic shift has taken place as the role of the surgeon in global health transitioned from a missionary trip model to that of the health system researcher and policy advocate. This shift has resulted in a new effort to better understand and improve the delivery of surgical care globally from an academic perspective. In line with the World Health Assembly's focus on five key areas: surgical and anesthesia workforce, information management, service delivery, essential medicines, advocacy, and surgical resource development [4].

To help address these core areas, academic institutions have begun to embrace a variety of collaborative techniques to further the global surgery agenda. Ensuring that a variety of instructions are represented from partner countries is critical to ensuring that the viewpoints and goals of those living and working in LMICs are represented under the efforts to achieve UHC. North–South, South-South and North–North (triangular) collaborations have emerged as a way to ensure capacity building and innovation exchange including those from instructions in LMICs. It also allows for experimental design and new training paradigms to have input from those clinicians and researchers who are most likely to implement changes at the ground level. Local academic instructions also provide a forum for collaborations between academia and professional societies and can liaison between governmental and non-governmental organizations in the advancement of advocacy and policy reform [5].

Additionally, academic institutions provide the research capacity to evaluate and track surgical indicators which help understand how surgical delivery aligns with priorities of the universal health coverage. Although adopted by the World Bank, the surgical indicators introduced by the Lancet Commission on Global Surgery remain adequately reported. To date, a number of academic endeavors have provided snapshots of surgical indicators for a variety of countries, but few to no countries have robust reporting measures that have allowed longitudinal data tracking.

3.7 Barriers Towards UHC Coverage

Significant barriers exist in ensuring that the broad goals of UHC are met with respect to surgical care. First, data collection remains limited for surgical care. The shift to the SDGs represented a prioritization of data driven, trackable metrics towards achieving global goals. While global surgery has followed suit with a set of core indicators, data collection remains limited. The difficulty in this data collection has been the result of lack of health reporting systems, and lack of consensus on the definition of several of the indicators. For example, measuring surgical volume and perioperative mortality (POMR) has been difficult due to variation in reporting of surgical volume (choice of procedures collected in different settings) and POMR (variation between in hospital, 30 or 90 day mortality). Additionally, barriers in terms of funding scale up of surgical care remain significant. For example, the cost of implementing NSOAPs have been calculated to be US $69.7 million in Rwanda and US $16.8 billion in Nigeria. While these costs may seem high, ensuring UHC requires both the availability of high-quality services coupled with mechanisms to prevent financial expenditure and may result in more substantial economic growth and financial wellbeing. Barriers to adoption of surgical system health policy also remain significant. Surgical prioritization by politicians is critical, but

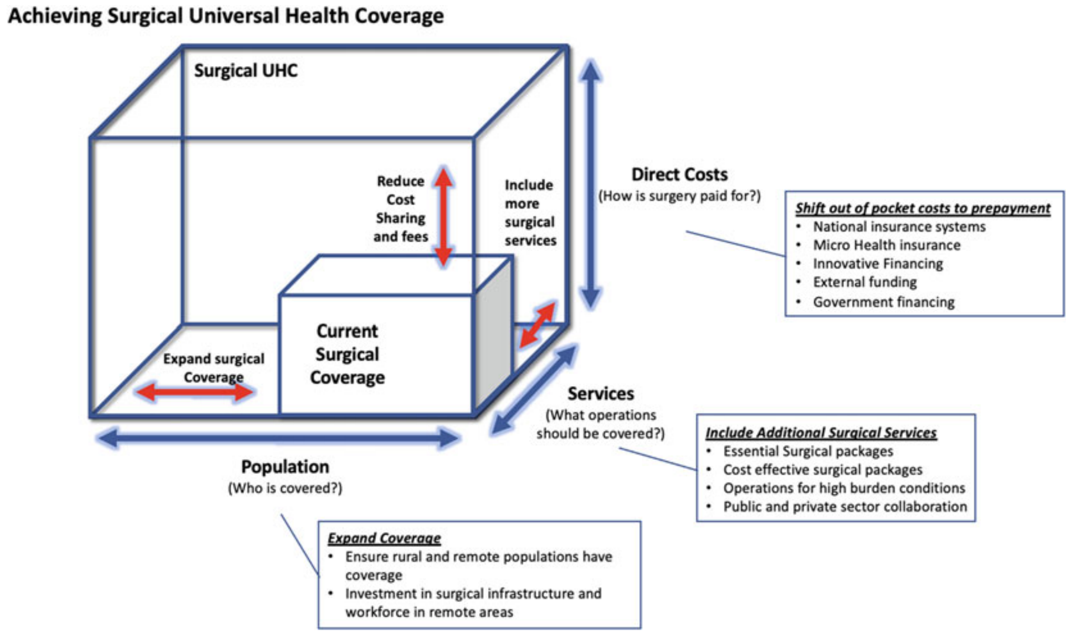

Fig. 3.1 Achieving Surgical Universal Health CoverageFigure: Three dimensions of financing surgical UHC: adapted from the World Health Organization 3 Dimensions Framework. Achieving UHC for surgical care. The universal health coverage cube reflects three dimensions of coverage; population coverage, service coverage, and financial coverage. Ensuring surgical universal health coverage similarly involves policy decisions across the three dimensions including choosing what populations have access to surgical care coverage, what services (operations) are covered, and how out of pocket costs are reduced (financial risk protection).

remains underappreciated as competing interests and lack of objectives measures of success make it unappealing for politicians. Recent work with NSOAPs in a variety of regions has started to change these priorities, but further work is needed to ensure that surgical care remains a core priority of health system scale up globally [6].

3.8 Conclusion

Universal Health Coverage Fig. 3.1 is a tactical and vital objective on the path to achieving the right to health for all, with universal surgical coverage entering the playing field rather recently. Despite facing multiple challenges, such as limited data availability and limited funding, opportunities for growth and scale up are on the rise and universal surgical coverage could soon become a closer reality. Continued commitment to surgical health system research, advocacy and policy work will ensure that surgical care remains on the UHC agenda and progress continues towards reducing the number of people without access to safe, high quality, affordable surgical care.

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4 Global Surgery Financing, Challenges and Possibilities

Juan Carlos Negrette

Abstract

Global surgery is increasingly gaining recognition as an important and essential component of the service mix needed to attain Universal Health Coverage. Lack of access to surgical care is not just tragic, it is also too costly for any society, currently and when costs are projected into the future. Research has demonstrated that cost effectiveness of surgical care is comparable to that one of well-known (and well-funded) public health interventions, raising the public pressure for access expansion to affordable surgical care. However, how to finance it remains a significant challenge. The prevailing paradigm that governments could not offer everything to everyone builds its foundation on the wrong mindset; a mindset that invites delaying the expansion of surgical care. It is true that resources can appear finite at a given time, but this equation does not include the potential for innovation, cooperation and decision that can stem from a serious challenge. The world is today, richer, healthier, with greater human capital, and for that, more capable technologically to finally bring surgery to those in need. The response to this call is already coming from multiple corners: groups of likeminded surgeons and health professionals, governments (from high-income countries as well as LMICs), international agencies, philanthropists, corporations and academic centers. Lessons learned from LMICs and from previous experiences in development assistance, realignment of countries priorities and private financial assistance provide tangible examples about how expanding surgical care to many in low resource settings can be done.

Keywords

Access to surgery · Development assistance · Financial sustainability · Global surgery · Service delivery · Universal health coverage

4.1 Health as a Right and the Movement Towards Universal Health Coverage

Surgery accounts for approximately 30% of the burden of disease; concomitantly, surgical expenses risk pushing approximately 44% of the world's population into catastrophic expenditures [1]. Healthcare services financing is closely related to the societal agreements reflected in countries laws; these also indicate what societies are willing to pay for and who should be covered. Comprehensive social protection that includes

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_4

surgical care results more from a rather lengthy social and legal process than from a single act.

The World Health Organization (WHO) defines universal health coverage (UHC) as "access to key promotive, preventive, curative and rehabilitative health interventions for all at an affordable cost" [2]; in other words it is a system that delivers the care people need, when they need it, without falling into financial destitution [3]. UHC has acted as a common term that brings together different concepts, from the Alma-Ata declaration to Health for All. UHC is, according to the 2010 World Health Report, an objective and a strategy to guide health sector reforms for its members [4]. Having this common denominator is important for understanding financing needs, subjects, sources and resources' channels.

We might believe that acknowledging health as a right, or signing declarations about commitments to universal care, would automatically result in the increase in service delivery output and in the concomitant improvement of the social condition of millions, particularly those who lack services they desperately need. In multiple conversations, participants in one way or another conflate Universal Health Coverage with the right to health. While the relationship between acknowledging health as a right, and creating the legal and regulatory framework that can result in UHC exists; this relationship is by no means linear and causality is in many instances hard to define.

In some instances, the appearance of a proto-UHC concept, like the memorable "Kaiserliche Botschaft", or the 1881 Imperial Message from Whilehm I, which marked the origin of the modern welfare state[1]—and the "Bismarck Model"-, offered very basic coverage to a small portion of the population. It took Germany 105 years to offer truly "Universal" healthcare [5]. It is important to note that a specific right to health is not in the German Federal Constitution (although it is enshrined in the constitutions of several Bundesländer[2] [6]). In contrast, Chile the first country to acknowledge health as a right in its constitution in 1925 [7], presents a different—almost opposite- case; as the first institutions devised to provide care in the Latin-American country were established in the 1940's, reaching universal coverage in the late 80's after multiple reforms [8]. In fact, less than 40% of national constitutions addressed health rights before 1970; the world would have to wait for almost 30 years until the vast majority (over 90%) of the countries legally acknowledged—from partially to comprehensive- health as a right [9]. Even when countries did not consider health as right, public institutions offered healthcare services; an example is Colombia, a country that had social contracts and institutions that offered a broad array of healthcare services to selected populations (i.e. public sector workers) decades before health became a right in the constitutional reform of 1991 [10]. In this country the heated discussion about the reach and scope of the new law, in terms of coverage and access, ended up with a form of social agreement summarized in the slogan TOTOYA (Todo, para todos, ya! Or Everything, for everyone, now!) [11]. This acknowledgement empowered Colombians to sue the Government when it did not meet their economic or civil rights. A report by the Human Rights Ombudsman's Office, estimated that 674,612 legal actions of this kind took place between 1999 and 2008 [12]. Litigations in this country includes demands for a wide array of procedures that go from drug therapies to surgeries, creating an important pressure on the public finances.

Important as it is to establish the necessary legal substrata for adequate healthcare financing; examples show that, historically, countries that have attained universal health coverage seem to follow a pattern in which they initially have pervasive internal pressures for the universal provision of care; then, society demands deep involvement from the government, although

[1] Konrad Obermann, Peter Müller, Hans-Heiko Müller, Burkhard Schmidt, Bernd Glazinski; Understanding the German Health Care System; Mannheim Institute of Public Health.

[2] Germany is a federal republic consisting of sixteen states, commonly known as bundesland (plural Bundesländer).

roles vary from country to country. Finally, the road to UHC is never straight, shaped by multiple negotiations instead of design, and achieving universal coverage takes time.[3] Understanding this, the 58th World Health Assembly (WHA) in 2005 called to its members to plan for the transition to UHC, including financing and social health insurance plans, aiming to attain universal coverage. Ten years later, the 68th WHA set 2030 as a concrete deadline for its members to achieve UHC, stressing on different elements such as financial protection, access to affordable quality services and medicines for all. In summary, UHC now embodies the right to health and offers a roadmap for universal healthcare that, in theory, includes surgical care in the template;[4] but more work must be done to ensure affordable surgery and anesthesia are considered as they are: Essential for quality and equitable care.

4.2 Scarce Resources, Delivery Failure and the Global Cost of Lack of Access to Surgery

Over the last 50 years, important progress has been made in advancing surgical care globally. Development cooperation programs have helped expand access to surgery in low resource settings, contributing to the social and economic progress of entire regions. In spite of the progress made, important challenges remain. The Lancet Commission on Global Surgery estimates that, just because of OR existing infrastructure, more than 2 billion people do not receive surgical care [13], and approximately 5 billion people lack access to timely safe and affordable surgery [14]. Large demand of services for a scanty supply is a compounding negative factor that makes surgery in poor areas, prohibitively expensive, inviting heavy—but not always effective- regulation or simply inaction from an overwhelmed society.

The cost of not having surgery: Societal and opportunity costs and losses. The need is particularly acute in the poorest regions. More than nine persons out of ten in Sub-Saharan Africa do not have access to timely and affordable surgical services when needed. The immense cost inadequate surgical care places on, particularly, poor societies is twofold: moral and economic. The moral cost of early, avoidable death or decreased quality of life is unfathomable; the economic cost of productivity loss due to early death and disability can be calculated, but still does not capture other opportunity costs such as increased investment due to aggregated income. Even more, this approach does not address the fact that poor surgical infrastructure and lack of access to surgical care, also pushes those with means to seek for expensive care abroad [15]—which amounted to more than $ 3 billion in revenues for US hospitals in 2013 [16], further contributing with a vicious circle of lack of investment and poverty.

Seeing surgical care (and healthcare in general) just as a cost, creates a singularity that diminishes its true economic contribution. On one side, it is an economic activity that generates revenues, salaries, investments in infrastructure and technology, all of which have a compounding factor in the rest of the economy (the entertainment industry offers a contrasting vision: we do not consider it as a societal cost). On the other side, it helps individuals to continue with—and prolong- their own contributions to the economy through labor and knowledge. In essence, access to surgical care is essential for poor regions of the world to improve their human capital, and to help to their economic development and poverty reduction.

As an example, in 2015, WHO estimated that in SSA, 47% of all productivity losses, approximately $1.4 trillion, were due to Non-Communicable Diseases (NCDs) and injuries, which in many instances are treated with surgery [17]. Contrast this figure with the $3,178 trillion spent in healthcare in the US in that year [18], or to the $1.7 trillion of the global cost of healthcare in 1990 [19]. It means that productivity losses in the African continent were equivalent to 44% of all healthcare expenditures in the US—arguably the "most expensive healthcare system"- and

[3] William D Savedoff; op. cit.

[4] Lawrence O Gostin; op. cit.

equivalent to almost 8% of the total American economic output of that year.

Lack of action in developing strong surgical infrastructure (human and material), has a compounded cost effect. According to the Lancet Commission on Global Surgery, by 2030 the potential loss related to lack of surgery in LMIC's could ascend to $12.3 trillion or a full 2% of GDP growth.[5] The World Bank estimated the total size of the Chinese economy output in 2019 at $ 14.34 trillion [20].

Another perspective that also provides a sense of economic magnitude of the problem is the future cost of not providing surgery when needed. In 2010, road-traffic injuries generated 75·5 million disability adjusted life-years (DALYs), approximately 20 million DALYs more than 1990. Investment in surgical care and infrastructure has probably been negatively impacted by the perception of surgery as an expensive intervention. In fact, surgery compares favorably with well-known public health interventions in terms of cost-effectiveness. For instance, male circumcision in Africa at $ 13.78 per DALY is lower than antiretroviral treatment with a range from $453.74 to 648.20 per DALY. Other examples are in the table below [21].

Procedure	Cost per Daly Adverted
Circumcision	$13.87
HIV ART	$453.74–$648.20
Cataract repair (Nepal)	$7.29
Inguinal hernia repair (Ghana)	$12.88
Expanded Program on Immunization	$12.96–$25.93
General surgery	$82.32
Ophthalmic surgery	$136
BCG Vaccine	$51.86–220.39

It could be argued that, amongst its many contributions to the discussion around access to affordable surgical care globally, the work that the Lancet Commission has done to increase awareness of the cost effectiveness of surgery, and placing it in the realm of desirable public health intervention, is simply remarkable.

Market failure in surgical services provision, the role of the government and the need for innovative financing. Competitive free markets are considered an efficient vehicle to make demand meet supply at an optimal price point. However, markets might fail when there is no balance between what suppliers might offer and what informed consumers would demand. As health services demand is mostly constructed around needs, poverty is a factor that makes difficult for that theoretical equilibrium to happen.[6] Market failures can be addressed through judicious and discipline government interventions, and the specter of individuals' catastrophic expenditures associated to health services delivery, particularly surgical care, makes the possibility and clamor for such an intervention increasingly possible.

Around the world close to 33 million cases of catastrophic surgical expenditures take place every year, and approximately 3.8 million persons are continuously in risk, should they need sudden surgical care. They are close to 22% of all individuals (approximately 150 million) who face catastrophic expenditures every year. Catastrophic expenses affect particularly the poor of the world. While this is true in all levels of economic development, it is more evident in SSA, South and South East Asia. It is important to note that almost all catastrophic health care expenses in the upper and high middle-income countries fall on the poor [22]. Findings show that individuals in lower-middle income countries tend to face more catastrophic expenditures than those in low-income countries as surgery, because as a function of income, costs are up to 15% higher in the former than the later. In the economic transition from low to lower-middle income, surgery costs can grow faster than household incomes, and for that reason, policy makers in countries making this positive economic transition, must anticipate this situation.

When considering third party financing for surgery, it is important to note that in addition to

[5] Desmond T. Jumbam, op. cit.

[6] Musgrove, op. cit.

surgical direct costs, non-medical costs such as lodging, food and transportation, contribute substantially to catastrophic expenditures. When these are taken into consideration, models predict that an additional 48.5 million cases of catastrophic expenditures occur, resulting in roughly 81 million annual cases globally [23].

Scarcity in Human Resources for Health and infrastructure results in care rationing. For the last twenty years, world health leaders have paid special attention to the pressing issue of human resources in health. In 2006, it was evident that in spite of the initial attention to the subject, worrying trends about health professional workers density just continued. At that time, reports showed that 57 countries had less than 2.3 workers per 1,000 population, out of which 36 were in SSA, 6 in South East Asia and 5 in the Americas; not a single country from Europe fell under this critical threshold. In 2013, the situation has not improved much; following the same classification, 31 out of 54 countries were in Africa, and 7 in South East Asia. The health workers shortage in 2006 was estimated at 4.3 million; by 2013, the gap had grown to 7.2 million. If this trend continuous, by 2035 we will need 12.9 million health workers more. The shortage, if conditions do not change, will likely be more acute in Africa [24].

This structural shortage is explained by the lack of formal training, particularly in Sub-Saharan Africa. In the region there are 11 countries with no medical school and 24 with just one. The continent graduates roughly 10,000 doctors a year, joining a pool of 145,000; similar in size to that one of UK; which has a population that is just a fraction-equivalent to less than 7%.[7] A compounding factor is the shortage of HRH in high-income countries—particularly nurses and physicians-, where a mix of misallocation or resources [25], changes in labor laws for trainees and stagnant number of training centers [26] have stimulated the importation of foreign providers, mainly from Africa and South East Asia. For East Africa to reach the same providers density as Canada, would have to train 42,000 more doctors.[8] Also, almost totally absent is the training of healthcare administrators and hospital managers, who can contribute to the overall systemic improvement [27].

Service delivery infrastructure poses an additional challenge. Extremely low density of beds[9]; need for reliable access to energy, water, and to an adequate supply of oxygen, make providing care difficult. For that reason, 24-hour provision of services is limited to less than 50% of the operational structure in some SSA countries and basic infrastructure is lacking [28].

Elements described make for a perfect storm in healthcare supply, particularly surgery as, different from primary care, requires a dedicated infrastructure and a team of professionals and managers that are not always available. In classic economy, demand for scarce goods results in higher prices and in a supply at a much lower level than society would be willing to get. While prices of surgical services in low resource settings might be lower than those in high-income regions, the truth is that, even at that low level, most people cannot afford them or simply there is not enough for everybody. Clearly, thinking creatively is of the essence to solve this tragic conundrum.

4.3 How Is Health and Surgical Care Paid?

Sources of healthcare payment can be divided into private and public; and into individual, pooling or government transfers. Government transfers are usually resources financed through taxation and other government revenues (i.e. mining rights and royalties, public enterprises, etc.). Pooling happens through social or voluntary health insurance. Private insurance plays an important role in high-income countries to fund services, including surgeries, not covered by public plans or other private insurance. These plans can be primary, which are the main source of insurance in the US and Chile (and roughly

[7] Ibid.

[8] Ibid.

[9] CIA Factbook, Jan 2014.

10% of the German population), supplementary (85% of the Dutch population) and complementary (95% of the French population) [29].

Individual direct payments to the care provider are referred as out-of-pocket payments. They can cover the price of services and products received, or they can be part of the insurance (pooling) arrangement. If the later, they can be co-payment, or the amount paid for every service received (a fix amount or a proportion of the service cost); and/or a deductible, which is usually an amount the insurance holder must pay (in one or multiple services) before reaching a certain threshold, in which the insurance starts providing coverage.

A different, but important form of global health financing is Development Cooperation (also known as Official Development Assistance or ODA), that involves foreign governments (through multilateral or bilateral programs) and private foundations. While not focused in surgery, they have played an important role in advancing the global fight against infectious diseases.

In general when looking at a low-income country national health accounts, it is quite difficult to establish with clarity the cost of specific interventions, like surgery. In many instances, these are aggregated to track a disease, like TB, or a program, like maternal health (which also includes surgery) [30]. This makes difficult to understand contribution, impact and service delivery capacity, and ultimately, how resources are allocated. However, general trends in payment or service delivery can offer an idea about how surgery is probably paid for in different settings.

In low-income countries, funding pools (government allocations and public and private insurance) finance only 38% of healthcare; a stark contrast with 60% in middle-income countries and 80% in high-income countries. It is also a core belief that the poorest of the poor need total subsidization and that low-income groups need, at least, some levels of subvention [31]. As pooling is an important source for surgical care (because of risk and cost), governments can either encourage citizens to enroll in national health insurance schemes, pay for services through direct budgetary allocations or through private contributions to regulated private insurance schemes. These solutions might work relatively well in middle- and higher middle-income countries, but due to a small taxation base it is difficult to do it in low- and lower-income countries. However, there is a fundamental problem with the contributive base of low-income countries: governments do not have a wide taxation base as vast proportions of the population are poor, and many who work, do it in the informal sector, which does not pay taxes[10].

Private sector is a major provider of all types of healthcare services in low- and middle-income countries. In Africa, the private sector (from traditional practitioners/healers, to private clinics, to mission hospitals) roughly provides 50% of health services. Healthcare expenditures follow a similar proportion; 50% go to private providers and 50% to the public sector. Surprisingly, this proportion is very similar for all economic quintiles [32]. These providers benefit (at least until 2019) from generalized economic growth, and from the perceived or real failures of the public sector to meet needs and expectations. In many instances, prices paid for surgical care in public facilities (that add costs by managing long waiting lists) are not substantially different from those offered by private institutions, in some instances located in the same area.[11]

Research shows that globally, medicines and clinical services are responsible for the majority of healthcare expenditures. Inpatient care (which includes hospitalization, medicines and medical diagnostic services) is a proxy for surgery aggregate costs. It presents significant variations from country to country and between income groups inside a country; inpatient cost share ranges from 15% in low-income countries to 33% in upper middle-income countries. Outpatient care presents a stark contrast; it goes from 27% and 24% share in low-income and upper-

[10] According to WHO’s Global spending on health 2020, in 2018 tax revenues in low-income countries represented less than 13% of GDP.

[11] Ibid.

middle income countries respectively; which means that while outpatient and inpatient care has a similar economic weight in upper-middle income countries, in low-income countries, the larger share of outpatient services could indicate a significant unmet need of surgical care. It does not come as a surprise that comparing the same groups of countries, low-income countries spend 13% in non-communicable diseases, while middle-income countries spend 29%, a proportion that mirrors the outpatient and inpatient "divide". It seems that allocation of resources reflect more systemic response capacities than response to health needs of the population.

Sources of payment also differ significantly between country groups. Low-income countries use 22% of domestic public sources to finance healthcare needs, while middle-income countries domestic public sources funded 44% of their healthcare expenditures. More significantly, in low-income countries external aid contributes to 30% to the total health expenditures, while this contribution drops to 11% in middle-income countries. It is important to note that two thirds of foreign aid goes to infectious diseases (with HIV taking the lion share) in both country groups, underscoring the interest of the donor community in this needed, albeit particular area of intervention. Out-of-pocket in low and lower middle-income countries cover 41% of total healthcare expenditures. In fact, in low-income countries, private sources explain up to 57% of injuries costs, another proxy for surgical costs.

In the 2005–2018 period, foreign aid more than doubled. However, as external aid increased, health priorities in domestic budgets declined. In low-income countries, government budgetary allocation to health has decreased from 7% in 2000 to 5.5% in 2018; in this group, military expenditures are still larger than health expenditures. Had domestic expenditures at least remained at similar levels, governments would have been presented an opportunity to expand social protection in their respective countries, with increased chances to expand access to surgical care as well.

Private health insurance (PHI) seems inadequate for low-income countries; if disposable income is low, opportunities for investing in risk mitigation seem equally low. That said, PHI is an alternative way to finance healthcare that has been used in a variety of settings, from most OECD countries today[12] to lower-middle income countries with large aggregate economies. In 1980, PHI companies started providing coverage services in a country like Colombia, which at that time had a GDP per capita of $1,240 ($4,150 in 2019 dollars), preceding by almost a decade when the national health reform introduced the concept of regulated competition. Healthcare financing—and by extension surgical financing-seems a fertile battleground for ideological warfare. It is clearly a complex problem. It requires a multidimensional approach that goes beyond the capacity of a single sector to respond to changing needs. The public-private divide seems nonsensical, at least from this perspective; it almost seems a lost opportunity for harnessing societal resources to create long lasting value.

4.4 The Spark: How Surgical Programs Can Advance in Low Resource Settings

To bring surgery to the regions and places in the world where is not accessible or not affordable, is inherently difficult. Experience shows that putting will, minds and financial resources together, has consistently helped us to surmount problems that seemed intractable. The 20th century and the beginning of the 21st brought new challenges, opportunities and innovative responses to social problems that we can use as tracers for interventions aiming to scale up access to surgical care worldwide. In the past few decades corporate social responsibility (CSR), philanthropy and development cooperation have emerged as important vehicles and contributors to advance complex programs and shape the global health agenda. Advancing global surgery is a long-term endeavor requiring the joint effort of host governments, international agencies, philanthropists, and civil society, not only as a way to procure

[12] Sato; op. cit.

necessary funds, but also knowledge and a structure that defines rules of engagement and identifies areas of responsibility.

CSR interventions. Corporate social responsibility (CSR) refers to activities, programs and strategies that businesses and corporations advance in areas of social interest like human rights, social welfare and environmental protection to name a few, intended to project a positive image for the institution, brands or products that the enterprise commercializes. Interventions might have different communication objectives, ranging from managing adverse public relations caused by an accident or quality process oversight, to strengthening the corporate image when entering discussions with regulatory authorities. As a result, target audiences can vary significantly, from authorities, to existing and potential investors, to the general public.

Because of the prominence of some cases, and because it is becoming a more ubiquitous communication tool, CSR has increasingly attracted the attention of development agencies and international organizations when seeking for potential partners to advance development agenda elements that require additional funding, and see positively the participation of civil society (commercial) actors. CSR has also attracted the attention of some governments; for instance, the Indian Government has required all for-profit companies contribute 2% of their profits to charitable causes as a form of compulsory CSR [33]. While this particular order distorts the intention of CSR as a corporate PR tool associated to the company's profit generation objectives, also indicates that third parties see the potential in involving corporations in social causes different from its commercial intent.

Companies like medical equipment, devices and supply manufacturers, and pharmaceutical companies are in business that have a direct effect on human health. Many of these companies are highly visible, which can be an asset, but also a potential source of reputational risk if things do not go well, even when making corporate decisions such as setting prices, discontinuing a product line or delaying entering a market without strong purchasing power. For these companies, CSR has become increasingly important; as such, there are important programs —such as differential pricing- for pharmaceutical products sold at significantly discounted prices in low and middle-income countries, where the need because of disease burden and economic disparities is greater.

CSR is a tool that not only helps to repair battered reputations, but also can help develop stronger bonds with employees and stakeholders and improve relationships with host governments. Establishing public and private partnerships will become a central part of business strategy that uses CSR tools to benefit the organization's image, achieve social impact through philanthropic means and turn them into sources of competitive advantage in new markets that while not economically developed today, have a positive economic and social outlook.[13]

Global surgery stakeholders and advocates must change the traditional perspective of corporations as external partners that provide funding and expertise to support the health development agenda in LMICs, giving room for establishing more productive and sustainable, mutually beneficial engagements. Global surgery stakeholders can help public health authorities and planners in developing agencies and host governments work closely with corporations interested not just in procuring funding for specific programs, but also engaging them in the broader and longer-term objective of developing sustainable markets [34].

Working in global surgery can help corporations in the domestic environment to improve its relationship with their stakeholders by providing a highly visible intervention, aligned with the global health development agenda, while simultaneously serving to advance foreign markets understanding, and creating conditions for long-term development and returns. This could also open the doors to financing mechanisms with social purpose, giving these interventions a new meaning, potentially improving overall standing and value of the corporation [35].

[13] Ibid.

The role of philanthropy. At the beginning of the 20th century, philanthropists like John D. Rockefeller and Andrew Carnegie contributed with their immense fortunes to advance the fight against disease. Institutionalization of their support has made their impact as long lasting as sustainable. While at that time, their interventions filled a void of what today many could consider as a government function, by mid-century, the cost of care and the increasing role of governments in healthcare services delivery and research, made wane the initial importance of private donors as charitable endeavors supporting global health [36]. However, the incursion in the global health scene of modern philanthropists has significantly changed programs policy design and implementation. In the US, there are more than 100,000 private foundations with approximately $ 569 billion in assets[14], contributing to global health activities. The Bill & Melinda Gates Foundation is the largest with financing greater than the entire WHO budget [37].

Private donors attract less scrutiny than CSR programs, in spite that both, private foundations and corporations largely funded efforts to achieve the Millennium Development Goals.[15] For instance, an important entity such as the Global Fund receive substantial funding from private foundations for its operations. Different from corporations that are subject to consumers boycott, or government officials scrutiny, private foundations have a greater independence in their charitable efforts. While some may criticize this lack of oversight, this concern might actually reflect an important strength of private donors: they are not subject to the political vagaries, therefore can remain steady in pursuing long-term global health objectives. That persistence has paid off in policy areas, like helping to bring greater transparency in the selection process of WHO's Director General, or in the protracted research effort for a vaccine against HIV.[16]

Global surgery stakeholders can harness the long-term endurance capacity that private foundations can provide precisely because of its particular independence. Defining what is important in global health is a dialectic process that requires looking at a myriad of possibilities, almost all of them promising greater human wellbeing. Working jointly with ascending or established relevant foundations, can help to develop the steady course needed to succeed in interventions in which persevering is essential. Global surgery offers that kind of field.

As an example, a team supported by the Swanson Foundation introduced laparoscopic surgery in Mongolia as part of a program to improve surgical care in that country. This was not the original intent, but is what resulted after discussions between the team and local practitioners. After 20 years of sustained support, this service is now offered in all Regional Diagnostic Treatment Referral Centers in that country, as an example of what can be achieved with targeted philanthropic support [38]. It is important to note that private companies CSR programs from Storz, Cardinal Health, Johnson and Johnson, and several others, have also provided resources for this program.[17]

Development cooperation assistance. Since the institutionalization of development cooperation after the success of the Marshal Plan, with the creation of USAID, high-income countries have developed increasingly sophisticated vehicles to support health programs in low and middle-income countries, initially as an instrument of the nation's public diplomacy. Per-capita international aid of health programs more than doubled between 2000 and 2018 in real terms. International aid represented 25% of low-income countries health expenditures, in 2000 the official development assistance (ODA) accounted for 16% of the low-income country expenditures. Trends show in 2010, 13% of ODA to low-income countries went from 13% in 2010 to 20% in 2018. Development cooperation programs

[14] These accumulated holdings are larger than the 2019 economic output of countries like Sweden, Argentina or Austria ("GDP (current US$)". World Development Indicators. World Bank. Accessed on 2/18/21).

[15] Ibid.

[16] Koop; op. cit.

[17] Conversation with Dr. Ray Price (2-26-21).

increased its focus in low-income countries and in health.[18] Africa receives 54% of aid resources for health [39]. ODA adheres to the five principles of the Paris Declaration; harmonization and alignment being the most important for this analysis. It means that donor countries coordinate between them, as much as they can, the allocation of resources to health programs in a host country and, at the same time, align that investment with the country's health plan. It has resulted in more than 50% of aid resources going to fight infectious diseases.[19] In the case of the US, only $ 100 million, out of almost $ 9 billion, went to "non-traditional disease" which includes surgical diseases. Some other programs have a minor surgery component (circumcision for HIV prevention, and obstetric and iatrogenic fistula, as well as cesarean section for maternal health programs). While ODA resources are vast, allocations to surgery are not significant and they focus in a narrow subset of surgical services.

In spite of their focus, some programs have contributed to advance surgery in LMICs. In 1973, Profamilia Colombia introduced laparoscopy for tubal ligation with USAID technical and financial support. The country's GDP was then $ 435 (Approx. $ 2,570 today). As the organization increased its outcome, it also improved its experience, so much so that by 1995 the organization provided close to 70 thousand surgeries. The organization estimated that in 2010, the direct cost of a laparoscopy was $ 60 per surgery, half the cost of the traditional laparotomy [40]. It is important to note that, before the Colombian health reform, Profamilia offered its surgical services at a very low nominal fee to the poorest of the poor, and charged patients based on their ability to pay. After the reform took place, the government contracted out with organizations like Profamilia to offer healthcare services to the general population.

To make surgery an ODA priority, global surgery advocates can work jointly with bilateral organizations, looking for opportunities to submit joint proposals with host governments in low-income countries interested in improving its surgical access and quality. This might offer the opportunity to influence other governments as well and nudge donors to support these programs in full alignment with the host nation's health priorities.

4.5 The Long Run: How to Sustain Efforts in Surgical Services Delivery

Complex problems rarely have a single solution. Usually different elements (knowledge, resources, etc.) have to be brought together to effectively address and solve it. Expanding access to quality surgery in low resource settings is a complex problem that requires multiple approaches. In this section we will see different approaches and how they can jointly work to provide effective and sustainable financing.

The role of government. Governments have a fundamental role as funders or direct providers of surgical care [41]. A distinct feature is that governments in high-income countries pay for a larger proportion of healthcare services, than governments in low- and lower-income countries.[20] We have seen that health financing is challenging for low-income country governments and might need significant adjustment to their national budgets to increase funding for health. Additionally, a narrow taxation base, makes funding difficult. As a result, it is essential to develop vehicles that can help governments to take advantage of initial support provided through development cooperation or through CSR and philanthropic efforts.

Governments give incentives to providers to ensure output and quality to improve access to health care services, including surgery. They also provide subsidies to the demand to incentivize the use of certain type of healthcare services, to reduce its financial burden.

Governments have several mechanisms for channeling financial incentives to both sides of the economic equation; for providers: pay for performance, prepayment, schemes and contracting;

[18] Global spending on health 2020; op. cit.

[19] Global spending on health 2020; op. cit.

[20] Global spending on health 2020; op. cit.

for service users: conditional cash transfers, vouchers and community loan funds (to pay for transportation or lodging) amongst others [42].

Demand side financing and incentives to providers are usually implemented together (an example is the Nepal Aama program—see box below [43]) where cash payments to women, incentives to providers and free delivery care are all offered [44]. As incentives and subsidies (also known as resource allocation and purchasing arrangements, or RAPs) seek to modify the perception of price for the consumer, while stimulating quantity of services offered, the supply and demand curves will meet at a different point (less services at higher prices) than they would meet without the intervention [45]. This approach brings he advantages of fee for service for providers, while empowering consumers to look for better quality care.

> The **Aama Surakshya Programme** is a Maternity Incentive Scheme (MIS) implemented by the Government of Nepal, with support from the UK's Department for International Development in 2009 and it is still in operation. It aims to provide free delivery care to all women at the point of use by reducing financial barriers to women seeking institutional care. It has the following elements:
>
> **Incentives to women**: Transport incentives offered to all women delivering in an institution, including additional cash payment on completing Four Antenatal Care Visits (4ANC).
>
> **Unit cost to health facilities**: Institutions receive a reimbursement per delivery provided.
>
> **Incentives to health worker**: Providers receive a stipend per delivery (includes home deliveries as well) paid with the reimbursement to health facilities.

Public-Private Partnerships/blended financing. Blended financing is a term that refers to bringing together resources from philanthropists, governments and international institutions to strategically fund development programs. It helps attract investors to countries that struggle to find them, particularly in social sectors. In 2015, this mechanism helped raise $27 billion of private capital [46]. In 2018, The World Bank's IDA issued $1.5 billion bonds that generated an ordering demand for $ 4.6 billion [47]. These instruments can help attract philanthropists, medical devices manufacturers, social insurers and many other private actors, to fund targeted health areas. Health has attracted close to 30% of the capital mobilized [46].

There are different funding mechanisms to place resources mobilized, ensuring that financial allocation is related to program performance. Some of these results driven funding mechanisms include: Debt buy-downs, development impact bonds, impact investment funds and loan guarantees amongst others [48].

The role of NGOs. For decades, governments and development cooperation agencies have worked with NGOS to advance national social agendas. The role of NGOs as institutions that can effectively meet needs of underserved groups is well known. USAID has worked with NGOS all over the world to provide reproductive and maternal health services, helping these organizations to improve their technical and managerial capacity, preparing them to function after donor support ends. In countries like Bangladesh, NGOs provide approximately 10% of primary care services to the poor (including tubal ligation, circumcision, cesarean section and fistula surgery services).[21] These organizations are not just extensions of the public sector, but also an important source of innovation. Institutions like the Edna Adan Hospital in Somaliland helped to train nurses to manage obstetric fistula; or Profamilia in Colombia, trained nurses in IUD insertion, formerly consider a medical intervention in that country. These examples serve to

[21] Between 2008 and 2011, the author served as the Chief of Party of Smiling Sun in Bangladesh. This network of NGOs provided services to close to 15 million Bangladeshis.

visualize how innovation might just happen when resources (human, financial or physical) are rearranged to perform a function. In both cases, the solution addressed an issue of scarcity (not enough trained personnel) to provide quality care and at a much lower cost, which helped to expand access.

Private sector involvement. Private sector providers, funders and suppliers are central to achieve the objective of expanding access and improving quality surgical care in low-resource settings. In SSA 50% of healthcare services are provided by private providers, so most likely any solution must consider this formidable force.

Governments in Africa can work with development cooperation agencies to establish impact investment funds that provide financing to private providers interested in developing surgical facilities. Governments could also work simultaneously with local banks to create loan guarantees with multilateral agencies financing. These activities could even help to develop new financing mechanisms.

Private investors can join forces to set up transnational insurance schemes in sub regions in Africa (like in the East African Community) to take advantage of the larger aggregate demand to establish financially viable, cost-effective insurance schemes. Using instruments like impact bonds, local entrepreneurs can collaborate with PHIs companies in high-income countries to develop the technical capacity to provide innovative insurance products that can complement those of local governments.

More importantly, direct contributions to surgical service delivery have appeared in private institutions (for profit and non-profit alike) in low middle-income countries in different moments and in different surgical specialties. Profamilia in Colombia created a singular surgical ecosystem that helped scale up a surgical procedure that, because of high volumes achieved, resulted in better quality and lower costs. Aravind Eye Care in India scaled up eye surgeries, improved surgical procedures, reaching the poor in a low-middle income country. They developed a business model that invites emulation.

While obstacles are real, multiple individuals have shown that what we deem impossible is possible. The world has never been richer and interconnected than today. Putting together a clear vision. Leadership and decision, we can take advantage of current technological and financial innovations to pursue the objective to provide quality surgery to all, everywhere, and when needed.

4.6 The Ecosystem

The global surgery financial ecosystem Fig. 4.1 involves an array of players with coinciding and diverging interests, which have a common gravitating point around the patients they exist to serve (even if it is a fraction of the organization like ODA agencies and governments). The value exchange takes its real dimension when institutions involved deliver health, and in this particular case, health through surgery.

The graph below Fig. 4.1 depicts the transactional elements described in the previous sections, giving a sense of the systemic complexity, not just because of the variety of actors involved, but also because of the foundational elements that make service delivery an action that fulfills a right, or complies with the law of the land, while aiming to develop wellbeing and wealth. Solid arrows represent the flow of financial resources and their direction; dotted lines refer to the flow of surgical services and supplies. It also provide a sense of the role organizations play or can play in sharing resources and sparking economic exchanges that can result in viable, sustainable systems.

4.7 Conclusion

Expanding access to affordable, quality surgical care, to reach all in need is a complex, extremely difficult enterprise; but is not impossible. Perhaps for the first time in history, humanity has the knowledge, technical means, organizational and legal structures and financial resources that turn

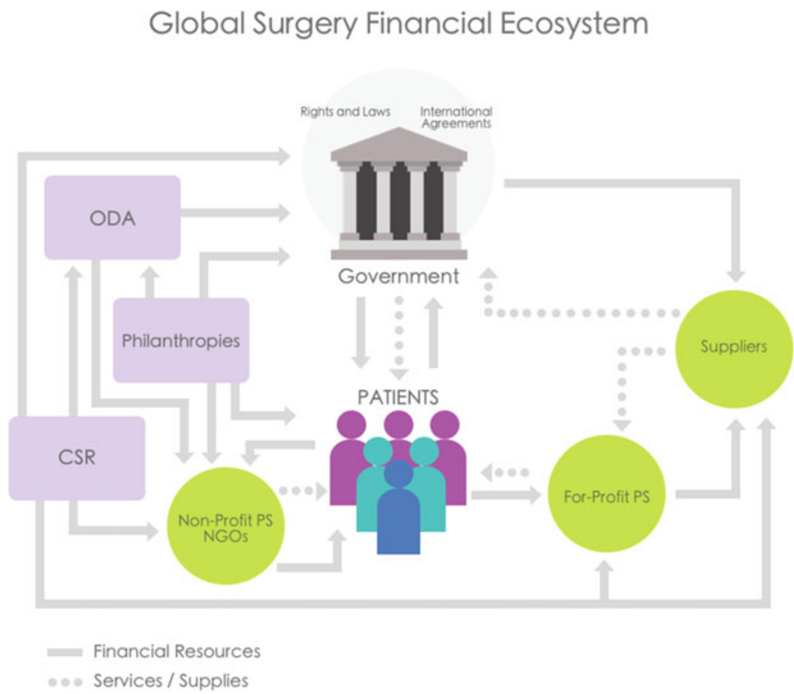

Fig. 4.1 Global surgery financial ecosystem

this idea into an attainable objective. Is not just the progress reflected in wealth in high-income countries that provides the example that it is possible? It is the multiple experiences of a myriad of interventions in low and middle-income countries that signal that it can be done, and should be done.

The increasingly pervasive inclusion of surgery in the country's definition of Universal Health Coverage packages is also a testament that the idea of globalized, universal access to surgery has left the expert's realm and is becoming a general public concern.

The debate if the surgery should be expanded through public or private means offers a false dichotomy, as societies are constructed through a myriad of pacts and societal contracts that responds to immediate and distant realities, to concrete axiologies and different belief structures. Low-income countries must harness resources (knowledge, capital, labor, etc.) from different sectors to be able to respond to the call and challenge of offering surgical care to all; it is also their responsibility. Governments, enterprises, foundations and individual philanthropists from high- and high-middle income countries can share their respective resources—including experience- with institutions in low-income countries, helping them find adequate responses to their challenges and obstacles in meeting people's surgical needs.

Stakeholders thrusting the idea of global surgery attainability are encouraged to find responses from the multiple lessons learned and the new ideas they can extract from combining experiences and having conversations that help create not one, but multiple pertinent paradigms. We must understand that solutions are general in concept but specific in context; we must be ready to get thousands of responses, all relevant in addressing the universal challenge we face.

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5

Leveraging Data Science for Global Surgery

Julian Euma Ishii-Rousseau, Shion Seino, Joanna Ashby, Leo Anthony Celi, and Kee B. Park

Abstract

Overview Starts

The opportunities of machine learning and AI applications for clinical care, especially for surgical applications have been well discussed, including system-wide approaches. However, in the context of low-resource settings, technology alone is not enough. What is the best way to leverage data science tools to improve healthcare access or strengthen surgical systems? What should practitioners do when data collection mechanisms are unavailable, and the discrepancy between the high-level, grassroots, and international coordination's prevent healthcare equity? Here, we provide the current status quo for global surgery and the opportunities for leveraging data science.

Overview Ends

Keywords

Global surgery · Low- to middle-income countries · Data science · Artificial intelligence · Machine learning · Interdependence · International coordination · Global health

5.1 Background

> All roads lead to universal health coverage, from emergency preparedness, to gender equality, to SDGs. [...] Surgical capacity is an essential part of universal health coverage and our political commitment and programmes must reflect that.
> – WHO Director-General, Dr. Tedros Adhanom Ghebreyesus [23].

Surgical conditions consisting of communicable and non-communicable diseases account for

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_5

approximately 30% of the global burden of disease [56]. Injuries alone are the cause of approximately 6 million deaths per year, which is higher than the total of all deaths from HIV/AIDS, malaria, and tuberculosis [68]. The majority of deaths from injuries occur in low- to middle-income countries (LMICs), where it is estimated that only 3–5% of all surgical operations take place [62],current estimates suggest that 5 billion people worldwide lack access to safe, affordable surgical and anaesthesia care [46].

According to researchers and experts, provision of basic surgical care could lead to the prevention of 1–5 million deaths per year, which includes 6–7% of all deaths in LMICs [41]. However, many knowledge gaps remain in the nascent field of global surgery,currently only a little over 4% of all global health research activity is related to surgery, and of all surgical research worldwide, only 4.3% is relevant to LMICs and underserved populations [46]. This has led to inaccurate assumptions regarding the provision of surgery, making it a neglected topic among other global health interventions [41]. Yet, recent trends in data accumulation and emerging technologies in health settings have opened new avenues in improving access to health and surgical care with particular opportunities for LMICs to leapfrog past developed nations. This chapter aims to explore how data science could be leveraged to improve capacity building, research, and education within the complex field of global surgery, and what the future holds for AI-based solutions.

5.2 Global Health and Global Surgery

> Global Health is about equity. It's about realizing fairer societies. It's about realizing the right to health. It's about science and using science as an instrument for political and social change.
> —Richard Horton, Editor in Chief of The Lancet

> Surgery is an indivisible, indispensable part of health care. I urge you to challenge this injustice, and to build a shared vision and strategy for global equity in essential surgical care.
> —Jim Yong Kim, 12th President of the World Bank

Global health is the area of study, research and practice that prioritizes health equity for all [32]. The field has also been described as a collection of known problems, rather than a full discipline [20]. Global health is derived from public health and international health, and uses elements of both, with a particular emphasis on ensuring worldwide health equity while rendering national borders irrelevant as disease knows no borders [59]. Within global health, global surgery refers to the field that aims to assess, understand, and improve surgical access within certain geographical boundaries, particularly within LMICs that have the greatest inequity in surgical access [16].

Surgery is essential for health equity, but is considered the "neglected stepchild of global health" [19], as 5 billion people a year do not have access to basic surgical, obstetrics, and anesthetics care worldwide [41]. Diseases treatable by surgery tend to cause a substantial amount of morbidities and deaths worldwide, especially among low-income communities due to the lack of surgical access [18]. Specifically, low-income communities tend to be at greater risk of certain diseases such as injuries, infections, noncommunicable diseases, and malignancies attributed to health access barriers such as physical distance and financial cost [41]. Experts estimate that the lack of surgical care access will cause millions of preventable deaths and disability to persist, and a decrease in the gross domestic product of LMICs by as much at 2.0% by 2030 [3]. The phenomena can be explained by the "health-poverty trap" coined by Dr. Jeffrey Sachs,citizens in LMICs that lack access to surgery and health tend to be pushed into a negative feedback loop limiting their ability to work, reducing economic opportunities, inhibiting educational attainment, and increasing medical debts [18]. The Lancet Commission on Global Surgery (LCoGS) has made similar predictions on the "crippling" effect that the lack of surgical access will have on LMIC governments and economies aiming to escape instability [41].

There are several reasons behind why this situation persisted. First, since the Alma Ata Declaration [66], global health priorities were placed on "cost-effective" solutions [18, 41]. This led to an early emphasis on areas such as communicable disease that permitted measurable health interventions (e.g. oral rehydration solutions, immunizations) to outcome (e.g. mortality) processes. Thus complex areas such as surgical care and disease burdens related to surgical negligence were sidelined as the prioritization of interventions such as vaccines were considered to be more cost-effective [41]. Recent studies have suggested that current global health priorities are no more cost-effective than surgery [12]. Moreover, although the initial investment for the total costs of expanding surgical services by 2030 is estimated to be up to $420 billion in LMICs [17], without this investment, the LCoGS estimated that "surgical conditions will be responsible for a cumulative loss to the global economy of $20.7 trillion or 1.3% of projected economic output between 2015 and 2030" [41, 42]. Second, surgeons tend to be concentrated in urban areas, and are almost non-existent in rural areas in LMICs [5]. Such "rural deprivation" has been commonly left out of current indices and measuring tools, leading to delayed delivery of surgical care in these areas [15]. Third, surgery tends to be a multifaceted intervention requiring various types of human resources, infrastructure, and equipment, making it a complicated challenge to measure, provide, and maintain high-quality surgical care in resource poor settings [18].

5.3 The Necessity of Data-Driven Strategies

Across the globe, copious amounts of health data are being collected through the likes of electronic health records (EHRs), wearables, and disease repositories [27]. Experts estimate that there could be as much as 2314 exabytes of new health data generated in 2020, a high surge from the 150 + exabytes collected in 2013 [43]. Despite this massive increase in medical data availability, the emphasis for data collection, curation, analysis, interpretation, and application has seen little progress [71]. Clinical informatics, or the clinical specialty that integrates clinical, health systems with information and communication technology expertise for the purposes of enhancing patient and population health, can be transformational with adequate governance, especially in LMICs [21]. At the patient level, the data accumulated can inform and improve decisions about health, wellness, and treatments. In a larger community or national level, health data can inform and facilitate innovation that lead to better quality of care, hospital efficiency, and outcomes for both individuals as well as population groups, usually contributing to an overall reduction in healthcare costs [27]. Global health informatics transcends institution or national-level health systems, and is the "the interdisciplinary study of the design, development, adoption and application of IT-based innovations in healthcare services delivery, management, and planning" [49]. The typical areas for data collection and types are through the use of electronic health records (EHRs), telehealth systems, mobile health systems, research translational systems, and healthcare professional training programs [39].

However, despite recent trends in data collection, there is a scarcity of academic literature and research regarding surgical care and workforce within the discussion of health access and quality of care [26]. Indicators determined by international organizations and development agencies have yet to include surgical workforce data as vital components of a comprehensive health system [67, 70]. This lack of information has made it difficult for the global community to understand both the consequences of a global surgical workforce crisis as well as the opportunities that lie in securing basic surgical care worldwide. Yet individual research has already shown the potential that lies in elucidating the field of global surgery. Chang et al. demonstrated that high surgeon density correlated with decreased mortality from vehicle accidents within rural areas in the US [11], and Adegoke et al. determined that the presence of trained birth attendants could lead to the reduction in maternal mortality [1].

5.4 Challenges of Data Collection in LMICs

While quality health data is fundamental in ensuring evidence-based decision making and policy implementation for improving health care delivery, root causes of health issues are difficult to pinpoint in LMICs due to poor data collection and governance [45, 71]. Statisticians or epidemiologists that are often critical for clinical informatics [52], are not priority recruits at hospitals as well as public health sectors in LMICs [47]. In addition, the lack of a centralized health data system has made data utilization difficult apart from census record keeping [47]. Furthermore, health systems in LMICs also tend to use paper-based systems that are decentralized, especially at the primary health care level [34]. At district levels, data is at times compiled on computer-based systems, yet many still also rely on paper-based systems for information curation, some even hand-written [24, 25].

While computer-based systems have been adopted on the national level in some LMICs, it has been a challenge to archive data without a standardized approach or effective governance at the hospital and district levels [45]. In a study conducted in 2013, zero LMICs reported data completeness (measurement of missing data within a health registry) of over 50% [45]. Several data collection challenges are described in Table 5.1 from the hospital, district, and national levels.

The aforementioned factors can greatly hinder data collection, management, analysis, and interpretation on all levels within a health system [28]. Further, although the national-statistics driven World Health Organization (WHO) [14] and data-plurality based Institute for Health Metrics and Evaluation [9], provide national-level and regional-level data, much of the data is not open source or peer reviewed [36]. Open and granular data sets such as MIMIC-III [31] and MIMIC-IV [30] should be the gold standard as it permits inter-institutional machine-learning based analyses and comparisons, providing extensive and clinical insights [8, 44]. Raw data from hospital and district levels is essential in making detailed national assessments, especially to improve surgical capacity and accessibility [46]. Transparency of data and assumptions for models is essential as its scrutiny is the foundation for metric accountability and trust [36]. However, this requires careful collection of institution-level data, which demands tremendous cost. To ensure replicability, and generalizability, LMICs are faced with facility-level collection of data for each district to enhance resource allocation in a financially appropriate manner [45].

To combat these challenges in LMICs, the creation and implementation of health

Table 5.1 Data collection challenges in LMICs

Level	Challenges
Hospital	• Wide spread use of handwritten and paper-based systems [45] • Inconsistencies across hospitals in types of data accumulated [45] • Shortage of hospital staff that are trained in data collection, maintenance, curation, and application [4]
District/regional	• Shifting from paper-based to computer-based systems [45] • Need for guidelines and protocol for improved information security, collection, curation, and pplication [4, 45] • Necessity to tackle excessive missing data to elucidate health issues and needs [45]
National	• Shortage of human resources as well as equipment and systems for health information curation and management [69] • Shortage of funding for sustainable technology implementation and rearing of more clinical informaticians for evidence-based national level health interventions and policy enactment [33, 45]

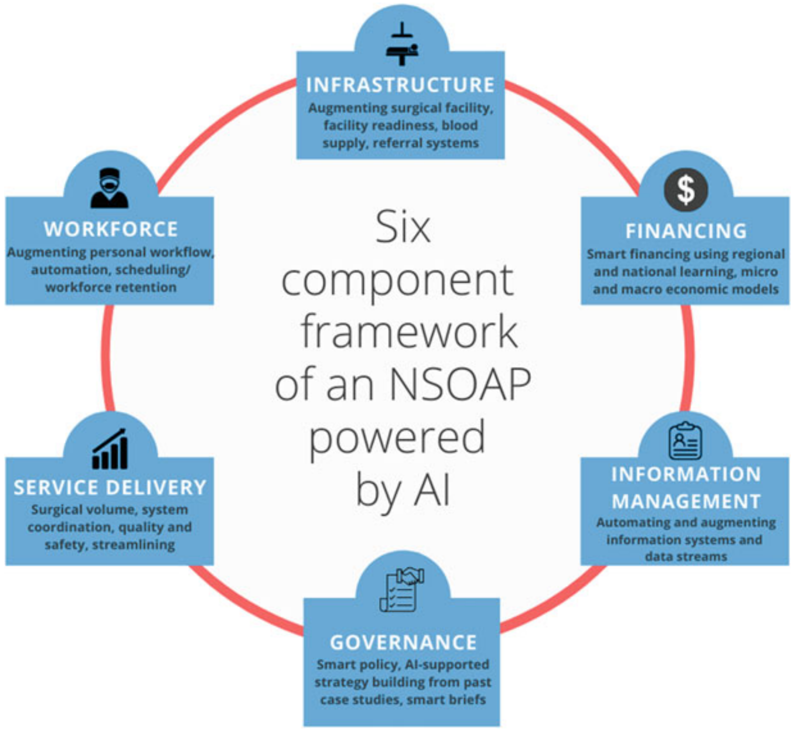

Fig. 5.1 Six component framework of a National Surgical Obstetric and Anesthesia Plan (NSOAP) [58] powered by AI

information management systems are essential [10]. These systems must support the process of health information data collection and utilization as well as a structure to operate and manage a health information system [45]. They also require a multifaceted and collaborative approach for policy based on, on the ground data collected from a district level, and to enhance evidence based healthcare policy and appropriate resource distribution [10, 45].

National health plans for surgery must be carefully planned as they require overall health systems strengthening through provision of infrastructure, well-trained and well-distributed workforce, efficient service delivery, integrated information management, quality assurance, and adequate financing and governance [41, 42]. Although surgical disease burden remains high, many national health plans do not have a surgery capacity plan [13]. To solve this issue, the Lancet Commission on Global Surgery (LCoGS) introduced a framework for national surgical, obstetric and anesthesia planning (NSOAP) (Fig. 5.1) [41, 42], a systematic surgical system strengthening protocol consisting of three domains and six indicators: infrastructure, service delivery, surgical workforce, information management, financing, and governance (Table 5.2) [57]. The NSOAP framework also provides a template "for strategic planning in developing policy plans including defining the current gaps in surgical care access and delivery, prioritizing solutions and setting targets, and providing a cost implementation framework together with a monitoring and evaluation plan" [57].

5.5 Opportunities for Technology and Data Science Approaches in LMICs

Although concerns regarding the quality of data, inadequate communication technology, human expertise, and financial resources have hindered the progress of implementing such systems, recent studies have shown that the application of technology could improve both the quality and the use of health data in LMICs [45, 64]. The

Table 5.2 The six LCoGS indicators for surgical system evaluation [58]

Domain	Indicator	Definition	2030 target
Preparedness	Access to timely and essential surgery	Proportion of population that can access a facility that can conduct bellwether procedures[a]	80% of each country's population has access to essential surgical and anaesthesia care
	Specialist surgical workforce density	Number of specialist surgical, anaesthetic, and obstetric physicians (SAO) per 100,000 population	All countries have a minimum of 20 surgical, anaesthetic, and obstetric physicians per 100,000 population
Service delivery	Surgical volume	Number of surgical procedures conducted per 100,000 population	All countries track surgical volume, with a minimum of 5000 procedures per 100,000 population
	Perioperative mortality rate	Percentage of all-cause mortality before discharge among patients that have undergone a surgical procedure within all surgical procedures conducted	All countries tracking perioperative mortality rates (national targets to be determined in 2020)
Financial risk	Protection against impoverishing expenditure[b]	Proportion of households that are protected from impoverishment due to direct out-of-pocket payment for surgical and anesthetic care	All households protected against impoverishment due to direct out-of-pocket payment
	Protection against catastrophic expenditure[c]	Proportion of households that are protected from catastrophic expenditure due to direct out-of-pocket payment for surgical and anesthetic care	All households protected against catastrophic expenditure due to direct out-of-pocket payment

[a]Bellwether procedures include caesarean delivery, laparotomy, and treatment of open fractures
[b]Impoverishing expenditure is defined as being pushed into poverty or being pushed further into poverty by out-of-pocket payments [35]
[c]Catastrophic expenditure is defined as the direct out-of-pocket payment >40% of household income net of subsistence needs [35]

benefits for digitizing health systems include improved patient follow up in remote areas, increased user satisfaction, better adherences to data quality management standards, efficient management of health facilities and health programs [45]. With the introduction of systematic, low-cost, and mobile-based technologies, LMICs have a particular opportunity to implement digitized systems at both regional and national level. Global stakeholders such as the WHO and the Centers for Disease Control and Prevention (CDC) have provided guidelines and suggestions for better health information management, and have outlined the opportunities in LMICs with the "leapfrogging" of intermediate development phases that occur and is met with challenges in disjointed high-income countries [71]. The increasing penetration of mobile phones in LMICs over the past two decades have given rise to countless ehealth/mhealth solutions, promoting effective health information exchange. Global health experts have also begun outlining practical approaches for digital transformations at local, national, and international levels [38].

Nationwide information management systems can be financially expensive initially, and difficult to execute in a timely manner [61], however the effects for reducing the burden on health centers and municipalities are extraordinary [10]. New technology-based interventions have permitted the introduction of telemedicine as well as innovative resource allocation through the adoption of drone delivery systems in some LMICs. These interventions have supported the lack of specialist surgical, anaesthetic, and obstetric physicians (SAO) in rural areas, and have contributed to the prevention of diseases from epilepsy to cervical cancer [65]. In Rwanda, the government has partnered with Zipline, a US-based drone startup to shorten the delivery of blood,in Kigali, the capital city, blood delivery from central blood banks to hospitals have been shortened from three hours to merely 15 min [6]. In South Africa, the Bill & Melinda Gates Foundation have funded the development of an iris identification method that integrates block-chain and biometrics to ensure privacy and security of HIV patients [7]. Similar projects are being developed at a global level, such as a fingerprint authentication tool for community healthcare workers created by NEC, Simprints, and Gavi [22]. The technology permits real-time data collection, which provides opportunities for transparent and evidence-based policy recommendations and implementations in a just and appropriate manner. Implementation of data science approaches can accelerate the introduction and adoption of these technologies, and improve the entire patient journey, as seen with initiatives by Sana, a multidisciplinary team of Harvard and MIT trained clinicians, engineers, public health experts, and researchers working to adapt and open-source the latest technologies to build sustainable and practical solutions to global health challenges [37, 54].

Case Study Starts

Case Study: Nepal

A country that initiates a nationwide surgical system strengthening project can serve as a valuable resource for data science and AI approaches as it can serve as a robust ground truth for determining local to national health center capacity and access to health indicators in impoverished areas. In the future, its integration with electronic health-level granular data permits nation-wide AI application for public and clinical health. The Harvard Program for Global Surgery and Social Change has developed an eight point process in creating an NSOAP (Program in Global Surgery and Social Change [50]; (1) Ministry support and ownership, (2) Situation analysis and baseline assessment, (3) Stakeholder engagement and priority setting, (4) Drafting and validation, (5) Monitoring and evaluation, (6) Costing, (7) Governance, and (8) Implementation.

In 2019, Nepal became one the first countries in Asia for preliminary research in drafting an NSOAP for national surgical capacity expansion, especially in its rural areas. The Nick Simons Institute (NSI), a Nepal-based organization whose mission is to innovate solutions in rural health care, had been seeking ways to realize and expand surgical capacity in rural areas in Nepal, and joined the National Surgical, Obstetrics, and Anesthesia Planning Conference in Dubai, UAE on March 20–21, 2019 [51] with representatives from the Nepali Ministry of Health as well as medical professionals from national hospitals in Nepal. Lack of surgical access outside of Nepal's capital, Kathmandu, has been a longstanding problem, especially due to the shortage of SAOs. In 2016, the Nepal Health Research Council and the NSI conducted a systematic, site-based study of 39 hospitals in 25 rural districts [53]. While 95% of the hospitals were performing surgeries, there were only 387 operations per 100,000 population, which is far below the Lancet target of 5,000 operations per 100,000 population [53]. Caesarean sections were performed at 69% of the hospitals, accounting for 5% of all operations [53]. Only 17 SAOs were found over the 25 districts, contributing to a severely low density of 0.4 SAO/100,000 citizens, once again well lower than the Lancet target of 20 SAO/100,000 [53].

Regardless of the aforementioned environment, Nepal has a unique opportunity in implementing a data-driven infrastructure for surgical system strengthening. The inception of a centralized database can provide a benchmark for tracking and monitoring populations, while also pool valuable evidence to inform health campaign coverage strategies and policy interventions. A holistic approach for the collection, analysis, and interpretation of patient socio-demographic and health data via the integration of government identification with biometrics [7] and geographic information system (GIS) spatial analysis technologies linked to a secure medical communication platform for healthcare professionals is a proposed solution to realize this. The database will store relevant patient information in a centralized cloud database to continually monitor and optimize current healthcare and implementation programs and ensure appropriate and evidence-based policy. A de-identified version of the database could be created for needs-based services as well as research and development (R&D), while a secure version would be available to all healthcare professionals at various health posts throughout the nation. In addition, a biometrics-based (facial and/or iris) identification (ID) system that integrates government ID to health and geographic information system (GIS) data. Digitized documentation can be created to include offline capabilities, where district health and socio-demographic data can be uploaded to a centralized cloud database upon internet access. The system could also be linked to a secure medical communication smartphone application for collaboration between healthcare professionals, and deposit patient information to a centralized cloud repository. Furthermore, Nepal has a particular opportunity as it recently started distributing its biometric (fingerprint) national ID card while gathering socio-demographic data. Through multidisciplinary collaboration, resource allocation and data generation can be optimized to promote effective evidence-based policies and health interventions (Fig. 5.2).

If Nepal can implement such infrastructure, future aims would be to implement the strategy across other nations, while also working to realize the following essential elements based on evidence-based recommendations; clinical specialization and collaboration, comprehensive and standardized triage, transparent sharing culture for best practices, telemedicine, continuous public health surveillance, and provision of universal healthcare coverage permitting medical access and screenings. By increasing local partner networks to address further clinical challenges specific to the nation, such as a drone-based blood and drug delivery intervention to solve their 'walking blood' issue [55], national surgical system strengthening which is essential in realizing Nepal's universal healthcare access.

Case Study Ends

5.6 Future Possibilities with AI

The big data era is said to be a significant milestone in the field of global health and global surgery [37, 55]. Although there are risks associated with increasing the amount of data accumulated in health settings, the process from data collection, curation, to analysis will enhance our understanding of clinical and public health challenges allowing for improvements in individual and population-level healthcare management [2].

Big data in surgery can support the discovery of ground truths and gold standards in surgical practices, which have opportunities for effective AI applications. With this, we can expect the following areas for "augmented surgery"; (1) decision support, (2) autonomous assistance, (3) education and training, (4) resource allocation optimization, and (5) innovation (Table 5.3) [37]. Experts have seen information technologies to enhance and complement human knowledge and decision making skills rather than a tool that can substitute human resources,not only will this alleviate workload but also increase accuracy in clinical prognosis, diagnostics, and resource

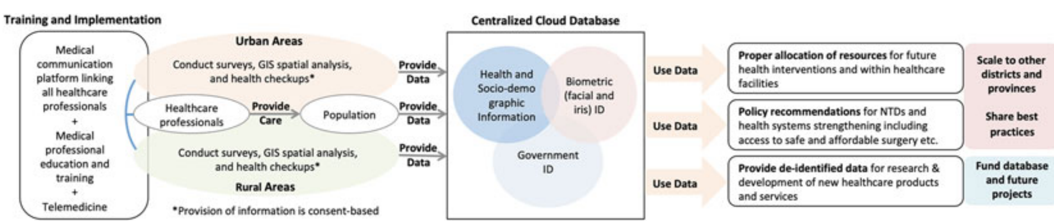

Fig. 5.2 Multidisciplinary collaboration to achieve a data-driven infrastructure for surgical system strengthening

Table 5.3 Opportunities in data science approaches in surgery

Area	Opportunities
Decision support	Predictive analytics including patient-specific simulations based on systematic data collection and curation [37]
Autonomous assistance	Increasing safety, quality, timeliness, and efficiency of care through autonomous assistance in scheduling, resource assessment, and monitoring of patient health [37]
Education and training	Discover ground truths about the challenges in surgical settings, and implement computer based training and skill evaluations to support patient and context-specific simulations, surgical coaching, and error detection [37, 63]
Resource allocation optimization	Pattern analysis of surgical resource needs can aid staff allocation, emergency response, and overall preparation [60]
Innovation	Better understanding of gaps in surgical provision can lead to the creation of improved equipment, occupations, and systems [40]

distribution [2, 48]. Furthermore, clarifying the costs associated with surgical access or lack thereof through data-driven approaches, can support advocacy efforts for global surgery in a world where "cost-effectiveness" has preceded all other tools, frameworks, and approaches [18].

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6 Global Surgery Innovation at Academic Medical Centers: Developing a Successful Innovation Ecosystem

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Abstract

Innovations in global surgery require creative and highly skilled multidisciplinary teams in order to succeed. Academic medical centers can be ideal institutions to support global surgery innovation, but leaders at these centers must intentionally develop supportive innovation ecosystems. In this chapter, key components of these ecosystems will be discussed with a focus on centers for medical innovation at academic medical centers.

Keywords

Innovation · Frugal innovation · Innovation ecosystem · Global surgery · Cardiac surgery · Global health

6.1 Introduction

Academic medical centers (AMCs) in the United States have increasingly recognized global surgery as an area for research and academic advancement. Many Centers for Medical Innovation (CMIs) at these universities support projects focused on improving care in limited resource environments. In this chapter, we will first introduce the broad topic of medical innovation and define a few terms that are important in the context of global surgery innovation including: frugal innovation, reverse innovation, disruptive innovation, and leapfrogging. Next, we will discuss the innovation ecosystem, detail essential components of CMIs, and explain how AMCs can be ideal hubs for global surgery innovation. Last, we will discuss the challenges of manufacturing and implementation with device innovation, and explain how CMIs at AMCs can aid innovators through these steps. Throughout the chapter, several examples of successful innovation projects and programs will be highlighted with a focus on innovation within global cardiac surgery.

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_6

6.2 Global Cardiac Surgery and the Need for Medical Innovation

The field of cardiac surgery has a rich history of surgical innovation. Device innovation has brought the incredible advancements of the heart-lung bypass machine [26], mechanical heart valves [21], drug-eluting coronary stents [28], pacemakers [58], and ventricular assist devices [46] just to name a few. Procedural innovation has enabled coronary artery bypass grafting, heart transplantation, ablation of arrhythmias, and minimally invasive approaches to aortic valve replacement [6]. Unfortunately, these remarkable innovations have not reached the globe in an equitable manner, and large disparities in access to cardiac surgery exist in rural and limited resource settings, especially due to lack of program innovations. For example, in high-income countries (HICs) there are 7.15 adult cardiac surgeons per 1 million population compared to only about 0.04 per million in low- and middle-income countries (LMICs). In addition, availability of other healthcare workers who are instrumental in delivering cardiac surgical care such as perfusionists, anesthesiologists, cardiac nurses, and intensive care providers is limited. Access to medical devices is also a challenge in many LMICs with some facilities having to rely on donations from facilities in HIC leading to an inconsistent supply of occasionally damaged or expired products [57]. Although the history of cardiac surgery innovation has not been inclusive of LMICs, a variety of innovation frameworks can be applied to address many of these disparities. Novel educational opportunities can help remedy workforce shortages, product innovation focused on frugality can create access to equipment and consumables for cardiac surgery, and process innovations to streamline care can make cardiac surgery more feasible with limited resources. All of these can be spurred by Academic Medical Centers and Centers of Medical Innovation in collaboration with global partners.

6.3 Medical Innovation in Limited Resource Settings—An Overview of Relevant Terminology

Medical innovation aims to develop creative solutions for challenges within the healthcare field. It can take many forms including development of new medications, design of medical devices and mobile health (mHealth) applications, creation of medical education systems, and improvement of existing processes for the way we deliver care [8, 23]. These solutions can be organized into three main "types": (1) products, (2) processes, and (3) education and credentialing (Table 6.1). Each type comes with its own potential pitfalls as well as specific benefits. In HICs, medical innovation is often synonymous with high costs and a focus on breakthrough therapies and technology. In the US for example, the estimated capitalized cost for the product and development lifecycle of a single new pharmaceutical drug is estimated to be around $2.87 billion dollars [15]. In the surgical realm, The da Vinci robotic system, which is arguably one of the most lauded medical device innovations of the last generation, costs a hospital millions of dollars in startup and maintenance costs [37] leaving some critics to argue its value even in high resource environments [13, 17].

In LMICs, this model of high cost innovation is not always feasible and may not present worthwhile tradeoffs. The concept of developing creative solutions for problems using limited resources is hardly novel [2], but after a 2010 article in "The Economist," which highlighted pared-down, cheaper, and highly effective Indian and Chinese innovations that have excelled, the term "frugal innovation" gained popularity as a way to describe products and processes that are designed for, or with, constrained resources [47]. Frugal innovation has subsequently been defined to include "substantial cost reduction, concentration on core functionalities, and optimised performance level" [59]. In short—accomplishing more with less.

Table 6.1 Medical innovation

Types of innovation	Products	Care process	Education and credentialing
	Medications, devices, and digital health products	Streamlining care, standardizing care, or implementing changes to create healthcare systems that are safe, efficient, and high quality	Developing or improving education systems and changing credential practices to increase the healthcare workforce
Examples	• Surgical devices • Mobile phone apps • Telehealth systems • Personal protective equipment	• Universal surgical safety checklists • Hospital protocols • Quality Improvement models • Systems to reduce waste	• Establishment of a cardiac surgery residency in an underserved area • Rural health-worker training to expand skill level • Credentialing mid-level providers to do minor procedures
Potential Benefits	• Provides tangible solutions to specific healthcare problems • Frugal solutions can expand care to previously unreached populations • Local production may boost the economy	• Typically less expensive than product innovation • Fewer regulatory barriers • Improves value and quality of care • Empowers communities to identify and make changes specific to their healthcare system	• Improves access to care for underserved populations • Can be broad and transferable across different systems or populations • Expands training opportunities for healthcare workers
Potential Barriers	• Requires resources long term for manufacturing and distribution • Must have a plan to appropriately navigate egulations or liability • Need for a viable business or financial model for long term sustainability	• Relies upon cultural shifts and community engagement • Changes in care process can be prolonged and slow to see true results or impact on patient care	• Requires infrastructure to enable education or skills training along with community buy-in • Must have a process to evaluate knowledge and skills acquisition to ensure safety • May require changes to local regulations of who can provide care
How can an academic medical center ecosystem mitigate these?	• Facilitate collaboration across different disciplines – from financial and regulatory to creative or engineering—to allow for the most efficient, ethical and impactful productions	• Foster cultural commitment by developing long term relationships based on mutual gain • Establish means to demonstrate effectiveness and impact of process innovation	• Promote long term education programs with established curriculums • Can provide coaching and education to future educators

Often discussed in tandem with frugal innovation is "reverse innovation", which in the context of healthcare implies harnessing an innovation developed in a LMIC for use in another setting, typically a HIC [24]. The term has been criticized because it implies the natural flow of information and innovation is from a HIC to a LMIC. Some authors argue that "shared innovation" is a more appropriate term [39]. In spite of this controversy, the concept of reverse innovation is now commonplace. An example of a process-focused frugal innovation that led to changes in HIC practice is Narayana Health (NH). Dr. Devi Prasad Shetty founded the initial NH Hospital in Bangalore, Karnataka, India in 2001 with the goal of making cardiac surgery more accessible to all populations. NH's model of containing costs while maintaining excellent outcomes has been highly successful and is ensured through numerous methods including supply chain optimization, waste reduction, and task shifting. The average cost of open heart surgery at NH is around $2,000 compared to $100,000 at a research hospital in the US and clinical outcomes are comparable [22, 44].

Inspired by NH's success in India, the Cayman Islands government and the US based not-for-profit health system, Ascension Health partnered with NH to bring this model of care to the Cayman Islands [48]. The Cayman Islands are a British overseas territory, and a HIC setting with a gross national income per capita of $41,790 [49, 50]. Numerous health regulations, laws, and challenges to cultural norms had to be addressed, but the Health City Cayman Islands (HCCI) project succeeded. A combination of several interventions led to significant cost savings including efficient planning of windows and ventilation in the hospital to minimize operational costs, utilization of medication and medical device suppliers in India to supply the hospital at a fraction of US costs, and sustainable practices such as making their own medical oxygen and by having a solar farm [22]. HCCI earned the "Gold Seal of Approval" from Joint Commission International in 2015 and to this day provides a wide range of services including cardiac, orthopedic, and bariatric surgery at 25–40% of the cost of equivalent care in the US (Health City Cayman Islands; [22]. This example highlights that reverse innovation is a process requiring adaptation to realize success in a new environment [22, 33, 44].

Two evolving concepts that are relevant to global surgery innovation are "disruptive innovation" and "leapfrogging". Disruptive innovation is a process of how "complicated, expensive products and services are eventually converted into simpler, affordable ones" [27]. Disruptive innovations target two specific markets—"low-end" customers who are seeking simplified and more affordable products, and new markets of individuals who were previously non-consumers [12]. These markets are often descriptive of LMICs, so many global surgery innovations are considered disruptive.

Leapfrogging is a concept often intertwined with disruptive innovation, especially in LMICs. Leapfrogging describes a process where previously compulsory steps in development of technology in one environment are able to be omitted [5]. As explained in the World Economic Forum white paper, "For emerging economies, the most valuable use of leapfrogging is not just to catch up with developed economies—but to use innovation that allows them to take a shortcut in reaching a more advanced development stage without accumulating inefficiencies along the way. Trailing behind can be turned into an advantage" [5]. The company Zipline provides an excellent example of leapfrogging. Using drone delivery, Zipline has improved access to blood products, cold chain products such as vaccines, and emergency medications in sub-Saharan Africa. Drone-based delivery has eliminated the need for hospitals to maintain their own blood banks and vast medication supply by centralizing the storage and supply of these products [41]. This technology was not available in the US until recently when it has now been used to provide medications and personal protective equipment directly to patients' homes [41, 7].

6.4 Centers for Medical Innovation at Academic Medical Centers and Innovation Ecosystems

Innovation is a complex process that depends upon effective multidisciplinary teams. Furthermore, the environment, or ecosystem that a project development team works within may have a significant impact on the success or failure of a project. As illustrated in the "Aligned Stakeholders" section of Fig. 6.1, healthcare innovation involves several groups including non-profit organizations, start ups, researchers/academics, and there is overlap across these sectors. AMCs naturally consist of many of the essential components of an innovation development ecosystem which explains why CMIs at AMCs can be ideal hubs to support global surgery innovation.

In business, an "innovation ecosystem" is "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" [1]. Collaboration enables teams to accomplish things that would not be otherwise possible if working independently. The organization Cambia Grove has developed a framework to describe the three key elements for a successful development

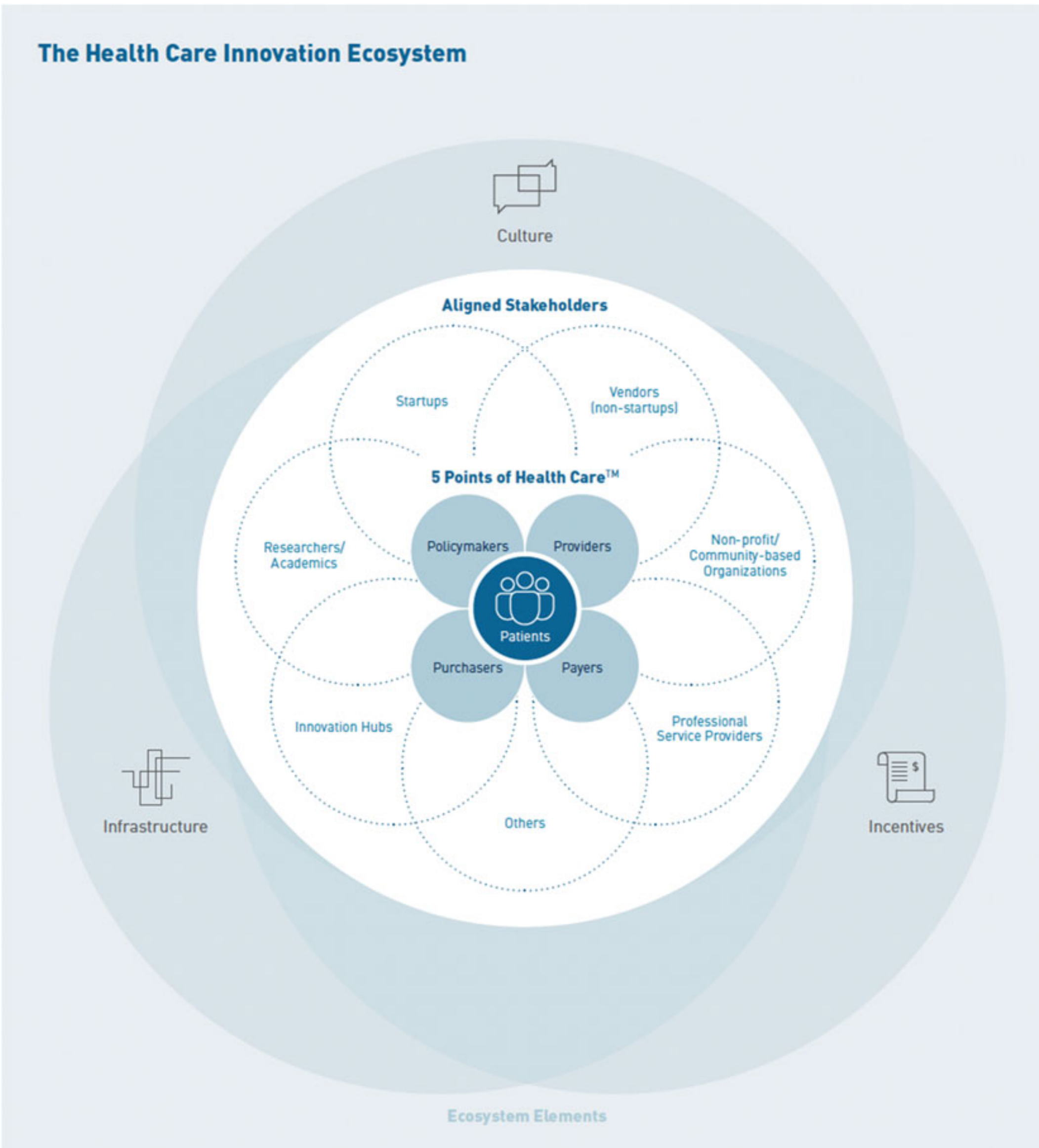

Fig. 6.1 The innovation ecosystem is driven by three main elements: culture, infrastructure, and incentives. The key actors in the ecosystem consist of several stakeholders including policymakers, providers, purchasers, and payers. Patients are at the center and are the focus of the ecosystem. *Shared with permission from Cambia Health Solutions, Inc*

ecosystem: infrastructure, incentives, and culture (Fig. 6.1). These elements support and drive all other aspects of the ecosystem. As we discuss specific components of the innovation ecosystem at an AMC, we will refer to these key elements and discuss their relevance to global surgery innovation.

6.4.1 Trainees and Training Programs

Students and trainees provide a unique and vital component of the innovation ecosystem at an AMC CMI. Although students and trainees may not be skilled in the technical aspects related to development and implementation of an innovation, they are often integral to ideation. Academic institutions often create a culture that supports innovation teams to take risks and fail which allows students and new innovators to feel comfortable proposing creative solutions to problems. Gene Thompson, one of the Caymanian businessmen instrumental in bringing the NH model to the Cayman Islands, emphasized this when saying, “Ignorance is empowerment. We knew no boundaries, limits, barriers; we only saw opportunities” [44]. At the University of Utah, the student-driven Bench-2-Bedside program has been widely successful over the last decade and has grown to include many international partners (Fig. 6.2). This state-wide, intra-university competition is a longitudinal program focused on collaboration between students in various degree programs including engineering, health sciences, law, and finance. Students go through a process of various seminars, form teams based on a problem identified by clinical faculty, design an innovation, pitch it, and create a plan to advance it. This has led to the development of over 100 patents and several small business start-ups across a variety of healthcare fields, including global surgery. Many participants in the University of Utah’s innovation programs have also been involved with and received support from the National Science Foundation’s Innovation Corps (NSF I-Corps) (Fig. 6.2). Increased interest in global health has led to international partnerships—such as Ghana, Nepal, Kenya and plans for a sister innovation center at the University of Utah Asia Campus in South Korea.

Another unique feature supported by the interface of AMCs and a university is access to innovation and entrepreneurship related courses and degrees. Master’s degrees and seminars focused on medical innovation can help make the ecosystem of an AMC CMI productive. These programs typically bring together students and faculty from a wide range of backgrounds including medicine, engineering, business, and law. Because successful medical innovation requires an understanding of intellectual property (IP), regulations, manufacturing, distribution, and market analysis, formal programs engaging these diverse professionals foster innovation.

Formal education programs at AMCs bring together multidisciplinary teams and provide participants with the broad knowledge base necessary to develop successful innovations. Box 6.1 highlights the unique training programs available through the University of Utah Center for Medical Innovation.

Box 6.1: University of Utah Center for Medical Innovation -Fostering Innovation through Education and Collaboration

The University of Utah Center for Medical Innovation (CMI) is a multi-faceted ecosystem centered on student-driven innovations with faculty mentorship, multidisciplinary collaboration, and entrepreneurship. The center emphasizes a team-based approach to successful innovation, with support through the initial steps of defining a clinical problem to solution ideas to creating marketable innovations. Three platforms are core to the center:

1. Education: masters and undergraduate degree programs and certificates including a novel Master’s track in Global Health Innovation and

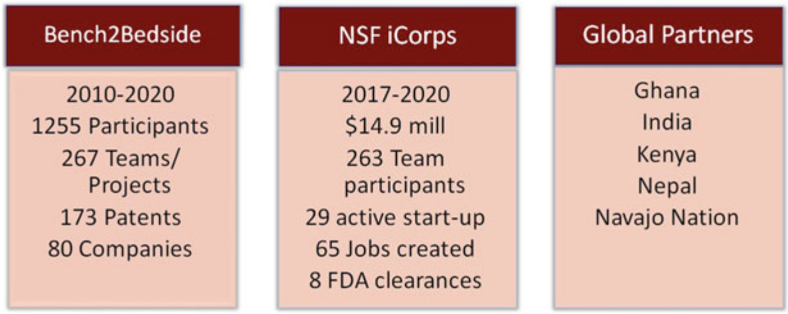

Fig. 6.2 Accomplishments of the University of Utah Bench to Bedside Program as of 2020

Technology based on the Bench-2-Bedside model (launching in 2022)

2. Development resources: technology and design incubator space with support from engineering colleagues as well as an ISO-13485 certified prototyping lab
3. Real-world application support: implementing technology advancements while navigating device testing, monetization, marketing and regulatory affairs consulting support.

6.4.2 Infrastructure

Physical spaces are critical to innovation. Space for innovators to interact with each other is an essential component of an innovation ecosystem. A supportive physical space houses equipment to develop and test prototypes and streamline the innovation process. These are often referred to as "makerspaces." A unique and valuable aspect of the Innovation Lab at The University of Utah's CMI is its ISO-13485 certification (Box 6.1) (Center for Medical Innovation). This international quality control standard is necessary for regulatory approval of medical devices, so the lab's certification eases the progression of a new medical device to market. Other important resources include a wide range of hand tools and measuring devices, 3-D printers, wet labs, machines for verification testing, and access to project software. In addition, many universities have veterinary and lab animal services that can serve as an excellent resource for innovators needing to arrange animal trials of medical devices. Box 6.2 highlights the company Strait Access Technologies and describes how the infrastructure at the University of Cape Town, South Africa supports the company.

Box 6.2: Strait Access Technologies Spin-off company from the University of Cape Town, South Africa

Arising out of the Division of Cardiothoracic (CT) Surgery at the University of Cape Town (UCT), South Africa, Strait Access Technologies (SAT) aims to develop cost-effective technologies to treat heart valve disease. They have a special focus on developing products to treat rheumatic heart disease in low-resource settings.

- **Founders**: Profs. Peter Zilla, David Williams, and Deon Bezuidenhout. Prof. Zilla is a CT surgeon and the Head of the Department of CT at UCT. All three founders are PhDs and experts in tissue engineering and biomaterials.
- **Evolution as a company**: Initially founded as a closed corporation (CC) in 2008 and converted to a private company (Pty Ltd) in 2009.
- **Major Funding**:
  – UCT continues to hold equity in the company since becoming a major shareholder in 2010.

- Technology Innovation Agency, a national public organization in South Africa that aims to support higher education innovations from proof of concept to pre-commercialization, provided initial major funding in 2011.
- Bidvest, a public company listed on the Johannesburg Stock Exchange, provided initial major funding in 2011 and additional second round of funding in 2014.

- **Support from UCT**: SAT is able to rent out and utilize the following resources and specialized technology at competitive rates through their continued support from UCT.
  - Offices, labs, and manufacturing space continues to be housed in the Cardiovascular Research Unit at UCT
  - Sophisticated manufacturing and durability testing equipment
  - Access to animal laboratories to conduct animal trials
  - Highly qualified surgical teams to test products

(Strait Access Technologies; Research Contracts and Innovation [38] 2011; Technology Innovation Agency 2019; [3, 56].

The innovation ecosystem infrastructure provides the technology and network capability to extend the physical environment as a virtual environment for access and connection to the diverse professionals and students within adjacent spaces. Even when not in the CMI, the interaction of professionals with diverse areas of expertise at the university can be the spark which can launch unique, unexpected partnerships (Dzau).

However, the physical location of innovation spaces can be a limiting factor, particularly for global surgery innovation where it excludes participation from international partners, which is unfortunately a recurring issue in the design conversation. Collaborative work spaces focused on teleconference and joint presentation are essential to facilitate regular communication between the teams. This can mitigate the risk of inadvertently excluding international partners outside of the university. Creating sister facilities, as the University of Utah is attempting to do both in Ghana and South Korea brings the resources to innovators as opposed to the other way around and may offer more chances for equitable, and not extractive, partnerships.

6.4.3 Partnerships

Perhaps the most important components of an innovation ecosystem are partnerships, both internal to and outside the university. AMCs are typically tertiary hospitals affiliated with a major university, which provides a rich supply of internal partners—colleges of medicine, veterinary medicine, education, engineering, business, law, etc., can collaborate together under the umbrella of the AMC CMI. Partnerships that extend beyond the university—across state, regulatory, financial, and industry partners are also essential for ultimate implementation and commercialization of innovative solutions. In addition, organizations with more geographically diverse networks and industry partners have higher research and innovation impact [20]. The partners engaging with CMI at the University of Utah are illustrated in Fig. 6.3.

The first and principal partner in global surgery innovation should be the community where the innovation will be implemented. As “academic global surgery” has developed into a recognized field throughout the early 2000 s [31], an increasing number of AMCs have established

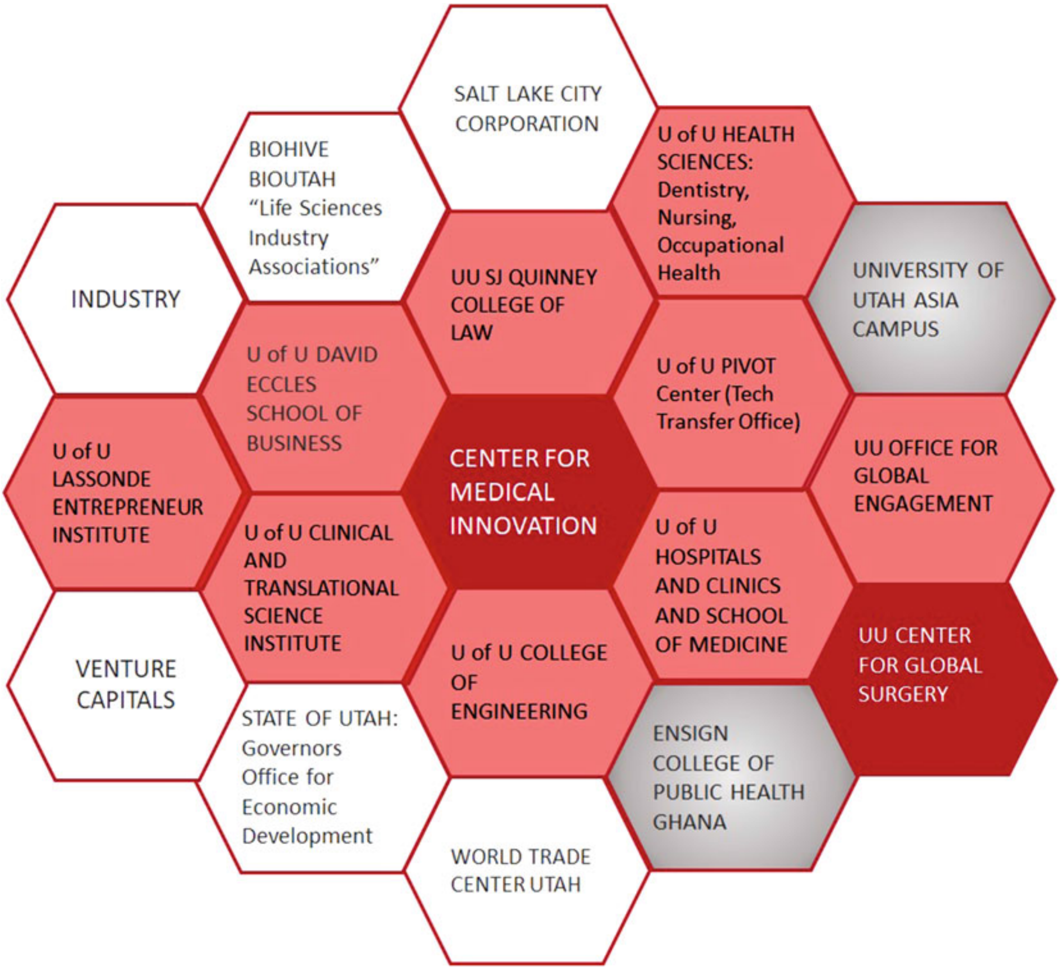

Fig. 6.3 Partnerships with the University of Utah CMI. Light red hexagons represent internal partners within the university, white hexagons represent public and private partnerships within the state of Utah, and grey hexagons represent international partners

relationships with institutions in LMICs. Existing global health partnerships can be the starting point for an innovation focused partnership. Successful collaboration between HIC and LMIC institutions requires careful planning and open communication to ensure ethical and sustainable relationships. The American Surgical Association Working Group for Global Surgery describes the "characteristics of successful partnerships" between HIC and LMIC academic institutions as including cultural sensitivity, enthusiastic leaders, a focus on long-term sustainable relationships supported by dependable funding, and involvement of the Ministry of Health in the LMIC or local health leadership, as appropriate [14].

When establishing a partnership between a HIC and LMIC institution, formal agreements such as a memorandum of understanding (MOU) that defines goals, leadership, expected milestones, and how to handle IP, funds, data, etc. is an important step [14]. The MOU acknowledges and supports the priorities established by the LMIC partners and makes the value added by each partner transparent. LMIC perspectives have to be primary to develop innovations that are feasible, ethical and sustainable. The HIC CMI or AMC must actively tune its awareness to the presence of neocolonialism in global health and intentionally plan to mitigate the power differential and ensure that the partnership is not extractive in nature. Eichbaum et al recommend one approach for "decolonizing" the partnership through thoughtful and intentional actions:

> **Addressing power dynamics and development narratives**
> The Asset-Based Community Development (ABCD) approach to community-based development intentionally counteracts "deficit oriented mentalities that reinforce colonial power dynamics." Such a mentality impels the HIC outsider to be impelled by development narratives whose storylines focus on the deficits of resource-limited settings rather than their implicit strengths and assets. By such narratives, the outsider is presumed to be knowledgeable and capable compared with local communities, which are considered incapable and needy. ABCD aims to counteract this dynamic and ensure greater equity between the less resourced and more resourced (and powerful) stakeholders. [16]

6.4.4 Funding and Innovation Networks

A critical component of innovation is partnership with industry which is not a routine part of AMCs. To address this gap, the National Institutes of Health runs two programs Centers for Accelerate Innovation (NCAI) and the Research Evaluation and Commercialization Hubs (REACH) that link academic institutions with NIH funding to encourage private-sector partnerships. These programs aim to accelerate innovation by providing innovators with experts and the resources necessary to bring innovations developed in the academic sphere to the market. As of March 2021, these programs have brought together 34 academic institutions into six centers/hubs and helped develop over 300 innovations [34]. Although these programs are not actively recruiting new universities, they are a great example of public-private partnerships to encourage innovation.

Funding is vital for innovation. Early stage funding may have to rely on seed support from interested departments before an idea can be developed enough to be "pitched" to external funders such as venture capitalists. Furthermore, unlike in traditional clinical research, innovators often do not have preliminary data available, so identifying grants and awards that do not require this can be quite challenging. There is increasing interest in funding global health innovation at the NIH through mobile health innovation grants among others (2020). Because clinical departments at AMCs are typically unfamiliar with these funding sources, internal partnerships across schools of business and engineering are essential. This is a major benefit to establishing CMIs since these opportunities are not concentrated in any particular department or school but are typically dispersed across AMCs. This transdisciplinary coordination of resources is central to the notion of "Convergence Research" as funded by the NSF (National Science Foundation) and has spurred substantial productivity at the University of Utah's CMI (see Fig. 6.2).

For well-tested innovations, examples of "high-risk, high-reward" funding opportunities include the Gates Foundation "Grand Challenges" and the National Institutes of Health (NIH) "Director's New Innovator Award". Grand Challenges is aimed at "fostering innovation to solve key global health and development problems," and includes initial grants of $100,000 [4]. LifeBox, a non-profit that aims to make surgery and anesthesia safer on a global scale, recently won a Grand Challenge to address surgical site infection after cesarean deliveries in Ethiopia [42]. The NIH Director's New Innovator Award funds "exceptionally creative early career investigators who proposed innovative, high-impact projects", does not require preliminary data, and awards innovators with $1.5 million for a 5-year project [35].

Aside from funding, innovation networks offering funding, mentorship and a variety of transdisciplinary resources can be crucial, especially for global health innovators. The US State

Department's Agency for International Development's (USAID) Center for Innovation and Impact (CII) offers tremendous resources in one place, in addition to funding, such as online learning courses. See Box 6.3 for details on how the USAID CII partners with and supports global health innovators, include innovators at AMCs.

Box 6.3: USAID Center for Innovation and Impact Supporting Global Health Innovation

The United States Agency for International Development (USAID) Center for Innovation and Impact (CII) supports innovations that aim to solve worldwide health challenges. They specifically focus on bringing innovation s to scale, where they can begin having a tangible impact. An overview of their numerous resources is below.

E-learning courses Free learning modules are available on USAID CII's website. These courses educate global health innovators on business-minded approaches to scaling innovations. Topics include:

- Innovation Realized, an introduction to innovation in global health
- Innovative Finance for Global Health
- Introduction to Digital Health
- Market Shaping and Introduction Planning for Global Health

Funding opportunities Over the last 10 years, USAID has supported >150 global health innovations in >40 countries. They fund various types of organizations including academic, non-profit, for-profit, and foreign governments. Their "Innovation Index Tool" assists innovators and potential donors with objectively assessing an invention. Funding opportunities include:

- "Development Innovation Ventures" is USAID's open innovation program. They offer tiered funding based on the stage of a project.
  - Stage 1: Pilot (up to $200,000)
  - Stage 2: Test and Position for Scale (up to $1,500,000)
  - Stage 3: Transition to Scale (up to $15,000,000)
  - Evidence Grants (up to $1,500,000)
- USAID CII partners with the Bill and Melinda Gates Foundation to fund "Grand Challenges for Development," which focuses on solving development problems. Specific programs within "Grand Challenges for Development" include:
  - Saving Lives at Birth
  - Fighting Ebola
  - Combating Zika and Future Threats

[10, 54, 55].

6.5 Common Challenges in Global Surgery Innovation—Manufacturing and Ethical Concerns

Even when working within an ideal innovation ecosystem, surgical innovators face many challenges throughout the lifecycle of an innovation. These challenges are varied depending on the type of innovation, as detailed in Table 6.1. Difficulties may be heightened in limited resource settings, especially when the innovation is a medical device. Lack of manufacturing support and absent or minimal medical device regulations in many countries can cause significant barriers in implementing an innovation.

The Global Strategy and Plan of Action on Public Health, Innovation and Intellectual Property was initiated by the WHO in 2008 to foster progress towards technology transfer and local production of medical products [52]. Their report, Local Production and Technology Transfer to Increase Access to Medical Devices, focuses on addressing the global medical device market and highlights the disparities in production across the globe. Further, currently only 13% of manufacturers for medical devices are located in LMICs [53]. The impact of this unequal distribution of manufacturing was acutely demonstrated during the COVID-19 pandemic when personal protective equipment, therapeutics, and vaccines were unavailable in poorer countries that depend on importing such goods to meet local demand [18, 19, 30].

In order to decrease reliance on medical device donations [29], there is increasing interest in improving local production of medical products to strengthen local health systems. However, the existing infrastructure is a significant barrier because only 32% of the World Health Organization (WHO) African region countries and 45% of LMICs have a legal framework for medical device manufacturing and regulatory practices [60].

Additionally, a comprehensive situational analysis also demonstrated that local production may not always be the most viable way to support the local economy and ensure access to the device [53]. Important factors to consider when determining the ideal manufacturing location include health systems financing, local policies and regulations, size of the local market, and competing suppliers. Differences in local regulations also impact the time and cost required to form a new business. In the US, it costs 1.4% of annual income per person and requires about six days of processing to start a business. In comparison, starting a business in Haiti costs 314% of local annual income per person and takes 105 days, according to the World Bank Group (The World Bank Group). If a local economy and health system has limited resources, the time and cost necessary to start a business and manufacture a specific medical device may divert capital from other local health priorities that can impact a larger number of patients [53].

In an attempt to aid innovators in considering all of these factors, the WHO developed a tool to evaluate the viability of producing a specific medical device in a particular location [53]. This can act as a resource for innovation teams as they work to implement a product. AMC CMIs can be instrumental in this process by using their innovation labs to trial various low-cost prototypes with different materials that are most conducive to local manufacturing. If local manufacturing is not feasible, partnerships through industry and networks such as USAID CII may yield potentially appropriate manufacturers.

Development of new medical products and operative techniques also creates ethical issues related to implementation. It is not possible to predict all the potential complications or challenges that may occur with a new medical device or procedure. Testing new solutions can be complicated. Clinical innovations require extensive testing to ensure safety as well as efficacy. Patients need to be informed of the potential risks, while emphasizing that all possible risks are unknown [32]. When introducing this type of innovation in an environment with limited access to care, true informed consent may be challenging if the patient has no alternative therapies available to them. In addition, if medical literacy is low in a community, thoroughly communicating risks and benefits is an additional challenge. Lastly, even when a product is developed with the principles of frugal innovation in mind, some of the most vulnerable patients may still be unable to access or afford it. This may especially be an issue in cardiac surgical care which requires a lot of resources.

6.6 Conclusion

Globally, heart disease affects half a billion people per year [40]. However, access to cardiac surgery is not equitable worldwide. There are many opportunities to use frugal and disruptive innovations to address these disparities. Global surgery innovation is a difficult process that requires creativity and a wide range of knowledge. AMC CMIs are poised to be advantageous partners for institutions in LMICs to develop a productive innovation ecosystem that addresses local surgical needs. By involving students and trainees, providing formal education in medical innovation and infrastructure to coordinate multidisciplinary teams, facilitating prototyping and funding early stage projects through equitable partnerships with LMICs, AMCs can spur global cardiac surgery innovation and expand access to much-needed care worldwide.

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The Role of Social Impact Innovation and Entrepreneurship in Global Health

7

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Abstract

The COVID-19 pandemic revealed systemic weaknesses and gaps in healthcare systems globally. Ecosystems with more of an entrepreneurial, systems-change approach saw these gaps as opportunities. Entrepreneurs in emerging markets face specific hurdles their counterparts elsewhere may not. However, even with so many innovators at work, the crisis illustrated that healthcare remains deeply influenced by local conditions, resources, systems, and policy despite the global reach of technology and healthcare innovation. Though there is no single recipe for effective, scalable, sustainable, and equitable healthcare innovation, we have identified examples from across health systems that can offer a blueprint to which governments, non-governmental organizations (NGOs), investors, donors, universities, research institutions, and entrepreneurs around the world can refer. Several essential ingredients are common among high-impact innovators in emerging markets, including resilience, focus on mission and values, systems orientation, personal motivation, local ties, and global outreach. Also, innovation-driven healthcare ventures take many forms but follow common paths, including identifying and filling systematics gaps, investing in local capacity, blending technology with human intervention, focusing on business models with social purpose, blending local and global capital, and embracing consumers. Moreover, to build vibrant innovation ecosystems that accelerate healthcare innovation, low and middle-income countries (LMICs) must assess and develop their innovation and entrepreneurship capacities by collaborating to build needed capacities, involving stakeholders in a collective ecosystem approach, and adopting new mindsets. An ecosystem approach is required to build sustainable and scalable healthcare innovations with real potential to improve the health and lives of people in LMICs. Governments, universities, corporations, NGOs, entrepreneurs, and investors can and

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_7

should collaborate to build a shared vision for local healthcare improvement.

Keywords

Entrepreneurship · Innovation · Social impact · Ecosystem · Healthcare · Global health · COVID-19 · Emerging markets · Low and middle-income countries (LMIC) · Multi-stakeholder

7.1 Introduction

The business of healthcare is like no other. The conditions are complex, the systems vast, and the stakes high. Pull one thread on any single healthcare issue and find countless interdependencies, co-dependencies, varied root causes, and, often, murky solutions. Innovation can literally save lives but is complicated by the interplay of public policy, societal norms, and financial resources.

The COVID-19 pandemic revealed systemic weaknesses and gaps in healthcare systems globally. Those with more of an entrepreneurial, systems change mindset saw these gaps as opportunities.

Even with those innovating, the crisis illustrated that despite the global reach of technology and healthcare innovation, healthcare remains deeply influenced by local conditions, resources, systems, and policy. At the same time, technology enabled remote collaboration and communication from virtually anywhere and spurred record-fast development of highly effective vaccines. Despite these accomplishments, it became difficult to celebrate the wonders of science in the face of a global inability to distribute vaccines to those most in need in an inclusive and equitable manner.

Though there is no single recipe for effective, scalable, sustainable, and equitable healthcare innovation, we have identified examples from across health systems that can offer a blueprint for governments, non-governmental organizations, investors, donors, universities, research institutions, and entrepreneurs around the world to refer to.

7.2 Healthcare Innovation Context

7.2.1 Emerging Market Operating Environments

Healthcare innovation is challenging in any environment, but emerging market healthcare systems present additional barriers including: overwhelming needs with limited capacity, insufficient funding and compensation, inadequate infrastructure, and shortages of skilled medical professionals.

These challenges are starkly illustrated by healthcare spending. Whereas France and Germany spent just over 11% of their GDPs on healthcare in 2018, according to the World Health Organization (WHO),[1] India and Ghana spent only 3.5%. Though many industrialized nations arguably spend too much on healthcare, many emerging markets do not have enough resources to adequately prioritize and fund healthcare improvement, let alone essential services.

Healthcare capacity varies widely as a result. On a WHO composite indicator of health system capacity, Canada scored 99 out of 100 in 2019; South Korea scored 97, Colombia scored 69, and Ghana scored 49.[2] No individual indicator tells the whole story of a public healthcare system's capacity, but emerging markets tend to involve nationalized health systems that leave many residents' healthcare needs unmet. These market-driven, cash-pay models create multiple tiers of service and often contribute to inequitable distribution of healthcare resources and highly variable quality of care. Private healthcare markets provide an alternative to overwhelmed, lower-quality public healthcare options. In

[1] World Health Organization. "Current health expenditure (CHE) as percentage of gross domestic product (GDP) (%)." https://www.who.int/data/gho/data/indicators/indicator-details/GHO/current-health-expenditure-(che)-as-percentage-of-gross-domestic-product-(gdp)-(-).

[2] World Health Organization. "Average of 13 International Health Regulations core capacity scores, 1st version of the questionnaire." https://www.who.int/data/gho/data/indicators/indicator-details/GHO/-average-of-13-international-health-regulations-core-capacity-scores-1st-version-of-the-questionnaire.

countries where the same professionals practice in both the public and private systems, the more lucrative financial incentives to practice in the private system can siphon capacity out of the public system.

While poor regulation in emerging markets can create opportunities for entrepreneurs, lighter government oversight of private-sector players can leave consumers exposed to unscrupulous actors and erode public trust in the system overall. COVID-19 and related economic crises have intensified reliance on public-sector healthcare services, particularly as wealthy residents were unable to travel for care during pandemic-related international border closings. Pressure to serve public health needs with high-quality, accessible care required local governments to adjust their healthcare regulatory frameworks. Unfortunately, in many cases, this did not take place.

7.2.2 Challenges for Emerging Market Healthcare Ventures

Entrepreneurs in emerging markets face specific hurdles their counterparts elsewhere may not. Many emerging market entrepreneurs are creating new markets, introducing whole new concepts to their countries, not just offering new products or services that offer incremental improvements. The added challenges, then, include working around or filling fundamental gaps such as in payment systems or basic technical infrastructure. In healthcare ventures, the fact that many doctors leave their home countries for medical training and do not return to practice is a further constraint on the talent required for some ventures. In more extreme cases, a country's stability and safety can add new layers of risk from which investors are likely to shy away. Nevertheless, entrepreneurs continue to innovate.

Speetar is a stark example of a healthcare venture operating in the most challenging conditions. The Libyan telehealth company launched in a conflict zone after years of Libyan civil war. In addition to the country's instability, the Libyan market opportunity is limited. The whole population is less than seven million people with a high degree of dispersion. Though 80% of the population lives in or near an urban area, only Tripoli has more than a million residents.[3] Basic infrastructure is lacking; mobile penetration is high, but broadband access is low. There are few healthcare facilities and not enough providers.

But these challenges also created opportunities for Mohamed Aburawi, Speetar's founder. A foreign-trained doctor, he recruited other physicians in the Libyan diaspora to provide telehealth consultations to residents of their native country, wherever the doctors may live. Aburawi leveraged the cash-pay market to bring telemedicine directly to Libyan consumers accustomed to making many of their own healthcare decisions, such as which specialists to see. However, he has had to work with suboptimal payment systems, using prepaid cards or even taking cash. His view on the market limitations, though, reflects a level of optimism many entrepreneurs share: if Speetar can work in Libya, it can work in more developed systems.

Convincing investors, though, has been an uphill climb.

"I think we have fundamentally efficient markets and capital will go to places where it can earn the best return for the risk that it can take and Libya is a terrible place for that," said Ted Levinson, founder and CEO of Beneficial Returns, an impact investment fund that operates in emerging markets.

Challenges accessing capital can suppress entrepreneurial activity and diminish the innovation ecosystem. Well-intended philanthropic aid can stunt local industry development by supplanting market forces with donated goods or services.

[3] World Population Review. "Libya Population 2021 (Live)." https://worldpopulationreview.com/countries/libya-population.

7.2.3 The Impact of the COVID-19 Pandemic

The COVID-19 pandemic strained healthcare systems across the world. Hard-learned lessons from early hot spots did not necessarily prevent the crisis elsewhere, and the rapid spread of the virus showed how connected the world is. The pandemic also highlighted important lessons for healthcare innovators and ecosystem players. Even mature health systems in the highest-income countries lacked sufficient capacity to handle the surge of patients simultaneously requiring hospitalization and intensive care. Healthcare providers, government officials, business leaders, and consumers had to adapt quickly and continuously as conditions changed.

7.2.3.1 Balancing Local Resilience and Globalization

Personal protective equipment (PPE) was in short supply for healthcare providers and citizens alike. Global supply chains were disrupted due to closed international borders and local demand in manufacturing centers that would otherwise export their products—sometimes dubbed "supply chain nationalism." These challenges illuminated the benefits of local reactive capacity to protect against supply shocks for countries across the income spectrum.

7.2.3.2 Necessity Spurs Technology Adoption

When telemedicine became the only safe way to get non-urgent health services, adoption spiked. Previously limited by regulation and by both provider and consumer comfort, necessity encouraged broader adoption and illuminated effectiveness of telehealth services. It is now difficult to imagine the future of healthcare delivery without a substantial role for remote care.

7.2.3.3 Consumer Power Rising

An important byproduct of the pandemic has been a renewed agency amongst consumers themselves. Individual decisions, beliefs, and behaviors are critical factors not only in the spread of the virus, but also in the adoption of new care delivery models, demand for innovation, and compliance with evidence-based guidelines. The power of healthcare consumers—already the focus of many cash-based health systems in emerging markets—became universally clear during the pandemic.

Technology adoption during the pandemic also highlights the enduring need for human intervention. Effective COVID-19 contact tracing, for example, blended technology for tracking infections with human outreach and, in some countries, quarantine enforcement.

7.3 The Role of Innovation Ecosystems

Low and middle income countries (LMICs) that want to develop innovation capacity and capture the value created by innovation-driven enterprises (IDEs) need to foster ecosystems that allow for these enterprises to flourish. This is of particular importance to a continent like Africa that is in dire need of healthcare innovation. Concentrating on local innovation to leapfrog current infrastructure limitations can support economic growth and address the specific health needs of existing communities deemed to be vulnerable from an infrastructure and access perspective.

Thriving ecosystems are characterized by the quality of interactions between the main system stakeholders, not simply by the existence of these stakeholders within an ecosystem. They enjoy strong infrastructure, regulatory frameworks, and policies, as well as high innovation capacity and entrepreneurial capacity.[4] Well-known innovation ecosystems such as Silicon Valley and Kendall Square in Cambridge, Massachusetts took decades to grow organically. Some developing countries are building their innovation ecosystems with more deliberate approaches, as in the cases of Singapore, Malaysia, India, and China. Many of these ecosystems are benefiting

[4] Budden and Murray, "An MIT Approach to Innovation: Eco/Systems, Capacities & Stakeholders".

from network effects—where the value of colocation increases due to the increased points of exchange and knowledge sharing. This benefits all players and reinforces cycles of growth.[5]

Vibrant innovation ecosystems around the world were able to respond quickly to COVID-19 by developing solutions and approaches to address the challenges presented. Major innovation hubs were associated with the significant testing and vaccination development, including Moderna's vaccine which was developed in Kendall Square. Emerging market innovation ecosystems also developed solutions to support national pandemic responses while considering local resources limitations. For example, the Genome Valley in Hyderabad, India, an emerging biotech innovation ecosystem, spurred innovations such as low-cost COVID-19 testing and the COVID-19 vaccine Covaxin[6]

Hyberdad's Genome Valley was conceptualized in 1999 as a deep-technology business district. Through public-private partnerships, the government developed state-of-the-art infrastructure, provided financing for both research and development and startup ventures. It also built partnerships with other innovation hubs in the U. S. and Malaysia and established incubators to connect industry with research institutions and academia. The initiative started with a clear focus on three sectors: pharmaceuticals, biotechnology, and life science. This focus permeated research funding and partnerships between academic institutions, government agencies, and the private sector with the goal of generating positive network effects. By 2019, Genome Valley hosted more than 200 organizations including Bharat, the developer of India's COVID19 vaccine, Covaxin.[7,8,9]

By accelerating the development of their local innovation ecosystems, LMICs can increase the density of local healthcare innovations and improve their capacity to provide better healthcare solutions and services. It will also increase their potential to leapfrog legacy systems by leveraging innovations in e-health, artificial intelligence (AI), biotechnology, and other innovations, just as LMICs leapfrogged into mobile phone telecommunications systems before full deployment of wired systems.

Health innovations within LMICs not only benefit these countries, but they have also inspired reverse innovation from LMIC to higher-income countries and across LMICs facing similar challenges.[10] Limited resources push innovators to develop cost-effective and widely accessible solutions, which also highlight potential solutions for use in resource-constrained communities in health settings globally. For example, surgical innovations from LMICs which show comparable outcomes at a fraction of the cost and can be used to reduce costs in high-income countries.[11] These same countries can further leverage their nascent innovation ecosystems by building them in ways that support the use of big data and AI for improvement.

[5] Phil Budden and Fiona Murray, "An MIT Approach to Innovation: Eco/Systems, Capacities & Stakeholders," October 2019.

[6] Reuters Staff, "Bharat Biotech Says Approved COVID Shot Trials 'Honest,'" *Reuters*, January 4, 2021, https://www.reuters.com/article/health-coronavirus-india-vaccine-idUSKBN2991IT.

[7] "Meet the Man behind India's Genome Valley—Rediff.Com Business," accessed March 25, 2021, https://www.rediff.com/business/slide-show/slide-show-1-meet-the-man-behind-indias-genome-valley/20110107.htm.

[8] Y. V. Phani Raj, "Telangana Gearing up for Genome Valley 2.0," Telangana Today, accessed March 25, 2021, https://telanganatoday.com/telangana-gearing-up-for-genome-valley-2-0.

[9] Pandey and Desai [1].

[10] Syed et al. [2].

[11] Cotton et al. [3].

7.4 Health System Innovation in Emerging Markets

Amidst difficult conditions, entrepreneurs have driven innovation out of necessity, building local capacity to serve the population's health needs as they build their businesses.

The challenges of limited resources that should be provided by other key stakeholders (i.e. universities, risk capital, corporations, and governments), limited innovation and entrepreneurship capacities, and weakness of the legal and physical infrastructure within which entrepreneurs are operating are characteristics of nascent innovation ecosystems. Addressing these challenges creates a more conducive environment for innovation. Nonetheless, entrepreneurs must be resourceful, even more than their counterparts in more advanced ecosystems to compensate for the limitations in the environment. They rely on building strong alliances, working with funders that understand the operating context, and getting innovation support from universities.

Many of the same challenges that make innovation difficult simultaneously create opportunities. For example, in markets with fewer regulations, there may be less public trust in healthcare innovations but greater flexibility for entrepreneurs. The immense needs can overwhelm any one venture, but also create immense opportunity for impact. The magnitude of need necessitates innovation and primes the conditions for change. Models from other markets can be adapted and implemented in more greenfield markets. Lack of third-party healthcare payers and adequate government spending on healthcare create substantial inequity and burdens consumers financially. Market signals may be clearer without intermediaries interfering with the provider or supplier relationship with end users.

Specific healthcare innovation opportunities exist in many corners of the sector, including telemedicine and remote services, data and artificial intelligence, and other technologies such as medical devices, monitoring, and therapeutics.

7.4.1 Innovation in Action: Case Studies of Global Healthcare Innovators

Theories of innovation are put to the test in their real-world application. Four healthcare ventures help illustrate the factors that are essential to scalable healthcare innovation.

7.4.1.1 Proximie—Winning Hearts and Minds with Industry Allies Around the Globe

In 2014, Dr. Nadine Hachach-Haram was traveling frequently to teach and learn about new surgical procedures around the world. As a reconstructive plastic surgeon, she recognized that there was an inherent challenge in scaling surgical expertise. Surgical pedagogy has not progressed significantly from its original model of surgeons teaching surgeons around an operating table. Hachach-Haram argues that this culture holds back the field. "Surgery is not built for scale," she said. "It's not data-driven. It's analog. Because everything's manual, we're not capturing data, and we don't learn from what we do."

This stagnant approach to surgical training not only affects trainees, it also holds back improvements in patient care. Because specialized expertise can be scarce in certain markets, patients in those markets have few opportunities to access quality care.

Hachach-Haram saw an opportunity to democratize surgery by expanding access to high-caliber surgical expertise. "We wanted to create the effect of a borderless operating room that could empower surgeons to remotely share knowledge that could ultimately reduce variation in care and help save lives," she said.

In 2016, Hachach-Haram founded Proximie, a multi-sensory platform to facilitate collaboration and extend the geographical reach of individual surgeons. Surgeons can virtually scrub into operating rooms worldwide through live camera feeds using augmented reality via Internet-connected devices. Experts remotely conduct procedures or assessments from start to finish and mentor local clinicians live. Remote practitioners provide oral instructions, draw, or overlay necessary patient scans or X-rays, and virtually reach into the clinical field to provide precise guidance to local surgeons.

Machine learning, artificial intelligence, and augmented reality allow two people in separate locations to interact virtually in an approximation of in-person collaboration. One can physically show the other where to make an incision in real-time or use gestures to illustrate a technique. Proximie also hosts a library of videos for practitioners to share recordings and instruct one another. By 2021, the company had subscribers in 40 countries and growing.

COVID-19 spurred Proximie's growth. Physical distancing measures, travel bans, and quarantines forced surgical professionals across the world to lean into new ways of sharing their expertise from outside of the operating room. In the year following the onset of pandemic, Proximie's user base grew tenfold. With elective surgeries on hold to reserve hospital capacity for urgent and COVID-19-related care, surgical training took a hit as trainees had limited access to surgical cases. Through Proximie, subscribing teaching hospitals were able to continue building their cohorts' skills and explore the role of remote learning in accreditation.

Beyond the pandemic, Proximie can bring innovation to global surgical training by removing the confines of teaching hospital operating rooms. Experts can share their knowledge with anyone anywhere.

Proximie also partners with medical device companies piloting new treatments. The platform makes it easier to provide patients with cutting-edge treatments. Accessibility is a particular boon in resource-limited environments. Some of the company's earliest milestones included connecting expert surgeons in the U.S. to clinical teams in Peru and El Salvador to advise on cleft lip and palate repair surgeries for local children.

Hachach-Haram is wary of the perception that developed markets have nothing to learn from developing ones because innovation exists worldwide, as does variation in care. She said, "We can actually learn quite a lot from the global South." Rather than discounting the expertise of talented surgeons in emerging markets, the global surgical community can learn from practitioners who make the most of what they have wherever they may be.

Despite the company's success, growing Proximie has not been without challenges. Hachach-Haram notes that the most significant obstacle her company faces is "winning hearts and minds." Proximie requires a new way of looking at surgery. Champions from early adopting hospitals and medical device companies have been instrumental in the company's growth. These early wins have served as the proof of concept to bring skeptics on board. Even with significant ground to cover in spreading this new mindset, Hachach-Haram is optimistic about the company's future to be "the backbone of every operating room" (Figs. 7.1 and 7.2).

7.4.1.2 Smart Medical Care Services—Finding the Right Investors

In Egypt, nearly half of the country's 100 million people face multiple barriers to healthcare services, a figure which reaches 79% of women in rural areas. As a practicing neurosurgeon in Cairo, Amr El Tayeb saw every day the stark reality of the risks and personal costs that families incurred when their loved ones had an operation and struggled to cover the costs of care due to a lack of health insurance. He practiced at a public hospital open to all patients in a country where almost one-third of residents live on less than 2 USD a day. Out-of-pocket healthcare spending regularly pushes an estimated 20% of Egyptians into financial hardship (Rashad and Sharaf 2015).[12] El Tayeb knew affordable access to care would be vital to improving health outcomes for millions of Egyptians. "It's easy being a doctor; you just smile, be efficient, have some compassion, and you're fine," El Tayeb said. "But that doesn't mean you have any impact."

To broaden his impact beyond the operating room, in 2010 El Tayeb founded Smart Care Medical Services. The company offers

[12] Rashad and Sharaf [4].

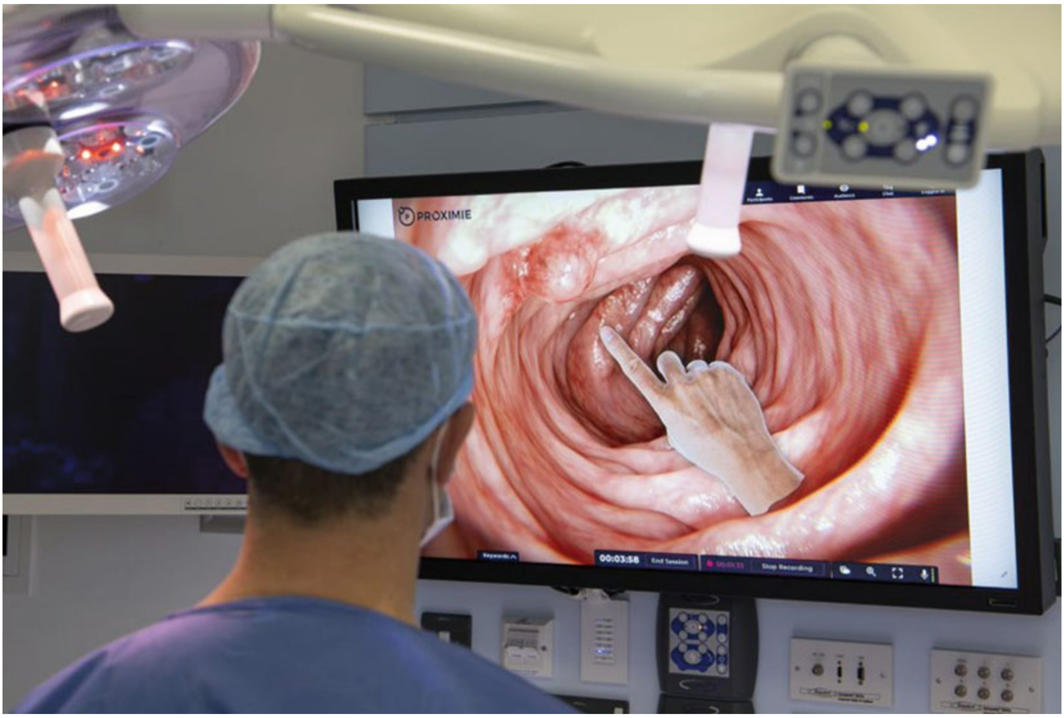

Fig. 7.1 Proximie allows surgeons to virtually scrub into operating rooms worldwide through live camera feeds using augmented reality via Internet-connected devices

customizable and low-cost health insurance plans for businesses and individuals. Smart's network covers almost 20% of Egypt's hospitals and includes 854 doctors and 629 pharmacies.

For companies, Smart manages many conventional healthcare plans, including self-funded schemes, managed care programs, and third-party administration (TPA). However, for individuals, Smart offers a radically affordable solution called Sehaty ("my health" in Arabic). In this program, subscribers gain access to a network of providers offering care at up to a 70% discount. The platform also offers users price visibility, price comparisons, and access to a medical directory so users can select providers that best fits their needs. Sehaty has more than 80,000 subscribers and costs only 250 Egyptian pounds a month, about USD 15, for a family of five. Smart's customers are pleased with this more affordable care. In 2020, 95% of subscribers reported being highly satisfied with their insurance and 95% renewed their plans.

Over the past ten years, El Tayeb has refused buyout offers and partnerships because he wants to make sure that whoever is involved with Smart shares the same mission. He said, "Money can make you change direction too early."

El Tayeb is driven by his commitment to creating impact. His vision is to create a genuinely inclusive healthcare system. "If you forget a component of society, the system will not be sustainable."

Smart's investors share this goal. The Egyptian American Enterprise Fund (EAEF) invested in Smart because of its potential to create inclusivity at scale, according to Yasmine Ghobrial, a senior associate at EAEF. Smart fits into the fund's interest in ventures that contribute to building a country's infrastructure, including healthcare and education.

EAEF's support has been instrumental in Smart's growth. EAEF complements El Tayeb's technical knowledge with the networks and entrepreneurship knowhow to attract follow-on

Fig. 7.2 Proximie's technology integrates into existing OR infrastructure and facilitates collaboration between remote and in-person teams

Fig. 7.3 In community outreach events, Smart Medical Care Services provides health screenings and connects people to different healthcare plans including “Sehaty”. In this program, subscribers gain access to a network of providers offering care at up to a 70% discount

Fig. 7.4 Smart Medical Care Services meets its customers where they are and hosts its outreach events in high-traffic areas such as grocery stores

investors and new users. Through their partnership, they have been able to strive for El Tayeb's goal of "combining impact and profitability" (Figs. 7.3 and 7.4).

7.4.1.3 Bloomer Tech—Building Entrepreneurship Capacity at Academic Institutions

Alicia Chong Rodriguez was shocked to learn how little data is systematically captured in women's cardiac health. She would learn that a significant percentage of women do not experience "typical" symptoms of heart disease common in their male counterparts. For example, pain in the jaw, upper abdomen, or back may point to an underlying cardiac condition in women, but these symptoms are untracked and often unnoticed by practitioners. This blind spot emerges because much of the research on heart disease has historically been based on male subjects. Women make up one-third of participants in research trials for heart drugs, and animal studies of heart disease focus on male subjects almost exclusively. This research gap leaves the field under-equipped to address the specific needs of women.

Rodriguez is an engineer by training and has two master's degrees from MIT. She applied her engineering knowhow to improve the collection of medical-grade cardiological data from women. Recognizing that healthcare is not one size fits all, Rodriguez wanted to create tools for delivering "true precision medicine."

She teamed up with co-founders Monica Abarca and Aceil Halaby to design a bra with sensors embedded in washable, stretchable fabric. The "Bloomer Bra" continuously tracks women's heart functions. It features a multi-lead electrocardiogram, accelerometer, and temperature sensor that gather vital information for diagnosticians and deliver real-time, medical-grade data to the user's smartphone. In contrast with the standard process for collecting at-home ECG data—which can be long and cumbersome and not optimized for women—the Bloomer Bra was designed for women's bodies, so it collects more accurate data and is easier to incorporate into users' daily routines. One of the bra's advantages, according to Rodriguez: "You never forget to wear it!"

Addressing the gender data gap in cardiac research is only the beginning. Bloomer Tech's wearable sensors make it possible to create more inclusive data sets across the world. After genetics, lifestyle and environment are two of the significant factors determining cardiac health outcomes. However, medical research paints an incomplete picture when accounting for these variations globally. Bloomer Tech's sensors allow for widespread and granular remote data collection in understudied populations and contexts. Whereas clinical trials often exclude communities in emerging markets, Bloomer Tech provides opportunities for researchers to build a more robust data footprint to improve the understanding and treatment of certain diseases and improve health outcomes.

Rodriguez credits MIT for Bloomer Tech's beginnings. When she started her first master's degree, she had planned to find a job after graduation. She did not think of starting her own business as a career option. However, at MIT, Rodriguez was exposed to entrepreneurship. She received ideation funding from MIT Sandbox and mentorship and networking support from MIT's Legatum Center. "That experience completely transformed entrepreneurship from being something weird to something normal," Rodriguez said. "Because others are doing it too, the group strengthens your confidence" (Fig. 7.5).

7.4.1.4 HM Habib Cardiac Endowment Fund—Measuring Quality for Sustainable Innovation

Dr. Babar Hasan learned the hard way the importance of cost-conscious healthcare. After 11 years training in the U.S. as a pediatric interventional cardiologist, he returned home to Pakistan and approached his first case as he would have in the U.S.: fix the heart defect at all costs. He did, but used extra devices in the process. The unit receptionist said to him. "Who's going to pay for the next two devices that you opened? Because the family just had money for one device." It required two months of his modest salary to cover those costs, and the lesson set him on a mission to improve access to lower-cost, high-quality healthcare.

Hasan's approach was not sustainable in a country with such a large burden of congenital heart disease. With access to even basic care so limited, children with congenital heart defects often present for care later and in worse condition, with other challenges such as malnutrition. Interventions, then, are more complicated and costly.

"No risk adjustment model factors in these [social determinants of health]," Hasan said. "So when I start comparing myself to centers in the U.S., I can never achieve those kind of outcomes."

Hasan raised private philanthropic funds to start the HM Habib Cardiac Endowment Fund to offset costs for the seven or eight patients out of ten who cannot pay. He took an innovative approach to the fund. Instead of simply counting the number of children served, he measured the quality of outcomes. This accountability is uncommon in Pakistani charities and required Hasan to focus on building capacity for outcomes measurement.

"Even within the private sector, even when people are paying through their pocket, nobody knows what the outcomes are," he said. Citing a Lancet paper, he added, "Access without quality in low and middle income countries is actually unethical because it leads to far more expensive

Fig. 7.5 The "Bloomer Bra" features a multi-lead electrocardiogram, accelerometer, and temperature sensor that gather vital information for diagnosticians and deliver real-time, medical-grade data to the user's smartphone

care, far more complications, and in the end, then leads to much greater mistrust between the customer or the patient and the healthcare system."

Despite skeptics who questioned why he was not solely focused on patient care delivery, Hasan hopes more philanthropists will follow and that the government will tie healthcare accountability and accreditation to outcomes. He also hopes to reframe healthcare quality in emerging markets by generating scientific data on local innovations and sharing it with global collaborators.

"You have to stop looking at [healthcare in our part of the world] as suboptimal delivery, and we have to start looking at it as an innovative way of delivery," Hasan said. With cost pressures nearly universal, Hasan believes the global North may be able to learn from necessity-based innovations in the global South.

He believes data can yield both cost and quality improvements in a virtuous cycle. High-quality care costs less by reducing complications, increasing throughput, and improving patient rehabilitation. But this approach requires systems which were not historically developed in Pakistan, like other markets, where medicine evolved as an individualistic, physician-centered field. His U.S. training ingrained in him a continuous quality improvement mentality, which requires humility and a focus on accountability for results. This systems development approach, more than any technical skills he learned, is the crux of his impact.

7.5 Blueprint for Social Impact Ventures and Ecosystem Players

7.5.1 Social Impact Entrepreneurs: Essential Ingredients

At the heart of innovation-driven enterprises are visionary entrepreneurs on a mission. There is no single profile or path to social impact success, but several essential ingredients are common among high-impact innovators in emerging markets.

7.5.1.1 Resilience

Emerging market entrepreneurs must overcome hurdles entrepreneurs face anywhere: accessing capital, developing their products or services, building the market, and developing their team. But emerging-market entrepreneurs also face additional risks and constraints. Limited infrastructure, small and fragmented customer segments, and underdeveloped talent pools are just some of the extra challenges. Add in governmental instability or lack of security in some countries and the entrepreneurs' challenges can mount exponentially. Only resilient souls can thrive in these conditions.

7.5.1.2 Focus on Mission and Values

Effective leaders of innovation-driven enterprises are zealously focused on a mission beyond profits. It is difficult to ignore the public good to which emerging market enterprises can contribute. These entrepreneurs tend to embrace that broader purpose to create a sense of urgency and fuel their focus on innovation, overlaying social impact with effective business models.

7.5.1.3 Systems Orientation

Social impact entrepreneurs look beyond their individual contributions to their potential impact on the overall systems in which they operate. For example, many physician entrepreneurs seek greater impact than they can achieve by treating one patient at a time.

7.5.1.4 Personal Motivation

Many emerging-market innovators are driven by personal experiences. They know firsthand the impact of the problem they are trying to solve. Success matters on a personal level, which adds urgency and persistence to the fabric of the enterprise.

7.5.1.5 Local Ties

Effective emerging-market entrepreneurs tend to have deep ties to the market in which they operate. They have relationships as well as knowledge of cultural norms and practices which can be difficult to deeply understand as an outsider. Whether they come from the market they're in or not, they share a deep respect and consideration for local talent and seek ways to build local capacity as they build their business.

7.5.1.6 Global Reach

As connected as entrepreneurs need to be to their local market, global connections also provide massive advantages. Overseas university experience or participation in competitive accelerator programs can give entrepreneurs access to capital and networks of advisors and collaborators. Perhaps most important, global connections open the aperture on entrepreneurs' vision and ambition. This broad view can propel entrepreneurs to think bigger and aim higher, and ultimately to achieve greater impact.

7.5.2 Innovation-Driven Ventures: Blending Ingredients for Success

Innovation-driven healthcare ventures take many forms but follow common paths.

7.5.2.1 Identify and Fill Systemic Gaps

In emerging market contexts, innovation-driven companies may encounter structural or systemic gaps that limit the venture's ability to thrive. Addressing these gaps, which might seem out of scope for an individual venture in more mature market contexts, can be essential to enterprise viability. Contributing to infrastructure by building foundational elements may be required or essential for business growth.

7.5.2.2 Invest in Local Capacity

New ventures can address systemic gaps and strengthening their operating environments by building local capacity, such as training local talent and filling local infrastructure gaps. For example, Speetar, the Libyan telehealth company, installed kiosks called "Health Boxes" in local pharmacies where patients can get basic diagnostics from a junior physician or intern, who is overseen remotely by a seasoned physician. This investment improves Speetar's ability to treat patients, but also creates additional diagnostic capacity while providing training for the local workforce.

7.5.2.3 Blend Technology with Human Intervention

Successful healthcare ventures often require a balance between technology with a role for humans. Unlike sectors where technology alone can deliver innovations, healthcare is a fundamentally human endeavor. Many customers and practitioners need the human touch to build trust, while technology can serve as an enabler, improving efficiency, scale, and effectiveness.

7.5.2.4 Focus on Business Models with Social Purpose

No venture survives without a sustainable, scalable business model, but for healthcare ventures, social purpose is also essential. Because outcomes of healthcare ventures involve human life and health, the stakes are high and entrepreneurs must stay focused on the most important outcomes.

7.5.2.5 Blend Local and Global

Though many successful entrepreneurs have global connections, to succeed in emerging markets, they must also tap into and support local talent and relationships. Local regulators and partners can tangibly open customer or funding doors, but they also provide credibility and build trust.

7.5.2.6 Embrace Consumers

In many emerging market health systems, consumers are the customers. Unlike third-party or governmental insurance-heavy systems, these markets enjoy more direct relationships between providers or suppliers and end users. Social impact innovators can leverage the lack of intermediaries to get closer to and better serve their customers. To work, though, these ventures must use authentic, human-centered design approaches to truly solve consumer problems and cater to consumer preferences and needs.

7.5.3 Accelerating Regional Innovation Ecosystems for Healthcare Innovation

As the stakeholders within low and middle income countries endeavor to build equitable and sustainable health systems, it is imperative to leverage technologies and innovations available to leapfrog the paths taken by more advanced health systems. In the process, LIMCs have the opportunity to avoid the pitfalls of more advanced systems.[13]

However, accelerating the development of innovation ecosystems requires more than a top-down approach, such as allocating space for innovation parks or creating private-sector-friendly regulations. To build vibrant innovation ecosystems that accelerate healthcare innovation, LIMCs must assess and develop their innovation and entrepreneurship capacities. They must consider how to improve the quality of interactions amongst stakeholders within the ecosystem and how to create collective impact through a shared strategy and vision, based on a region's comparative advantage.[14]

7.5.3.1 Collaborate to Build Needed Capacities

Thriving innovation ecosystems depend on the availability and strength of two distinct yet related capacities within an ecosystem: innovation capacity and entrepreneurship capacity.

LMICs have to prioritize their investment in these capacities to allow for the development of an innovation ecosystem. Established innovation ecosystems enjoy not only the capacity to develop new solutions "from idea to implementation' (innovation capacity), but also the capacity to build new enterprises around these innovations and manage their scaling and growth (entrepreneurship capacity). It is the coexistence

[13] "Health Systems Leapfrogging in Emerging Economies," World Economic Forum, https://www.weforum.org/reports/health-systems-leapfrogging-in-emerging-economies-ecosystem-of-partnerships-for-leapfrogging/.

[14] Fiona Murray and Phil Budden, "MIT's Stakeholder Framework for Building & Accelerating Innovation Ecosystems".

of these two capacities within an ecosystem that provides the ecosystem with "twin engines of innovation."[15]

Developing innovation and entrepreneurship capacities within a regional ecosystem requires the collaboration of all stakeholders to make available the relevant inputs for each capacity: human capital, funding, infrastructure, demand, culture, and incentives. While universities in LMICs could be natural incubators for the development of necessary human capital, to play that role they must adapt their approaches to allow for new ideas to move into implementation, provide innovators with opportunities to develop entrepreneurial skills, and partner with other types of private-sector enterprises. Universities must also adopt policies that allow for a culture that prioritizes research in innovation that lends itself to implementation.[16]

Universities in LIMCs have the potential to catalyze health system innovation. To do so requires that they overcome internal institutional resistance and administrative challenges associated with university bureaucracy. International donors can also help universities develop their research capacity by fostering new development models where research capacity is valued as much as the research outcomes.[17]

LMIC governments should develop policies that are friendly to innovation. Such policies include easing the mobility of human capital into a region and between organizations, directing funding into innovation, and creating incentives for corporations and universities to invest in innovation through research and development spending, and through tax and investment policies. Governments and corporations can also increase demand for innovation within an ecosystem through procurement policies that are friendly to startups, as well as by offering innovation grants and prizes.[18]

7.5.3.2 Involve Stakeholders in a Collective Ecosystem Approach

The complexity of healthcare innovation cannot be addressed through isolated efforts of individual ecosystem stakeholders. Different stakeholders need to engage in collective action aligned around a shared vision.[19]

The MIT Framework for Innovation Ecosystems identifies five key stakeholders that are critical to the acceleration of regional innovation ecosystems that spur innovation-driven enterprises: (1) entrepreneurs, (2) governments, (3) universities, (4) large corporations, and (5) risk capital. Other stakeholders, such as nongovernmental organizations (NGOs) and international organizations, are also critical when addressing health systems.

As the main actors behind turning the innovative solutions into organizations and companies, entrepreneurs are central to the acceleration of any innovation ecosystem. Innovation ecosystems that do not give entrepreneurs' voices a central position are unlikely to yield the desired results.[20]

While any of the key stakeholders could play a leadership role in ecosystem acceleration by convening others and facilitating collective impact, whoever plays a leadership role must have a long-term commitment to the ecosystem and ensure other stakeholders are engaged in the process. Acting in isolation, stakeholder-developed innovation will not address the full scope of complexity. Effectively addressing healthcare challenges holistically requires multiple stakeholders to take an ecosystem approach. Collective action aligned around a shared vision

[15] Budden and Murray, "An MIT Approach to Innovation: Eco/Systems, Capacities & Stakeholders".

[16] Fiona Murray and Phil Budden, "An MIT Framework for Innovation Ecosystem Policy: Developing Policies to Support Vibrant Innovation Ecosystems," October 2018.

[17] Franzen et al. [5].

[18] Murray and Budden, "An MIT Framework for Innovation Ecosystem Policy: Developing Policies to Support Vibrant Innovation Ecosystems".

[19] "Health Systems Leapfrogging in Emerging Economies".

[20] Feld and Hathaway [6].

allows each stakeholder to mobilize their resources and contribute to collective goals.

John Kania and Mark Kramer articulate five conditions for collective impact initiatives: (1) a common agenda, (2) shared measurement systems, (3) mutually reinforcing activities, (4) continuous communication, and (5) backbone support organizations. These backbone support organizations play the convener role to help facilitate the collective process.[21]

7.5.3.3 Adopt New Mindsets

The collective impact approach presents its own set of challenges. Various stakeholders must partially set aside individual enterprise interests and adopt new mindsets to allow for collaboration at the ecosystem level. With this shared commitment, the ecosystem can coalesce and be fruitful.

A World Economic Forum study of a three-year intervention to support ecosystem programs in three LMICs highlighted the importance of the mindset change required. The study identified key impedance to collaboration as bureaucracy, lack of shared vision, and distrust. It also stressed that for collaboration to work, stakeholders must be open to new forms of partnerships. Governments need to be open to other sectors and delegate key responsibilities to them. Corporations need to prioritize long-term impact beyond short-term profits. NGOs must understand and be open to private sector partners. To bridge common distrust among corporate and nonprofit organizations, stakeholder leaders and participants should facilitate shared priority and agenda setting according to community needs and ecosystem objectives.[22]

[21] John Kania and Mark Kramer, "Collective Impact," Stanford Social Innovation Review (SSIR), 2011, https://ssir.org/articles/entry/collective_impact.

[22] "Health Systems Leapfrogging in Emerging Economies".

7.6 Conclusion: Collaborating for Sustainable Healthcare Impact

Healthcare innovation can seem overwhelming, in the best of circumstances. Challenging conditions in emerging markets can make improvements seem downright futile. But, talent is a global resource which, if strategically deployed and supported, can begin to address immense and urgent health needs. An ecosystem approach is required to build sustainable and scalable healthcare innovations with real potential to improve the health and lives of people in low and middle income countries. Governments, universities, corporations, NGOs, entrepreneurs, and investors can and should collaborate to build a shared vision for local healthcare improvement. Through collective commitments to innovation, entrepreneurs and the ecosystem players who support them can have global impact. If the global pandemic has taught us anything, it is that healthcare innovation needs to be a global priority, which can no longer be delayed.

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Part II

Cardiac Surgery as an Indispensable Component of Health Systems Strengthening

8 Global Cardiac Surgery and the Global Burden of Disease

Dominique Vervoort and A. Thomas Pezzella

Abstract

Cardiovascular diseases are the leading cause of morbidity and mortality worldwide, responsible for 18 million deaths and 366 million disability-adjusted life years lost each year. Over 80% of these take place in low- and middle-income countries, where access to cardiology and cardiac surgery services is limited. Congenital heart defects, rheumatic heart disease, ischemic heart disease, and endemic pathologies such as endomyocardial fibrosis and Chagas disease are highly prevalent in low- and middle-income countries. In particular, the burden of ischemic heart disease is rapidly increasing along with the epidemiological transition from communicable to non-communicable diseases as globalization and economic growth takes place. The growing global burden of cardiovascular disease places even more priority on addressing gaps in access to diagnostic, preventive, and curative services to better understand the burden of, more timely detect, and adequately treat cardiovascular pathology.

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Keywords

Global cardiac surgery · Epidemiology · Rheumatic heart disease · Congenital heart defects · Ischemic heart disease

8.1 Introduction

Cardiovascular diseases (CVD) are the world's leading cause of mortality, causing nearly 18 million deaths each year [1]. Of these, over 80% take place in low- and middle-income countries (LMICs), where cardiological and cardiac surgical infrastructure and capacity is minimal [2]. Over 485 million people are affected with CVD worldwide, with a cumulative of 366 million disability-adjusted life years (DALYs) lost per year [3]. Although the age-standardized CVD death rate has declined in high-income countries during the past decades, the CVD burden is on the rise in LMICs due to the epidemiological transition away from communicable diseases and towards non-communicable diseases. Table 8.1 summarizes the morbidity (in DALYs) and mortality (in deaths) of major CVD worldwide in 2017.

8.2 Rheumatic Heart Disease

Rheumatic heart disease (RHD) affects over 33 million people worldwide [4]. Recent reports even suggest a multitude of RHD cases globally

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_8

Table 8.1 Morbidity (in disability-adjusted life years, DALYs) and mortality (in deaths) due to cardiovascular diseases worldwide in 2017. Data are obtained from the Institute for Health Metrics and Evaluation Global Burden of Disease Results Tool

	Morbidity (DALYs)		Mortality (Deaths)	
	Number	Rate per 100,000	Number	Rate per 100,000
Ischemic heart disease	170,275,348	2,228.60	8,930,369	116.88
Stroke	132,051,366	1,728.32	6,167,292	80.72
Rheumatic heart disease	9,393,560	122.94	285,517	3.74
Congenital heart defects	22,223,897	290.87	261,247	3.42
Hypertensive heart disease	16,543,202	216.52	925,675	12.12
Non-rheumatic valvular heart disease	2,529,178	33.10	144,860	1.90
Cardiomyopathy and myocarditis	10,247,081	134.12	368,536	4.82
Aortic aneurysm	3,039,858	39.79	167,249	2.19
Endocarditis	2,228,363	29.17	83,391	1.09
Atrial fibrillation and flutter	5,976,005	78.22	287,241	3.76
All cardiovascular diseases	365,869,825	4,788.58	17,790,949	232.85

as a result of the common presence of subclinical RHD that remains undetected [5]. RHD mostly presents with mitral valve involvement (nearly 100% of cases), of which mitral regurgitation is the most common RHD presentation, and RHD is the most common cause of mitral stenosis worldwide [6]. Approximately 20–30% of RHD cases have (typically concurrent) aortic valve involvement [6]. Histological findings have shown that 15–40% of cases also have tricuspid valve involvement, although this is rarely of clinical importance [6].

In high-income countries, RHD has been nearly completely eradicated apart from continuing incidence in immigrant, indigenous, and disenfranchised populations, due to timely diagnosis and antibiotic treatment of acute rheumatic fever as a result of group A Streptococcus infection. In LMICs, the exact RHD burden has been poorly documented, but the incidence of acute rheumatic fever and prevalence of RHD varies widely. For example, in Pacific island states, RHD prevalence has been found to be as high as eight percent of the adult population [7]. This is often aggravated by living conditions and access to preventive and diagnostic health services, and, therefore, RHD has been deemed a disease of poverty. Moreover, growing data from endemic regions suggest that latent RHD (i.e., without prior clinical presentation of acute rheumatic fever) may be the most common presentation of RHD, further complicating adequate disease prevention [8].

8.3 Congenital Heart Defects

Congenital heart defects (CHD) are the most common congenital anomalies, affecting one in every one hundred live births, the leading cause of under-five mortality in high-income countries, and increasingly revealed in LMICs as a result of the resolution of other infant pathologies [9]. Of these, approximately 25% are considered critical CHD, requiring urgent surgical care within the first year of life. In the past decades, substantial gains in life expectancy and outcomes in children with CHD have been gained as a result of increased experience and familiarity with operating in the newborn period [10]. Nevertheless, as a result of a lack of comprehensive medical and surgical care, nearly 200,000 preventable child deaths continue to occur each year due to CHD [11]. Although over one million babies are born with CHD each year, and half of CHD cases will require surgery, it has remained a neglected topic on the global and child health agenda in LMICs, where over 90% of the population lacks access to the care they need [12–14].

The most common defects include ventricular septal defects and atrial septal defects, both of which may close spontaneously if small, whereas more severe defects range from Tetralogy of Fallot to life-threatening transposition of great vessels and single ventricle disease. However, CHDs present in several dozens of different anatomical variations. CHD can be divided into those inducing a right-left shunt and left-right shunt, the latter risking the development of Eisenmenger Syndrome, which results in a bidirectional and eventually right-left shunt causing hypoxemia (Table 8.2). In the newborn, CHD can be further distinguished based on the CHD's dependency on a patent ductus arteriosus (PDA) (Table 8.3) [10]. Those with pulmonary flow ductal dependence require a PDA to ensure adequate pulmonary flow, whereas those with systemic flow dependence require a PDA for adequate systemic blood flow. Defects with oxygenated ductal dependence require a PDA to ensure mixing oxygenated with non-oxygenated blood.

8.4 Ischemic Heart Disease

Worldwide, ischemic heart disease (IHD) is the most common CVD and the leading cause of premature mortality, affecting over 125 million people and causing 9 million deaths each year [3]. The most common etiology of IHD is coronary artery disease driven by lifestyle, such as a sedentary lifestyle, smoking habits, and unhealthy diets. In LMICs, IHD is proportionally less common compared to the burden in high-income countries, yet the epidemiological transition is leading to a rapid surge in IHD around the world. IHD affects LMIC populations at a younger age compared to high-income country populations, whereas the increase in overall life expectancy further causes concern with regards to the lacking cardiovascular infrastructure. Although three-

Table 8.2 Classification of congenital heart defects by cardiac shunt direction

Left-to-right shunt	Right-to-left shunt
Ventricular septal defect	Persistent truncus arteriosus
Atrial septal defect	Transposition of great vessels
Atrioventricular defect	Tricuspid atresia
Patent ductus arteriosus	Tetralogy of Fallot
	Total anomalous pulmonary venous return

Table 8.3 Ductal-dependent lesions. Adapted from Fiore et al. [10]

Pulmonary flow ductal dependence	Systemic flow ductal dependence	Oxygenation ductal dependence	Ductal independence
Critical pulmonary valve stenosis with intact ventricular septum	Congenital valvular aortic stenosis	Transposition of great vessels	Total anomalous pulmonary venous return
Tricuspid atresia	Coarctation of the aorta		Truncus arteriosus
Tetralogy of Fallot	Interrupted aortic arch		Anomalous origin of the left main coronary artery from the pulmonary artery
	Hypoplastic left heart syndrome		

quarters of IHD mortality takes place in LMICs, death rates vary widely across countries, which may reflect different levels of risk factors, other causes of death, extent of preventive and curative services, and the stage of epidemiologic transition of a country [15]. This may be exacerbated by the COVID-19 pandemic, either due to the cardiovascular manifestations of COVID-19 or due to indirect effects of the fear of seeking care amidst an outbreak or the mental and financial ramifications of public health measures such as lockdowns [16, 17].

Although the burden of IHD is growing across the globe, countries can take actions to reverse these trends and strengthen both preventive and curative care for IHD. For example, obesity, high cholesterol, unhealthy diets, reduced physical activity, and tobacco and excessive alcohol use are associated with IHD. Furthermore, socioeconomic conditions are important drivers of IHD, which are particularly important in LMICs and among poorer populations in high-income countries [18]. Medical care should emphasize the use of "polypills" for elevated blood pressure and may even be protective in patients without CVD [19, 20]. Additionally, timely referral for medical, interventional, or surgical revascularization is needed to timely treat patients presenting with acute coronary syndrome. Lastly, long-term care for patients with IHD sequelae such as heart failure must be improved, as CVD are typically lifelong conditions. Thus, multisectoral and systemswide interventions will be needed to reduce the epidemiological trends of IHD.

8.5 Aortic Pathologies

While less common than cardiac pathologies, aortic disease imposes a substantial burden on the world's population. Aortic aneurysms (AAs) are responsible for nearly 200,000 deaths each year as a result of rupture and dissection [3]. These can be divided based on location (ascending thoracic, aortic arch, descending thoracic, thoracoabdominal, suprarenal abdominal, and infrarenal) as well based on their association with syndromes (e.g., connective tissue disorders such as Marfan's Syndrome and Loeys-Dietz Syndrome) versus non-syndromic origins. The lack of timely (imaging-based) diagnosis and the scarcity of urgent cardiovascular surgical services in LMICs lead to extremely high rates of preventable deaths due to AAs. However, even in high-income countries, AAs remain among the top 20 causes of death as a result of an overall lack of screening programs (except for abdominal AA screening in elderly men) and the typical acute onset.

In addition, the burden of blunt thoracic aortic injury is slowly growing in LMICs. Trauma constitutes the leading cause of death in young adults, whereby blunt thoracic aortic injury commonly occurs [21]. This is particularly frequent in high-impact collisions such as road traffic incidents and falls from great heights. Although less than two percent of thoracic trauma is associated with blunt thoracic aortic injury, up to 80% die before reaching the hospital whereas in-hospital mortality is as high as 50% [22, 23]. In the past decades, outcomes have substantially improved as a result of advances in diagnostic imaging, staging, and treatment, notably including endovascular modalities [24]. Nevertheless, LMICs, which bear the brunt of road traffic injuries globally, have less access to comparably prompt and advanced treatment.

8.6 Other Cardiovascular Diseases

Stroke is the second most common cause of mortality due to CVD around the world, affecting over 100 million people worldwide, and imposing substantial morbidity and mortality at 132 million DALYs lost and 6 million deaths each year [3]. Although not traditionally treated by cardiac surgeons, the infrastructural capacity for (neuro) vascular diagnosis and treatment is comparable in both need and absence, and may pose opportunities for multidisciplinary collaboration at the clinical and health systems level [25].

Endemic conditions such as Chagas disease and endomyocardial fibrosis (EMF) remain of concern in South America and equatorial African countries, respectively [26]. Chagas disease, also called

American trypanosomiasis due to infection with the protozoan parasite *Trypanosoma cruzi*, is estimated to affect seven million people worldwide [27]. Although traditionally restricted to poorer Latin American countries, due to migration, increasing numbers are observed in other countries; for example, an estimated 300,000 people in the United States have Chagas disease [28]. Chagas cardiomyopathy is a form of dilated cardiomyopathy as a result of widespread immunological reaction, causing cardiac enlargement and myocarditis [28]. Although the majority of patients with Chagas disease remain asymptomatic, those developing cardiac involvement and symptoms generally have a poor prognosis [29].

Lastly, EMF is a form of restrictive cardiomyopathy and prevalent among poorer and rural populations in African countries along the equator [30]. However, as it is ill-defined, both etiologically and epidemiologically, it is unclear how prevalent EMF is across the globe [31]. Surgical care is necessary to ensure a chance of survival, although up to one in three still dies within ten years after EMF surgery [32]. As such, EMF remains a common, yet neglected debilitating cardiac disease in tropical regions.

8.7 Conclusion

The burden of cardiovascular disease remains large around the world, including a substantial part requiring surgical care to treat or prevent life-threatening complications. Increased attention is needed by governments and international organizations to ensure and support adequate disease awareness, prevention, diagnosis, and treatment in all countries worldwide.

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9 Monitoring, Evaluation, and Disease Surveillance for Cardiovascular Surgical Disease

Dominique Vervoort, Louvenser Minthor, and A. Thomas Pezzella

Abstract

Cardiovascular diseases are the leading cause of morbidity and mortality worldwide, and rapidly growing with the epidemiological transition of low- and middle-income countries (LMICs) from communicable to non-communicable diseases. Timely detection is paramount to avoid progressive disease with a poorer prognosis, yet screening mechanisms for cardiovascular diseases are limited beyond dedicated clinics and centers in LMICs. Moreover, diagnostic modalities are sparse, limiting conclusive diagnosis for many living with cardiovascular diseases in LMICs. However, opportunities arise to train community health workers and non-clinicians to screen people in their communities, whilst generating knowledge on the true burden in countries and regions to hold policy-makers and decision-makers accountable for the gaps in cardiac care.

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Keywords

Global cardiac surgery · Cardiovascular diseases · Epidemiology · Disease surveillance

9.1 Introduction

The burden of cardiovascular diseases (CVD) is vast around the world, constituting the leading cause of mortality with 18 million deaths each year, of which over 80% take place in low- and middle-income countries (LMICs) [1]. While the relative burden of ischemic heart disease is higher in high-income countries, the epidemiological transition from communicable to non-communicable diseases projects an added burden of ischemic heart disease on top of highly prevalent congenital (CHD), rheumatic (RHD), and endemic heart disease in LMICs [2, 3]. RHD is particularly endemic in LMICs, where over 30 million people live with RHD and hundreds of thousands die each year [4]. Meanwhile, one million babies are born with CHD each year in LMICs, but less than 10 percent can access the life-saving and life-changing care they need [5, 6]. The disparities in access to care and available cardiovascular care infrastructure lead to a substantial unmet need, resulting in large delays in seeking care (e.g., lack of diagnostics) and reaching care (e.g., distant specialty care) [2, 7]. As a result, CVD patients in LMICs often present

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_9

with progressive disease, which hampers the attainment of optimal short- and long-term outcomes, as well as the ability to return to work in a timely fashion. Thus, timely disease detection and establishing longitudinal monitoring and evaluation mechanisms are necessary to optimize outcomes and better inform national and international priority setting.

In this chapter, we present and describe the importance of monitoring, evaluation, and disease surveillance for CVD with a focus on variable-resource contexts where extensive screening mechanisms and diagnostic equipment are less commonly available.

9.2 Disease Surveillance

9.2.1 Importance of Surveillance

Timely screening is critical to improving the outcome of patients with CVDs. Detection of subclinical CVD, when patients have not yet experienced a true cardiovascular event or symptoms, can delay or even prevent morbidity and mortality associated with CVD. For example, through early diagnosis and subsequent timely treatment, newborn and prenatal screening can lower infant morbidity and mortality [8]. Similar paradigms hold true for all patients with CVD. Unfortunately, existing screening criteria may not be fully sufficient to detect all CVD, especially in its subclinical phases when treatment can be highly effective. For example, the World Health Organization echocardiographic criteria for RHD are estimated to miss three-quarters of subclinical RHD cases, requiring careful reconsideration of contemporary screening guidelines in low-resource settings [9].

Integrated, comprehensive, and systematic disease surveillance enables decision-makers and policy-makers to maximize and rationalize resources by integrating common disease surveillance [10]. Thus, remarkable trends in disease burdens and hotspots can be identified through data collection, be analyzed, and enable authorities to make data-driven decisions and targeted community and/or public health interventions. For example, the Framingham Heart Study comprised three generations of almost 15,000 individuals who were longitudinally followed to identify cardiovascular risk factors [1, 12]. The study led to the identification of high blood pressure, high cholesterol levels, and evidence of left ventricular hypertrophy on electrocardiogram to be significant longitudinal risk factors for the development of CHD [11]. It further established the strong association between cigarette smoking and the incidence of lung cancer, stroke, transient ischemic attacks, intermittent claudication, and all CVD [13]. Similarly, hotspots of RHD, which are commonly associated with poverty and crowded housing, can be targeted for treatment of acute rheumatic fever and early detection of RHD. While driven at the national level by the appropriate health workers under the country's public health system and Ministry of Health, this is aggregated and evaluated through regional bodies (e.g., the Africa Centres for Disease Control and Prevention). The extent of information technology systems at the national and regional level, as well as the frequency of reporting to regional agencies, determines the effectiveness and efficiency of disease surveillance and resulting programmatic responses. It is thus no surprise that regional grassroots efforts have sought and continue to seek such developments and commitments by policymakers and funders. For example, the Addis Ababa communiqué built upon the growing public health, medical, and biological knowledge generated over the past decades and posed seven key actions to address the RHD burden across Africa [14]. Of note, this includes the communiqué's first key point, which seeks to "*create prospective disease registers at sentinel sites in affected countries to measure disease burden and track progress towards the reduction of mortality by 25% by the year 2025*" [14].

9.2.2 Community-Level Screening

About 20% of CHDs may be attributed to genetic syndromes, teratogens, and maternal diabetes mellitus type 2 [15]. Those conditions can be addressed at preconception consultations where sought; however, for that to be effective, pregnant women need timely access to health centers and hospitals, and receive the recommended prenatal screening. Moreover, newborn children should be screened for CHD by well-trained health care providers. Although this generally occurs by specialists (i.e., pediatricians or pediatric cardiologists) in high-income countries and/or state-of-the-art centers, this may be suitable through task-sharing models, for example through nurses and community health workers [16]. Typically, CHD is considered in the presence of a cyanotic baby and can be easily screened through pulse oximetry before being referred to a facility to confirm the diagnosis and, where possible and needed, receive the care they need. However, some CHD patients do not present with cyanosis at or early after birth and may go undetected until more progressive disease sets in later in life.

RHD is a common and neglected health issue in LMICs and among Indigenous Peoples and immigrant populations in high-income countries [17]. Acute rheumatic fever is usually underdiagnosed in low-resource settings, which causes delayed treatment and late or no secondary prophylaxis, ultimately resulting in RHD [18]. Screening for RHD starts with access to a health center where the infectious history is reviewed for group A beta-hemolytic streptococci. Basic auscultation is very effective, although experience is highly variable even among clinical experts. In contrast, handheld echocardiography can be used as an effective diagnostic tool at the health center or in communities, even with non-experts [19, 20]. In addition, prophylactic follow-up is needed even with antibiotic treatment to assess potential progression to and of RHD.

Similar to CHD and RHD, IHD can be effectively screened for by trained community health workers through task-sharing models [21]. For example, in India, the Heart Attack Prevention Program for You (HAPPY) initiative successfully trained novices in using a cardiac ultrasound to detect the presence of carotid stenosis in working-age adults in rural India [22]. Timely detection and treatment is especially critical in light of the limited availability of cardiac rehabilitation programs in LMICs [23].

9.3 Monitoring and Evaluation

Monitoring and evaluation (M&E) of the global burden of disease occurs both at the national (e.g., Ministry of Health) and international level (e.g., World Health Organization). Simultaneously, aggregate resources, such as the Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease (GBD) study complement country-level and regional disease reporting [24]. The latter has been particularly influential in driving a large-scale academic understanding of the global burden of disease, including for CVD [1, 25–27].

Longitudinal M&E, on top of baseline disease surveillance, is critical to inform local practices with regards to disease prevention and targeted investments in curative and long-term healthcare services. For example, tracking the burden of RHD can identify high-incidence areas where antibiotic treatment of rheumatic fever and screening for RHD can be scaled. Similarly, a higher prevalence of untreated IHD in certain areas or communities may enable targeted interventions in a context-specific manner (e.g., related to local diet) as well as provide opportunities for longitudinal secondary and tertiary prevention.

Such mechanisms are also critical to measure the impact of and appropriately target public health and healthcare funding stemming from both the government, private funders, and development assistance for health. Although non-communicable diseases make up almost half of the global burden of disease, they receive only 1.5% of development aid for health [28]. Similarly, only 1% of global health funding is dedicated to global surgical care, of which a fraction is dedicated to cardiac care [29].

9.4 Diagnostics

At the core of disease detection is the widespread availability of adequate diagnostics. Population-based and community health screenings largely rely on clinical parameters (e.g., history taking and auscultation), with the more recent development and adoption of low-cost and portable technologies such as pocket echocardiography and smartphone applications. However, more advanced imaging in health centers is limited [30]. In LMICs, the presence of imaging modalities such as chest x-rays is limited even in some established tertiary centers. Two-thirds of the world does not have access to basic radiology services [31]. For example, although the World Health Organization recommends 20 general radiography units per million population, there are only 5.7 per million in the Tanzanian public sector [32]. It is estimated that one computer tomography scanner is needed per 10 general radiography units, although the availability thereof is even more scarce [32].

Bioimaging modalities such as nuclear cardiology, especially for subclinical CVD, is feasible and available in LMICs, although highly concentrated in capitals [30, 33]. Even then, costs are typically prohibitive: one stress single-photon emission computed tomography myocardial perfusion imaging (SPECT MPI) in India costs almost half of the average monthly income of the middle-class population [34]. Lastly, the lack of trained technicians and limited oversight of available equipment and donated supplies leads to over half of local equipment in LMICs being out of use, either due to lack of know-how or due to dysfunction [30, 35].

9.5 Conclusion

Millions of people continue to die from cardiovascular diseases each year, many of which are left undiagnosed or untreated. Timely disease detection and longitudinal monitoring, evaluation, and reporting on cardiovascular disease burdens are necessary to better inform policymakers' priorities and decisions, and treat patients earlier in their disease course.

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10 Global and National Advocacy for Cardiac Surgery—Start with the Children

Bistra Zheleva

Abstract

This chapter will examine the role advocacy can play in increasing the access and availability of pediatric cardiac care globally. It will examine the role of different actors but will specifically focus on the role of nongovernmental organizations (NGOs). It describes the different types of advocacy, presents several frameworks for developing advocacy strategies and existing global and national opportunities for advocacy. Finally, it will discuss opportunities for collaboration among different stakeholders and how a rights-based advocacy for pediatric cardiac care and childhood onset heart disease in low- and middle-income countries is the most unifying approach for organizations and individuals.

Keywords

Advocacy · Congenital heart disease · Rheumatic heart disease · Childhood onset heart disease · Pediatric cardiac care · Population health · Public health

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10.1 Burden of Heart Disease in Children

The biggest burden of cardiovascular disease in children and with childhood-onset heart disease lies squarely in the low- and middle-income countries of the world. Congenital heart disease (CHD) is the most common birth defect globally. In 2019 [1] there were over 13.3 million people living with CHD in the world and 217,000 people died from CHD. And unfortunately most of the deaths were in low- and middle-income countries (LMICs) and almost 70% of the deaths were in infants. CHD is now the 7th cause of infant mortality and 2nd cause of mortality in the 28–364 days-old age group globally and in upper-middle-income countries, respectively, according to the 2019 Global Burden of Disease (GBD) data. Increasing over the years, the prevalence of rheumatic heart disease (RHD) was 40.5 million in 2019. While mortality decreased until 2012, it started increasing again since 2017, reaching 306,000 in 2019. In addition, after 15 years of age, women bear a higher prevalence burden of the disease across the world. Coupled with the complications of unfollowed and untreated CHD, both diseases affect women more in their childbearing age.

The GBD study on congenital heart disease [2] compared CHD with RHD (Fig. 10.1) and that data showed that both diseases contributed to this significant burden however CHD largely affects infant mortality (years of life lost), and

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_10

RHD has a larger share of years lived with disability and the mortality is the highest in the 20- and 30-year-old population. This is important to note because RHD is endemic in poor regions and lower income countries, it is a disease of poverty and those countries have the highest unaddressed burden. When we advocate for pediatric cardiac services, we have to consider the burden in both diseases and what services are necessary to address both. The hope and goal should be that cardiac services developed to address RHD will eventually transition to serving more CHD patients as RHD gets eliminated through primary and secondary prevention and overall development. These numbers present many opportunities for advocacy. In fact they are not just opportunities, these are imperatives.

Despite the evidence we have about the burden of disease there is still a significant gap in trained healthcare professionals. There are no studies today that have shown what the exact availability of services are even though few are underway right now. One estimate [3] suggests that 93% of the world lack access to quality cardiac surgical services and another [4] tried to estimate the number of cardiac surgeons per million population. It estimated what the distribution of cardiovascular centers in selected countries and continents was and the author found severe gaps between North America and Europe and South America, Asia and Africa where his estimate showed that there is one cardiac surgeon to 38 million population. Unfortunately, very little has been done to look at what is the discrepancy in the availability of well-functioning multidisciplinary cardiac teams that include not just surgeons caring for children with heart disease, a now widely accepted standard practice assuring quality surgical outcomes.

These numbers give a clear direction of where advocacy efforts should be focused in low- and middle-income countries to ensure that newborns and children do not die preventable deaths, and that we are not leaving backlogs of millions of children awaiting life-saving surgery. The global trend is clear that as more countries transition from the low-income category to lower-middle income and upper middle income (Fig. 10.2), fewer children will die from easily preventable causes such as most infectious diseases and the contribution of diseases such as CHD will be increasing (Fig. 10.3). To care for children with heart disease it is essential to build pediatric cardiac services quickly.

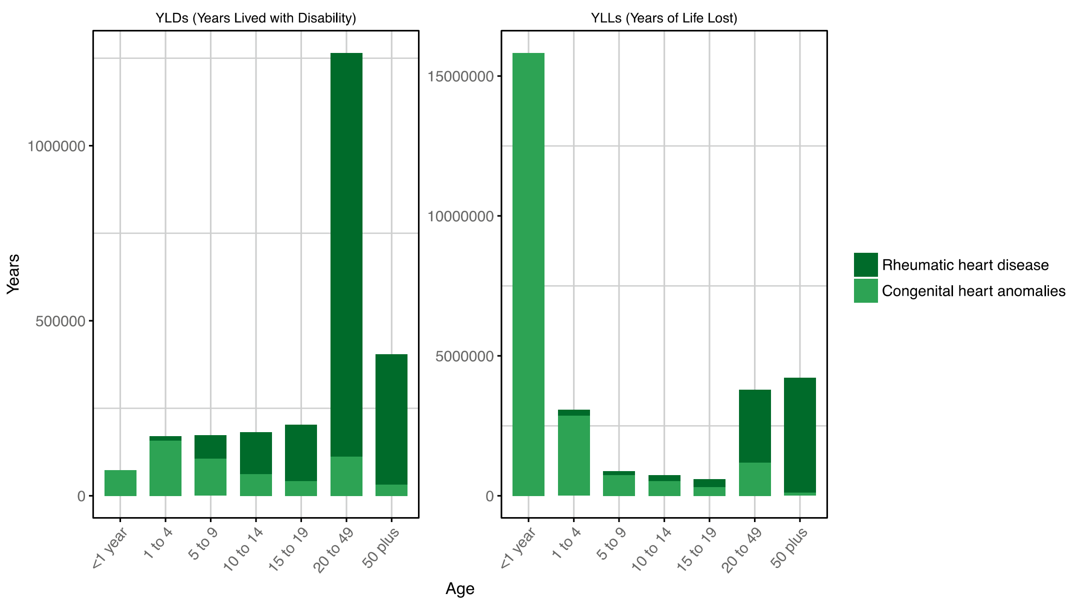


Fig. 10.1 RHD and CHD: Global YLDs and YLLs by Age, 2017

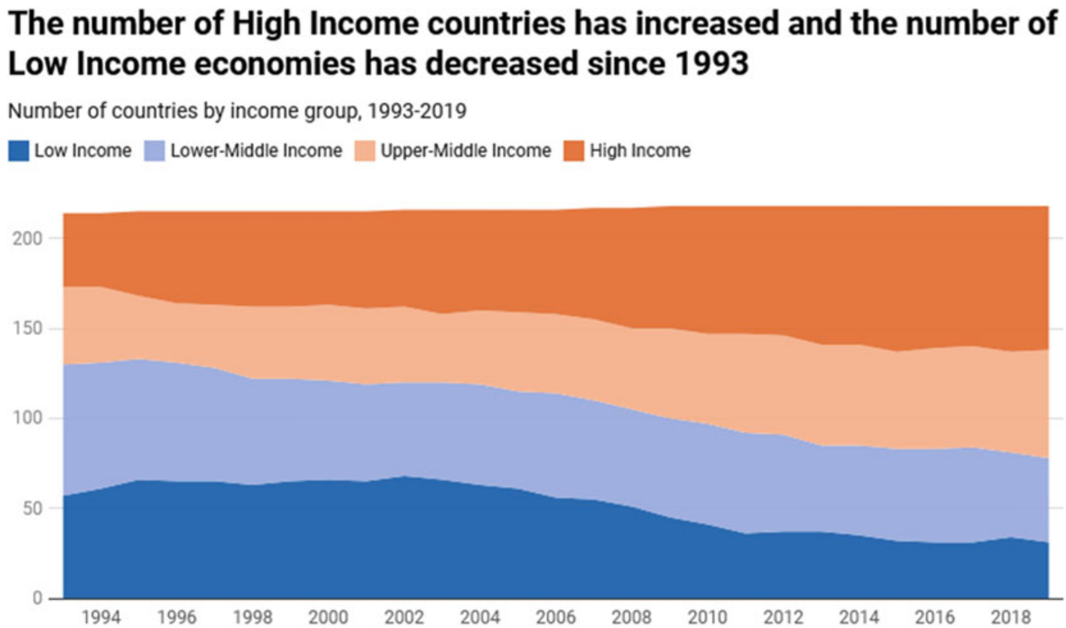
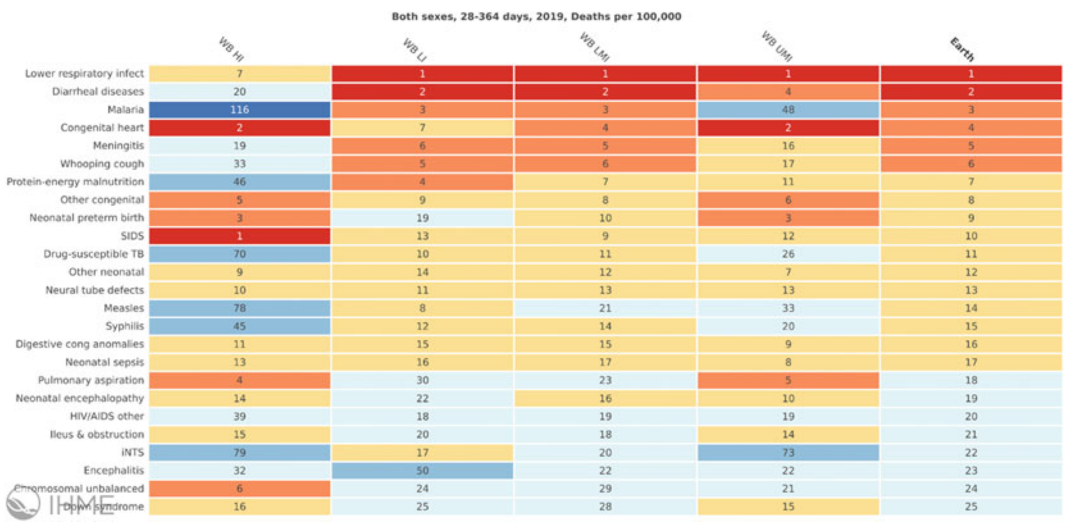


Fig. 10.2 Progression of countries across income categories, 1993–2019 [5]



Both sexes, 28-364 days, 2019, Deaths per 100,000

	WB HI	WB LI	WB LMI	WB UMI	Earth
Lower respiratory infect	7	1	1	1	1
Diarrheal diseases	20	2	2	4	2
Malaria	116	3	3	48	3
Congenital heart	2	7	4	2	4
Meningitis	19	6	5	16	5
Whooping cough	33	5	6	17	6
Protein-energy malnutrition	46	4	7	11	7
Other congenital	5	9	8	6	8
Neonatal preterm birth	3	19	10	3	9
SIDS	1	13	9	12	10
Drug-susceptible TB	70	10	11	26	11
Other neonatal	9	14	12	7	12
Neural tube defects	10	11	13	13	13
Measles	78	8	21	33	14
Syphilis	45	12	14	20	15
Digestive cong anomalies	11	15	15	9	16
Neonatal sepsis	13	16	17	8	17
Pulmonary aspiration	4	30	23	5	18
Neonatal encephalopathy	14	22	16	10	19
HIV/AIDS other	39	18	19	19	20
Ileus & obstruction	15	20	18	14	21
iNTS	79	17	20	73	22
Encephalitis	32	50	22	22	23
Chromosomal unbalanced	6	24	29	21	24
Down syndrome	16	25	28	15	25

Fig. 10.3 Mortality in children aged 28–364 days, deaths per 100,000. GBD 2019 [6]

10.2 What Is Advocacy

We would like to start first with a definition of what advocacy is. Some define it as an activity that aims to influence decisions within the political, economic, and social systems and institutions to make a positive change. When we talk about health advocacy, what we typically mean are activities that enhance community health policy initiatives that focus on the availability of safe and quality of healthcare. Often advocacy is related to the legislative process. Legislative advocacy relies on the legislative processes, whether national or sub-national, as a strategy to create a change in specific policies. And last, often advocacy is confused with lobbying. Lobbying tends to be similar to legislative advocacy but has a bit narrower focus.

In public health, advocacy is one of the strategies of health promotion and communication. Risk communication, is a sustained communication process with diverse audiences about the likely outcomes of health and behavior attitudes. Another strategy is crisis communication, which is more of a reactive communication effort in the face of an unforeseen event, not unlike the current COVID-19 pandemic. This is followed by social marketing which uses social marketing tools to conduct public health improvement programs. Outbreak communication helps to bring outbreaks under control as quickly as possible with as little social disruption as possible. We also have advocacy for improving health literacy among the general public through health education which aims to influence a person's knowledge attitudes and behaviors connecting to health in a positive way; and finally health advocacy, the strategy to raise awareness and promote health and access to quality health care at the individual and community levels.

When engaging in advocacy there are several important components that have to be identified. The first and most important is to determine as specifically as possible the change we are advocating for, whether it is a policy change, a change in guidelines or building awareness. The next important step is determining the target audience or who are the decision makers or influencers that can make the change that we are aiming for. Often there may be more than one target audience. The next component is identifying the messages for each of those audiences. Then comes identifying the messengers, or who do the decision makers need to hear from. We need to identify what are our approaches for communicating, plan our activities, and of course plan any evaluation to understand if our advocacy efforts have been successful. UNICEF offers a great example of how advocacy works within the policy decision-making cycle [7], and an especially helpful aspect of it is the focus on human rights (Fig. 10.4). And since we are discussing heart disease in children which is considered a chronic disease, it is worth also mentioning the WHO chronic disease advocacy handbook [8] which is based on similar principles.

10.3 Global and National/Subnational Advocacy

Any advocacy must be framed within existing health systems and the goals they are trying to achieve. For heart disease in children it has to start with the Sustainable Development Goals (SDGs) [9] and specifically SDG3, Good health and wellbeing. SDG3 has several targets that are very applicable to pediatric cardiac services, they are:

1. By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births
2. By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births
3. By 2030, reduce by one third premature mortality from non-communicable diseases (NCDs) through prevention and treatment and promote mental health and well-being
4. Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all
5. Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing states

Countries have endorsed the SDGs and have developed targets nationally and at subnational level too. For example, in India, most states have specific contextual targets to address childhood mortality. In the case of Kerala, the most southern state in the country, the local government had committed to reduce infant mortality from 12 to

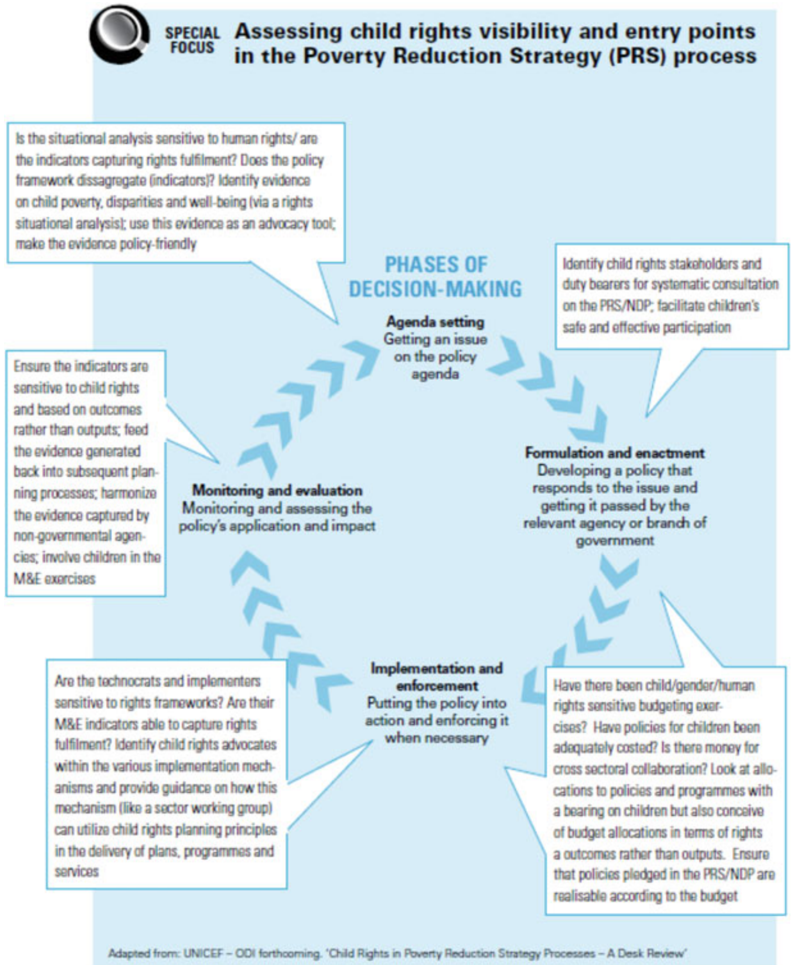


Fig. 10.4 UNICEF Advocacy Human Rights Framework

8 per 1,000 live births by 2020 and to 6 per 1,000 live births by 2030. This state-level goal created impetus to invest in the development of strong referral pathway and continuum of care for CHD in 2018, as one of the main contributors to infant mortality at the time.

Of course, other goals can also be applicable for this cause. For example SDG1, eliminating poverty, is very relevant for pediatric cardiac services because if it gets included in universal health coverage and in public financing for health, fewer families will be financially burdened by out-of-pocket expenses they have to pay for the care of their children with heart disease.

In addition to the SDGs, several guidelines and recommendations developed and promoted by the WHO offer opportunity for global and national advocacy. Those include:

- Global Strategy for Women's, Children's and Adolescents' Health
- Survive Thrive Transform, a Global Strategy for Women's, Children's and adolescents' health monitoring report
- Every Newborn Action Plan (ENAP)
- Ending Preventable Newborn Deaths and Stillbirths by 2030, an ENAP monitoring report
- Standards for Improving Quality of Care for Children and Young Adolescents in Health Facilities
- Standards for Improving the Quality of Maternal and Newborn Care in Health Facilities

- Standards for Improving the Quality of Care for Small and Sick Newborns in Health Facilities
- Human resource strategies to improve newborn care in health facilities in low- and middle-income countries
- Global Action Plan for Healthy Lives and Well-being for All

Furthermore, the WHO passed at its 63rd World Health Assembly a resolution on birth defects [10] promoting primary prevention and improving the health of children with birth defects by developing and strengthening registration and surveillance systems, developing expertise in building capacity, strengthening research and studies on etiology diagnosis and prevention, and promoting international cooperation. In 2018 a similar resolution was passed for RHD that called for more international partnerships for mobilizing resources sharing best practices methodologies, developing, and supporting a strategic research and development agenda, and facilitating access to existing and new medicines and technologies.

Each one of these publications, has commitments, recommendations, and guides that are applicable to pediatric cardiac services and NGOs can engage in their revision or with the WHO offices in charge of their development. Each of these documents presents opportunities for advocacy on a global and national level. This could be advocacy with the WHO for inclusion of pediatric cardiac care in the different normative documents developed by them, or in advocacy with member state governments who have approved and ratified the resolutions. The unfortunate reality is that most of the documents do not explicitly mention children and people with heart disease. Even more, in the noncommunicable diseases (NCD) space goals such at the WHO NCD Global Monitoring Framework, 25 by 25 (a 25% reduction in premature mortality from noncommunicable diseases by 2025) [11] do not refer to children or congenital heart disease at all, despite recent publications that in people younger than 30 years of age the largest NCD-related causes of death in 2016 were congenital heart anomalies [12].

The WHO also celebrates a number of commemorative dates and occasions that also provide a chance for organizations to advocate globally. Such are the just passed 2020 Year of the Nurse and Midwife and the current 2021 Year of Health Worker, both providing excellent platforms to build awareness about the gaps in pediatric cardiac services for the training of more specialist health workforce both at the global and at a national level. A list of relevant global health dates is in the appendix.

At a national level in many countries, commitments often languish and are never fully addressed beyond a country health plan published on the Ministry of Health website. Instead they are only revived when reporting has to be done at the World Health Assembly. Still, they do offer openings to base the advocacy efforts on an existing platform and national comittments made instead of trying to build a new one and advocates and NGOs ought to take advantage of them. Advocacy efforts are always easier when done as part of an organization, so in the next we will refer to NGOs only.

Organizations and individuals can engage in both global and national/subnational level of advocacy. On a Global Level, this means engaging in policy influencing and agenda setting processes within international multilateral organizations to increase attention to disparities in access to services for treating heart disease in children and to affect the prioritization of global health policies. This can be achieved through several separate efforts:

a. Utilizing resources of larger advocacy organizations, such as the Global Health Council, NCD Alliance, NCD Child, Every Woman, Every Child, Partnership for Maternal, Neonatal and Child Health, and others, to collectively meet and influence global policymakers. This brings strength but also can dilute the message.
b. Participation in international organizations' committees and working groups and international conferences and providing consultative services to represent the issue. This also means acting to include it in official documents and recommendations and emphasizing the need to prioritize access to pediatric cardiac care.

c. Publication of data, research and/or personal testimonies and strategically referring to this information during important meetings and debates to helps to inform and positively influence the decisions of members of international organizations.
d. Present and emphasize research advocating for pediatric cardiac care policies at international conferences and linking the data with other important global priorities, such as the Sustainable Development Goals.
e. Finally, NGOs may also develop a coalition of likeminded stakeholders as a global movement and bring strength in collective advocacy and lobbying efforts, such as global professional organizations or other NGOs working in the field.

Engagement on the global level can help NGOs to establish their legitimacy with national and regional policymakers. If an organization has a reputation as a global leader, policymakers will be more likely to seek it out for technical assistance or advising on international best practices.

Still, key opportunity for engagement is at the national and even sub-national level for larger countries such as India, Brazil, or China, where health care is the domain of state/provincial governments and national governments only provide guidelines. On national and regional level, NGOs can aim to influence public policy and programs relevant to improving access to quality pediatric cardiac care and engage in awareness building, education, collaboration and policy formulation and implementation role. This could be acting as a technical expert with decision-making bodies in a consultative role to advise planning of implementation programs and in discussions about the design of health policies. In addition, NGOs can work towards building awareness and changing perceptions about children with heart disease in the community. Efforts supporting this approach would include:

a. Convening stakeholders for meetings, conferences, workshops, commissions to inform policy decisions.
b. Engaging in publication and dissemination of data and research, collecting personal testimonies to inform policy decisions and represent Children's HeartLink and partners goals for the country/region, or to build awareness within communities and change perceptions about children with heart disease.
c. Assisting with maintaining, but also monitoring, government commitment to implementing guidelines and policies, especially those established on a global level.
d. Holding governments accountable to international and domestic commitments and encouraging them to engage with international bodies to promote pediatric cardiac care access improvement.
e. Engaging with professional organizations to encourage and support their advocacy efforts.
f. Build community awareness by engaging patients and families in advocacy efforts; collect patient and family stories to emphasize need and to use with decision makers.

A critical opportunity for advocacy at the national level should be in domestic financing for health care services. This continues to be one of the main barriers to the development of and access to care for the majority of families around the world. There is little published on this topic but some studies [13] demonstrate the burden out of pocket payments place on families with children with CHD. At the same time, there is a perception that pediatric cardiac services are costly and that perception possibly drives the hesitancy behind the lack of investment. A study of NGO's cost effectiveness [14], estimated that the cost-effectiveness of the NOG's intervention was only $171 per disability-adjusted life-year averted. Advocacy for health financing needs a lot of this type of data so this is something capacity building NGOs, patient and family organizations, professional societies, and individual health professionals can act on to bring more evidence to demonstrate the return on investment in pediatric cardiac care in terms of lives saved, disability adjusted life years averted, or quality-adjusted life years (QALYs) gained.

This is probably the most complex advocacy capacity to develop in terms of the skills needed to conduct it, the necessary partnership with health economics professionals and the monitoring and evidence gathering required to inform the advocacy activities. It also requires long-term commitment, as it has to work with political leaders' agendas. Sadly, sometimes political uncertainty may revert hard-earned commitments. Yet, this is one area where advocacy is needed, and changes would make the most difference in the lives of many.

10.4 Advocacy for Children with Heart Disease

Advocating for access to quality heart care for children is important not only because of the high burden but it is also of the specifics of the disease. Cardiovascular diseases in children are unique as they, unlike in adults, have onset in childhood and largely remain chronic disease for life. As such, they require a life-course approach from infancy that includes access to treatment and follow up care. Given that the birth prevalence of CHD tends to be the same across the world, with some minor regional differences, it is a disease where the burden can be predicted based on the population and the birth rate trends in a region or country. For that reason, CHD lends itself well to a population health approach. The medical and surgical advances of the last 50 years have made survival with CHD a reality for most children born today except for the most complex defects. Unfortunately, a negative consequence of that has been that CHD has been treated like a surgical condition resolved only with surgical management in a hospital. And while surgery remains the definitive therapy in many patients, we have missed an opportunity to address other determinants of outcomes and quality for CHD. A public health or a population health approach assures that all children are screened for it prenatally, as newborns or in the first years of life and that all children with CHD receive a timely diagnosis which would then lead to a timely treatment. Following the treatment in a tertiary care facility would be important to create a system for a follow up care for life as any chronic lifelong condition would require. Only recently have providers began thinking about a public health-like management of CHD through the introduction of the Public Health Approach to Improve Outcomes for Congenital Heart Disease Across the Life Span [15], developed through the excellent work of the Congenital Heart Public Health Consortium. Their framework looked at surveillance, research, and prevention. However, because it was developed to address the needs of this population in the United States, it does not sufficiently address the problems of LMICs where the lack of understanding and addressing the disease is much greater. It also does not identify the actors who need to be involved in the process.

What determines that all children have equitable access and high-quality cardiac care? We have identified five determinates. First is availability of care—a hospital facility has to be in place where the surgery will happen. Second is quality—the hospital needs to be providing high-quality care which means doing a sufficient number of cases with low mortality and morbidity. As a complex disease needing a complex intervention, it is now well documented that poor quality leads to either mortality or life with disability, either one of which would defeat the purpose of existing access. The next determinate is affordability. Pediatric cardiac care can be expensive for any individual family and very few around the world can afford to pay for it out of pocket. The next determinate we identified is general awareness—in society, but also within the primary care level of the health system, where providers need to be well informed and aware to refer patients in a timely fashion. The last determinate is physical accessibility, which can be a big barrier to families for accessing care, especially in countries where care is available in just a few large urban centers and they have to travel far from their homes and spend extended periods of time away from other family members and from their jobs.

To address the five determinates of access to quality care, we propose a Population Health

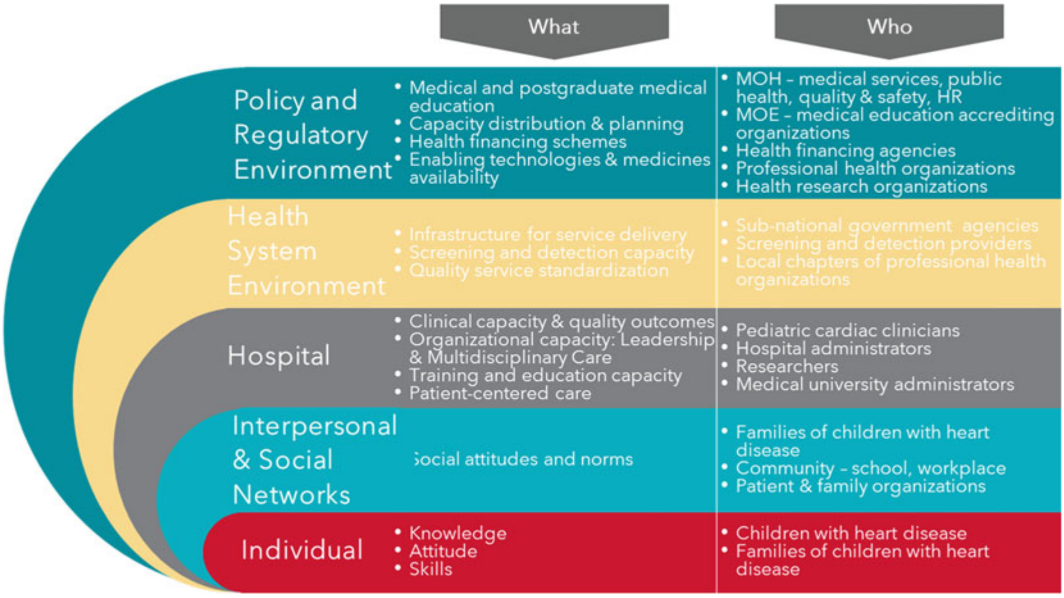


Fig. 10.5 Population Health Framework for Heart Disease in Children

Framework for Heart Disease in Children developed by Children's HeartLink that can be used as a framework for both advocacy and for interventions at the different levels of the health system (Fig. 10.5).

The framework is based on existing social and ecological models [16, 17] and describes the actors who should be engaged at the different levels for the advocacy (in most cases policy) changes to happen. It can also be used to assess the barriers to care that exist in a health system or in a country. Naturally, the most impact will be at the policy level, but most NGOs tend to work at the hospital level because of size and inexperience with policy advocacy. It is worth considering what social barriers exist for children to access care at the interpersonal and social network level. Being an invisible disability, CHD is often perceived with a lot of societal stigma for the family due to the lack of understanding and lack of societal awareness about the incidence and prevalence of the disease. So in addition to the very important policy changes, advocates can also put efforts in raising awareness about the disease and the options for its treatment. There are several examples of organizations doing exactly that, such as Conquering CHD in the United States, Kardias in Mexico, Brave Little Heart in South Africa, and Brave Heart Fund in Lebanon.

10.5 Collaboration

Advocacy is strongest when done collaborative, as it was pointed out earlier. In a recent publication [18] we performed a stakeholder analysis of existing groups within the field of pediatric global cardiac surgery and identified gaps and opportunities in advocating for cardiac care for children with CHD. The analysis identified stakeholders working globally in pediatric cardiac care and provided some recommendations for collaboration among them. We discussed the role of global professional societies such as the World Society of Pediatric and Congenital Heart Surgery, which can play an important role in bringing educational resources and with the recent establishment of the Global Council on Pediatric and Congenital Heart Surgery Services is setting the stage for standardizing pediatric surgical education globally.

Other stakeholders included NGOs such as Children's HeartLink and Reach, organizations already advocating globally and nationally, and the International Quality Improvement Collaborative for Congenital Heart Disease, which with its registry with over 105,000 cases registered from 64 sites in 25 countries has not only helped improve quality outcome but can also contribute greatly to national and global advocacy efforts.

Two important groups that can play a role especially in national level advocacy are national professional societies and patient and family groups. In many countries national professional societies have been engaged in varying degrees in advocating for pediatric cardiac services. In India, the Pediatric Cardiac Society created the Working Group on Management of Congenital Heart Disease in India that developed the *Indian guidelines for indications and timing of intervention for common congenital heart diseases* that focused on the specifics of caring for children with CHD in India taking in consideration the limited availability of services in some parts of the country. In another example in Brazil, the Brazilian Society of Pediatrics and the Brazilian Societies of Cardiology, Cardiovascular Surgery, and Interventional Hemodynamics and Cardiology recently successfully advocated with the federal government for increased investment in CHD surgery infrastructure in the public system and increased reimbursement for complex CHD.

The patient and family groups are an important and underutilized advocacy stakeholder for pediatric cardiac care. Domestically, in each country patient and family groups have been fundraising and providing support for new patients' families. Others have been building awareness through social and the conventional media and few have been even advocating for policy changes with their governments. The Global Alliance for Rheumatic and Congenital Hearts (Global ARCH) is a global alliance of patient and family organizations and individuals affected by CHD and RHD, with the aim to advocate and promote global awareness of CHD. Global ARCH has been working to build advocacy skills with its member organizations through webinars and training and listening sessions.

We also proposed a collaborative framework (Fig. 10.6) that can align advocacy initiatives to increase the efficiency of the different actors' efforts in the global community to advocate domestically and internationally holding national and international policy makers accountable for existing gaps and disparities in CHD care. Similarly to the earlier discussion here, this framework allows stakeholders to plan for structured advocacy activities through analysis of the needs and goals and through multi-stakeholder discussions ensuring the integration of all voices, especially those of the patients and families, and to prevent duplicative efforts.

Global ARCH's mission is to empower CHD and RHD patients and family groups around the world to make an impact both in their communities and globally. Global ARCH helps its community connect in-person and online. Member organizations share ideas and resources via the Global ARCH website, member discussion forums, training webinars, and in-person meetings. The organization coordinates activities to promote global awareness of CHD and RHD and partners with professional and humanitarian organizations to represent the CHD and RHD community. Global ARCH currently has 32 member organizations from 25 countries.

Patient and family advocacy groups are uniquely positioned to leverage awareness,

Fig. 10.6 Stakeholder collaboration framework for advocacy activities

resources, and policy change to improve outcomes for people living with childhood-onset heart disease. Although such advocacy is well-developed in high-income countries, the action is needed to promote patient-provider partnerships in LMICs to inform policy changes that can improve long-term outcomes for children and adults affected by childhood-onset heart disease. Global ARCH aims to fill a gap in the global noncommunicable diseases community by creating a collective voice for those affected individuals and heightening awareness of the disease burden and unmet needs. Strengthening the voice of this community will promote action to enhance service delivery to this severely underserved population. The organization gained steam recently by producing a number of educational materials and translated them in several languages.

The most important advocacy document Global ARCH has delivered recently is the *Declaration of Rights for Individuals with Childhood-onset Heart Disease* [19]. The Declaration is a formal document stating the basic health rights for every person affected by CHD and RHD. It lists actions that governments should take to meet these rights. It is based on documents such as the 1948 WHO founding constitution, the UN Convention of the Rights of the Child, the UN Convention on the Rights of Persons with Disabilities. CHD and RHD children and adults have the same right to health as every other citizen. The goal of this declaration is to raise awareness of the ways in which CHD and RHD patients are being denied their right to health. It can be used to educate patients, families, health professionals, policy makers, and the general public about the needs of people with CHD and RHD. It can also be used as a tool to promote needed actions by governments and other policy makers. Global ARCH and its partners are asking for organizations and individuals to endorse the declaration and share it widely exemplifying the collective power and voice that can emerge from a rights-based approach to advocacy.

10.6 Challenges

We have suggested several options that advocates can and should consider when advocating for improved access to services for heart disease in children. Naturally, many challenges and risks have prevented this from happening and continue to do so. First is the significant lack of awareness among governments, donors, multilateral agencies and global health NGOs about the scale and scope of the problem.

The second challenge stems from the first, as it relates to the lack of funding in the multilateral donor space, in the private donor domain and in the domestic public financing for health. This severe underinvestment leaves the public and private fiscal space still very small to sufficiently cover needed expenses. The reality is that catalytic investments would come most likely from the private sector, but pediatric cardiac programs would only be sustained with domestic public funding. A significant problem to be overcome is also the perception that pediatric cardiac care is expensive and unaffordable. More evidence is needed to prove not only that it is most likely not the case, but also to demonstrate the collateral positive effects on the health system of developing highly specialized medical services such as pediatric cardiac care. Still, more advocacy is needed with donors and governments to drive action.

Reliable, sustainable funding is a key challenge and advocacy funding is available even less at national level. Most funders expect quick results with a small investment with little appreciation for the fact that advocacy is a long-term investment in largely someone's time to do it. Short-term expectations also lead to the challenge of showing concrete results which creates a vicious cycle of lack of funding due to inability to show results.

Lack of strong institutions is the third challenge in some countries, especially the lack of political stability. Related to that is the lack of capacity within countries at both the government level to understand what is necessary to develop pediatric cardiac services, but also in the civil society to advocate for those changes.

Another barrier that prevents advocacy from growing in this field is that the heterogeneity of CHD creates people and families with very diverse experiences, based on the complexity of the CHD of their child. In addition, there is still insufficient understanding among some providers and policymakers of how CHD affects patients' adult lives. RHD, on the other hand, is largely a disease of poverty. The complexity of cardiac diseases also requires a complex multidisciplinary teams to manage them in and out of the hospital and such large group of health professionals require a strong health system to get organized along a pathway of care. A great way of overcoming such challenges is finding a shared advocacy goal which focuses on a human rights framework, such as the Rights Declaration developed by Global ARCH and of being inclusive of all stakeholders and especially of families and patients of all age groups.

10.7 The Invisible Child Series

Between 2015 and 2017 Children's HeartLink published the Invisible Child series of policy papers [20]. The series brought to light the burden of childhood heart disease and the tremendous inequity in access to pediatric cardiac care, outlined the barriers to improving access to quality care, and provided examples of locally driven success. In the concluding paper, *A Voice for the Invisible Child*, Children's HeartLink called on leaders in health and development to acknowledge pediatric heart disease within the global health agenda:

- Investments in increasing capacity at all levels of the health-care delivery system to screen, diagnose, and treat children with heart disease.
- Building accredited pediatric cardiac training programs in all regions globally to assure systematic recognition of the basic signs and symptoms of congenital and rheumatic heart disease.
- Improve surveillance through systematic data collection on pediatric heart disease in national health surveys and include in burden of disease and cause of child death statistics.
- Assuring pediatric cardiac care will be included in benefits packages in universal health coverage and social protection platforms, and patients will be protected from catastrophic expenses related to their care.

The Invisible Child series made the case and demonstrated the "asks" that the advocacy community can make of actors with ability to impact, change and improve the lives of children with heart disease around the world. The series created a framework that anyone can use to advocate for children with heart disease and more such publications with additional data and evidence are necessary to build the global awareness, and even more so, at the national level.

10.8 Conclusion

In summary, there are many opportunities for advocacy for global cardiac surgery. However, these efforts should not be limited to surgery only but instead encompass a broad scope of services that assure lifelong access to care. There are different frameworks that can be used, and part of the success will be in identifying where the change needs to happen and understanding the context of the health system. It also requires knowing what the problem is, finding champions and cultivating relationships, and preparing and looking for the opportunity to advocate. The most impactful activities will be at the national and sub-national level with long-term goals. Advocacy should be local and community driven. Such approach gives the best opportunity for monitoring and accountability tracking.

The Invisible Child offers a clear path and makes a case of why more investments are needed but more data is still needed, especially around the economic impact on both patients and families, and the needed investment to develop more pediatric cardiac services.

Global ARCH has demonstrated that putting a strong emphasis on justice and disparity and linking health to human rights should be the main way to unite the global narrative around cardiac diseases originating in childhood. The Right to Health should be the overall driver elevating grassroots voices with a bottom-up approach. Children and adults with childhood onset heart disease deserve to receive the best possible care regardless of where they were born, and our global community has an obligation to advocate for it.

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Costing and Health Systems Financing of Global Cardiac Surgery

11

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Abstract

The establishment of cardiac surgical centers and delivery of cardiac surgical care is expensive, limiting access to care for patients without comprehensive health insurance or philanthropic support. In this chapter, we describe the costs associated with cardiac surgical care and lay out opportunities to increase health system financing to afford and expand cardiac surgical care delivery in light of competing health (e.g., infectious diseases) and non-health agendas (e.g., education). We conclude by proposing opportunities for different stakeholders to reduce procedural costs, ultimately expanding access to care for patients in need, and fostering locally-driven solutions, thereby promoting the local economy.

Keywords

Health economics · Financing · Global cardiac surgery · Global surgery

11.1 Introduction

Cardiac surgery remains expensive worldwide. The need for adequate pre-operative screening, diagnostics, utilization of intra-operative consumables, workforce, and infrastructure, use of post-operative intensive care, and hospital stays lead to insurmountable medical bills for patients without the financial means or risk protection to afford this. Similarly, cardiac surgical centers come with high upfront costs to be established, requiring government or private sector support to be financed.

Despite prevailing myths that cardiac surgery is a supposed luxury in low- and middle-income countries (LMICs), early results suggest that the provision of cardiac surgery in LMICs is highly cost-effective [1]. Performing pediatric cardiac surgery in LMICs has been found to cost US $171 per disability-adjusted life year (DALY) averted, which is more cost-effective than various common global health interventions, such as oral rehydration therapy (US$1,062 per DALY averted) and highly-active anti-retroviral therapy for HIV (US$922 per DALY averted) [1–3]. For many, this may not be a surprise: cardiovascular

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_11

diseases are the leading cause of morbidity and mortality worldwide with ischemic heart disease taking the lead, rheumatic heart disease affects over 30 million people, and one in 100 babies is born with a congenital heart defect [4–6]. The impact of the lack of cardiovascular care, importantly including cardiac surgical and interventional care, significantly impedes socioeconomic growth in countries around the world [7, 8]. Similarly, screening for cardiovascular diseases is limited outside of secondary and tertiary centers in LMICs, and community-level screening is largely limited, thereby resulting in late presentations with more progressive disease. Yet, access to safe, timely, and affordable cardiac surgery remains an illusion for six billion people, in large part due to the financial barriers in the absence of adequate financial risk protection, whether through private, public, or philanthropic support [7, 9].

Here, we describe the costs associated with cardiac surgical care and opportunities to increase health system financing to afford and expand cardiac surgical care delivery in light of competing agendas. We conclude by proposing some opportunities for all stakeholders alike to reduce procedural costs, ultimately expanding access to care for patients in need.

11.2 Cost of Cardiac Surgery

Various factors determine the costs of cardiac surgical care, which can be categorized as follows:

- *Labor costs*: salaries of the operating team and other health workers are commonly noted as the biggest drivers of cardiac surgical costs. With visiting teams, these costs are typically covered by foreign institutions, non-governmental organizations, or personal philanthropy. Local teams, where present, are generally supported by local governments or private sector facilities, whereas they may decide to task-share certain activities to non-specialist health workers in order to reduce costs of specialist staff.
- *Overhead costs*: assuming that a fully-equipped cardiac center is in place, operating room time and intensive care unit stays are considered the most important overhead costs associated with cardiac care. These costs include but are not limited to infrastructure establishment and monthly fees, fees for electricity, water, and oxygen, and other operational costs. Furthermore, hospital length of stay substantially affects post-operative overhead costs, posing opportunities to limit such stays by enhanced recovery after cardiac surgery protocols and less-invasive treatment modalities when and where feasible.
- *Costs of consumables, devices, and disposables*: the use of heart valves, stents, rings, pacemakers, and other materials are highly variable depending on the suppliers, the purchase volumes, and the types. Careful reduction of resource use and the thoughtful selection of instruments in surgical kits for operations may reduce the costs of instruments and equipment, their resterilization, and associated personnel time [10].

While the absolute costs are lower in LMICs (e.g., as low as US$2,000 for coronary artery bypass grafting in India) compared to high-income countries (e.g., up to over US$100,000 in the United States) [9], the relative financial burden on LMIC populations without health insurance or other financial risk protection is enormous. In West Africa, less than 20% of patients needing cardiac surgery are able to obtain the necessary funds within a year of being diagnosed [11]. Furthermore, the non-medical costs, such as the opportunity costs of taking time off work for treatment and recovery and the costs of transportation, food, and accommodation of patients, families, and caregivers, pose substantial financial barriers for LMIC populations. Financial means to pay for surgery and associated expenses typically come from out-of-pocket expenditure, foreign governments, charities such as foundation and non-governmental organizations, and private and corporate donations, if health insurance is not available. Trips by visiting teams may be associated with equally if not higher expenditure compared to local care delivery: travel costs of visiting teams and the expenses associated with the shipping of equipment and/or consumables are substantial, whereas workforce from other (e.g., high-income) countries benefit from higher salaries, either paid directly or as opportunity costs if volunteering and thus foregoing salary.

11.3 Health Systems Financing

True independence of cardiac centers requires close support by governments and broader health system strengthening, especially ensuring financial risk protection for patients to be able to access and afford cardiac surgical services and lifelong outpatient care. Although all African countries signed on to the Abuja Declaration in 2001 pledging 15% of Gross Domestic Product to healthcare, most countries to date have not achieved this promise, requiring countries to also rely on development assistance for health. It must be acknowledged that, while development assistance for health is necessary in the short-term, it cannot forego domestic investments in healthcare [12]. It is suggested that government financing of health services is reduced when able to rely on foreign aid, requiring improved buy-in and investments by governments to gradually become independent on the road to universal health coverage.

Health systems interventions such as National Surgical, Obstetric, and Anesthesia Plans (NSOAPs) provide an opportunity for systemwide incorporation of cardiac surgical care in the broader health system, rather than vertical interventions focused solely on cardiac surgical care [13]. NSOAPs are driven by governments as long-term strategic plans to strengthen the broader surgical ecosystem; integrating cardiac surgical care scaling within NSOAPs can ensure appropriate investments in workforce, infrastructure, and financial risk protection. Although the costs to fully implement NSOAPs are large, it is estimated that countries are able to fully fund their own NSOAPs, provided that buy-in is present and healthcare spending is increased [14].

In light of competing agendas, such as infectious diseases and education, it must be stressed that investing in cardiac surgery does not equal to rerouting investments from other priorities in budding and growing health systems. Current government spending on sending patients abroad for cardiac surgical care is significant, comprising up to 10% of annual health spending in some LMICs [15]. Thus, local investments in cardiac surgical capacity provide an opportunity to reduce spending on care abroad—which is associated with high travel costs—and invest in high-quality, low-cost domestic services, thereby saving millions of dollars in government spending each year [16]. Integrating cardiac surgery within initiatives such as NSOAPs can further facilitate such local investments [13]. Doing so can strengthen local health systems with considerable spillover effects on other health services. For example, the expansion of cardiac surgical care delivery improves community-based and primary care screening and prevention of cardiovascular diseases, strengthens referral mechanisms between primary and tertiary care, expands diagnostic modalities such as laboratory and imaging services, promotes blood bank and essential medicines availability, increases critical care capacity and skills, and fosters post-operative follow-up mechanisms. By extension, investments in cardiac surgical care create local job opportunities and supply chain infrastructure and allow patients to be treated closer to home and in familiar environments.

Beyond government support, opportunities arise to leverage public–private partnerships (PPP) and venture funds to scale low-cost alternatives and health system interventions. PPPs allow public and private hospitals and industry to strategically collaborate and find means to reduce the cost of care (e.g., by leveraging economies of scale or discounted purchase of materials) whilst creating regional networks that prioritize regionalization for complex or costly procedures. Similarly, social ventures and venture capitals can facilitate early investments in lower-cost innovations that may not be of interest to larger industry in the earlier stages of development, thereby encouraging grassroots innovations to be explored with fewer barriers. Examples may include supporting surgical supply chains, scaling platforms for telemedicine and virtual surgical education, or developing and improving lower-cost, context- or population-specific heart valves.

Lastly, philanthropy, such as through non-governmental organizations, charities, and individual donations, continues to play an important role in paying for individual cardiac surgical procedures, visiting teams' trips, or financing hospitals' operations. Combining philanthropy with robust impact assessments allows for a better understanding and transparency of use of funds, whilst enabling funders and recipients to better allocate funds to specific resources and activities.

11.4 Innovative Financing Instruments

Innovative financing mechanisms are novel or unconventional sources of funds that can be used to invest in healthcare whilst improving the efficiency of available financial resources within a health system and further mobilize funds from the private sector or philanthropy [17]. They can be leveraged to supplement traditional financial resources (i.e., government budget and development assistance for health) by financial pooling mechanisms (e.g., domestic taxes and trade levies) and reducing wasteful spending within a health system [9]. Examples of such innovative financing instruments include but are not limited to social impact bonds, investment funds, levies, advance market commitments, and debt-swaps, in-depth explanations of which fall outside the scope of this chapter.

Social impact bonds are noteworthy, however, as they are increasingly used and considered to support international development. These bonds were first introduced in 2010 and serve as a way for social impact-oriented investors, typically from the private sector, to prioritize impact (i.e., performance) over economic returns. With social impact bonds, investors set up a contract with the government or public sector facilities to fund activities that pursue societal impact (e.g., scaling surgical services) whereby the investor is willing to accept a loss (i.e., no or limited financial returns) if there are no profits made at the end of the activity. Conversely, if the funded activity succeeds, the government or public sector facilities repay the principal of the bond to the investors. Similarly, development impact bonds, whereby aid agencies or philanthropic organizations repay the principal instead of the government, have enjoyed increasing interest in recent years, with their volume expected to increase five times to over US$2 billion by 2023 [18]. While the use of impact bonds for non-communicable disease management, including cardiovascular diseases, have yet to become clearly elucidated [19], they have been successfully applied to other health [20] and non-health sectors [19]. However, to successfully and most effectively leverage such innovative financing mechanisms, stronger engagement of the private sector, well-defined health outcomes that serve as success metrics, and increased transparency are needed.

11.5 Cost Reduction Opportunities

In order to scale cardiac surgical care delivery and be able to provide cardiac surgery to more and especially poorer patients, centers must find ways to reduce the costs associated with such care episodes. Various opportunities arise to reduce the costs of both cardiac centers and cardiac surgery in LMICs. These include but are not limited to:

- *Developing and scaling low-cost alternatives*: for example, the Del Nido cardioplegia is a low-cost solution that can be self-made at the cost of a few dollars, compared to up to US $225 for standard (Buckberg) cardioplegia [21]. Results with the Del Nido cardioplegia are non-inferior, thus providing an opportunity for easy cost reduction [21]. Furthermore, off-pump or, as technical experience grows and infrastructure is in place, minimally-invasive techniques prevent the costs of a cardiopulmonary bypass, and may allow patients to leave hospitals faster, thereby reducing the costs of total hospital stays. Other innovations can similarly provide low-cost alternatives to standard practices, both saving costs for local centers and patients as well as better tailoring to the reality faced in variable-resource centers.

- *Creating economies of scale*: increasing institutional surgical volume inevitably leads to reductions in cost as a result of the ability to mass-purchase supplies, improve outcomes, and distribute overhead costs. This may be achieved by the development of a regional center of excellence, centralizing services within a country or region, prior to establishing further centers nearby [22]. For example, in India, Narayana Health has adopted such a model to perform the highest institutional cardiac surgery volume anywhere in the world at the lowest costs per procedure anywhere in the world.
- *Promoting local and regional supply chains*: by introducing locally- or regionally-sourced equipment and materials, overhead, material, and labor costs can be reduced, thereby driving down suppliers' prices. Moreover, shorter supply chains lead to greater efficiency, fewer stockouts, and reduced administrative costs, as well as the avoidance of import tariffs [23]. Lastly, these can enable locally-driven and context-appropriate consumables and disposables that are tailored to the needs of a patient population but which have not previously been prioritized by existing high-income country industry. This has been efficiently leveraged by larger countries such as China and India, where close collaborations with local suppliers are instrumental in the success of high-volume centers such as, for example, Shanghai Children's Medical Center and Narayana Health, and may be done in a similar regional fashion elsewhere in the world [7]. For example, in 2018, the Southern African Development Community (SADC) politically committed to scaling surgical healthcare delivery in the region through the development of NSOAPs. The close interaction of SADC with its Member States' ministries of health and ministries of finance can ensure further regionalization of the healthcare infrastructure and industry.

These cost reduction opportunities are of value to all countries worldwide, especially in light of the surge of healthcare spending in many high-income countries. For example, healthcare spending is among the most common causes of financial catastrophe in the United States, where cardiac surgery can cost up to over US$100,000 [9]. Thus, models of shared learning can be considered crucial to support bilateral exchange of clinical knowledge, biomedical expertise, and tangible solutions that can benefit all parties across different health systems.

11.6 Conclusion

While cardiac surgical care remains expensive, opportunities to reduce costs and increase health system financing and patients' financial risk protection are plenty. Strategic partnerships between local centers, international centers, the government, industry, and non-governmental organizations are critical and must be embedded within countries' health systems to mitigate inefficiencies and promote domestic coverage of healthcare costs.

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12 The Global Cardiothoracic Surgery Workforce in 2020

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Abstract

Knowing the size of the workforce in any specialty and understanding the number of years it takes to produce a specialist makes the difference between future shortages or surpluses. While studies on the cardiothoracic workforce at country level are somewhat available in the Western hemisphere not much is known, other than shortages are abundant, about the current size of the global cardiothoracic surgery workforce, particularly in low and middle income countries. While this ambitious attempt to catalogue our global workforce suffers the same limitations as its sources, it will hopefully shine a light on the need to a more robust and accurate specialty database. Beyond the relative shortcomings of this study, our results undoubtedly point at the overall global shortage of surgeons in each branch of our respective sub-specialties (Adult Cardiac, Thoracic and Congenital), but most importantly, it confirms vast inequities on the global distribution of our workforce.

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Keywords

Cardiac · Thoracic · Congenital · Cardiothoracic · Surgery · Workforce · Global

12.1 Introduction

> "Look closely at the present you are constructing. It should look like the future you are dreaming."
> Allice Walker

Knowing the size of the cardiothoracic surgeons' workforce is essential for planning long term sustainability and avoiding serious healthcare shortages. Much has been published at the country or region level about the size of a local cardiothoracic surgery workforce, yet while we have a vague understanding about shortages and over-supplies of cardiothoracic surgeons in some parts of the world, we still fail to capture its significance at the global level.

There are multiple barriers when trying to assess with some degree of certainty the true size of the global cardiothoracic surgeons' workforce. Some of the difficulties begin at defining a cardiothoracic surgeon in the world today followed by the diversity in training considerations and how vastly they change from country to country [1].

Another significant barrier to assess the true size of the workforce resides in the fact that the term cardiothoracic surgeon encompasses a very

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_12

heterogeneous workforce. In the United States as well as many other countries there is a tendency, based on tradition, to call a thoracic surgeon anyone who operates the organs residing on the chest. This tradition dates from the mid 1900's when cardiac surgery was at the threshold of becoming a free standing specialty and it was up to thoracic surgeons, used to operate on the esophagus, lungs and airways, to take the first steps into the newborn field. But today, given all the technical challenges and intricacies of the different fields, we need to address practitioners in this field according to their sub-specialization, since it is unlikely to find a surgeon capable of being up-to-date while being a top performer on all three fields of cardiothoracic surgery.

Many surgeons may dispute this concept, claiming they live in areas of the world so underserved that they feel it is their ethical and professional obligation, and it is expected of them, to serve a population confronted with the lack of sub-specialists.

We agree wholeheartedly that such arrangement is better than the alternative, but we must recognize the shortcomings of this conception. It would be unfair to expect perfect results for the most challenging cases in any of these fields when the surgeon has not specialized in any particular one.

If the field diversity in our specialty was not enough, the problem is aggravated by the fact that the main depository of this information, the CTSNet database, presents a challenging number of duplications, misrepresentation and inconsistencies, lessening its value as a reliable source for workforce research, particularly when attempting to count individuals practicing in the different fields of the specialty.

Surgeons are expected to self-register into this database according to their area of practice, with cardiac, thoracic and congenital as the available options. It is not entirely clear, upon entering or updating data on the database, as to what are the boundaries of each area of practice and it is entirely up to the surgeon entering the data on how to interpret it. For some of us, it refers to describing the very specific area of expertise or sub-specialization where we perform most of our surgeries, publish the results of our research and spend the majority of our time. Other surgeons seem to understand that area of practice refers to general knowledge or exposure during their training.

As a result, we have a significant number of members listed in the database registering two (most commonly cardiac and thoracic or cardiac and congenital) or even all three areas of practice with little specific information on the amount of time spent on each sub-specialty or the level of complexity of the cases they perform.

This distortion may result in double (or triple) counting surgeons, clearly undermining the efforts to gage the actual workforce size. For instance, the number of surgeons listed on CTSNet database as having a congenital practice in the USA totals 693 surgeons by May 2020 [2]. We must assume, since it is not clearly defined on the database, congenital has been interpreted by the enrolling surgeons as either pediatric cardiac surgery or adult congenital cardiac surgery. When verified by confronting the data with more specific and reliable sources on this specific field [3, 4] the real number of full-time pediatric cardiac surgeons is closer to a mere 262. A dramatic reduction of over 60% on the workforce size if we were wrongfully assuming that all surgeons listed as having a practice in congenital surgery were pediatric cardiac surgeons. While it is very likely that the rest of the cardiac surgeons self-classified as having a practice in the congenital field in the United States may be able to solve many simpler congenital cases in the adolescent/adult population, the vast majority are not affiliated to any of the country's pediatric cardiac surgery programs, consequently it is unlikely they routinely perform congenital heart surgery in children, infants and certainly not in neonates.

This phenomenon is not unique to the USA and it repeats itself in other countries around the globe, resulting in truly inflated figures, particularly when it comes to the congenital heart surgery global workforce. A similar example but at a regional level, the first systematic review of the pediatric cardiac surgery workforce in South America by Sandoval et al., quotes a total of 195 congenital surgeons [5], while the number of individuals registered as dedicated full-time to the practice of congenital surgery on the CTS database for the region amounts to just 48 surgeons (a 75% difference), with the rest of the surgeons listed as practicing both, cardiac and congenital.

For the purpose of clarity in this chapter, as we explored the CTSNet database, we have made a significant effort to count individuals and to avoid duplications. We achieved this by counting full-time surgeons practicing on each of the cardiothoracic surgery fields. Those who registered themselves as exclusively thoracic or congenital surgeons were separated from the rest of their peers. Those who listed double specialty (cardiac and congenital, or thoracic and cardiac) as well as those registering all three areas of specialization were only included under the *Cardiac* category. This way, we sidestepped double or triple counting the many surgeons that have listed two or all three areas of practice as their own. We also believe separating thoracic and pediatric from the bulk of cardiothoracic surgeons, gives us a better idea of the true level of development those two specialties may have achieved in any particular country.

12.2 Describing the Landscape

After manually surveying the CTSNet surgeons' database, removing duplicates, triplicates and misrepresentations while separating the individuals by area of full-time practice, the results are predictably low.

As of May 2020, the practice of cardiothoracic surgery in all of its branches around the globe was limited to a total of just **17 474** individual surgeons. The number of practicing surgeons listed as having an exclusive thoracic surgery practice is **4 457**, while the number of surgeons self-listed as practicing exclusively congenital heart surgery reaches only up to **840** individuals. Lastly, after removing those listed as exclusive thoracic and congenital surgeons from the total, the number of those individuals listed as cardiac surgeons was consolidated at **12,177** and it includes all surgeons that may have listed more than one area of practice but were not accounted as exclusive specialists in either thoracic or congenital. For instance, 2,527 surgeons listing a double area of practice (cardiac and congenital) were not included in the exclusively congenital surgeons list. The results of our search are represented on Fig. 12.1 showing the distribution by continent and area of practice with the population of the continent where they practice. When contemplating the number of individuals practicing in each continent and compare those numbers to the populations they serve, the disparities in supply of cardiothoracic services become self-evident.

Incidentally, during the data collection we also found a large number of misrepresentations (n = 63) among surgeons listing the USA as their country of practice. When delving into the specifics, all of these surgeons listed their contact addresses abroad (55 from Russia, 6 from Vietnam and one surgeon from Hong-Kong) but for unclear reasons elected to mark United States as country of practice. They were allocated back into the workforce of their respective countries during our accounting of individual surgeons.

Once the number of individuals practicing the different fields of cardiothoracic surgery are known, we can move forward and try to answer the following question: What is the meaning of having 885 individual surgeons practicing cardiothoracic surgery in India? or only 75 congenital cardiac surgeons in sub-Sahara Africa? The simple answer is, none without some context. The true value of knowing the cardiothoracic workforce numbers dwells in the availability of denominators.

In the search for context by means of reliable denominators, several ratios have been described in an effort to have a truly meaningful description of our workforce. While a commonly used ratio to assess the size of the workforce at the country or regional level is the one based on number of surgeons per 100,000 or 1 M population, other ratios perhaps more representative of the local situations have been used.

For instance, in 2004, *Neirotti* [6] published data on the distribution of cardiac surgery centers

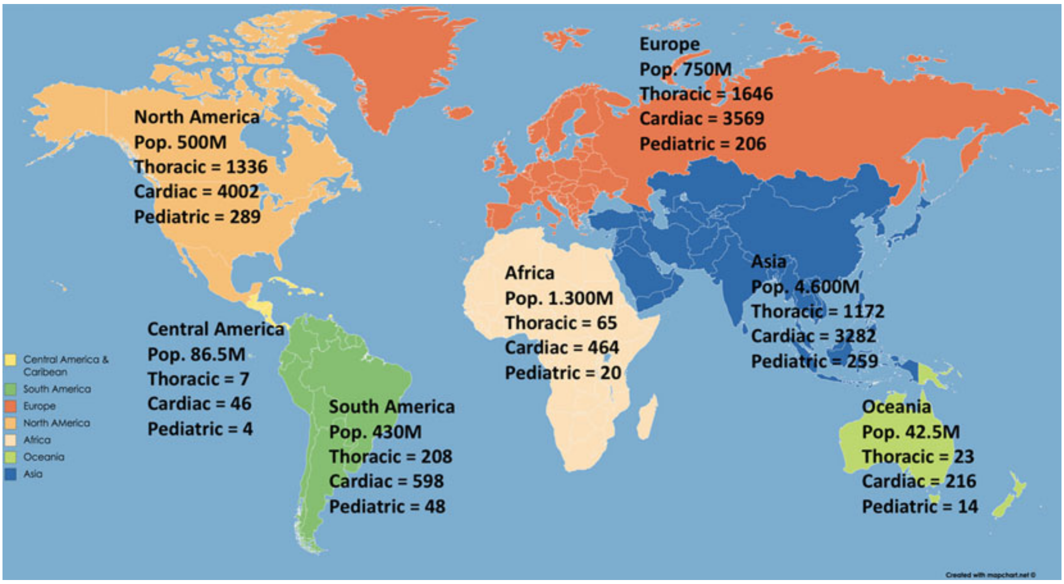

Fig. 12.1 Global distribution of individuals practicing cardiothoracic surgery. Listed by self-description of area of practice and with population of each continent or region

based on a survey from 1999, estimating the number at that time to be around 4000 cardiac centers worldwide. In the first part of his work, we are presented with an original proxy description of the workforce in number of cardiac surgery centers per capita in different areas of the world. With an average of a cardiac center/120,000 population in North America, one every 1 M population in Europe and Australia, but only one center every 16 M in Asia or one every 33 M in Africa, this clearly illustrated the global mal-distribution of surgical centers and, by proxy, of surgeons around the globe.

In the second part of this investigation, we are introduced to a more commonly used ratio, namely the number of cardiac surgeries per million habitants. Again reveling numbers showing the discrepancy between high income countries with an average of 860 cardiac surgeries per million people in sharp contrast with Asia, Africa, Latin America and the Russian Federation having about 60 surgeries per 1 M population at that time.

Back to the more traditional ratios of surgeon per population, *Bernier et al.* [7] assessing the pediatric cardiac workforce based on the ratio surgeon per 1 M population, estimated a ratio of 1 pediatric cardiac surgeon for every 3.5 M population in North America and Europe, showing a strong contrast with the ratios in South America (1in 6.5 M); Asia (1 in 25 M) and Africa (1 in 38 M).

In a recent publication using 2017 data, *Vervoort et al.* [8] emphasize the existing disparities within different world regions regarding the variable size of our workforce. This work, commendable for its taxing nature, is also based on data form the CTSNet database and accounts for a global workforce of 12,180 adult cardiothoracic surgeons and 3,858 self-described congenital cardiac surgeons (unlike our own recount).

The authors estimated the global ratio of adult cardiac surgeons at 1.64 (0–181.82) and congenital heart surgeons at 0.52 (0–25.97) per million population respectively.

The mal-distribution becomes rather evident when analyzed by region, with ratios ranging from 0.12 adult cardiothoracic surgeons and 0.08 congenital cardiac surgeons per 1 M population (sub-Saharan Africa) to 11.12 adult cardiothoracic surgeons and 2.08 congenital cardiac surgeons per 1 M population (North America).

These disparities are not less dramatic when the supply of cardiac surgeons is based on country's income, showing that low-income countries have only access to 0.04 cardiothoracic surgeons and 0.03 congenital cardiac surgeons per million people, compared with ratios of 7.15 adult cardiothoracic surgeons and 1.67 pediatric cardiac surgeons per million population in high-income countries.

Unsatisfied with the uncertain implications of a generic ratio involving surgeons per million population, back in 2012 we attempted to produce a more meaningful indicator [9]. Using the indiscriminated total numbers on CTSNet database for congenital surgeons at that time, we explored the concept of an ideal ratio of surgeon per incidence (new cases per year) of congenital heart disease (CHD) at which countries seem to be able to efficiently manage all the children born with heart defects within their borders. This ideal ratio turned out to be an estimated incidence of around 140 new cases per congenital surgeon per year. As the number of new cases per surgeon moved away (higher) from 140, countries seem to develop serious difficulties managing children born with CHD within their borders. Note that this ratio should be taken as a proxy indicator to match demand and supply for pediatric cardiac surgery services and it does not have any relationship with the number of CHD surgeries any given surgeon may perform during the course of a calendar year.

Using this ratio of 140 new cases per year/congenital surgeon we accounted for only 57 countries where CHD was properly addressed on time at the time of the study.

While a significant portion of the published work on global cardiothoracic workforce has been done in the field of pediatric cardiac surgery, the limited number of publications available on the adult thoracic and cardiac fields are mostly restricted to high income countries [10–12].

It is close to impossible to predict with any degree of accuracy the number of cardiac, thoracic and congenital procedures that we will be performing in just a decade from now [13], the only certainty is that there will continue to be shortages in human resources. While many of those publications on workforce may be focused on planning for future surgeon shortages in the US, most of the created ratios can, and will, easily translate to the global scale.

In 2009, Grover et al. while exploring in detail the demand for adult cardiothoracic surgeons in the United States and trying to predict a future shortage, came up with a very practical ratio [14].

After obtaining the size cardiothoracic workforce data from the American Medical Association Practitioner Masterfile (not the CTSNet database!) to accurately represent the supply of surgeons in the country and acquire multiple sets of national official data stratified by age, gender, race and location to represent the demand, the authors were able to model the need for surgeons at a given specific age group stratifications.

According to their results, while the population under 45 years of age would only need 2 cardiothoracic surgeons (without further discrimination into sub-specialties) per 1 M population, the demand raises sharply for older populations reaching up to 77 cardiothoracic surgeons for every 1 M population at age group 75 and above.

Using the same stratified ratios, while understanding the many differences between the USA population (income, diet, race, health habits, genetic, etc.) and the rest of the world, we extrapolated the need for surgeons for the same age groups but for the global population. The results of this theoretical exercise can be seen on Table 12.1.

With a projected global need of over 88,000 surgeons and a current workforce of just 17,468 the magnitude of the problem to solve is self-evident, more so when 29% (n = 5,068) of the global workforce is located in just one country.

12.3 Changing the Landscape

While most middle and low income countries are in need of stronger services and a larger, better trained workforce, the sheer volume of cases in some of those countries makes them an ideal target for a focused emphasis on the education of

Table 12.1 Results of extrapolating the demand for cardiothoracic surgeons by age stratification in the United States to the global population (Based on data from Grover et al.)

Age group	Global population (*)	Estimated surgeons per 1 M pop. needed in the USA	Estimated surgeons needed for each age group globally
Above 75 y	246,830,982	77	18,942
65–75 y	462,808,092	61	28,182
45–65 y	1,619,828,323	19	30,761
Under 45 y	5,399,427,743	2	10,798
Total	**7,728,895,140**		**88,683**

Data source United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2019 Revision. https://population.un.org/wpp/ (downloaded May 2020)

the new generations of surgeons (and the complementary team members needed to accomplish such difficult task). Countries with the highest incidences of cancer of the lungs and esophagus need to concentrate on training the largest numbers of thoracic surgeons and countries with highest incidences of acquired coronary or heart valve disease should facilitate the growth of their adult cardiac surgeon workforce.

Similarly, we could envision a higher concentration of congenital cardiac surgeons in countries with the highest numbers of children born with congenital heart defects. On Fig. 12.2 we have mapped the top 10 countries responsible for about half of all the new cases of CHD globally, an estimated total of 440,000 new cases a year [15]. According to the CTSNet database, there are only 550 congenital surgeons among those ten countries (a ratio of 1 surgeon per 800 new cases of CHD per year) and only 150 of them with exclusive dedication to the congenital field, demonstrating once again the magnitude of the problem.

A similar ratio of surgeons per affected population could be produced regarding the number of thoracic or cardiac surgeons to the incidence of acquired chest ailments in the adult population. Figure 12.3 shows the top-10 countries with the highest mortality for lung cancer, esophageal cancer and coronary disease and the limited concentration of thoracic and adult cardiac surgeons on these countries.

Unlike CHD with its fixed incidence over live births across the globe [16] the incidence rates for acquired diseases (rheumatic fever, coronary atherosclerosis, lung and esophageal cancers among others) are variable and influenced by a rather large set of health determinants such as poverty, race, diet and culture among others, preventing us from using simple ratios of surgeons per number of deaths related to a particular diagnosis as a planning tool. For instance, when contemplating the incidence of esophageal cancer mortality per 100 K Population (see Table 12.2), it is clear that the number of thoracic surgeons is inadequate for countries with both, the highest and the lowest mortalities. If we were to analyze the list of countries with the highest mortality rate, we may wrongfully assume that the high mortality is simply related to the lack of thoracic surgeons. But if we analyze, in the same table, the list of the countries with the lowest mortality rates in isolation, we may arrive to exactly the opposite conclusion, not having thoracic surgeons has a protective effect on mortality for esophageal cancer. Therefore, when it comes to planning healthcare forcetraining, it would be far too simplistic to take ratios of surgeons to mortality in isolation.

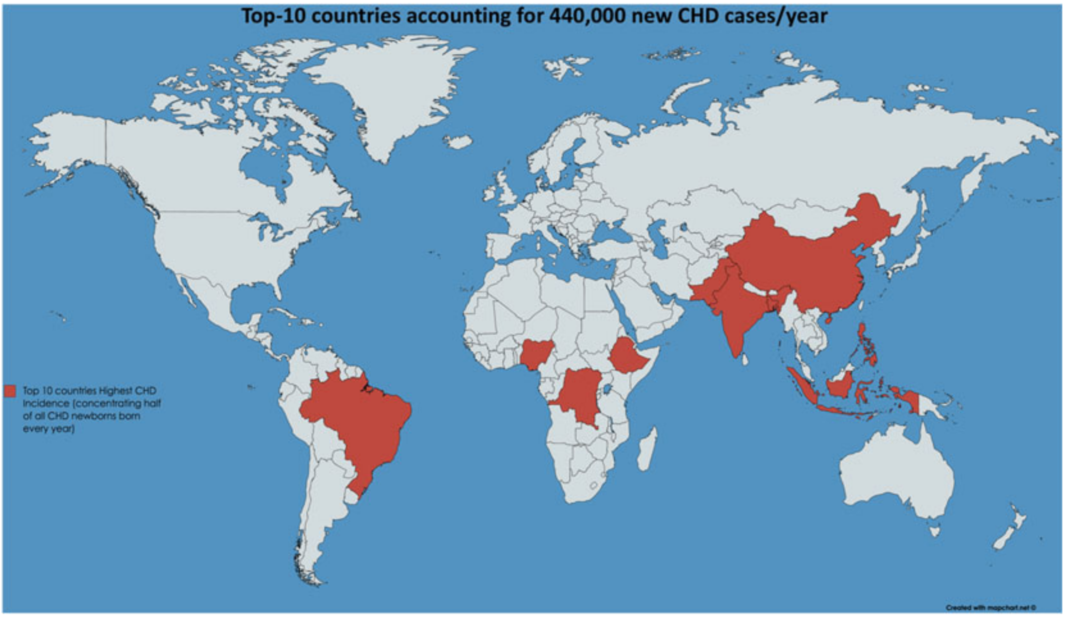

Fig. 12.2 Top 10 countries accounting for about 440,000 new cases of congenital heart disease every year.Number of surgeons with an adult and congenital surgery practice in those countries = 550Number of surgeons registered on CTSNet as having an exclusive congenital practice in those countries = 150

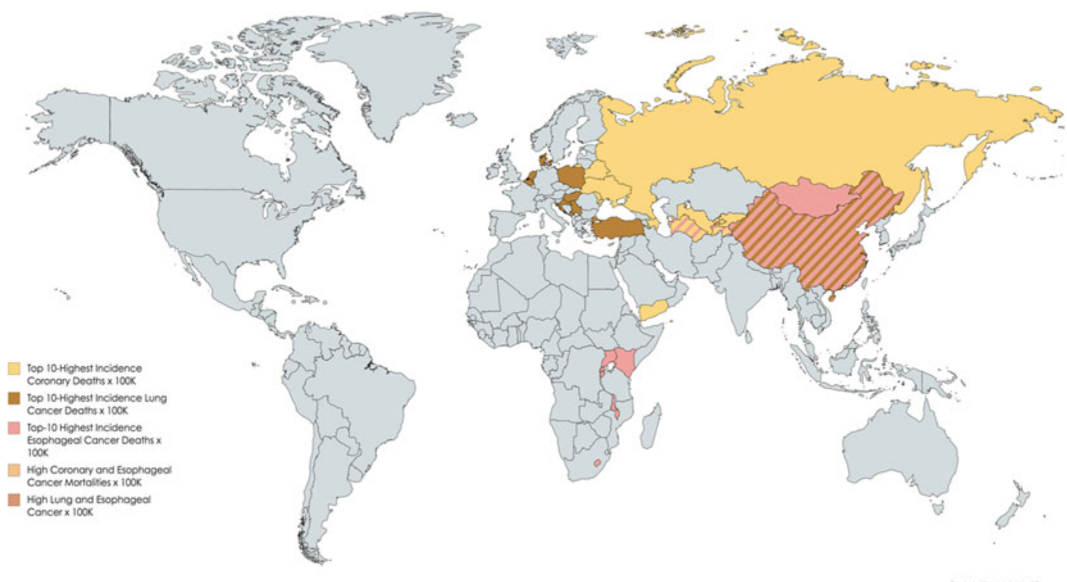

Fig. 12.3 Top-10 countries with the highest mortality rates for lung cancer, Esophageal cancer and coronary disease per 100 K population and the total number of specialists available in those countries coronary atherosclerosis yearly deaths=1M/cardiac surgeons = 173 Esophageal cancer yearly deaths=200,000/thoracic surgeons = 210 lung cancer yearly deaths = 610,000/thoracic surgeons = 667

Table 12.2 Mortality for esophageal cancer (both sexes) in the countries with the highest and lowest incidence and number of Thoracic surgeons per 100,000 pop

Countries with highest incidence in mortality	Deaths per 100,000 pop	CT surgeons per 100,000 pop	Countries with lowest incidence in mortality	Deaths per 100,000 pop	CT surgeons per 100,000 pop
Malawi	25.16	0.06	Vanuatu	0.01	0
Turkmenistan	19.73	0	Solomon Islands	0.17	0
Kenya	18.94	0.008	Antigua/Barbuda	0.26	0
Uganda	18.49	0.004	Cape Verde	0.33	0
Mongolia	18.45	0.1	Nigeria	0.47	0.001
Lesotho	15.75	0	Ghana	0.50	0.006
Burundi	14.05	0	Guinea	0.53	0
Rwanda	12.63	0	Tunisia	0.53	0.006
Tajikistan	12.13	0.01	Algeria	0.53	0.009
China	11.72	0.02	Guinea-Bissau	0.56	0

Source https://www.worldlifeexpectancy.com/cause-of-death/oesophagus-cancer/by-country/ (last accessed Dec 2020)

12.4 Conclusion

When planning healthcare service for large populations, thoughtful policy efforts to improve health determinants can actually play a role on the incidence, the morbidity and the mortality of acquired cardiothoracic surgical diseases. Long-term enhancement of health determinants may in time lower the demand for surgical services. Likewise, when planning for congenital heart surgical services in low and middle income countries, the long term focus, beside training of new generations of surgeons and ancillary personnel, should be on poverty eradication, with the understanding that better socioeconomic status, the empowerment of women through education and a lower infant mortality rate has a proven and direct effect on lowering the fertility rate of a country [17, 18], consequently and over time, lowering the total number of children born with congenital heart disease.

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13 Team-Based Care Along the Cardiac Surgical Care Cascade

Lynette Lester, Benson Njuguna, and Rajesh Vedanthan

Abstract

The burden of cardiovascular disease (CVD) is increasing in low-and middle-income countries (LMICs), and it is estimated that nearly one-third of the CVD burden requires cardiac surgery as a component of management. Establishing an effective system for delivery of cardiac surgery in LMICs requires a team-based approach to CVD care. Non-surgical team members include cardiologists, internists, general practitioners, advanced practice providers, pharmacists, nurses, and community health workers. A multidisciplinary approach to CVD care promotes shared decision-making among these providers and results in improved outcomes for patients. Team members are involved throughout the care cascade which includes primordial, primary, secondary, and tertiary prevention, in addition to acute perioperative care and long-term follow-up. Though challenges may arise in implementing the team-based model in LMICs, many can be addressed through health systems strengthening. Ultimately, the team-based model can effectively leverage the healthcare workforce and provide integrated and effective care to cardiac surgical patients in LMICs.

Keywords

Cardiologist · Cardiology · Internist · General practitioner · Advanced practice provider · Pharmacist · Nurse · Community health worker · Team based care

13.1 Introduction

Cardiovascular disease (CVD) is a leading contributor to disability-adjusted life years worldwide [1]. While it is estimated that 32% of the burden of cardiovascular disease in low- and middle-income countries (LMICs) could be addressed by surgery, 93% of patients in LMICs lack access [2]. This translates to an estimated 4.5 billion people without access to cardiothoracic surgical care [2, 3]. In LMICs, the main drivers of CVD that can be addressed by cardiothoracic surgery are rheumatic heart disease (RHD), congenital heart disease (CHD), and coronary artery disease (CAD) [2, 4]. Additional drivers of atherosclerotic CVD, such as hypertension and diabetes, are also growing contributors to the global surgical CVD burden and must also be addressed [4].

While cardiac surgery in LMICs is most often carried out in tertiary level or specialized cardiac referral hospitals, optimal cardiovascular

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_13

management requires the coordination of multiple providers across the entire care cascade. This team-based approach encompasses the spectrum of surgical CVD care from primordial prevention through tertiary prevention, combining a cardiothoracic surgical, cardiologic, and non-specialist workforce. This type of team-based approach is necessary for any successful cardiac surgery program [5].

In this chapter, we will discuss the specialty and non-specialty members of the non-cardiac surgical workforce and their roles in supporting a cardiac surgical program in LMICs. In addition, we will provide an overview of the differing levels of cardiovascular care along the entire care cascade, as well as the constraints to effectively mobilizing the cardiac workforce.

13.2 Team-Based Approach to Care

Given the complex nature of surgical CVD, a team-based approach has been recommended by European and American professional society guidelines for the management of patients [6]. A multidisciplinary approach consists of input from providers across the spectrum of clinical specialization and across the entire CVD care cascade, particularly for patients with advanced disease and comorbid conditions [7, 8]. This type of team-based approach has been shown to yield improved outcomes for patients with CVD [8]. It is well known that a multidisciplinary "Heart Team" represents a well-established treatment group that has been shown to minimize error and promote evidenced-based decision making [7, 9]. The "Heart Team" refers to, at minimum, a cardiac surgeon and cardiologist, and is a well-recognized example of collaborative CVD care [9, 10]. The purpose of the "Heart Team" is to promote shared decision-making in patient selection and intervention for advanced CVD.

While integrated, multidisciplinary care is imperative for the successful management of surgical CVD patients, human workforce shortages impact most members of the care team in under-resourced settings such as those that occur in many LMICs. Globally, providers are distributed unequally between high-income countries and LMICs. Africa, for instance, is home to 24% of the global disease burden but only 3% of the medical workforce [11]. The implications of these workforce limitations are clear, as treatment and survival rates decline in proportion to the number of health care workers available [11–13]. Notably, the difference in health care outcomes is not limited to physician density alone, and is reflective of the critical role played by all cadres of health care workers in managing CVD [13].

Reconciling the provider-dependent nature of CVD management with the reality of workforce shortages presents a significant challenge for LMICs [14]. Task-redistribution and task-sharing strategies are often employed to combat these challenges [5, 12, 15]. As cardiovascular care in LMICs continues to progress, however, emphasis should move beyond task-oriented targets and towards coordinated, comprehensive care across the CVD continuum [14]. In general, efforts to implement evidenced-based guidelines, define provider roles clearly, and promote collaboration and communication can be employed at each level of CVD care [8, 16]. We outline below the roles of the non-surgical cardiovascular workforce that would support patients outside the peri-operative period, and how these roles may be carried out in a LMIC setting. A detailed description of the members of the cardiothoracic surgical team is discussed in Chap. 14.

13.2.1 Cardiologists

Cardiologists play an essential role in the management of cardiac surgical patients at all stages of care, including assessment, pre-surgical management, referral, the acute peri-operative period, and long-term follow-up. Cardiologist care of the cardiac surgical patient occurs in both the inpatient and outpatient setting. Additionally, cardiologists are in many cases the primary providers in dedicated cardiac rehabilitation centers [17]. In each of these settings, the expanding role of cardiologists includes moving beyond preventing premature mortality from CVD to addressing morbidity and quality of life. Though the overall rate of specialization in LMICs is increasing, a relative lack of specialized cardiologists remains and leaves many LMICs susceptible to implementation gaps in CVD care [12, 18]. The limited number of specialized cardiovascular providers has been attributed to inadequate training and the focus of available resources on acute and communicable diseases [8, 12].

13.2.2 Internists and General Practitioners

Internists and general practitioners play a crucial role in the acute and chronic management of surgical CVD [8]. In the acute phase, these physicians are often responsible for the inpatient management of patients, particularly in settings where cardiologists are not uniformly available. Chronic CVD management involves prescribing medication, promoting medication adherence, encouraging healthy behaviors, and preventing loss to follow-up [8]. These providers can also play an essential role in CVD management through the oversight of task-redistribution and team-sharing efforts [8, 14]. In particular, hypertension, diabetes, and heart failure management are often overseen by internists or general practitioners who provide further direction to advanced practice providers (APPs), nurses, and community health workers (CHWs).

13.2.3 Advanced Practice Providers

Given the known human resource limitations that exist at the physician level, the training of APPs has been suggested as one mechanism for expanding capacity for CVD care [12, 19]. APPs may refer to nurse practitioners, physician's assistants, clinical officers, certified registered nurse anesthetists, and similar non-physician providers. Though task-redistribution and task-sharing efforts are often implemented at the primary care level, delivery of surgical care is also possible with specialized training of APPs. In addition to assistance in surgery, APPs are often deployed in tertiary care settings to manage post-operative cardiac surgical patients [20].

13.2.4 Pharmacists

Though not specific to care delivery in LMICs, the role of pharmacists in cardiac care includes medication distribution, patient education, adherence monitoring, and long-term follow-up. Pharmacists can have substantial impact in these roles as they have frequent and repeated contact with patients [21]. Pharmacists play a substantial role in maintaining access to essential medicines, including those taken by cardiac surgery patients. Additionally, for cardiac surgery patients, pharmacists may play a role in managing anticoagulation [22]. Access to appropriate medication, however, remains a barrier to CVD care in LMICs where up to 80% of eligible patients do not receive any of the recommended medications for the secondary prevention of CVD [23]. Even when availability and affordability of CVD medications is improved, access to trained pharmacists remains a constraint [24]. In addition to increasing the number trained pharmacists available to deliver care, LMICs are also tasked with creating innovative methods to increase their medication supply chains [22].

13.2.5 Nurses

In many task-redistribution and task sharing efforts to address the burden of CVD, nurses play a central role. Nurses are able to screen patients, administer prescriptions for uncomplicated disease, and reinforce positive lifestyle changes. In primary care settings, this has been effective in hypertension management and diabetes control [5, 15]. Successful nurse-led models for care delivery have been enhanced by clinical decision support in addition to steady medication supply streams, appropriate retention and linkage systems, and stakeholder engagement [15, 24–26]. The development of user-friendly surgical CVD management protocols may also support accurate risk assessment and facilitate the effective delivery of care by nurses. These protocols allow the provider to access evidence-based recommendations for treatment or referral based on pertinent details of a patient's history, physical exam, and laboratory results [5].

13.2.6 Community Health Workers

Community health workers (CHWs) are laypeople who have not had formal healthcare training, but instead receive short-term, specialized training and then are deployed to augment primary health care initiatives [27]. The responsibilities of CHWs vary by initiative, but are frequently focused on lifestyle modification, patient education, adherence counseling, and engagement in care [28]. Despite undergoing relatively short training periods when compared to physicians, APPs, and nurses, CHWs have been shown to deliver effective, low-cost care [28, 29]. In addition to appropriate training and professionalization, close supervision, feedback and financial remuneration are required for successful implementation of CHW programs [27, 28]. To avoid issues of attrition, CHW programs should incorporate appropriate compensation and opportunities for career advancement for those involved in addition to non-financial benefits such as a reasonable workload [30].

13.3 The Care Cascade

13.3.1 Chronic Disease Management

Much of surgically correctable CVD can be attributed to chronic disease processes requiring ongoing care. The care cascade for CVD consists of primordial, primary, secondary and tertiary prevention strategies, ranging from avoiding the development of risk factors to mitigating the progression of disease. In many instances, surgical CVD is preventable [31]. However, even when a surgical intervention is required for CVD, the development of complications is of particular concern and preventative efforts continue to remain important. After an acute exacerbation of disease or procedure, patients may have increased screening needs such as a requirement for periodic echocardiograms or medication adjustments requiring collaboration between multiple members of the care team. Ultimately, patients with surgical CVD require integrated management and adequate long-term follow-up [29, 32].

13.3.2 Primordial Prevention

Primordial prevention refers to interventions to avoid the development of risk factors for surgical CVD [4]. For atherosclerotic CVD, literature suggests that intervention as early as infancy and the prenatal period may be beneficial for preventing the development of risk factors [33]. These efforts include the identification and treatment of pregnancy-related hypertensive disorders and maternal diabetes. Life-long efforts to avoid tobacco smoke, maintain a normal BMI, eat a nutritious diet and exercise regularly are beneficial in preventing atherosclerotic CVD and can be promoted by CHWs, nurses and APPs during routine health visits [33]. Primordial prevention of RHD requires addressing the social determinants of health and includes promoting sanitation, reducing overcrowding, and increasing access to education, employment and health services, factors that require collaboration with those outside the healthcare workforce [34]. Such efforts are also aligned with the concept of "proactive prevention," which aims to focus preventive efforts on currently low-burden individuals and communities, with the goal of maintaining them in a healthy state [35].

13.3.3 Primary Prevention

The goal of primary prevention is to modify risk factors and avoid their progression to overt disease [4]. The role of primary care in preventing the development of CVD is well established, though published research on interventions and outcomes in LMICs is limited [36]. In addition to the efficacy of primary care initiatives in preventing morbidity and mortality, they are also cost-effective [32, 36, 37]. Primary prevention is guided by several principles including providing an integrated approach and emphasizing community participation [29, 36]. For these reasons, CHWs can be particularly impactful in primary prevention efforts [28]. Most primary care interventions are delivered in community clinics and pharmacies facilitating involvement of, and communication between, advanced practice providers, nurses, and pharmacists (Fig. 13.1) [36]. In the management of surgical CVD, community efforts often involve education interventions and screening campaigns [32, 36]. The most common interventions for atherosclerotic CVD are those that target blood pressure and glucose screening, weight management, and smoking cessation [32, 34]. Efforts to prevent RHD include early identification and treatment of Group A streptococcus infection. These interventions can occur in the community or inpatient setting. Campaigns that focus on community education and raising awareness have resulted in declines in acute rheumatic fever and can be facilitated by CHWs [38].

13.3.4 Secondary Prevention

Secondary prevention involves halting disease progression. An important first step includes the accurate diagnosis of disease when present [39]. In the case of CHD, diagnosis prior to birth is uncommon in LMICs and many patients succumb to undiagnosed disease in the prenatal period, highlighting one area for intervention [40]. Beneficial tools for the diagnosis of all types of surgical CVD are echocardiography and cardiac catheterization. In addition to equipment maintenance, echocardiography and cardiac catheterization require the presence of providers skilled in image acquisition and interpretation [22, 41]. While echocardiography can be conducted by physicians, APPs, or nurses, cardiac catheterization requires the presence of a trained interventional cardiologist [42, 43]. Once surgical CVD is diagnosed, secondary prevention includes continued risk factor modification, pharmaceutical treatment and may include some medical procedures [37, 44]. For this reason, at the level of secondary prevention, the care team involves primordial and primary prevention providers, as well as cardiologists (Fig. 13.1).

The successful implementation of secondary prevention interventions is closely linked to access to essential medications and patient

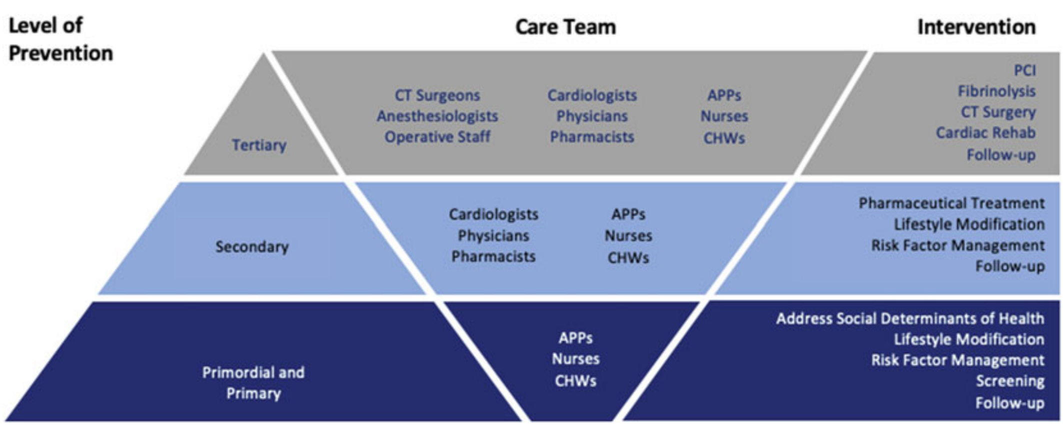

Fig. 13.1 Diagram of team-based care delivery and intervention across the cardiovascular care cascade. CT: cardiothoracic; APPs: advancedpractice providers; CHWs: community health workers; PCI: percutaneous coronary intervention

adherence [45, 46]. In addition, regular follow-up and surveillance of patients is necessary in order to prevent or detect progression of CVD. While some patients may receive appropriate treatment at the point of care, long-term access to effective cardiovascular drugs is difficult to obtain, therefore efforts to maintain linkage to care are imperative [47]. These challenges may be addressed by providers across the care cascade. While pharmacists play an essential role in medication management as described above, initiatives focused on education and adherence can be carried out by all providers [8, 45].

13.3.5 Tertiary Prevention

Tertiary prevention aims to improve quality of life and reduce morbidity and eventual mortality among those with manifest CVD. Many tertiary prevention interventions in LMICs are focused on the timely diagnosis and management of advanced CVD [48]. Tertiary prevention vis a vis cardiac surgery involves pre-operative, operative and post-operative care, which is delivered by an expansive team including general practitioners, internists, surgeons, anesthesiologists, APPs, pharmacists and nurses. Providers take part in imaging, laboratory studies, blood banking, perfusion during surgery, and ICU care [2] (Fig. 13.1). In addition to acute intervention, cardiac rehabilitation is a multifactorial approach to tertiary prevention in CVD which includes behavior modification, supervised exercise and functional improvement [49]. Cardiac rehabilitation has been shown to reduce hospitalizations, health care expenditure and mortality.

13.4 Health Systems Strengthening to Support Surgical CVD Care

While integrated team-based cardiac surgical care is the ideal, in reality there are significant barriers to care delivery in LMICs. Many of the challenges related to delivering effective team-based cardiac surgical care, however, could be addressed by overall health systems strengthening as the cardiac care workforce does not exist in isolation. The most substantive and long-term impact can be achieved by situating surgical CVD care in the context of interventions targeting the WHO health system building blocks: health workforce, health service delivery, access to essential medications, health information systems, leadership and governance, and health systems financing (Fig. 13.2) [50]. The following outlines current challenges in each of the six domains that can be addressed to promote improved capacity for cardiac surgical care.

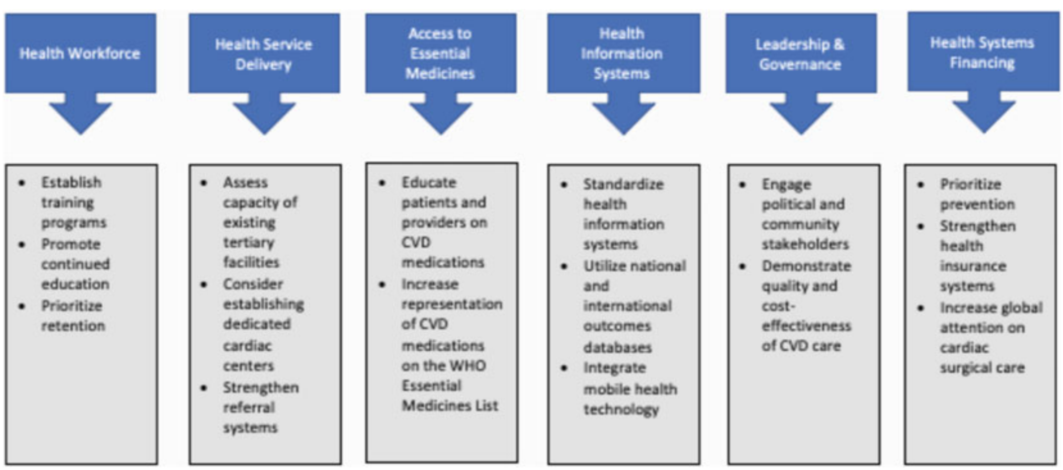

Fig. 13.2 Health system interventions to support the delivery of team-based surgical CVD care. CVD: cardiovascular disease, WHO: world health organization

13.4.1 Health Workforce

Given the provider scarcity in LMICs, capacity building efforts to augment the workforce across the surgical CVD care cascade are necessary [11, 51]. An early priority should include the initial training of providers through the establishment of residency and fellowship programs for physicians and surgeons; increased training programs for APPs, pharmacists, and nurses; and formalized initiatives for CHWs [2, 3, 27]. Training efforts should be tailored to the CVD epidemiology most likely to be encountered in LMICs. Historically, training has occurred via visiting physicians in an apprenticeship model; however, remote learning may offer novel ways to supplement education [52]. As providers gain experience, continuing health professional education programs must also be in place to ensure maintenance of clinical and technical competency. Finally, once trained, efforts must be made to retain providers in LMICs by offering appropriate salaries, opportunities for career advancement, and adequate support [3, 48].

13.4.2 Health Service Delivery

Service delivery encompasses the distribution of health facilities in a population and their readiness to offer services [50]. In the peri-operative period, surgical CVD care is delivered in tertiary facilities which should have a cardiothoracic operating room, intensive care unit, laboratory and thoracic imaging capabilities. In reality, the cost and maintenance of the complex tools and equipment required for surgical CVD care present a challenge to many tertiary centers in LMICs. Many facilities often lack the infrastructure and capacity to meet the needs of surgical CVD patients as they are often understaffed and underequipped [3, 53]. For this reason, dedicated cardiac centers have been proposed for the management of cardiothoracic surgery patients in LMICs [48]. The goal for dedicated cardiac centers would be for sustainable, independent management of advanced CVD in a centralized location [54]. While feasible, such centers should include a cost-effectiveness assessment and thoughtful interventions to avoid creating systems of inequitable access and siloed care. Outside the peri-operative period, limited health care access in LMICs results in low referral, poor retention, and high rates of loss to follow-up [15]. Adequate referral requires appropriate patient selection, available transportation, effective follow-up, strong health information technology and peer support. Conversely, inappropriate referrals further strain the health system [19, 55, 56]. Once patients are successfully identified and referred, retention strategies must then be implemented to ensure consistent long-term follow-up.

13.4.3 Access to Essential Medicines

Limited access to effective medication and medication non-adherence are significant barriers to CVD management in LMICs [23, 24, 57]. In addition to chronic CVD management, cardiac surgical patients require consistent prescriptions prior to and following surgery. Interventions to address medication access must address affordability, availability, and accountability to benefit patients in LMICs [46]. However, even when available and affordable, effective utilization of essential cardiovascular medications is low. This may be due to knowledge and attitudes towards medication from both the provider and patient [23]. The role of providers is reflected in existing disparities between indicated therapy and prescribed medication. Patient-targeted interventions include education and simplified medication regimens, while strategies focused on providers address enhanced training and team-based management [45]. These initiatives are critical to improving access to CVD medications, and ensuring positive outcomes for cardiac surgical patients.

13.4.4 Health Information Systems

Effective health information systems allow for the reliable delivery of patient health information, facilitating referral, management and long-term follow-up. Standardized health information systems in LMICs are rare, however, resulting in disjointed care [56]. Development of, and contribution to, national and international databases could facilitate surveillance and tracking of CVD and disease interventions. In the setting of CHD, the International Quality Improvement Collaborative is a volunteer registry that tracks outcomes for CHD surgery performed in low-resource settings and has made global assessments of treatment progress more feasible [58]. By utilizing a centralized database, providers at all levels could more easily communicate, monitor patients and facilitate integrated care [51, 59]. Mobile health systems also present an additional avenue for storing, transferring and tracking patient health information as their role in CVD care delivery continues to grow [60].

13.4.5 Leadership and Governance

The political climate in LMICs may also pose a barrier to team-based CVD care. Without government support, large-scale interventions are challenging and efforts towards policy change are limited. If CVD interventions garner stakeholder support from community and political leaders, then governments can participate in licensure, regulation, and funding of the public and private sector [3, 48]. As with other CVD initiatives, to engage community leaders in LMICs, cardiac surgical programs should address quality of care and cost-effectiveness. CHWs can play a particularly impactful role in partnering with community gatekeepers and opinion leaders to translate proposed policies to effective care [26].

13.4.6 Health Systems Financing

Limited financing is a challenge that manifests across the spectrum of surgical CVD care in LMICs given the complexity and expense of cardiac surgery [51]. The most cost-effective strategy is prevention. In the case of RHD, primary prevention interventions are estimated at $319 per person per year whereas cardiac surgery can range from $35,000 to $50,000 [38]. When surgical care is required, cost is often prohibitive for patients as health insurance systems are frequently absent or inadequate [48]. For CVD patients, health outcomes are correlated with a country's economic status and with patients' socioeconomic status, highlighting the importance of social determinants of health [4, 12, 61]. While cardiovascular care may be financed by non-governmental organizations or private support, sustainable, accessible interventions necessitate expanded and stable health insurance infrastructure [2, 3]. Alternative approaches include collaborative multi-hospital networks that have demonstrated reduced cost for surgery [51, 59]. Ultimately, efforts to continue expanding global attention on access to cardiac surgery must continue. Providers must continue to demonstrate the vital nature of cardiac surgery and to advocate for the prioritization of surgical CVD within health systems to ensure sustainable programs [2].

13.5 Summary

Surgical CVD represents a complex condition requiring integrated management of providers across various treatment levels and sites. A team-based approach to surgical CVD care allows for continued collaboration between several different types of providers and improved outcomes for patients. While human workforce limitations pose a significant challenge to team-based care in LMICs, efforts to strengthen the six WHO health systems building blocks offer a path towards supporting health workforce efforts for surgical CVD patients, as well as the sustainable delivery of cardiovascular care in general. A commitment to strengthening the workforce across the cardiac surgical care cascade is integral to the success of any cardiac surgical program.

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14 An Advanced Heart Team Model: Can It Be Adapted to Africa?

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Abstract

An advanced concept of "heart teams" plays a pivotal role in shaping the future of cardiac care locally, regionally, and beyond at the University of Ottawa Heart Institute (UOHI). Heart teams are comprised of clinical experts from the various cardiac subspecialties including general cardiology, interventional cardiology, cardiac surgery, electrophysiology, cardiac anesthesia, and cardiac imaging. These multi-disciplinary "think tanks" drive innovation and patient-centered care by identifying initiatives under three pillars: clinical practice, research and education. There are seven important characteristics of a high-performing heart team model which includes a shared vision and leadership, trust and respect, autonomy and a diverse team composition. The rapidly growing burden of cardiovascular diseases (CVD) in sub-Saharan Africa (SSA) coupled with healthcare system barriers such as inadequate infrastructure, shortage of cardiologists and the high cost of treatment and procedures present an opportunity for an advanced heart team model to identify creative solutions to problems. A well implemented model that includes primary and secondary prevention strategies and leverages a hub and spoke network of care has the capacity to resolve many complexities of any healthcare system for cardiac patients including in SSA and other low resources areas.

Keywords

Heart teams · Cardiac · Multidisciplinary · Africa

14.1 Introduction

The University of Ottawa Heart Institute ("UOHI") is the largest cardiac center in Canada dedicated to understanding, treating and preventing heart disease; employing more than 1,400 staff. It performs nearly 2000 cardiac surgery procedures annually including transcatheter aortic valve implantation (TAVI) and mitral clip; implants nearly 1200 devices (pacemakers and implantable cardioverter-defibrillators), and performs 1000 catheter-based arrythmia procedures and more than 2500 percutaneous coronary interventions (PCI).

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_14

UOHI also integrates a large cardiac prevention and rehabilitation program, built as a regional hub and spoke model. Our prevention team created the Ottawa Model for Smoking Cessation, offered at more than 350 healthcare sites across Canada and worldwide expansion. In 2018, it launched the Canadian Women Heart Health Alliance a program stemming from UOHIs Canadian Women's Heart Health Centre established in 2014. UOHI provides care to more than 235,000 patient visits annually with many patients coming from across Canada.

UOHI has pioneered an advanced concept of "heart teams" which has been published [1, 2]. At UOHI, heart teams play a pivotal role in shaping the future of cardiac care locally, regionally, and beyond. These multi-disciplinary "think tanks" are driven by UOHI's desire for collaboration and innovation; ingredients that are central to delivering on UOHI's mission of leadership in patient-centered care, research and education and expanding its extensive hub and spoke network.

UOHIs robust hub and spoke model of care extends well beyond its region to include remote areas across Canada; some more than one-thousand miles away such as Nunavut. As a quaternary center, it acts as a central hub leveraging technology, raising awareness and knowledge, organizing scarce resources, and building capacity in rural and under-served areas; eliminating the need for travel. Such a model enables care in remote areas and low-resource settings that lack the infrastructure and clinical expertise.

Heart teams were formally introduced and prioritized in the 2015–19 strategic plan and have continued to grow and evolve (Fig. 14.1). UOHI introduced its first three heart teams–Coronary Artery Disease, Arrhythmia and Women's Heart Health in 2015. Success of these teams led to the addition of four more teams—Critical Care (2016), Cardiac Imaging (2018), Heart Failure and Valvular Heart Disease two years later (2020), and most recently the introduction of the Virtual Care Heart Team (2021) accelerated by the COVID-19 pandemic.

Heart teams at UOHI are comprised of clinical experts from the various cardiac subspecialities: general cardiology, interventional cardiology, cardiac surgery, electrophysiology, cardiac anesthesia, and cardiac imaging and include members from medicine, nursing, allied health, and research [1]. Many teams consult patients with lived experience and other members based on team needs.

Team members are encouraged to challenge existing practice patterns and views; push for innovative change and practice based on evidence; measure long-term outcomes, foster ground-breaking research and build and nurture relationships and networks—locally and beyond —essentially bringing UOHI everywhere. Heart teams meet 2–4 times a year and are tasked with identifying initiatives under the following three pillars: clinical practice, research and education (patient and provider).

14.2 UOHI Advanced Heart Team Concept

While multi-disciplinary teams had been well established in clinical practice at UOHI and beyond for more than two decades in subspecialties such as heart transplantation, heart failure and TAVI, the concept and term "heart team" was formally introduced in 2010 by the European Society of Cardiology with the release of the myocardial revascularization guidelines [3]. This was reinforced soon thereafter by the release of guidelines for coronary disease by the American College of Cardiology Foundation/American Heart Association [4, 5] and Canadian guidelines [6].

Since this time there has been a growing trend towards heart teams for managing cardiac disease. This trend has been spurred by the

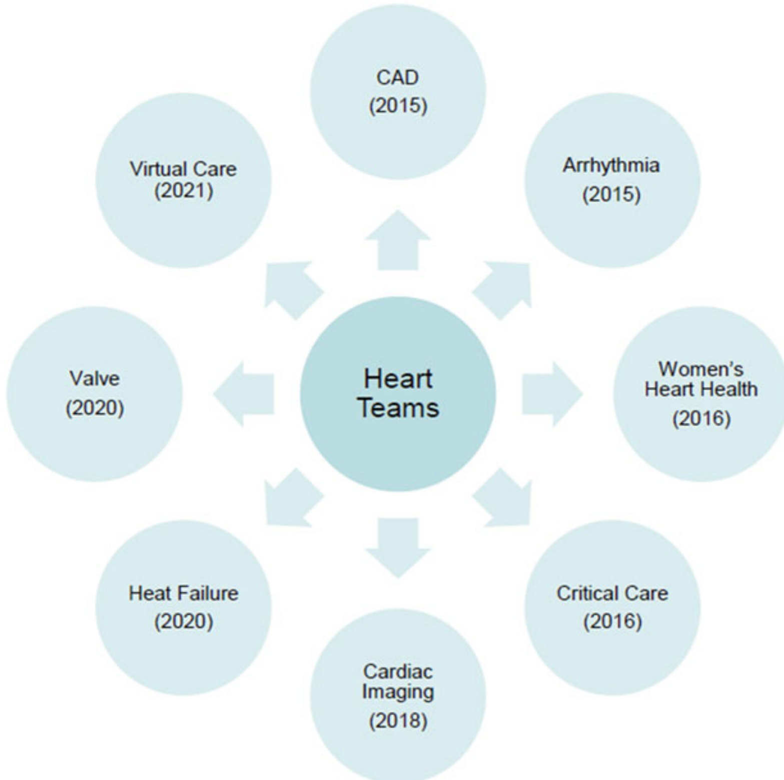

Fig. 14.1 UOHI heart teams and launch date

increasing complexity of cardiovascular patients and interdependence of medical specialties, rapid advances of new technologies and approaches, and often conflicting and evolving data for treatment and outcomes [2]. Heart teams in this context involve a group of physicians with diverse expertise jointly discussing and recommending the optimal course of treatment for patients with heart disease. While this is part of the mandate of heart teams at UOHI, heart teams at UOHI function with a much broader scope. Heart teams have the autonomy to identify multidisciplinary projects within the terms of reference based on team consensus. Financial resources are limited, so teams are encouraged to select projects that require little to no investment. However, if a team feels very strongly about an initiative that requires investment, a business case can be brought forth to the senior management team for consideration.

14.3 Three Pillars–Clinical, Research, Education

Heart teams at UOHI have the autonomy to select projects of interest if these initiatives are multidisciplinary in nature, fall under one of three pillars—clinical practice, education and research—and, aligned with the organization mission and strategic direction. For insight into the type of work that has arisen from heart teams at UOHI, we highlight some important initiatives.

14.3.1 Clinical Practice Initiatives

Changing clinical practice can be difficult and often encountered by resistance despite medicine being an evolving field in constant flux. Teams are tasked with challenging existing practice patterns and helping champion this change supported by evidence. They are also strongly encouraged to measure long-term outcomes. Change management and perseverance plays a critical role from championing stakeholder buy-in to removing barriers to sustaining momentum.

One of the most challenging initiatives undertaken by our CAD Heart Team and perhaps most rewarding has been the implementation of weekly multi-disciplinary heart team rounds to review complex CAD patients. While some team members were highly engaged and supportive of the practice change others remained less interested in changing the status quo despite evidence-based guidelines promoting team review of patients with complex CAD disease. Building trust and harmonizing cultures has been a slow but steady process. Five years later, we are now seeing extensive buy-in and participation from both interventional cardiologists and cardiac surgeons. The forum has provided a tremendous learning opportunity for all participants as different perspectives based on experience along with new interventional techniques and surgical alternatives are presented, discussed and debated. Additionally, this forum has been extremely valuable for medical trainees who experience this collaborative learning environment as a standard of practice and can bring this philosophy to future roles and work settings.

The StopAfib (Strategies to Optimize Post-Operative Atrial Fibrillation) program is another collaborative program spearheaded by our Arrhythmia Heart Team. StopAfib is a clinical care pathway aimed at the prevention of new onset postoperative atrial fibrillation after cardiac surgery with the use of amiodarone. Research by one of our team members (cardiac anesthiologist) demonstrated a 35% incidence of atrial fibrillation after cardiac surgery and that these patients had more complications leading them to longer stay in hospital by an average of 4–5 days. Multidisciplinary team members include a head pharmacist, cardiologists specialized in electrophysiology, cardiac surgeon, cardiac anesthesiologists working in the pre-admission unit, operating room and the cardiac surgery intensive care unit, and nurse managers and nurse educators from the ICU and wards where patients are often transferred to before discharge. There have been numerous challenges along the way, from starting the amiodarone load to stopping too early to moving from paper-based charts and protocols to electronic medical record, that have required modifications to the protocol and retraining of staff. Despite these challenges the team has continued to push for change given the enormous benefits to patients.

A third example, led by our Valvular Heart Disease Heart Team, has been the establishment of the Centre of Valvular Heart Disease (CVHD) which provides multidisciplinary care to patients presenting with valve disease. At the clinic, patients meet the CVHD team of highly specialized valve disease experts including cardiologists, cardiac surgeons, nurses and research coordinators. All tests and consults are scheduled for the same day providing the patient with same day diagnosis and treatment plan. Research is a key component of this program. The CVHD research registry, which aims to better understand the mechanisms and natural history of valvular heart diseases, captures information on the patients' baseline characteristics and outcomes. In addition, patients can choose to be part of the CVHD "biobank" by contributing blood samples for clinical use and for future heart valve disease research.

The above presents three very different clinical practice initiatives undertaken by heart teams at UOHI. These examples highlight the importance of multidisciplinary team members working together to change practice based on evidence with the goal of enhancing patient care.

14.3.2 Research

Research is the backbone of innovation in medicine and improving health outcomes. UOHI has more than 65 active scientists and clinical investigators and close to 200 research staff. It closely integrates research with clinical care and has established disease-themed Innovation Hubs that are closely aligned with UOHI's heart teams in addressing key knowledge gaps and charting new paths for diagnosis, treatment and management. These Innovation Hubs push for sex and gender considerations in research studies and leverage partners to maximize expertise and access to state-of-the-art facilities, and involve patient partners in pertinent research.

We present three very different research projects to highlight the unique and diverse research initiatives undertaken by heart teams at UOHI and start with our Cardiac Imaging Heart Team. This team is leading the charge on artificial intelligence (AI) and machine learning through a partnership with a research and development organization with extensive expertise in AI. Through this partnership, UOHI is leveraging AI to harness UOHI's vast datasets to create applications that can advance the diagnosis and treatment of cardiovascular disease and advance UOHI's leadership position nationally and globally. The team has four projects in progress, one of which is using artificial intelligence and machine learning in the interpretation of wide-complex tachyarrhythmia.

In partnership with the oncology team at its sister site, members of the Arrhythmia Heart Team have developed an innovative, completely non-invasive cardiac radio-ablation to treat life-threatening arrhythmia by combining radiotherapy and cardiology techniques. Patients experience little or no pain and do not require hospitalization. Initial findings from this groundbreaking research are extremely positive and research efforts are currently being expanded. Such innovation serves to reinforce the power of multidisciplinary research and collaboration in advancing medicine.

A recent innovation in the face of the COVID-19 pandemic has been the development of a model, CardiOttawa LOS Score, by members of the Critical Care Heart Team. To limit exposure to COVID-19 and preserve hospital capacity, elective surgeries have had to be postponed. This model has helped to optimize triage of surgical patients and decrease cancellations by predicting length of stay (LOS) [7].

UOHI benefits from a critical mass of patients and immense datasets. To facilitate research, UOHI has invested a significant amount of technological and human resources into developing Cardiocore, an institute-wide research database with numerous modules integrating data from procedures and follow-up care. The goal of Cardiocore is to eliminate duplication of data entry, streamline resources and facilitate interdisciplinary research [1]. Data from other databases and registries feed into Cardiocore. UOHI also has the ability to link its data with provincial-wide databases to further enhance research capabilities. Cardiocore is an essential tool in supporting the heart teams' data management and research needs.

14.3.3 Education

Education is fundamental to improving health outcomes. UOHI offers a vast array of educational activities for both providers and patients.

As experts in cardiac care, UOHI takes education seriously and sees it as part of its responsibility to help educate and support community providers in the region and beyond. It quickly adapted to the COVID-19 pandemic by moving education virtually; further expanding its reach. For example, prior to the pandemic, UOHI organized an annual regional symposium where close to 150 providers; many from rural parts of the region, would attend to learn about the latest evidence on prevention, diagnosis, treatment, and management of heart disease. Given the current pandemic, the symposium has morphed into bi-monthly webinars with topics rotating through the various heart teams.

UOHI is also proactive in engaging providers and the scientific community nationally and internationally. Through, the Women's Heart Health Team, UOHI proudly co-hosts the international Women's Heart Health Summit, a unique event for health professional including primary care providers, cardiologists, gynecologists, nurses, allied healthcare providers, researchers, policy-makers seeking up-to-date knowledge of women's heart health. The goal of the Summit is to enhance women's health through care, research, awareness, and policy development. It recently held its third annual Summit moving to an online format and tripling registration to 457 attendees from across the globe.

Patient-centered care is a fundamental philosophy of UOHI. It means treating every patient with dignity and respect and encouraging them to participate in decisions involving their care. Therefore, educating patients on their condition and treatment and involving them in the decision-making is key to engagement and empowering patients to take ownership of their health. UOHI provides patients and caregivers with access to numerous educational sources from booklets to teaching at the bedside and ward classroom to numerous online educational programs. Heart teams are tasked with evaluating current education resources and identifying gaps and improvements to patient education. UOHI takes prevention seriously and provides a number of onsite and online classes that are open to patients and caregivers, with several also open to the general public.

For example, understanding that atrial fibrillation (AF) patients experience significant anxiety from their condition and require more information than can be provided during an ambulatory visit, the Living with Atrial Fibrillation class and AF Ablation class originated from the Arrhythmia Heart Team. These weekly interactive classes delivered by an advanced practice nurse receive high ratings for patient satisfaction. As another example, the CAD Heart Team developed a booklet that promotes shared decision making by informing patients with stable coronary artery disease about possible treatment options and providing a list questions for patients to ask providers.

14.4 High Performance Teams

Building high performance teams is a key ingredient to the success of the heart team model. It can be challenging in healthcare as you cannot mandate teamwork and force collaboration especially when physicians, and other team members are volunteering their time outside of their busy day. UOHI has written about the process of implementing teams [1] and has learned that bringing people together does not make a high-performance team without these essential characteristics (Fig. 14.2).

1. Shared Vision–Heart teams are guided by terms of reference that provide a clear mandate and a compelling reason to be part of the team. However, "vision comes alive only when it is shared" [8]. For a team to be successful, it is important that members share a common vision; one that is aligned with UOHI's mission as well as their individual goals as emotional connection further drives passion and commitment.
2. Shared Leadership–Shared leadership is associated with innovation [9, 10]. While heart teams typically have co-chairs that help guide the work of the team; heart teams are all about shared leadership. The culture at UOHI has always been one of inclusion and a flattened hierarchy. Therefore, all team members, whether it be a physician, nurse, technician, patient or other member, are listened to, valued, and encouraged to express their ideas and suggestions.
3. Multidisciplinary–Team membership is defined based on the specific theme and needs of the team; but diversity is key to heart team composition. A multidisciplinary structure brings together professionals with different expertise and knowledge. Functional diversity promotes creativity and innovation as different perspectives, experiences and attitudes forces debate of alternatives and creative solutions [11]. Team members can include physicians, clinical managers, researchers, pharmacists, psychologists, technologists and other allied health professionals [1]. In addition, patients with lived experience are often part of the membership or consulted on projects.
4. Trust & Respect–Building a culture of trust and mutual respect is a necessary ingredient. Creating an environment that respects diversity of thought and experience and one of psychological safety where team members feel comfortable speaking up and contributing

Fig. 14.2 Elements of high-performance heart teams

their ideas builds trust and promotes creativity [12]. Innovation stems from constructive brainstorming and sharing ideas no matter how far-fetched or impractical they may seem.

5. Autonomy–Heart team members have the freedom and initiative to identify projects that resonate, as teams that come up with their own projects are more motivated and engaged [10]. Projects that require resources beyond team members and the project management provided must submit a business case for approval from the senior management team.
6. Project Management–UOHI has demonstrated its commitment to heart teams by dedicating resources and assigning a dedicated project manager, who works closely with all teams. The project manager has a diverse skillset and support extends beyond the traditional project management role of developing workplans, executing, monitoring and controlling projects. Other supports can include business case development, literature searches, environmental scans, analytics and presentation development. This role is vital to minimizing the amount of time clinicians spend on project activities. This is important as physicians are not compensated for their time.
7. Measurement–Heart teams are responsible for identifying key performance measures under each of the three pillars–clinical, research and education—that are tracked regularly and reported to the senior management team. In addition, project performance is monitored to make sure projects stay on track from a schedule, scope and budget (if applicable) perspective.

Building high performance heart teams takes work and the above components increase the likelihood of team success and raising the bar on patient care.

14.5 Heart Teams in Reducing the CVD Burden in Africa

The rapidly growing burden of cardiovascular diseases (CVD) in sub-Saharan Africa (SSA) accounts for 13% of all deaths; representing 37% of all non-communicable disease related deaths [13]. Hypertension is the major driver of CVD, but other contributing risk factors include smoking, dyslipidemia, obesity, and diabetes [13]. In comparison to the global population, those affected are much younger, disproportionately women and from low-income and rural communities [14].

The healthcare system in SSA presents several barriers to addressing this growing burden including inadequate infrastructure, shortage of cardiologists and other cardiac healthcare providers, high cost of treatment and procedures, and funding models that favor communicable diseases [13].

In low resource settings, such as SSA, creative strategies are required for primary and secondary prevention of CVD. A heart team model, which brings together multidisciplinary experts to collaborate and identify creative solutions to problems, may be an effective approach to tackling the burden of CVD in in SSA and other low resources areas. The following are areas that could benefit from a heart team approach (Table 14.1).

The prevalence of heart diseases in children and young adults is SSA is high and growing rapidly. Heart teams offer a framework for identifying creative strategies for the prevention of primary and secondary heart disease.

14.6 Conclusion

The heart team concept, if well implemented, has the capacity to resolve many complexities of any healthcare system for cardiac patients. It should be promoted in low-middle income countries where resources are limited. It builds a more efficient model of care, getting people to work closer together for better care at less cost. It resolves problems related to practice changes, facilitating a patient-centered approach by moving away from of a physician-centric approach which does not always best serve the patient.

An advanced heart team concept not only applies to procedures performed in cardiac surgery or interventional cardiology, but to strategies of cardiac prevention and remote care. Establishing a virtual care heart team could prove extremely valuable for countries where remote care could be the first line of care in many circumstances; facilitating early diagnosis and early management. With appropriate resources, network and technology, teams of cardiologists, cardiac surgeons and other health professionals with cardiac expertise could provide advice and guidance for patient management, but also contribute to prevention and education in remote parts of African countries based on a hub and spoke model similar to that developed at UOHI. Heart team experience in more developed countries can help colleagues in less developed countries. Lastly, considering the lack of infrastructure and qualified personnel in most African countries, AI-based virtual care could dramatically expand in the future with a heart team approach.

Table 14.1 Adapting heart team model in Africa

Heart team	Challenges	Strategy
Prevention [13, 15]	Risk factors–hypertension, obesity, diabetes, cholesterol, smoking, stroke–play a critical role in CVD. An estimated 46% adults 25 + years old are diagnosed with hypertension	• Programs to raise awareness for both the public and healthcare workers • Programs that focus on primary prevention and risk factor modification
Coronary artery disease [13, 16]	CAD is rare in SSA accounting for less than 10% of cases compared to high-income countries which account for greater than 50%; possibly stemming from misdiagnosis or under-diagnosis	• Programs to raise awareness for both the public and health workers • Programs that focus on primary prevention and risk factor modification • Cost-effective strategies for screening, treating and managing disease
Arrythmia [17]	Atrial fibrillation is under-reported and an unrecognized risk factor for stroke	• Strategies to raise awareness • Cost-effective strategies for screening, treating and managing disease
Valve [17]	High prevalence of rheumatic valvular heart disease in Africa affecting the young and progressing rapidly	• Programs for awareness and prevention • Adoption of TAVI, a cost-effective solution that is minimally invasive and requires minimal hospitalization; implement protocols and criteria for patient selection
Heart failure (HF) [18, 19]	HF is predominantly caused by hypertensive heart disease, cardiomyopathies and rheumatic heart disease and affects young adults. High readmission and mortality rates. Treatment is costly preventing regular follow-up visits. Lack of diagnostics and medicines	• Programs to control primary risk factors • Healthcare provider education on the available best practice treatments for HF • Creative diagnostic strategies that are implementable in low resource setting • Strategies for management and medication supply
Women's heart [14, 20]	Women from low-income areas disproportionately impacted by rheumatic heart valve disease, untreated congenital heart disease and peripartum heart disease	• Programs to raise awareness for both the public and healthcare workers • Risk factor control programs as above • Improvement in coordination of maternal health services
Telemedicine/ virtual care [21]	Shortage of cardiologists, nurses and other professionals with cardiac expertise and access to health care services particularly for those in rural areas	• Leverage partnerships to tap into cardiac expertise via telemedicine • Leverage phones, mobile apps and compatible peripheral devices that facilitate image and data transmission as a large majority in SSA own mobile devices • Utilize virtual education to build health workforce capacity/competencies • Leverage AI to accelerate data collection, diagnosis and treatment in rural communities and automate care delivery • Build a hub and spoke network of care that increases connectivity and care

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Part III

Bioethics, Education and Role of Societies in Global Cardiac Surgery

15 Ethical Considerations in Global Heart Surgery

Kathleen N. Fenton

Abstract

Consideration of the ethical questions that arise in the context of global cardiac surgery can help us to more readily recognize and avoid obstacles to collaborative work and program development. One question that often arises concerns whether and when scarce resources should be allocated to heart surgery, which may seem expensive relative to other interventions. The growing recognition of the excess worldwide mortality that is associated with heart disease and other noncommunicable diseases, in combination with data based on cost effectiveness analysis, can form the scientific basis on which we can build an ethical evaluation of just resource allocation. Once a decision has made to invest in program establishment, ethical guidelines recently established by cardiothoracic surgical organizations can help navigate the working relationships between all stakeholders. These guidelines emphasize responsibilities toward the patients first, of course, but also include those toward local providers, volunteers, donors and other payors. Because establishment of sustainable programs is key to achieving a long term solution, teaching and mentoring local providers, and helping them to succeed, should almost always be the intentional focus of cardiothoracic global health initiatives, and visitors should attempt to avoid being perceived or presented as the "experts" or "heroes" to the detriment of the local health care team. Finally, differences in values and norms, particularly but not only regarding questions of end-of-life care, should be identified and discussed early, openly, and often, rather than being left to a moment of crisis.

Keywords

Ethics · Global health · Cardiothoracic surgery

At first glance it might seem unnecessary to devote much time to a consideration of ethics as related to global cardiac surgery. After all, providing needed patient care while helping to develop surgical programs worldwide would clearly seem to be a good thing, and those involved generally have the best of intentions. A brief reflection, though, allows us to recognize that many of the pitfalls along the program development path are rooted in ethical questions or dilemmas; identifying and considering them in advance can help us avoid these obstacles, or to

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_15

recover from any stumbles we encounter along the way.

We can begin by asking, but this time from an ethical perspective, a question that came up earlier in the text: why promote heart surgery in settings where people are dying from things that are apparently easier and cheaper to treat? Next: what ethical norms should be respected by those who want to help with patient care and program development? Then: how should foreign advisers best interact with and support the local/domestic providers? Finally, how do we navigate the myriad questions and potential problems that may arise related to values, preferences and practices in cultures that differ greatly from our own?

15.1 Allocation of Scarce Resources to Cardiac Surgery: The Ethical Perspective

In the wealthiest parts of the globe, cardiac surgery is common and readily available to virtually all who need it. The great majority of the world's population, though, lives in places where heart surgery is either not available at all, or is accessible only to those with the financial means to pay for it. Often, there is an assumption that scarce resources should be directed toward interventions perceived to be cheaper and easier. From an ethical standpoint, can we justify investing money, whether government (taxpayer) funding or humanitarian donations, toward heart surgery and cardiac program development when people are still dying of malnutrition and infectious diseases that seem easier to treat or prevent? Why should we encourage developing countries to direct their own scarce resources toward heart surgery?

Although the early work in Global Health was largely focused on infectious diseases, in recent years there has been a growing recognition of the excess mortality (and morbidity) in low- and middle-income countries (LMICs) that is associated with noncommunicable diseases, including both congenital and acquired heart problems. Most recently, as elucidated in an earlier chapter, the important role of surgical care has been emphasized. More than 25% of medical problems worldwide are amenable to surgical treatment, with LMICs bearing the dual burden of a higher incidence of surgical illnesses and a lower availability of surgical treatments [1–3]. Given this information, how should cardiac surgery be prioritized in LMICs?

The four ethical principles of respect for persons, beneficence, non-maleficence and justice can help us begin to explore this question [4]. The right to autonomy, following from the principle of respect for persons, recognizes that each person has an inherent right to self-determination. This principle forms the basis for the requirement that informed consent be obtained for medical treatment and research participation, among other things. Autonomy applies properly to individuals, but it can help us to consider the right of sovereign nations to determine, for themselves and based on their own values, how to prioritize heart surgery in relation to other things. As in the case of informed consent, such decisions should be made only after having been given the appropriate information; we will return to this topic. The principle of beneficence emphasizes that we should attempt to do good. Provided that cardiac surgery can be done safely and (in general) effectively- not a "given" in every situation–making this option available is certainly a good thing for the patients involved. Here, where we are talking about beneficence at the level of a society or country, program development has additional benefits. We might also add, as beneficiaries, the members of the medical team, not so much because they are able to make a living as because of their ongoing professional development and the fact that they are able to exercise their skills for the greater good. These improved skills of the medical team also then benefit other critically ill patients.

Applying the principle of non-maleficence becomes more complicated. Here we need to consider whether and when harm is done not only to the individual patient, but also to the society as a whole. At the level of the individual patient, not doing harm relates largely to the ability, already mentioned, to provide surgery (in general) with good results; this means that if the appropriate infrastructure (training, laboratory and blood bank facilities, sterilization, etc.) do not exist and cannot be provided, surgery should not be offered. In many parts of the world, the concept of non-maleficence at the individual level may also include avoiding financial ruin for the patient and family. This is not a trivial concern: introduction of the mere possibility of a life-saving option, while objectively good, may impose an apparent duty to provide it, even at an unbearable cost. Faced with a critically ill child or parent, an entire extended family may be willing, and indeed feel compelled, to sacrifice everything they have to try to help; cardiac surgical program development must include some plan to assure that costs assumed by families are both reasonable and just. Non-maleficence also requires consideration of harms done to others: to patients with other medical problems, who may not receive treatment if resources are dedicated to heart surgery, to children whose schools are not built or staffed, and so on. This transitions into consideration of the principle of justice- giving each one his due. How can all these different interests be balanced?

Our considerations of justice and non-maleficence can be aided by recourse to consequentialist ethics. In this ethical system, promoted by John Stuart Mill among others, actions are considered right or wrong, good or bad, according to their outcomes or anticipated (or likely) outcomes [5]. To apply a consequentialist ethical analysis to the question of whether or not to provide or recommend cardiac surgery in any given environment, we would need to take into consideration who would benefit and who would lose (or pay). On the benefit side, for example, are not only the patient who receives a successful operation, but also her family and the society that benefits from her productive contribution. This circle of beneficiaries could be expanded further. On the loss side are not only those who bear the financial cost, but (in resource-limited settings) anyone who may not get needed care (surgery or otherwise) because this patient did, as well as those denied funding for any other project or cost. Two things, then, become immediately apparent: that life-saving heart surgery should be provided, when and where possible, unless there is a proportionately grave reason to not do so, and also that we need to find a way to figure out what would be proportionately grave, or rather, how to prioritize different needs.

Cost effectiveness analysis can help us compare different ways to allocate scarce resources for health care. In cost effectiveness analysis, a total dollar figure is calculated in order to put a price on the desired outcome of an intervention; this can then be compared directly to the price of obtaining the same outcome of a very different intervention. One of the earliest measures used was the cost per year of life saved. This allowed mathematical comparison, for example, of a high-cost intervention (like heart surgery) that saves a life to a low cost intervention (like a mosquito net or a vaccine) that needs to be given to many people in order to save one life. Surgery in general and pediatric cardiac surgery in particular have been shown to be highly cost-effective [6], meaning that in many parts of the world, the benefit (to the patient and society) of providing this care may well justify directing scarce resources to it. (Cardiac surgery is less cost-effective in adults, so here the analysis becomes less straightforward [7]). Recommendations may be made to provide interventions that are highly cost effective, to avoid those that are less so, and for the country itself to make choices regarding prioritization of similarly-ranked interventions if not all can be funded. Here we can return to the principle of autonomy at the level of the sovereign nation: up-to-date cost effectiveness information for a wide variety of medical treatments and procedures can and should be provided to decision makers and other stakeholders, so that they can use this information to make resource allocation decisions.

Consequentialist ethics and cost–benefit analyses are clearly not the only means of justifying (or denying) establishment of cardiac surgical programs in LMICs. It is certainly morally justifiable for a surgeon, cardiologist or other specialist to want to practice, and find reward in practicing, his own profession. There is therefore no ethical reason to demand, for example, that one stay home, work hard, make a lot of money and donate it to help underserved regions as opposed to taking time off to go there oneself. Both types of help are necessary and appropriate, and (to invoke virtue ethics) the practitioner will grow in virtue by doing either. (Whether or not there is an existing moral obligation to do *something* within one's power to help the disadvantaged is beyond the scope of this chapter.) Similarly, the "rule of rescue" often leads us to prioritize addressing acute, identified danger or suffering in an individual patient whose treatment might be more expensive (or less likely to be successful- but we tried!) rather than invest resources in preventive care for a group of people who remain nameless and faceless. Ideally, both should be done; where resources are limited, a balance must be sought between caring for those in immediate need and providing for the population as a whole. This balance is perhaps as elusive in high income countries as in LMICs.

15.2 How Can I Help? Ethical Guidelines for Assisting in the Establishment of Cardiac Surgical Programs

Once a decision has been made to work toward establishing a cardiac surgical program at a given site, the next ethical questions that arise concern exactly *how* to help. Humanitarian assistance has become increasingly common, and has been both lauded and criticized. Supporters recognize its clinical benefits, both immediate (saving the lives of patients who are here right now) and long term (program development) [8, 9], as well as seeing it as a sign of solidarity with those in need [10]. On the other hand, critics see many such efforts as "surgical tourism" or neocolonialism [10, 11]. Recently-established guidelines approved by major cardiothoracic surgical organizations emphasize responsibilities to the patient first, but also outline those to the local medical team and other stakeholders, the volunteers, and providers of financial resources [12].

15.2.1 Ethical Guidelines for Cardiothoracic Surgery Global Health Initiatives

1. Responsibility to the patient is paramount and requires:
   a. Surgery should be offered to patients who have a reasonable chance of benefitting from it, based not only on their diagnosis and condition but also on the resources and personnel available.
   b. Surgeons and other practitioners should operate (only) within their ability and their normal scope of practice.
   c. Patients should be able to expect that the surgeon performing the operation will evaluate them before surgery, explain the surgery to them (with a competent translator if need be), and take care of them after surgery.

2. Responsibility to the local providers and to all other local stakeholders requires:
   a. Program organization and goals should be clearly outlined in advance with all stakeholders, including local providers, ministries of health, and others. plans should be developed in keeping with local needs and priorities.
   b. "Service only" initiatives without efforts at teaching or program building may be appropriate in some circumstances but should be uncommon.
   c. Emphasis should be placed on teaching and empowering the staff in the target country; a limited number (usually one or two) of our own trainees may participate as observers but should only be active participants if there is truly no appropriate local person available.
   d. Respect for persons includes respect for local norms, priorities, and customs.

3. Responsibility to volunteers and other participants requires:

   a. Information should be available that allows participants to align their own priorities and goals with those of the humanitarian organization, and with a specific STGHI.
   b. Pre-departure education should include information regarding logistics, available resources, local personnel, and cultural norms.
   c. Team leaders, usually staff or seasoned volunteers, should be identified as resources for questions and concerns while in the country.
   d. Post-trip debriefing should be encouraged.

4. Responsibility to donors and other payers requires:
   a. Donors should always be given honest and transparent information regarding local needs, goals, and expected results, including both patient outcomes and program building.
   b. All sponsors should be informed of the results after completion of each STGHI, including clinical outcomes, local team education provided, and lessons learned. They should be provided with links to or copies of local media reports of the trip.

It is hoped that attempts to establish ethical guidelines can both make these efforts more successful and eliminate some of the problems that have led to the criticism.

To these guidelines might be added other ethical norms which might seem self-evident but merit mentioning. Selection of patients and allocation of resources should be fair, not based on favoritism, and independent of any bias related to sex/gender, race/ethnicity, religious or cultural group, or similarly irrelevant factors. Funders must not try to unduly influence patient selection or place conditions on provision of resources. Every effort should be made to assure that, once established, the surgical program will continue to function in this manner.

15.3 Interaction with Local Providers

The long term solution to the lack of cardiac surgical care in most of the world is to train surgeons and other providers, and to help them establish sustainable programs [13]. Recognizing this, many or most humanitarian organizations have gravitated away from efforts that are directed (only) toward providing patient care, and instead focus more intentionally on teaching and mentoring. This must begin at the planning stages and continue throughout the entire process, until a surgical program can be completely managed by the local team including all aspects of patient care, organization/logistics and funding.

One of the most common criticisms of humanitarian surgical efforts is that, rather than building up the domestic health care providers, visiting surgeons present themselves, or are presented by their organizations or lay media, as the "experts" or even "saviors," thus diminishing the reputation of the local surgeons and creating an environment of mistrust [14]. From a purely pragmatic standpoint, avoiding this is key both for program development and for the sake of the patients who must not be, or be allowed to feel, abandoned when the visitors necessarily leave. From an ethical standpoint, the duty to uphold and promote the local surgeon and other team members stems primarily from the principles of respect for persons and justice. Visiting providers who interact respectfully with their local counterparts will rapidly recognize that, although they may not share the same education, skills and experience, their abilities are often complementary to those of the visitors and each can learn a lot from the other. This collaborative working style results in the best patient outcomes; it also helps both sets of providers to grow in the virtue of humility (by accepting the advice and assistance of each other), and it creates an international bond of solidarity that extends beyond the confines of the hospital walls.

15.4 Navigating Differences in Cultural Norms

Perhaps some of the most difficult ethical dilemmas faced in the context of global cardiac surgery program development stem from differences in cultural norms. When it comes to science and medicine, at least "Western" medicine, we can all come to an agreement about what the data shows, or (in the absence of definitive research) we can agree that we need to subject something to empirical testing. Cultural norms, though, are ingrained and often based on an understanding of the human person that is tied to deep-seated philosophical and/or religious belief systems. In many cultures, for example, there is no practice of "informed consent," and to tell a patient what his diagnosis is or what are the risks of surgery may be deemed cruel. There are also often discrepancies regarding who makes decisions; in many traditions the concept of personhood is of a relational nature, and decisions are made by the whole family, or by one or more family leaders rather than by the patient alone. An explanation to the patient may or may not typically be included. This is one of the most difficult dilemmas to negotiate, because it involves true differences in understanding of "right" and "wrong" in relationships between physicians, patients and families. These differences in practice can cause moral distress for both the visiting surgeon and her local counterpart if they have not been anticipated in advance. Surgical program development, though, must include teaching not only the technique of surgery and the preoperative and postoperative care, but also the main bioethical principles that transcend culture. Signing an "informed consent" form is not important, but the principle of respect for persons is, and must be honored.

It is best to deal with these questions early and openly, and in a way that allows the underlying principle of respect for persons to be honored by all involved. For example, in a culture where the official "consent" is given generally by the male head-of-household, an agreement could be made that includes a discussion, ideally in private, with a female adult patient or a child's mother. Care must also be taken to identify and respect the wishes of individual members of any community whose ideas may not align with local norms.

Negotiating questions concerning end-of-life care may also be difficult, and may cause significant moral distress for various members of both teams. In many cultures there is no experience with withdrawal of support and there may be no legal basis for determination of death by neurological criteria, thus creating angst for the local providers and effectively "forcing" the visitors to provide ongoing care that they may deem futile or even harmful. Once again, every effort should be made to identify and discuss such questions well in advance, rather than trying to negotiate them once there is a complication, and all involved are stressed and exhausted. These are just examples of many clinical dilemmas that may arise, often unexpectedly.

There are also cultural differences that are objectively less serious but that may create an environment that is unpleasant or even counterproductive. Visitors who are unaware of or fail to adhere to local customs regarding their own attire or regarding preserving patient modesty may unwittingly cause offense, for example, and in some parts of the world care needs to be taken to avoid particular items of food or drink. These things may seem trivial, but they may greatly affect how the visitors are perceived by both staff and patients.

Following again primarily from the principle of respect for persons, we recognize the importance of respecting cultural differences. In almost all cases, a point of agreement can be found, or the differences can be acknowledged and the individuals can "agree to disagree." In almost no situation should anyone, whether visiting provider, local provider, financer or patient, be forced to violate his own conscience. Many of these seemingly irreconcilable dilemmas can be avoided or mitigated by (bilateral) education, beginning early and extending throughout the entire process of interaction, whether it is a single trip or a multi-year process of program development.

15.5 Conclusion

Contemplation of the ethical issues involved in efforts to establish cardiac surgery programs globally can help all involved do the right things for the right reasons. This reflection can help us to determine when and where such efforts should take place, and how domestic and international teams can best work together. Perhaps most importantly, consideration of different value systems and identification of potential ethical dilemmas in advance will facilitate program development and assure a more rewarding experience for all involved.

Conflict of Interest Disclosure None. There were no external sources of funding used for this publication.
DisclaimerDr. Fenton is an employee of the National Heart, Lung, and Blood Institute (NHLBI), National Institutes of Health (NIH). The views expressed in this article are those of the author and do not necessarily represent the views of the National Heart, Lung, and Blood Institute, the National Institutes of Health, or the United States Department of Health and Human Services.

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16 Role of Humanitarian Cardiac Surgery Missions in Developing the Next Generation of Global Surgeons

Parth Patel, Zachary Enumah, and Percy Boateng

Abstract

With a lack of comprehensive health care systems in resource constrained countries, Global Cardiac Surgery plays a vital role in bridging the gap in access to surgical care. Global Cardiac Surgery relies primarily on voluntary humanitarian multidisciplinary teams whose make up vary but often include medical students. The inclusion of medical students on humanitarian missions has been called into question because of the perceived limited sociocultural competence, risks to patient safety, ethical concerns, diverting focus to medical education over patient care, and financial burden. However, there is growing evidence that for appropriately selected medical students, surgical mission trips can serve as a professional investment by providing them knowledge in global health and surgery and help foster a future career in Global Cardiac Surgery. In order to help develop the next generation of global surgeons, medical students should be adequately trained and encouraged to participate in Global Cardiac Surgery while ensuring their education does not come at a cost to the local population or patient safety.

Keywords

Global cardiac surgery · Medical students · Education · Next generation

16.1 Background

Cardiovascular disease continues to account for more than one third of all mortality worldwide, with over three quarters of deaths affecting low- and middle-income countries [1, 2]. The disproportionate impact of cardiovascular disease is primarily due to the limited primary healthcare programs and surgical services to allow early detection and treatment before leading to significant disability and premature death [2]. Global cardiac surgery over the past 40 years has emerged to support and strengthen local healthcare systems and surgical services, increase international investment in cardiac surgical care to alleviate disability and premature death, and support local leaders and the general public to advocate for equitable access to cardiac surgery [3–6].

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_16

Voluntary humanitarian efforts have been a major component of global cardiac surgery. Historically, voluntary humanitarian efforts have emerged as mission trips in which a visiting team of surgeons travel to a host nation that lacks an onsite program to offer their services over the course of weeks [4]. While this approach continues to persist, the traditional model of mission trips have evolved to develop a five-to-ten-year partnership between local healthcare centers and NGOs and academic institutions, through which a visiting team will still travel to offer their surgical services but will also provide on- and off-site support for the development of the local center [4, 6]. Ultimately, the collective goal of voluntary humanitarian efforts have been to offer host nations with development support, assistance in establishing hospitals and accruing medical supplies, educating and training local providers, and addressing acute patient needs by the visiting team [7–9].

While primarily advancing these goals, voluntary humanitarian efforts have fostered education among medical students and residents who attend mission trips. As part of the multidisciplinary team of surgeons, intensivists, nurses, perfusionists, and coordinators who attend mission trips, medical students take on variety responsibilities. Their roles have ranged from shadowing providers, providing basic care, assisting surgeons in the operating room to coordinating logistics of the trips, triaging patients, and assisting in research studies. Through these roles, medical students have gained both direct and indirect education while supporting the primary objectives of the mission trips. However, the introduction of medical students, especially those who are inadequately trained have raised several challenges, including limited sociocultural competence, risks to patient safety, diverting focus to medical education over patient care, and financial burden. These challenges have brought into question the benefit of bringing medical students on mission trips and have raised the possibility that perhaps students can have a greater impact on the local population by donating the cost of their attendance to support the work of NGOs and academic institutions rather than attending mission trips. Despite these arguments, there is growing evidence that for appropriately selected medical students, attending surgical mission trips can serve as a professional investment by not only providing them knowledge in global health and surgery but also help foster a future career in global cardiac surgery. In order to help develop the next generation of global surgeons, medical students should be adequately trained and prepared to ensure their education does not come at a cost to the local population or patient safety (Fig. 16.1).

16.2 Challenges to Incorporating Medical Students

Incorporating medical students, especially those who are untrained as part of mission trips can pose unique challenges, as their goals, expectations, skills, and knowledge might not align with the needs of the local community. This in turn can create opportunities where the presence of medical students can lead to undue harm to the student, patient, local providers, and the community. Common concerns with untrained medical students include limited sociocultural competence, risks to patient safety, diverting focus to medical education over patient care, and financial burden.

Global cardiac surgery does not happen in isolation but occurs in the context of local healthcare systems, cultural beliefs on health and medicine, and local economies and politics. Unlike surgeons and other providers who may have many years of experience with the host community, medical students, especially those attending a mission trip for the first time tend to focus their knowledge on pathology and disease presentation without adequately conceptualizing medical conditions in the context of social, cultural, political, and economic factors [10]. This lack of understanding can result in unforeseen consequences. In particular, the ignorance of the local culture can lead students to make cultural assumptions, impose their Western beliefs on the local population, and react inappropriately to unexpected circumstances [10–12]. As a result,

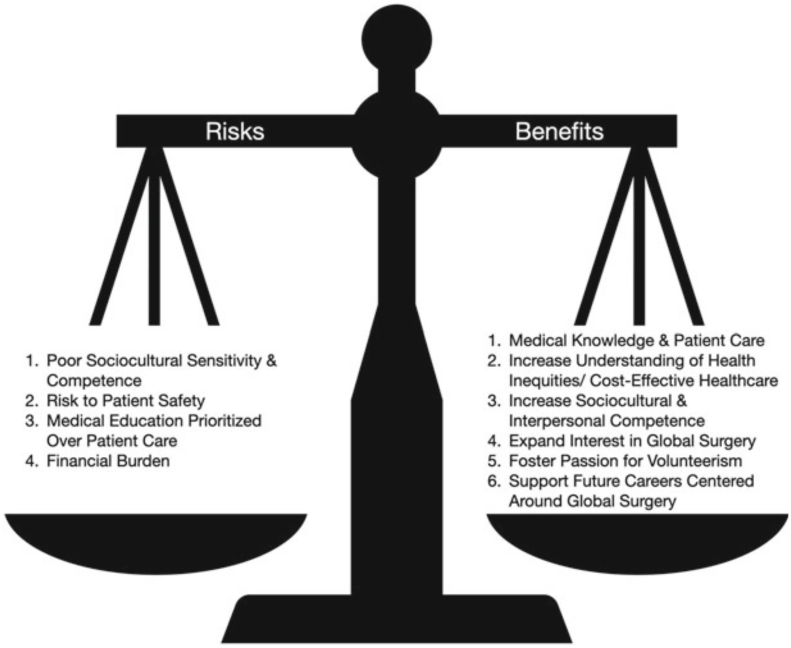

Fig. 16.1 Benefits and Risks of Incorporating Medical Students on Global Cardiac Surgery Mission Trips. While medical students pose major challenges when attending mission trips, these risks are minimized among culturally and ethically competent students. Among this select population, mission trips represent an approach to develop the next-generation of global surgeons to further support the ever-increasing needs of global cardiac surgery

students may overlook the stigma of certain conditions, dissuade patients from engaging in treatment by imposing Western frameworks, and cause offense by overlooking local norms and customs [12, 13]. Ultimately, such blunders run the risk of damaging the therapeutic alliance with the patient and possibly even the rapport the visiting team has created with the community.

Untrained medical students on surgical mission trips can negatively impact patient safety. Coming to low-income communities from a Western nation, medical students exhibit a power imbalance between the local population and themselves [11, 14, 15]. This imbalance can transform into an exploitative relationship that allows medical students greater freedom to engage in the medical care of patients despite their limited training level [14]. Such exploitative relationships can become more prevalent in settings where limited to no care is available for the local population or the students possess greater knowledge than local providers [11, 14]. Ultimately, medical students operating outside of their training level can result in patient safety being compromised. The risks to patient safety and suboptimal care of patients can have significant downstream effects. Local communities might lose trust in the visiting team, partnerships with local healthcare institutions might corrode, and local government and international partners might minimize or eliminate support for the mission trips.

The power imbalance can also result in medical education being prioritized over patient care. Given the eager desire of medical students to gain as much knowledge as possible from their short-term trip paired with the power differential between themselves and the patient, they can be present in all clinical encounters between the physician and the patient without limited to no say from the patient [10]. Moreover, sensitive information and physical exam findings might be openly shared and displayed to them in the presence of the patient to highlight a teaching point. Ultimately, the physical presence of medical students and the priority to medical education can minimize patient privacy and impact a patient's capability to fully disclose information that might be critical to their management [10, 11, 13].

Medical students can pose a financial burden, and their cost of attendance especially through NGOs and academic institutions where funding is limited can divert funds that would otherwise directly benefit the local population. In order to accommodate medical students on mission trips, their cost of airfare, travel to the local community, and living and meal arrangements need to be managed [13]. The cost of a mission trip in 2008 was estimated to be approximately $2,400 exclusively for travel and housing [16]. However, the cost of attending a mission is highly variable and primarily dependent on what geographic locale the trip is organized to. On certain occasions, medical students may personally cover their costs. However, in most instances, the cost of the trip is partially or fully subsidized through the institution that they are traveling with. NGOs and academic institutions have limited funding when organizing mission trips, and the cost of having medical students can divert funds which might otherwise have been used to support the development of a hospital, acquire medical and surgical supplies, finance additional surgeries, and much more [13, 16, 17]. Given the challenges posed by medical students in addition to the financial burden of sponsoring their trip, the benefit of bringing medical students on mission trips have been questioned. It has raised the possibility that perhaps it may seem more beneficial for the larger field of global surgery to have medical students donate the cost of their attendance to support the work of NGOs and academic institutions rather than attending mission trips.

16.3 Surgical Mission Trips as an Investment into the Next-Generation of Global Cardiac Surgeons

Appropriately selected medical students who are adequately trained might not pose these challenges. Rather, the financial investment into their trips might serve as a professional investment by not only providing them knowledge and skills development but also helping foster a future career in global cardiac surgery.

Attending surgical mission trips provide medical students with short-term advantages in medical knowledge and patient care, system-based understanding of health inequities, resourcefulness, and further improvement in sociocultural and interpersonal competence. Through international rotations to resource-limited settings, students are more likely to be exposed to novel surgical pathologies, advanced presentation of disease processes, and tropical diseases, thus helping increase their scope of medical knowledge, which they would not have otherwise gained firsthand through their medical education at their home institution [18, 19]. Moreover, students as part of the mission trip gain a better understanding of resource poor settings and develop a greater appreciation for delivering cost effective care [19–21]. During their trip, medical students are often immersed in low-income, rural healthcare systems, where they directly witness inequities as presented in the patient population. This provides them with a system-based understanding of how local economies, politics, and policies impact the disease presentation and the delivery of care [20]. At the same, working intimately within the local healthcare system, medical students have reported increased appreciation of being cost-effective and have developed a greater understanding of how to deliver high quality care with the limited resources [19–21]. Furthermore, attending surgical mission trips have shown to improve sociocultural and interpersonal competence [18–20, 22]. Despite the cultural and language barriers, medical students have reported improved communication with patients, improved their skills utilizing an interpreter, and increased cultural awareness in order to develop more meaningful relationships with patients [18–20, 22].

While these short-term advantages provide significant benefit to medical students, the true value of incorporating them into mission trips is supporting their development as the next-generation of global cardiac surgeons by providing early exposure to global surgery in order to foster a career committed to service and humanitarian work. Interest in global surgery remains strong among U.S. medical students. In fact, based on a survey of 754 medical students across 18 U.S. medical schools, 66% of the participants reported significant interest in global surgery [23]. However, that interest was not matched by their medical school, as 79% reported that lack of incorporation of global surgery within their medical curriculum [23]. Medical student idealism and desire to help support global surgery remains high early in their medical career [23, 24]. As they progress through residency and fellowship, that interest progressively declines. Capturing the early interest among medical students through a global surgical curriculum in medical school and inviting adequately trained medical students on mission trips can help foster a future career in global cardiac surgery. In fact, studies have shown that medical students who volunteer at low-income healthcare settings in rural, international communities as part of multidisciplinary mission trips have reported increased interest in volunteerism, future participation in humanitarian work, and a greater desire to establish a career centered around serving underserved and neglected populations as future physicians [21, 24, 25].

Within the field of cardiac surgery, capturing medical students' early interest becomes even more essential in order to build a workforce to support the growing needs of global cardiac surgery. In the U.S. alone, the current size of the workforce is far less to meet the burden of disease. In fact, the demand for the cardiac surgery workforce is projected to increase by 46% by 2025 despite a projected decrease by 21% during this timeframe [26]. The disparity in the cardiac surgery workforce is even more striking among low- and middle-income countries. Among low-income countries, 0.04 adult and 0.03 pediatric cardiac surgeons are present per million population compared to 7.15 adult and 1.67 pediatric cardiac surgeons in high-income countries [27]. Among the total population of cardiac surgeons, those who participate in humanitarian efforts are even significantly less. Providing medical students with immersive experiences as part of mission trips meets their interest in global cardiac surgery and can influence their future career choice to pursue cardiac surgery with a particular emphasis on volunteerism and serving underserved populations, especially given that nearly 90% decide on a future career in cardiothoracic surgery as medical students [28].

16.4 How Best to Prepare for Mission Trips?

Supporting medical student interest in global cardiac surgery should not come at the cost of patient care and safety. Therefore, the previously mentioned challenges of incorporating medical students on mission trips need to be adequately addressed to ensure that any undue harm caused by their presence is minimized. To appropriately train medical students for mission trips requires them to be exposed to a comprehensive global surgery curriculum that covers health disparities, healthcare systems, social determinants of health, sociocultural competence, history of the host nation, and local politics and economics [14, 15, 29]. Moreover, in-depth exposure to fundamental principles of ethics must be a core component of any global surgery curriculum. This ensures that students prioritize patient interests and safety at all times despite their interest to learn from the local population. Several comprehensive curriculums have been devised to achieve these goals. In fact, the "Ethical Challenges in Short-Term Global Health Training" by Johns Hopkins University and Stanford University and the "Global Ambassadors for Patient Safety" by the University of Minnesota are two such online curricula that prepare medical students for mission trips by increasing their awareness of the involved ethical issues, helping them identify strategies to navigate these issues, and increasing their confidence in addressing them when encountered on their trip [30, 31]. While many other curricula exist to adequately train medical students for working in resource poor settings, it is especially needed for students to develop self-awareness in order for them to critically evaluate their self-interests and actions and successfully engage in ethically challenging environments

[32]. Ultimately, among culturally and ethically competent medical students, mission trips represent an approach to develop the next-generation of global surgeons to further support the ever-increasing needs of global cardiac surgery.

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17 Role of Cardiothoracic Surgery Societies in Global Health Disparities

Luis A. Godoy, David T. Cooke, and J. Nilas Young

Abstract

Background: Cardiothoracic surgeons have been at the forefront of the long lists of surgical and medical advances addressing cardiac health over the last half century. Unfortunately, these advances have not yet found their way to most parts of the world, especially developing countries. Most affected by these disparities are patients in low- and middle-income countries which may lack resources and infrastructure. There are numerous humanitarian Non-governmental Organizations that provide cardiac surgical care, however, there is no standardized comprehensive quality control measures currently in place. The lack of oversight and research in this aspect is a missed opportunity within our specialty. **Conclusion**: There is dire need for comprehensive quality control, oversight, and organization. With membership spanning the globe, the large cardiothoracic surgical societies are in a good position to centralize, coordinate, oversee, and streamline humanitarian global cardiac health. The infrastructure is there and the blueprints for success have already been created. By putting these together, we can ensure that as developed countries continue to advance that developing countries are not left far behind.

Keywords

Global health disparities · Global cardiac surgery · Health disparities · Humanitarian surgery · Medical tourism · Non-Governmental Organization (NGO)

17.1 Current State of Cardiac Surgical Disparities

Over the past 60 years, cardiac surgery has had an exponential evolution. Early advances in cardiac surgery were initially driven by two major objectives (1) correcting congenital heart defects, and (2) restoration of cardiac valvular function in valves affected by rheumatic heart disease (RHD) [1]. In just over half a century, industrialized countries have experienced a dramatic decrease and near eradication of RHD. Most current cardiac operations are now performed primarily to address degenerative,

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_17

lifestyle- related cardiac disease which now are the leading indications for open heart surgery.

Advances in the field have been driven by new technology and research that has focused primarily on issues associated with valvular repair and replacement, coronary revascularization, aneurysm repair, mechanical circulatory support, transcatheter-based intervention, repair of all including the most complex congenital lesions and minimally invasive surgery.

In their review article, Zilla et al. provide a detailed report on the status of cardiac surgery in developing countries. They point out that advances similar to those in developed countries have yet to be made, and the predominant cardiac pathologies are reminiscent of the early era of cardiac surgery because rheumatic fever and RHD are still prevalent, and congenital heart disease management is typically limited [1].

According to the World Health Organization (WHO), ischemic heart disease continues to be the number one leading cause of death worldwide accounting for 16% of the world's total deaths [2]. This translates to 17.5 million deaths every year, of which 80% occur in low- and middle-income countries [3]. These alarming numbers are even more pronounce in developing countries which continue to battle prevailing mortality from rheumatic heart disease and congenital heart disease. They are now also seeing the effects of increasing numbers of patients needing cardiac intervention due to lifestyle-related cardiac disease.

According to the United Nations (UN) Migration report, in 2017, the total world population was approximately 7.6 billion people [4]. Of these, approximately 5.3 to 6 billion people live in developing countries [1, 5]. These numbers are projected to significantly increase over the next 30 years. Over the past decade, the birth rates in industrialized countries has continued to decline. In contrast, the birth rates in developing countries has continued to increase. According to the United Nations, more than half of global population growth between now and 2050 is expected to occur in Africa, with the population of sub-Sahara Africa expected to more than double [6].

It is well known that a large proportion of these individuals lack access to basic medical care. It has been reported that less than 1% of the total global health investment is intended to address global general surgical needs [7].

It is more alarming that the access to life-saving cardiac surgery is even more limited. The lack of access to cardiac surgery is most notable in Africa. With close to 1 billion people living in Sub-Saharan Africa outside of South Africa have access to only 22 cardiac surgery centers [8]. According to Yankah et al. there are 1,222 open heart operations per million population in North America, and 18 per million in Africa, which translates into 1 center per 120,000 people in the United States and 1 center per 33 million people in Africa. It is estimated that 10,000 cardiothoracic (CT) surgeons in 6,000 centers globally perform more than 2 million open heart operations per year. Africa has 18 operations per million people versus the global mean of 169 cases per million [1, 8, 9]. In sub-Saharan Africa, excluding South Africa, there is only 1 cardiac surgery center per 38 million inhabitants [10].

Vervoort and his colleagues reviewed workforce data collected from the Cardiothoracic Surgery Network (CTSNet) database to map the current global state of access to cardiac surgery. A total of 12,180 adult cardiac surgeons were listed in the CTSNet registry, which translates to 1 adult cardiac surgeon per 0.61 million people globally, or, conversely, 1.64 adult cardiac surgeons per million people (Fig. 17.1) [11]. They used the data to calculate numbers and ratios of adult and pediatric cardiac surgeons to population. Their calculations confirmed that large differences existed between regions. Disparities exist between and within world regions, with a positive correlation between a nation's economic status and access to cardiac surgery. More specifically, they found disparities ranging from 0.12 adult cardiac surgeons and 0.08 pediatric cardiac surgeons per million population (sub-Saharan Africa) to 11.12 adult cardiac surgeons and 2.08 pediatric cardiac surgeons (North America) [11]. Similar disparities existed when dividing countries per income group (Fig. 17.2) [11].

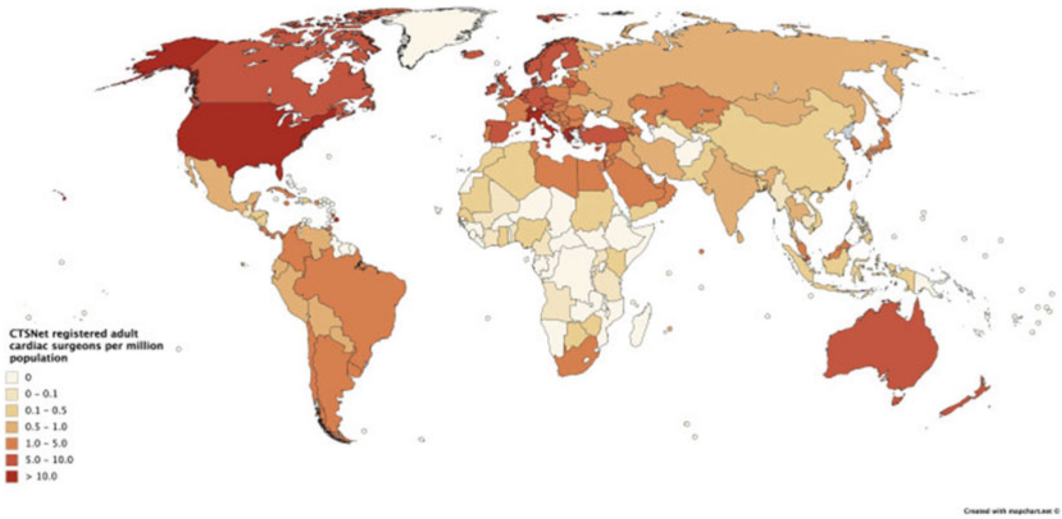
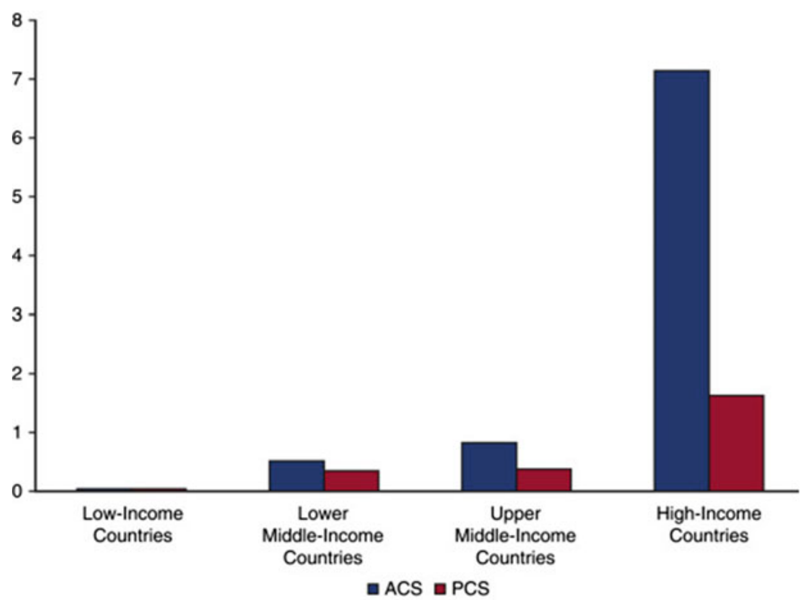


Fig. 17.1 Adult cardiac surgeons per million population registered with the CTSNet in August 2017 (n = 12,180). Map created at www.mapchart.net. CTSNet, Cardiothoracic Surgery Network [11]

Fig. 17.2 Adult and pediatric cardiac surgeons per million population for the different World Bank Income Groups registered with the CTSNet in 2017. ACS, Adult cardiac surgeon; PCS, pediatric cardiac surgeon [11]



With such limited access to regional care, some countries rely on the medical tourism industry. For example, in 2016 Edwin reported that 100,000 patients traveled to India annually with sub-Saharan Africa being the number one contributor to the Indian travel industry [12]. Seeing such harrowing disparities, one must ask whether there is anything that can be done or should be done to address these disparities. Does the responsibility lie within the regional governments and health centers, or is there as role for the CT surgical societies in addressing these issues?

17.2 Global Cardiac Surgery

Due to the lack of access and limited resources, many low-and-middle-income countries (LMIC) currently rely on the help provided by Non-governmental Organizations (NGOs). These are defined as nonprofit organizations that operate independently of any government, typically one whose purpose is to address a social or political issue [13]. Many humanitarian efforts have led to the formation of many different cardiac surgical programs. These programs can range from overseas treatment to fly-in fly-out missions, however, it is important to note that there are no comprehensive quality control or impact assessment in place to evaluate the benefit or harm introduced by surgical NGOs [11]. Despite this, the role that NGOs play in global cardiac surgical care is significant. NGOs attempt to fill the gaps in access and delivery of much needed cardiac surgical care and to strengthen these national health systems.

17.3 Pitfalls of Humanitarian Surgery

Addressing global health disparities with limited budgets and volunteer providers can be a very daunting task. Most NGOs and many international humanitarian organizations often set out to do the best that they can under the given circumstances. There is a paucity of data to evaluate how the lack of comprehensive quality control ultimately affects the overall benefit versus harm introduced by surgical NGOs.

In Seven Sins of Humanitarian Medicine, Welling et al. discuss potential problems and pitfalls in the delivery of humanitarian medicine. They list what they call “The seven deadly sins of humanitarian medicine” (Table 17.1) [14]. The list includes common mistakes and pitfalls and provide suggestions for avoiding them to maximize effectiveness as humanitarian providers. This serves as an excellent guide to ensure that providers are doing the right things for the right reasons.

17.4 Successful Programs

Some of the most successful and sustainable programs are those that don’t merely fly in, operate, and fly out. Bolman outlines a “path to sustainability” in which he emphasizes several key points. These include team teaching, skill and knowledge transfer, International training of key providers, influencing policy, and transitioning to more of a mentoring role to the local teams [12].

One such program is the Heart to Heart Global Cardiac Care program established in 1989 by one of our authors, Dr. Young [15]. The program is unique because it utilizes a multidisciplinary approach to a “train-the-trainer” model. The program has partnered with several Heart to Heart sponsored pediatric cardiac centers abroad including centers in Russia, and more recently in Peru, and Mexico. More than 2,000 children receive life-saving cardiac procedures each year.

Their model has changed the landscape in the of access to pediatric cardiac care in the host countries. Heart to Heart’s approach remains (1) data-driven, (2) education-based, and (3) implemented by professionally coordinated advanced specialists working as medical volunteers. The organization has had a major impact on congenital cardiac care for the regions involved and the country as a whole. More than 16,000 children born with congenital heart disease in Russia have had congenital cardiac surgery or catheter-based interventions by cardiac specialists trained by Heart to Heart. Currently, each year approximately 1500 children receive surgical cardiac interventions at their established programs (Fig. 17.3) [15].

This unique program model has proven itself to be not only cost-effective, but also replicable and scalable as has been shown with the successful programs that are now in cardiac surgery centers in Peru and Mexico. Its success continues to attract advanced pediatric cardiac specialists from leading U.S. children’s heart centers to travel halfway across the world, year after year, to transfer their knowledge and experience to develop lifesaving programs [16]. The

Table 17.1 The seven deadly sins of humanitarian medicine [14]

Sin #1: Leaving a mess behind
Sin #2: Failing to match technology to local needs and abilities
Sin #3: Failing of NGOs to cooperate and help each other, and to cooperate and accept help from military organizations
Sin #4: Failing to have a follow-up plan
Sin #5: Allowing politics, training, or other distracting goals to trump service, while representing the mission as "service"
Sin #6: Going where we are not wanted, or needed and/or being poor guests
Sin #7: Doing the right thing for the wrong reason

foundation and success of the program rests on four core components which include (1) data collection and analysis, (2) strategic guidance & leadership development, (3) annual surgical-educational missions, and (4) scholar exchange & continuing education (Table 17.2).

Outcomes analysis, quality improvement, education, sustainability, and service are key components to the success of programs such as Heart to Heart. Just as important is the concept of "ownership" by the host institutions which are considered partners in these endeavors.

17.5 Future Perspective and the Role of CT Surgery Societies

The four leading U.S. thoracic surgery societies: The American Association for Thoracic Surgery (AATS), The Society of Thoracic Surgeons (STS), the Southern Thoracic Surgical Association (STSA), and the Western Thoracic Surgical Association (WTSA) have all demonstrated interest in charitable endeavors. A member from

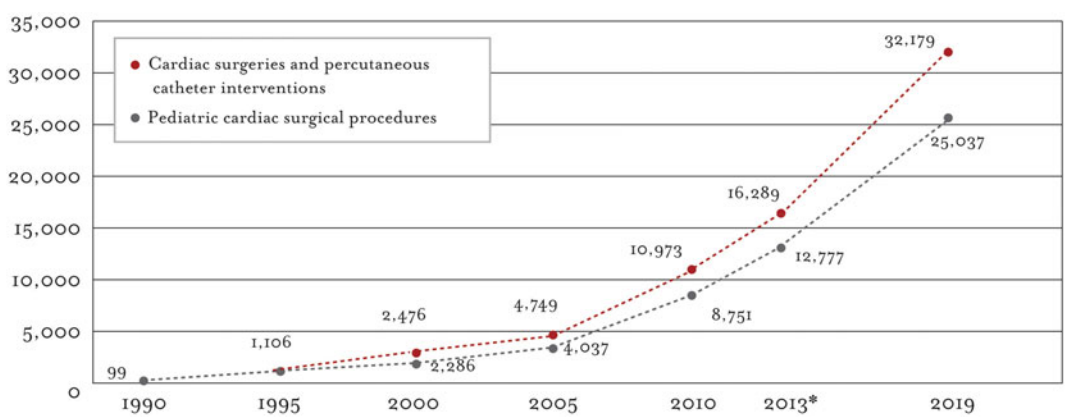


Fig. 17.3 Pediatric cardiac case volumes at all of heart to heart's collaborative sites in Russia. Figure indicates projected volumes to 2019 [15]

Table 17.2 Heart to Heart four core components [16]

1. Data collection and analysis
Year-round rigorous analysis of each developing team's surgical outcomes
Provide concise tailored feedback for improving outcomes
Teach emerging teams to collect and track their surgical outcomes data
Teach the local team how to use their data to self-evaluate and continuously improve outcomes
2. Strategic guidance & leadership development
Provides year-round guidance on program development toward self-sustainability Formulation of tailored "next steps," guiding department heads to: (A) Refine internal systems (B) Enhance teamwork (C) Improve staff knowledge base and clinical skills (D) Utilize surgical outcomes data for self-evaluation
3. Annual surgical-educational missions
Team of medical volunteers (12–15 practicing cardiac specialists) works with a cardiac team abroad at their home institution for two weeks each program year
Side-by-side, the joint team cares for children with heart defects—from diagnosing and performing open heart surgery, to managing patients in intensive care post-operatively
The experiential, clinically-based, patient-centered training provided is complemented each day by tailored case conferences, workshops, and lectures
4. Scholar exchange and continuing education
Arrange for physicians to learn best practices and specific surgical/clinical techniques at more advanced centers in the U.S
Sponsor our colleagues to attend international conferences
Provides educational materials such as software, textbooks, and on-line journal subscriptions. Actively promote quality research projects collaboratively with our colleagues abroad, including abstract and manuscript production for international meetings
Promote educational conferences locally and on a regional/national level
In 2012, with funding from the World of Children Award, Heart to Heart established the Nilas Young World of Children Traveling Fellowship. This annual fellowship to enable Heart to Heart—in perpetuity—to bring aspiring pediatric cardiac specialists to the U.S. for training and education at leading children's heart centers

each organization sits on the Board of Directors for the Thoracic Surgery Foundation (TSF) which is the charitable arm of the STS [17]. The AATS Foundation has activities that are all centered around fostering the next generation with efforts aimed at the education of a spectrum of individuals from the medical students in the summer intern program to junior faculty via named research awards, with a smattering of research scholarships and traveling fellowship [18]. These efforts can potentially be expanded to include a branch dedicated towards international health and training. Pezzella reports that the major CT surgery societies have developed a number of educational initiatives to address these challenges [19]. They have also provided satellite conferences for NGOs at their annual meetings to increase awareness and interest. CTSNet has developed a volunteer portal to increase awareness [19, 20]. None of these organizations are actively involved with on-site host team developing projects or providing financial assistance. There thus remains a need for dedicated and robust leadership to guide and coordinate the efforts of the independent NGOs, volunteer professionals, health care and industry donors, and the on-site host clinical centers [19]. We believe that the major CT surgical organizations have the infrastructure in place to help address the disparities facing global cardiac surgery.

CT surgeons have been at the forefront of the long lists of surgical and medical advances addressing cardiac health over the last half century. Unfortunately, these advances have not yet found their way to most parts of the world, especially countries that are developing. Most affected by these disparities are patients in low- and middle-income countries which may lack the resources and infrastructure. There are many humanitarian NGOs that provide cardiac surgical care. It is important to note that there are no standardized comprehensive quality control measures currently in place [11]. The lack of oversight and research in this aspect is a missed opportunity within our specialty.

One potential way to help address these disparities is by looking at the structure of successful organization such as Heart to Heart. With a track record spanning thirty years, can programs like this be used as a blueprint for the major CT surgical societies to help address cardiac surgery disparities throughout the world?

Organization

At present there is no international umbrella like-structure or organization that coordinates or oversees the independent NGO volunteer activities, though some NGOs are developing more cooperative partnerships and projects [19]. Nguyen and colleagues identified 80 NGOs worldwide supporting pediatric cardiovascular programs in 92 low-middle-income countries with 40 of them being based out of the United States [21]. The CT surgical societies can potentially establish a central hub for registration of these individual organizations which can help establish a network for collaboration. Establishing a centralized member volunteer portal similar to CTSNet [19, 20] will allow these organizations to recruit surgeons from within their membership to participate in these global health endeavors. This central hub could serve several purposes to help with research, data collection, funding, oversight, and quality improvement. There is potential for establishing a dedicated workforce with focus on global health to help oversee four main areas: (1) Data collection, (2) Research, (3) Education/ Training, and (4) Funding (Fig. 17.4).

Data Collection

There is a need for a central data base for many reasons. To date there is no global database that documents the annual number of CT surgical procedures, their outcomes, the number of trained and certified CT surgeons, or the number of qualified CT surgical teams, hubs, or centers [19]. Vervoort has demonstrated that it is possible to map out the current global workforce by looking at membership registries to identify regions where access to a cardiothoracic surgeon is problematic [11]. A central database could help to help foster a validated data infrastructure and generate robust longitudinal transnational registries to collect data. In addition, a standard database could open the door to establishing NGO oversight by the major societies. Outcomes data could be used to establish a certification process for NGOs as well as allow for annual outcomes reporting which could potentially be discussed at annual meetings.

Research

The CT surgical societies can help promote this by inviting research in this area to be presented at the large annual meetings and by promoting the research by publishing the manuscripts in their high impact journals. It is not unthinkable that research in global CT surgery disparities can evolve into its own branch of research as there is very little data currently available and reported. When data is presented, it can be used to justify allocating funding towards addressing these disparities. There is also opportunity for U.S. CT surgery academic training programs to encourage interested trainees to participate in these global health efforts as part of dedicated research electives.

Training/Scholar exchange

In addition to traveling abroad to teach, Heart to Heart has perfected their "train the trainer" model. They have established a fund to provide financial support for host institution surgeons,

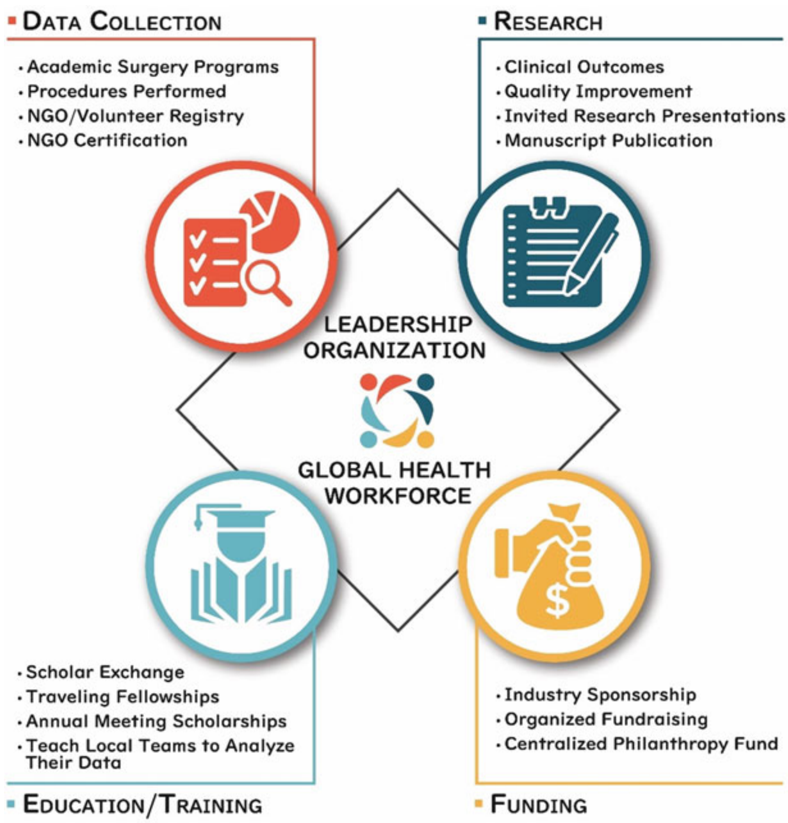


Fig. 17.4 A global health workforce could oversee these four main areas: (1) Data collection, (2) Research, (3) Education/training, and (4) Funding

cardiologists, intensivists, and anesthesiologists to visit centers of excellence in the United States [15, 16]. In addition, a funded "traveling scholars" fellowship has been created to ensure continuity of this important educational function [15]. This model is one that can be replicated on a larger scale. Scholarships can be created to sponsor trainees from other countries to attend and present at annual meetings. In addition, there is opportunity for academic centers of excellence to partner with and host surgeons and trainees from CT surgery centers abroad. A partnership such will provide mentorship, role models, and promote education and research. Training the local teams is a key aspect to ensure sustainability. As quoted by Backer, Dr. Gary Raff states that the success of a program "should not be measured by the number of successful operations on any given mission, but by the successful operations that our colleagues perform after we leave" [22].

Funding

NGOs are groups that are volunteer-driven and function independently of the government [13]. The success of these organizations and their financial sustainability is dependent on considerable volunteerism. Young et al. note that all of their medical volunteers, board of directors, medical advisory board, chief statistician, and many important nonmedical personnel are volunteers [15]. Although volunteerism is a major component of the success of these organizations, their goals would be almost impossible to accomplish without financial support to carry out their missions. Philanthropic funding from the general public can be unpredictable. A central philanthropic fund like that of the TSF could establish a separate philanthropic fund for global CT surgery. Industry-sponsorship for these NGOs is equally important. These NGOs could not perform many of their procedures without the support from industry sponsors that provide medical supplies, devices, and equipment. This is another area where having a central hub would be beneficial.

There is dire need for comprehensive quality control, oversight, and organization. With membership spanning the globe, the large cardiothoracic surgical societies are in a good position to centralize, coordinate, oversee, and streamline humanitarian global cardiac health. The infrastructure is there and the blueprints for success have already been created. By putting these together, we can ensure that as developed countries continue to advance that developing countries are not left far behind.

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18 Deconstruct One, Document One, Simulate Many, Assess Many. Role of Simulation in Cardiac Surgery

Paul Sergeant and Jan De Raet

Abstract

The My Virtual Surgery project is a global surgical simulation project, addressing in essence the cardiovascular domain. It uses a translational approach of the science of strategy maps, business and process management, science of learning and lots of empathy for the scholar. The project integrates an online simulation learning platform, online assessments, in combination with seminars and webinars. The low-fidelity non-biological simulators have been wiki-designed and are produced in a protected workshop. The project targets surgical scholars from any socio-economic reality, at the benefit of the patient.

Keywords

Induced learning · Conceptual learning · Simulation learning · Deconstruction · Teachable components · Low-fidelity simulators

18.1 Introduction

"See one, do one, teach one" (S0D0T0) has been the old paradigm on training knowledge and technical skills to surgical residents as well as on proctoring a new approach or procedure to more experienced surgeons. It was compactly formulated but it included in a subliminal way several major limitations. Three of these can be easily identified.

First, it failed totally versus the development of the science of learning. It did not include induced learning, conceptual learning, nor simulation learning. Organizational or operational learning were completely absent.

Second, it failed totally versus a distributed implementation process of the progress in surgery in countries with different socio-economic realities. It demanded to "see", therefore, to travel and stay. This travel and stay were confronted with legal, ubiquitous availability and resource limitations.

Third, it failed totally versus the ultimate respect for the patient, entitled to receive at each moment and place the best possible therapy.

This contrast becomes most obvious when one compares musicians playing a symphony or workers in a high-risk environment with surgeons manipulating surgical instruments. Most surgeons have never reflected on how to interact optimally with their instrument or a cascade of instruments, towards an ultimate control.

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_18

Musicians have universal standards and create in consequence symphonic harmonies! Within the My Virtual Surgery project we have had the privilege of observing and witnessing the strangest configurations in close to 10,000 surgical scholars, interacting e.g. with a Castroviejo needle holder at the beginning of our educational pathways.

The **My Virtual Surgery project** (MVS) has undertaken from its inception in 2012 a paradigm shift, vastly different from S0D0T0. Distribution of knowledge and technical skills is a complex and resource-demanding process. This demands a strategy map, a business plan, the strictest possible application of the science of learning and distributed processes reaching the most distant places. All this is done to the benefit of the patient. The **My Virtual Surgery project** reaches annually more than 3200 surgeons (Fig. 18.1) from all continents and uses the DD0SMAM paradigm (Deconstruct and Document One, Simulate Many, Assess Many). This document will describe the major concepts.

18.2 The Science of Learning

The science of learning has clearly identified that a performing distribution of knowledge and skills, as in surgical training, demands an appropriate stepwise process. Surgery is an integrated combination of knowledge, skills and attitude, that should not be learned in a high-risk patient-centric environment.

An **induced learning phase** [1] starts the process and is followed by an organizational or operational learning phase. Other names have been used, but that is only semantics. The induced learning phase is then further sequenced in a conceptual learning phase and a simulation learning phase. This manuscript does not address the organizational and operational learning phases.

Induced learning is an active process where the learner learns, driven to achieve a higher goal, beyond the educational demand. Examples of such a higher goal could be status within scholars or versus the teacher but should in surgery preferentially target towards a lower risk and a higher benefit for the treated patient.

The **conceptual learning phase** deconstructs the procedure into teachable components. Every movement, every reflection, every interaction is written down in standard operating procedures (S.O.P.) by the team guiding the educational pathway. This process is very demanding for the educational team but is the core of any distribution of knowledge. The conceptual learning phase demands also that each component needs to be appropriately documented. This

Fig. 18.1 The engagement on the MVS platform in the last calendar year

documentation demands a rich text, a picture if there is a positive leverage obtained with the picture versus the text. A video of the complete teachable component is preferably avoided because a text and a still pict allow a richer documentation and higher definition visualization. Only if the movement (in itself) adds an educational value, does it make sense to add a short video of a few seconds. It will be the task of the learner to study these teachable components, similar to a pilot studying the departing or landing checklists, before entering the simulation phase. So, a live procedure or a one-hour video fails versus this aspect of the science of learning.

The **simulation learning phase** follows the conceptual learning process. Simulation learning was strongly present in the Roman gladiator schools or “ludi”, even in the very first ones in Capua (Italy) [2]. Not astonishing when once in the arena, the life expectancy was only minutes and the mortality rate close to 25%. The gladiator who had not started his simulation training was the “novicius”. This simulation gladiator training was the basis of the military efficacy of the Roman legions.

In this process the learner will build the underlying mechanisms for each teachable component of the interaction between knowledge and skills, and this in a learner-centric environment. For each teachable component an appropriate environment, process and assessment needs to be developed. The approximation to the true-to-life experience is presented in the simulator. The teachable component needs to be simulated repeatedly in a monitored environment with a formal assessment, as often as needed, till the learner reaches the maximum possible score repeatedly.

18.3 The Domains of the MVS Project

The MVS project addresses at this moment three domains: the anastomosis, the aortic valve and root, the mitral valve repair.

The **anastomotic domain** targets all surgical residents, confronted with an anastomosis, whether the host is an urethra, an artery, or a vein, whether the graft is a biological or non-biological one. An anastomosis in 2021 is performed in very reduced airspace, often angulated versus the line of vision, often on an unstable or moving (beating) platform. So, the traditional parachuted techniques are considered outdated since they demand airspace and create a “Gigli” trauma to the anastomosed wall when approximated. The deconstruction starts with the posture, the stabilization of body, shoulder, arm, elbow, hand. It is continued with an in-depth analysis of the holder and the interaction with each finger to minimize drift at rotation below the level of a few micron. The next step is the release of the fixed relationship between holder and needle, and it finalizes with a series of anastomoses performed under gradually more difficult situations as there are: flat surface, angulated surface, airspace reduction and sequential anastomoses.

The **aortic valve and root domain** targets CV surgical residents. Three procedures are trained: the aortic valve replacement, the non-valve sparing technique (Bentall procedure) and the valve sparing technique (David 1 procedure). These three have been selected since they are all three mandatory components of CV surgical training.

The **mitral valve domain** similarly targets CV surgical residents. Two procedures are trained: the mitral valve annular repair (annuloplasty) and the mitral valve posterior leaflet repair in combination with the annular repair.

18.4 The Format of the MVS Project

The format of the project complies as much as possible with the science of learning, as stated earlier. Therefore, it is a combination of seminar/webinars and the platform. Once the participant is identified, he/she is invited to the **platform** and to the educational path. The HIPAA/GDPR compliant platform makes the interaction confidential between the participant and the educational guide. The guide has insight in the access, the engagement, the assessments and provides the qualitative and OSATS-based quantitative assessments. So, before a seminar or a webinar, the participant is supposed to be already engaged on the platform.

The **seminar** is the next interaction. These are following the same educational paths of the platform but involve direct interaction between participant and guide. Therefore, the number of participants has been limited in relation to the number of guides available. A normal participation is 15 individuals for one guide. Only a limited number of participants allows a maximal one-on-one interaction and guidance. Figure 18.2 shows this interaction. Close to 600 seminars have been organized worldwide in every continent and in close to 100 countries. This demands considerable time and financial resources. It should therefore always be considered suboptimal. In addition, organizing a perfect sequence of seminars in different countries of the same continent is extremely complex; it also demanded each time pre-travel agreement by the government of the guide on every aspect of the travel. But the benefit of the interaction took priority on the resource cost.

Before the COVID pandemia, a few very distant webinars were explored when conflicts of agenda excluded seminars. The evaluations of this approach were inferior to seminars through the reduced interaction with a group of scholars sitting together in one room, the difficulty of one-on-one interaction and by the reduced visibility of the simulation performance of the scholars.

Fig. 18.2 The one-on-one interaction during the seminar

This was only partly solved with large screens and mobile image and video capture.

From the start of the Covid pandemia it was decided to eliminate the seminars and replace them with full interactive limited-attendance webinars. The number of attendees was restricted to 10, exceptionally up to 15. The scholars were suggested not to meet in one single larger room but to stay at their homes and meet online. This dramatically improved the one-on-one contact, because the educational guide could now observe macroscopically (Fig. 18.3) the needle, the holder, the fingers, the hands but also listen to questions of the scholar or the sound of the holder. As soon as the scholars are identified, they receive a simulator and the necessary suture and simulation material for the total period of the educational process.

The remaining issue was the high resolution and the time needed to evaluate a suture of 200 micron, or the difficult angles to visualize the inside of an anastomosis or the underside of an aortic annulus. The quality should preferably be 4 or 8 K. Several methods of augmented reality were researched and tested, but the best and most affordable method was identified in the real time use of an additional electronic channel. Through this additional channel, a 10-participant webinar creates more than 100 4–8 K picts. They are taken by the scholar and within one second shared with the guide, exploded to full screen mode (Fig. 18.4), and presented to the group for group discussion or assessment, whatever continent each participant or guide was calling in from.

The webinars are limited in duration to a total of 3 h, usually with a short break half-way. After the webinars, the participants are invited to return to the platform, to repeat the simulation process and use the platform system for submitting the videos and picts for assessment.

The assessment applies strictly the OSATS-based system as proposed by James Fann, as well on the platform, as during the seminars or webinars. The number of webinars in the exact last calendar year is presented in Fig. 18.5.

The participation to the webinars, seminars, or the platform (including the assessments) is free

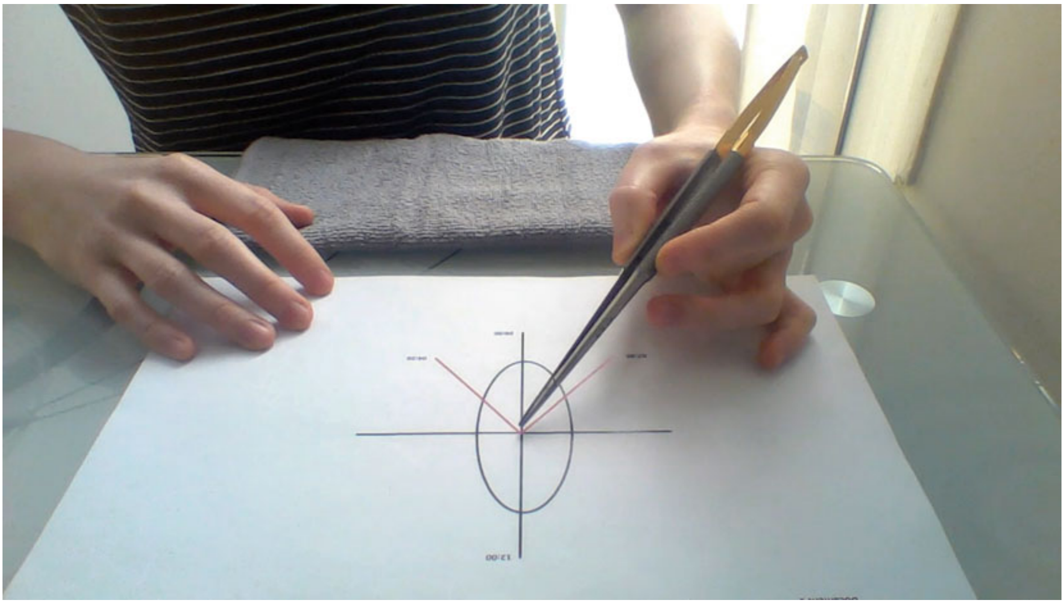

Fig. 18.3 The macroscopical assessment in real time of the scholar during the webinar, thousands of miles away from the educational guide

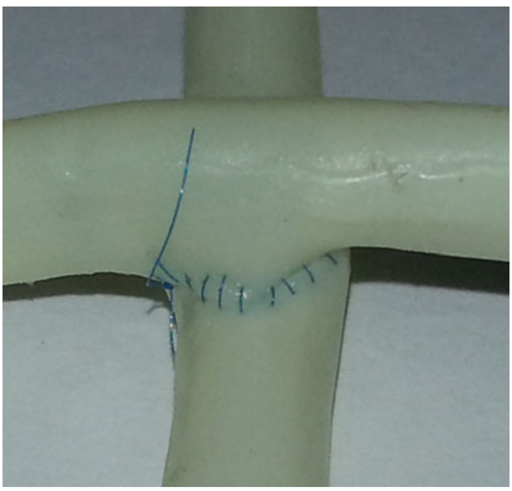

Fig. 18.4 The macroscopical assessment in real time of the sequential anastomosis during the webinar, thousands of miles away from the educational guide

of charge for the scholar from any continent. The whole cost is sponsored by industrial partners.

18.5 The Simulators of the MVS Project

The science of learning has considerably developed the criteria for simulators. There are six different types of simulators. Four of these are biological: the living human, the human cadaver, the living animal, the animal cadaver. Two of these are non-biological: the virtual reality simulator and the low fidelity simulator. Each of these has positive and negative criteria in the ethical aspects, the ubiquitous availability, the cost and the educational capacity as well for the scholar as the assessment capacity for the

Fig. 18.5 The 64 webinars in an exact calendar year, directed towards 5 continents

educational guide. A critical review of the existing literature proposed the **low-fidelity non-biological simulator** [3, 4] as the only one to have no major limitations and most of the major benefits. It was the dream to provide every possible scholar from whatever socio-economic environment with his own simulator.

Such low fidelity non-biological simulators can be bought, but they are awfully expensive. The science of learning stated also that the scholars needed to be committed to their simulator. What better way than to use the clever imagination of a group of scholars in a **wiki-design approach** of their own simulators. Therefore, three wiki contests were organized with participants from all over the globe to design an appropriate simulator for the three domains addressed at this moment by the project. These three events had an attendance of several hundred scholars. The proposed simulators were each time proposed to a group of the world leaders in each domain and in simulation. The enthusiasm of the crowd was close to chaos, different groups supporting their favourites! Anyway, three perfect simulator designs were selected. These designs were then further developed so they could be **mass-produced in a protected workshop**. This approach resulted in a social project, delivering simulators and their materials at a price under 80 € each. The tubing material needed not to simulate one particular arterial or venous wall. An anastomosis could be any type of wall. Essential was that it could identify all the possible failures in suture and knot placement as well as in wall tension. The cost of the selected tubing is 0.9 € per graft with up to 10 anastomoses possible (Fig. 18.6).

18.6 The Online Platform of the MVS Project

The only possibility to comply with the ruling that simulation needed to be repeated and assessed, was to create an online platform. If we wanted to assess submissions, then the platform

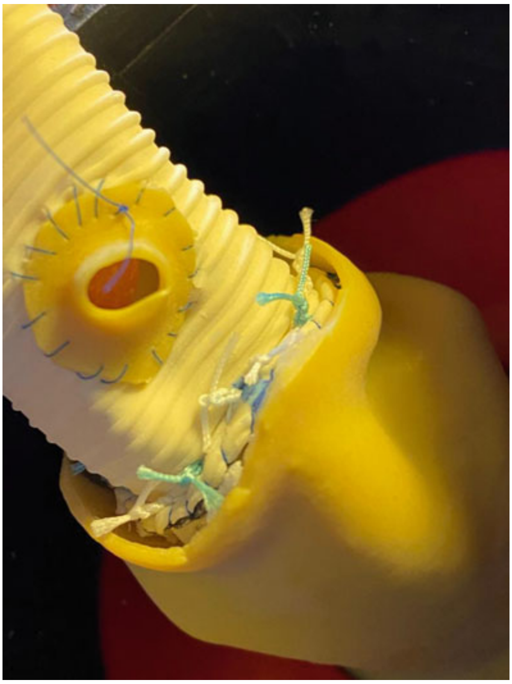

Fig. 18.6 The re-implantation of a coronary in the aortic root Devotini simulator during a Bentall simulation

needed to be HIPAA/GDPR compliant. The platform transforms the submitted videos into a standard format and is continuously updated with the changing video and browser standards. The platform informs the educational guide that a submission has been submitted. The whole process of accessing and assessing a video submission by the guide is basically the time taken to record it, a couple of minutes.

A submission on the platform is usually completed by the reviewer within hours, sometimes minutes. This submission and the assessment are only accessible by the submitter and by the reviewer, in strict compliance of the HIPAA and GDPR rules.

18.7 The Assessments of the MVS Project

There are formative and summative assessment methods in simulation.

The **formative assessment** aims at monitoring a trainee's progress over time and giving structured feedback. It should be able to identify different levels of performance (construct validity). The construct validity is the agreement between a theoretical concept and a specific assessment tool. The discriminant validity is how it discriminates between different levels of expertise.

A **summative assessment** is required for credentialing. Higher standards for construct validity and reliability are required with this form of assessment than with formative assessment. Clear cut-off values have to be defined adherent to the predefined consequences and, ideally, the sensitivity and specificity of these values should be tested. A summative assessment is used for selection and therefore needs predefined levels of outcome.

The assessments used on the platform, during the seminars and during the webinars combine a qualitative assessment and a quantitative formative one. The qualitative assessment allows a rich description of words to describe the positive and negative components of the performed simulation. The quantitative method used in the MVS project is an OSATS tool, defined by James Fann [5].

He implemented the OSATS technology, developed by Reznic [6] towards the assessment of an anastomosis. An OSATS is an objective structured assessment of a technical skill and deconstructs the technical skill in several teachable components. An optimal OSATS implementation has 5 possible scoring values.

The Fann OSATS deconstructs the anastomosis in 10 components and uses indeed 5 possible scoring values. Other OSATS can be used if a whole clinical procedure is assessed. The checklist, the crew resource management, the pace, the announce, the interaction, the debrief… are not included in the Fann OSATS (Table 18.1).

The MVS project collaborates formally since 2020 with an international group on the use of numerical data [7, 8] and artificial intelligence in evaluating an anastomosis. It is the vision that artificial intelligence would not replace but could

Table 18.1 The deconstructed criteria of the Fann OSATS

Arteriotomy	Size graft versus host, orientation
Graft orientation	Orientation toe-heel, start and end-points
Bite appropriate	Entry, exit points, number of punctures, constant distance from edge
Spacing appropriate	Consistent distance from previous bite
Use of needle holder	Finger placement, instrument rotation, lack of wrist motion, drift
Use of forceps	Finger placement, instrument manipulation, drift, no touch tissue
Needle angles	Angle relative to tissue, anticipation of subsequent angles
Needle transfer	Needle placement and preparation for next stitch
Suture management	Tension, to assist exposure, avoid entanglement
Knot tying	Tension, facility, finger follow for deep knots

leverage these quantitative and qualitative assessments. Bringing in the rules and strictness of data has optimized every human project. The human interaction remains a major component of driving the scholar towards simulation, but a mathematical model of the flow and wall tension characteristics can leverage this drive, conditional that the artificial intelligence is timely (immediate), practical, ubiquitous available and affordable, also in regions with difficult socioeconomic realities.

18.8 The Profile of the Participants

The participants in the MVS projects are coming from formal training units from anywhere in the world, academic and non-academic. The training unit responsibles are contacted by the project, or more recently we receive demands from the units themselves. They usually appreciate, after participating as observer, with the concept and process. Sometimes the participation has been organized through scientific national or international organizations. During Covid the residents themselves have asked to participate in the other educational pathways, after a successful participation in a first one.

Recently the MVS project has been used to prepare the scholars for a major residency selection process. In that case the MVS evaluates the learning capacity of the scholar. A high learning capacity is more important than a higher technical skill at the start of a residency.

18.9 The Future of Simulation Versus the Future of Cardiac Surgery

The future of surgical simulation will strongly depend on the future of surgery. Surgery in general is in a retreat situation, for different reasons and in nearly all continents. The Covid pandemia has clearly demonstrated that any prediction of the future, as always, is fragile. Military strategists as Sun-Tzu, de Jomini, and Von Clausewitz describe a retreat situation as one of the most difficult military exercises. Most retreats have failed massively. Even Napoleon, probably one of the most brilliant strategists, failed in his retreat from Borodino to Berezina. But all strategists identify that training is essential because the best soldiers must defend the rear guard at retreat. On top of the retreat for the domain is the gradual increase of legal age of practicing surgeons. Extremely limited clinical activity is reserved for the junior professionals in the coming years. In some countries the first major CV procedure is done at the age of 40, when in other high risk and complex domains the professional activity is halted. The retreat situation further reduces the number of interested scholars and the available time and financial resources.

The future of surgical simulation will strongly depend on society. One day society will no longer accept that major procedures never have been simulated, that these simulation processes have not been documented and not been assessed appropriately.

The future of surgical simulation will strongly depend on the optimal integration of the science of learning. Simulation is not placing a simulator in front of a scholar and tell him or her to go ahead.

An evolution towards high fidelity, high cost, non-ubiquitous available, simulation environments could benefit an elite of highly selected scholars at the end of their training process but would be in total opposition to the science of learning and very unfair to those living and working in difficult socio-economic realities. These realities are not limited to emerging countries but are similarly present in the most developed areas of the world. So, the only solution is to participate or build a simulation program using a translational approach of the science of strategy maps, business and process management, science of learning and lots of empathy for the scholar. All this at the benefit of the patient.

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19 Utility of Simulation in Transthoracic and Transesophageal Echocardiogram-Based Training of a Cardiovascular Workforce in Low and Middle-Income Countries (LMIC)

Ibrahim Quraishi, Feroze Mahmood, Kamal Khabbaz, Jacques Kpodonu, and Mark J. Robitaille

Abstract

The second leading cause of mortality in the world is cardiovascular disease (CVD), causing 17 million deaths in 2013. CVD disproportionately affects low- and middle-income countries (LMIC), which account for 80% of these deaths. The use of ultrasound technology has been a mainstay in the medical field for formal diagnostic purposes for years and has recently received increased interest for point-of-care diagnostics and procedural guidance. Transesophageal echocardiography (TEE) is routinely used for diagnosis and monitoring during cardiac surgery, and transthoracic echocardiography (TTE) is increasingly used as a point-of-care diagnostic modality both in the perioperative setting and in critically ill patients. In recent years, there has been emergence of portable ultrasound devices that offer many of the functionalities of traditional ultrasound machines. These handheld portable ultrasound devices have been shown to be very effective as a diagnostic modality and are a promising technology for increasing adoption of ultrasound use in LMIC. Significant training and expertise is required to achieve a level of expertise needed to perform and interpret an echocardiographic examination. Traditional training with direct supervision of an experienced and certified practitioner is not practical for widespread adoption of echocardiography in LMIC. There is a range of simulators available in the market for replicating a TTE and TEE exams. These simulators give learners the added benefit of familiarizing themselves with echocardiography before application in a patient care setting. A variety of simulators are available in the market across various price points, each with its own benefits and limitations, from static simulation to 2D and 3D imaging, as well as AR capability. It is possible to develop curriculums that include simulators as part of the teaching to train learners in echocardiography. Such technology increases the number of possibilities for future

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_19

applications and may help in the early diagnosis of deadly diseases such as RHD and CVD.

Keywords

Anesthesia · Cardiac surgery · Curriculum · Echocardiography · Imaging · Low-income countries · Middle-income countries · Simulators · Training · Technology

Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AI	Artificial Intelligence
AR	Augmented Reality
CVD	Cardiovascular Disease
LMIC	Low and Middle Income Countries
NICM	Non-ischemic cardiomyopathy
OR	Operating room
POCUS	Point of Care Ultrasound
RHD	Rheumatic Heart Disease
TEE	Transesophageal echocardiography
TTE	Transthoracic echocardiography
WHO	World Health Organization

19.1 Introduction

The second leading cause of mortality in the world is cardiovascular disease (CVD), causing 17 million deaths in 2013. CVD disproportionately affects low- and middle-income countries (LMIC), which account for 80% of these deaths [1, 2]. Atherosclerotic diseases, including ischemic heart disease and stroke, are principal causes of death in Latin America, Eastern Europe, South Asia, East Asia, and North Africa and the Middle East [3–8]. Non-atherosclerotic diseases including rheumatic heart disease (RHD) and non-ischemic cardiomyopathy (NICM) are very prevalent in Southeast Asia and parts of South Asia [4, 9, 10]. RHD is a preventable disease that affects up to 40 million people worldwide [11]. It is endemic in impoverished children and young adults. Early diagnostic imaging is imperative in diagnosing and managing RHD and NICM, especially to prevent the deadly long-term consequences. The World Health Organization (WHO) published a report in 1998 that said 60% of the world does not have access to any diagnostic radiological services [12], however, even if imaging is available in many LMICs, marked disparities exist in utilization of such imaging and access is provided on a fee-for-service basis [2]. More than half of the installed equipment is not utilized due to a lack of maintenance or trained users. New paradigms must be developed to train healthcare providers in ultrasound imaging, especially for early detection of these morbid conditions, as training for and availability of technicians is nearly non-existent in LMICs [13].

The following is a discussion of the technology, availability, and utility as well as applicable content of simulation for training providers in LMIC to appropriately use transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE) for diagnosis, treatment, and guidance during procedures while treating their patients.

19.2 Ultrasound

The use of ultrasound technology has been a mainstay in the medical field for formal diagnostic purposes for years but has recently received increased interest for point-of-care diagnostics and procedural guidance [14]. This increased interest is becoming formalized in medical training in the United States as multiple specialties incorporate curriculum changes to teach ultrasound techniques in residency programs. Surface ultrasound is regularly used to guide placement of peripheral and central intravenous lines, regional blocks and as a non-invasive monitor of cardio-pulmonary function. TEE is routinely used for diagnosis and monitoring during cardiac surgery, and TTE is increasingly used as a point-of-care diagnostic modality both in the perioperative setting and in critically ill patients. Initially, TEE was only used to capture images in patients who had suboptimal echo windows during TTE. However, the importance of TEE has increased considerably and has become an indispensable tool during cardiac valve surgery and in the diagnosis and management of life-threatening hemodynamic instability [15, 16]. In 1985, the WHO published a report concluding that there are "very real advantages to be gained from the use" of ultrasound for imaging in developing countries by noting its potential for "improved patient management and care of the individual" [17]. Despite the time that has passed, there has not been widespread adoption of echocardiography in LMIC. Training and skill are important barriers to adoption that can, at least partially, be overcome with robust simulation programs.

19.2.1 Point of Care Ultrasound (POCUS)

In recent years, there has been emergence of portable ultrasound devices that offer many of the functionalities of traditional ultrasound machines [18]. These devices can be used to perform a TTE and come with a portable display unit and probe that be used any time. These devices have a rugged design that can be easier to maintain compared to larger ultrasound workstations. Clinicians can carry around these portable devices very easily and incorporate this technology into their initial assessment and physical examination of a patient [19], and they are relatively less expensive than traditional ultrasound systems. Telecommunication over cloud-based platforms is also possible with these devices, allowing for remote peer evaluation and viewing of locally captured images. Manufacturers such as SonoQue (Yorba Linda, CA); Philips (Amsterdam, The Netherlands); TENS Pros (St. Louis, MO); and Butterfly Network, Inc (Guilford, CT) (Fig. 19.1) offer this functionality. Some limitations of these portable devices still exist—such as overheating with continuous use—but these devices can assist in performing a focused examination to identify acute pathologies, even if the image quality might be inferior to standalone ultrasound machines.

These handheld portable ultrasound devices have been shown to be very effective as a diagnostic modality. Studies have shown that these devices can be used to diagnose left ventricular hypertrophy and can then be used as an indicator for starting anti-hypertensive regimen [20]. RHD can also be screened through POCUS and multiple studies have shown it to be superior as a screening tool compared to cardiac auscultation alone [21–23]. POCUS has also been shown to have high diagnostic accuracy compared to comprehensive echocardiograms when evaluating ejection fraction, valvular regurgitation and wall motion according to two studies from Brazil [24, 25].

These advances in technology, and the demonstrated utility that comes with it, will lead to increased adoption and utilization of echocardiography in LMIC but require robust training and operator expertise prior to widespread use in clinical care.

19.2.2 Training

The WHO Ultrasound Manual states that in order to reliably interpret ultrasound scans, a physician requires at least 6 months of full-time training at a recognized academic center. They should also have at least 2–3 years of healthcare training [26]. The vast majority of personnel performing ultrasound scans in LMICs do not meet the abovementioned criteria to practice ultrasonography and have little or no formal training [13].

Significant training and expertise are required to achieve a level of expertise needed to perform and interpret an echocardiographic examination. Traditionally, training is performed under direct supervision of an experienced and certified practitioner. The learner is expected to appreciate the normal anatomic cardiac structures, and then differentiate the abnormal structures. The anatomy of heart must be learned from both the perspectives of TTE and TEE. The learner must familiarize themself with these alternative image orientations and mentally visualize the three-dimensional image of the heart from multiple two-dimensional image planes. Vertical and

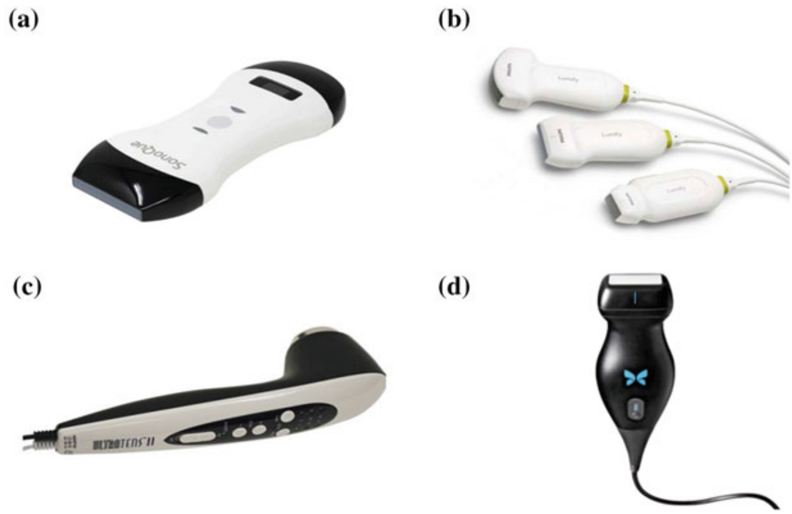

Fig. 19.1 **a** SonoQue portable pocket probe (SonoQue, Yorba Linda, CA). **b** Lumify portable probes (Philips, Amsterdam, Netherlands). **c** UltraTENS II portable ultrasound probe (TENS Pros, St.Louis, MO). **d** Butterfly iQ (Butterfly Network, Inc, Guilford, CT)

oblique plane imaging can make this very challenging. Following mastery of normal and abnormal anatomy, the learner is then taught to assess ventricular and valvular function. This formalized training is only available in major academic centers during dedicated fellowship training [27]. There is significant variation in exposure to ultrasound education for learners, and proficiency in POCUS is not a compulsory milestone [28]. Introducing ultrasound courses focused specifically on POCUS as part of the curriculum, however, is feasible and helps the learners improve their cognitive and technical skills. Training to perform an adequate TEE exam requires a substantial learning curve and multiple sessions to be fully competent. Use of simulators is a clear measure that can be implemented to help bridge this gap. Incorporating simulators as part of echocardiography training can suitably supplement the existing training methods to develop the necessary skills for performing echocardiography.

19.3 Role of Simulators

There is a range of simulators available in the market for replicating a TTE and TEE exams. These simulators give learners the added benefit of familiarizing themselves with echocardiography before application in a patient care setting. These simulators also give the learners the chance to practice multiple times without any time or patient safety constraints, which allows for individualized training and evaluation of competency. Simulators have high fidelity and help learners feel as if the procedure is being performed on humans due to anatomically accurate simulations and images. When choosing a simulator, one must consider price, hardware and software requirements, and capabilities. These simulators can then be integrated and adopted by an institution as part of a curriculum.

Below is a discussion of different simulators available in the market and how these can help medical professionals obtain essential echocardiography skills.

19.4 Static Simulation

There are simulators available in the markets that allow static simulation of the heart to perform a TTE or TEE. One such model available in the market called The Blue Phantom Model (CAE Healthcare) is designed to be compatible with ultrasound and aids in teaching echocardiography skills to learners [29]. It is made of durable rubber that is echogenic to allow for easy visualization using any ultrasound system with an appropriate transducer. The rubber is designed with a convex contour to allow realistic scanning and cannulation to more accurately mimic human tissue. The interior of the Blue Phantom Model houses an anatomically accurate heart model with precise corresponding atria, ventricles, appendages and vessels. This heart model can also be clearly seen with an identical translucent copy of the Blue Phantom Model. The total dimensions of the model are 10.5 × 5.3 × 5.7 inches. It features two ports: one of the ports is connected to tubing with a stopper that is used for filling and emptying fluid for to simulate pericardial effusions. The company produces a specific fluid called Red Ultrasound Refill Solution (BRS180-Red; CAE Healthcare) to replicate pericardial effusion that can be purchased separately. The second port is used to insert a TEE probe. The model also allows for actual needle punctures to be performed to better train for pericardial effusion drainage (Fig. 19.2).

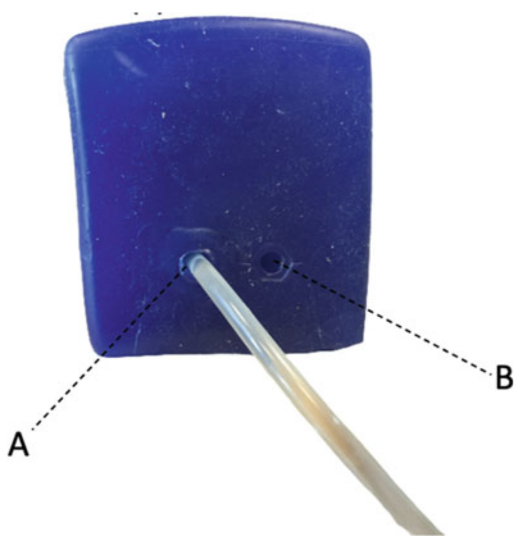

Fig. 19.2 The echocardiography phantom model with **a** Fluid injection port. **b** TEE probe inserted through the port

19.4.1 Workflow

Learners are required to follow the same steps to acquire images from the Blue Phantom Model, as they would for standard ultrasound machines. This includes:

1. Connecting an ultrasound machine to a power source.
2. Initializing the probe and having the system ready for starting echocardiography.
3. Entering "patient information" on the ultrasound machine.
4. Inserting the TEE probe through the port in model with adequate lubrication.
5. Positioning the probe at the upper esophageal, midesophageal, transgastric and deep transgastric windows accordingly.
6. Visualize the image.
7. This model allows for adjustment of depth, gain, harmonics, compression, and zoom on the ultrasound system for better image optimization.

The TEE image in the Blue Phantom Model is visualized as a static image, devoid of any motion, with appropriately positioned intracardiac chambers and valves. The walls of the heart have appropriate thickness with well-defined endocardial and epicardial borders. The vena cavae, ascending aorta, and pulmonary artery can also be visualized. This simulator also allows the learners to practice various three-dimensional (3D) imaging modes in real time. All the images that are captured can be stored and reviewed (Fig. 19.3).

19.4.2 Limitations

The most significant limitation of the Blue Phantom Model is that it is static and it does not allow flow information to be visualized; therefore real valve motion and doppler flow profiled cannot be generated. The image quality is also

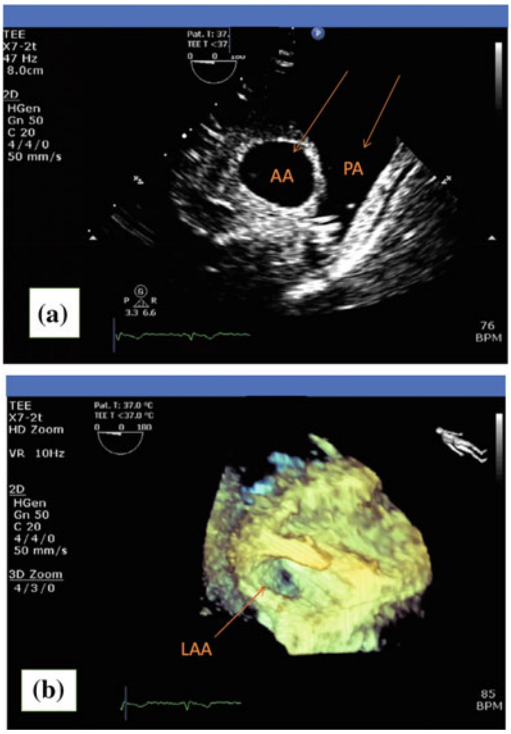

Fig. 19.3 Anatomic structures as visualized during a TEE exam of the phantom heart model. **a** Ascending aorta and pulmonary artery. **b** A 3D view of the left atrial appendage and the Coumadin ridge

not consistent throughout different TEE views. The variability could be due to differences in probe position and contact, use of lubricant material, or due to the orientation of the model in the gel suspension. However, by using more lubricant gel at the time of probe insertion and filling the pericardial cavity beforehand does improve the image quality.

19.5 Live TEE Simulation

Simulators designed for training of TEE and TTE have simplified the teaching of the complex process of echocardiography. One such simulator, called the HeartWorks Simulator, was developed at Heart Hospital in London UK, in collaboration with a graphics animation company (Glassworks, London, UK). The simulator comes with an external mannequin and a realistic TEE probe that learners can use to accurately visualize the anatomically correct model of the heart [27]. As the learners manipulate the probe, a digital image of the heart and the probe is displayed automatically on the computer screen in real time to give the learners an accurate understanding of their anatomic orientation. The internal and external anatomy of the heart is displayed. A Microsoft Windows based computer (Redmond, WA) with a suitable graphics card and adequate processing power and memory, is connected to the mannequin and the TEE probe via a standard USB port. The TEE probe allows for anteflexion, retroflexion, and left and right tilt with controls that mimic modern TEE probes. The mannequin houses the positioning sensors for the TEE probe for orientation in relation to the digital heart (Fig. 19.4).

19.5.1 Modes

This simulator comes with a number of modes that can help in teaching basics of echocardiography and anatomy. "Camera mode" allows the user to change the viewing angle of the heart through mouse control, allowing for a better understanding of the internal anatomy of the heart. The "Manipulator mode" allows the user to keep the camera angle constant, but the slice plane can be changed from multiple perspectives and angles. The "TEE mode" allows for a complete TEE exam to simulated by using the TEE probe, complete with the controls to anteflex and retroflex the probe, as well as advance and withdraw the probe in the mannequin. The digital probe on the computer screen automatically reproduces the probe manipulations, and at the same time, a three-dimensional (3D) image is generated in real time on the computer to give perspective to the learner and improve their skills. The teacher observing can assist the learner accordingly. The software on the computer also has the ability to digitally remove certain cardiac tissues according to the users' interest and focus. The anatomic structures can be easily highlighted and linked to explanations via text (Figs. 19.5 and 19.6).

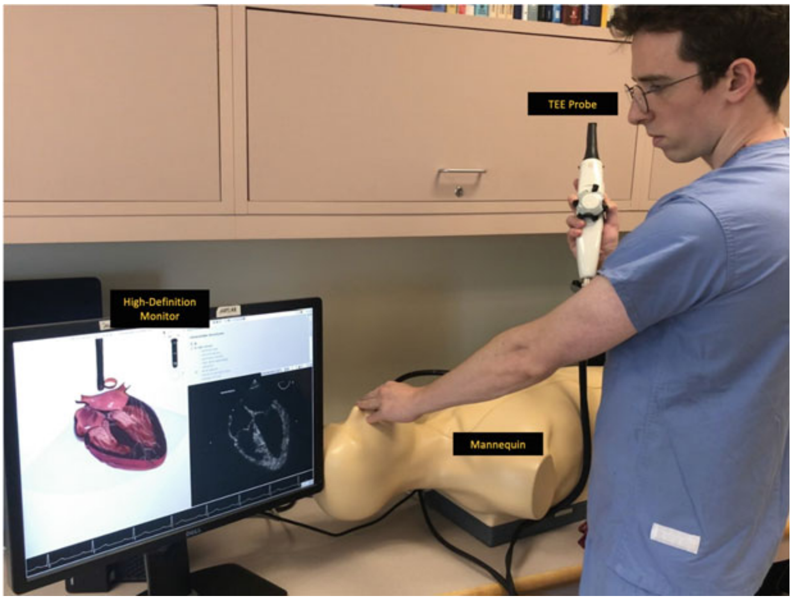

Fig. 19.4 A learner performs a TEE exam using the HeartWorks simulator (Glassworks, London, UK)

19.5.2 Limitations

The biggest limitation of this simulator is that it is expensive, and the initial cost may inhibit a more common uptake of this technology. It is available in varying configurations, however, which may reduce the cost. The simulator also does not allow Doppler functionality and the graphics and videos are not able to be saved for future reference.

19.6 3D TEE Simulator

A 3D-TEE simulator offers accurate views of cardiac physiologic and pathologic cardiac anatomy, while also providing real-time volumetric scanning, allowing learners to practice both qualitatively and quantitatively.

One such simulator is the Vimedix TEE/TTE simulator (CAE Healthcare, Montreal, Canada) that is capable of both 2D and 3D echocardiography. A computer is connected via standard USB port to a mannequin that includes a standard TEE probe, capable of all maneuvers of a standard probe. This mannequin houses the positioning sensors to allow the orientation of the TEE probe in relation to the digital heart. The mannequin is also capable of working with a TTE probe (Fig. 19.7).

This simulator is equipped with multiple modes that can help in teaching basics of 3D echocardiography and anatomy. The simulator is capable of a wide array of standard 3D echocardiography technology, including live narrow and wide sector imaging, single beat full volume imaging, orthogonal biplane imaging, multiplanar reconstruction from 3D datasets. This allows for the learner to familiarize themselves with the "knobology" and anatomy specific to 3D echocardiography. This is an expensive simulator that needs a large physical space to house the unit and it needs regular upkeep for maintenance. These limitations, as well as the advanced nature of 3D echocardiography, currently limit its applicability for LMICs.

19.7 Augmented Reality (AR)

Augmented Reality (AR) is an immersive technology that adds an artificial layer of computer-generated information over an actual real-world image, most commonly done through a headset. AR helps improve situational awareness and understanding by greatly enhancing spatial

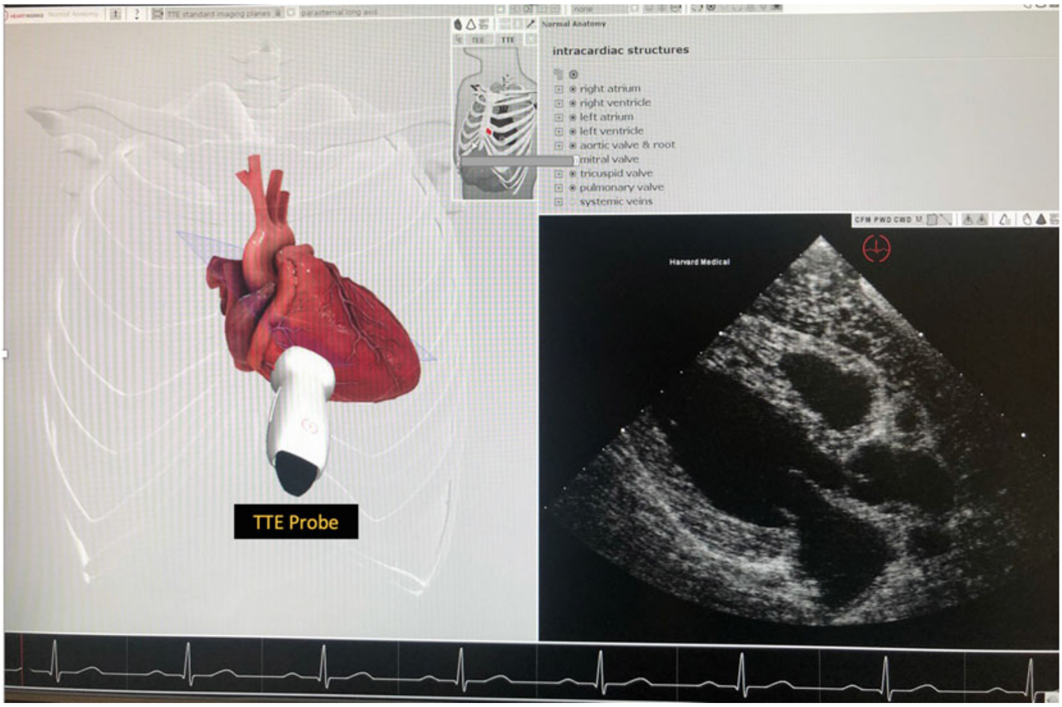

Fig. 19.5 A TTE exam on a HeartWorks simulator (Glassworks, London, UK), showing the positioning of the TTE probe, the 3D image of the heart, and its corresponding echo image of parasternal long axis view in real time

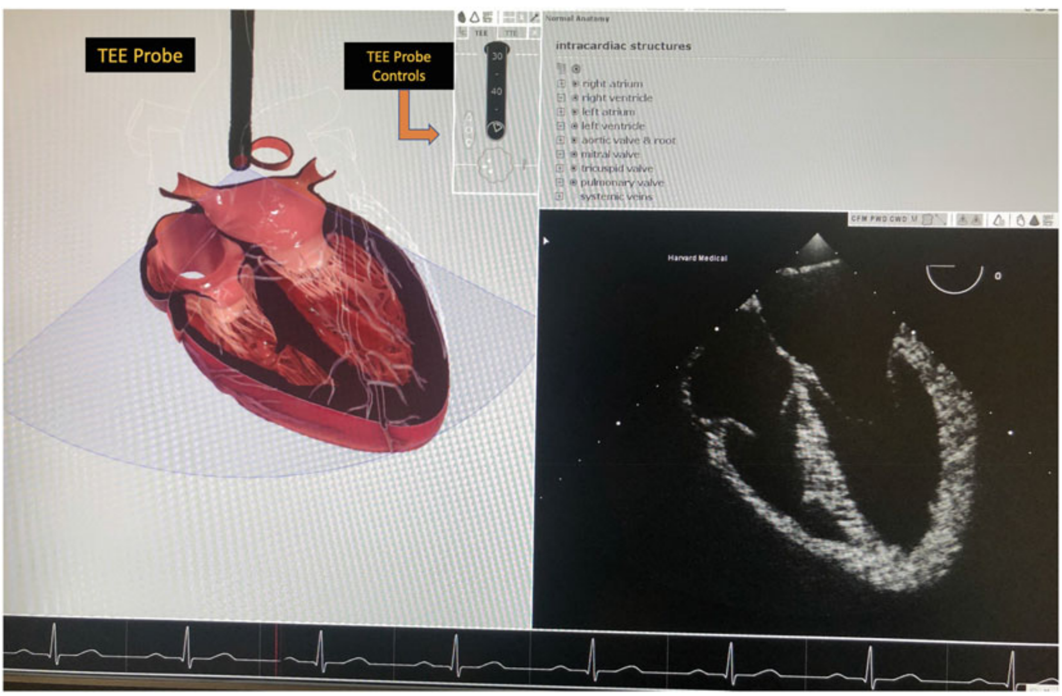

Fig. 19.6 A TEE exam on a HeartWorks simulator (Glassworks, London, UK), showing the 3D image of the heart, the positioning of the TEE probe and its controls, with its corresponding echo image of midesophageal 4 chamber view in real time

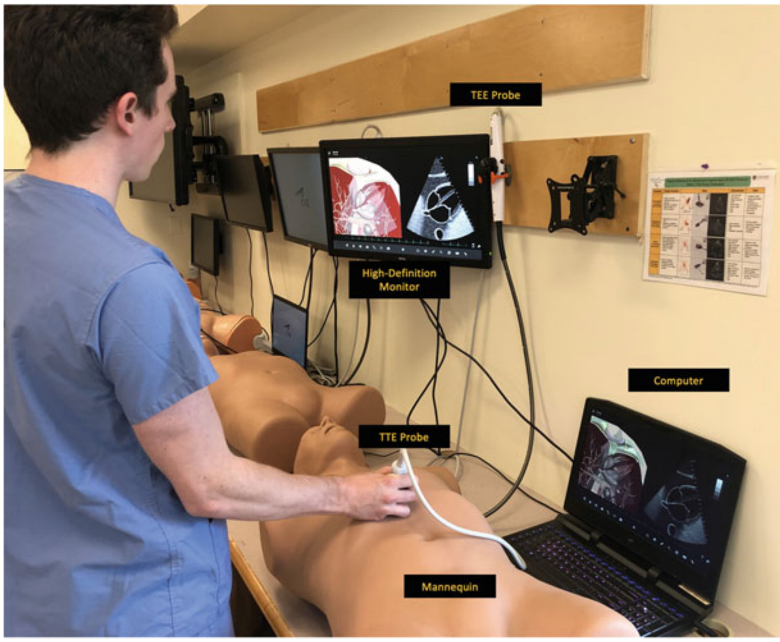

Fig. 19.7 A learner performs a TTE exam using the Vimedix TEE/TTE simulator (CAE Healthcare, Montreal, Canada)

orientation [30]. It is most commonly used in the gaming industry or in the military, but its use is also increasing in the healthcare sector as it has shown promise. Healthcare related applications include visualization of subcutaneous veins, treatment of psychiatric disorders, displaying patient data using a head-mounted display during surgery, task training and procedure planning adjuncts.

AR can also be applied to echocardiographic imaging modalities such as TTE and TEE. Typically, the person performing a TTE or TEE has to undergo extensive training to understand the cardiac imaging that is presented as a two-dimensional (2D) cross-section via ultrasound technology. The operator is then expected to construct a mental picture of a 3D image of the anatomy for orientation. AR can be used instead to supplement the generated ultrasound image by overlaying the corresponding virtual anatomic perspective. This can be done, for example, by using an AR Headset such as Hololens (Microsoft, Redmond, WA) alongside a Vimedix TEE/TTE simulator (CAE Healthcare, Montreal, Canada). This has the potential to improve training and orientation for learners and reduce their learning curve to perform a TEE/TTE. Such kind of technology can then be incorporated as part of future didactics and custom tutorials for the learners to improve their understanding of the procedure.

19.7.1 Limitations

There are, however, limitations to AR Technology. The technology is nascent and, therefore can be expensive to buy and maintain, and these simulators have cross-compatibility issues to overcome. The AR headset has limited battery life with a limited field of view and prolonged use of an AR headset can also be associated with neck muscle fatigue.

19.8 Curricula for Application of Simulation Technology

In order to fully utilize the benefits of the aforementioned simulators, it is important to incorporate this technology to existing teaching curriculums in academic centers that focus on teaching the necessary skills in performing a TEE or TTE, in an effective and systematic manner.

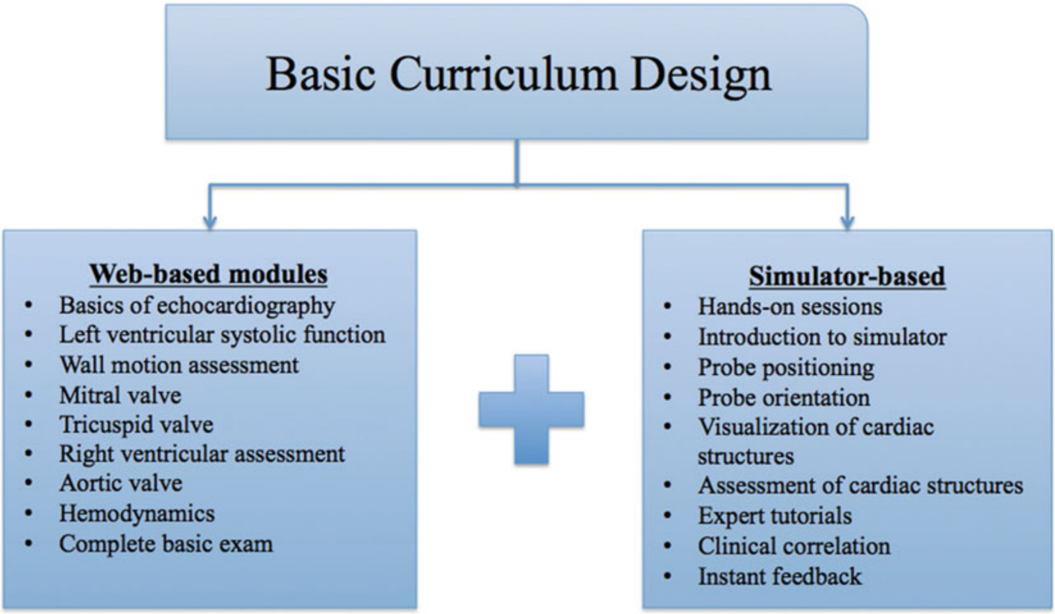

Fig. 19.8 Overview of a basic curriculum design

One study demonstrated a curriculum that integrated simulators to teach trainees over a period of four weeks [31]. This curriculum included multiple approaches to teaching, with clearly defined objectives for learning and instantaneous feedback for improvement. The first part of the curriculum was focused on topic specific web-based teaching modules orienting the learners on the fundamentals of echocardiography, probe positioning and orientation, and the visualization of different structures of the heart, such as right ventricle and tricuspid valve, aortic valve, mitral valve, left ventricle systolic function and wall motion assessment. This is done via various online lectures, quizzes, and practice exercises, primarily through visual learning. Learners could access this content at their own convenience at any time to appropriately cover the didactic materials, and a test is taken before and after undergoing these web-based modules to assess its effectiveness and measure the knowledge acquisition. The second part of the curriculum focused on teaching the learners through the TEE simulator, with sessions taking place two times a week. Expert attending physicians gave tutorials to the learners and then they were encouraged to reciprocate the skills obtained by practicing hands-on on the simulators. Instant feedback was then provided to the learners to correct their mistakes and improve proficiency. As part of this section of training, the facilitators also held focused discussions on review of real-world cases and scenarios in order to increase contextualization with clinical relevance (Fig. 19.8). This study, among others, demonstrates the effectiveness of simulation technology for learners in an academic setting. The curricula proposed could be easily adapted to suit practitioners in LMIC. The short period of time, web-based modules and online assessment lend themselves particularly well to remote or asynchronous teaching techniques. These advantages may serve to improve participation for learners from disparate geographical areas.

19.9 Future Applications

Multiple studies have shown the effectiveness of using simulators to teach echocardiography skills to learners, specifically TEE. All these studies have shown promising results by demonstrating that learners did better after undergoing simulator-based training compared to others who did not train on simulators before being tested [31–33]. It is possible to develop and implement a curriculum to teach echocardiography that is web-and-simulation-based, which could encourage more widespread adoption. Studies have also shown that learners who underwent simulation-based teaching, with no prior knowledge of echocardiography, performed significantly better than learners who underwent traditional didactic-based teaching or those who underwent hands-on training in the operating room. AR can be used to teach learners at multiple different sites at the same time. A single instructor can demonstrate the necessary skills using a simulator and then also evaluate and assess learners performing the same skills at remote locations, allowing greater outreach for teaching [30].

Measuring the time or number of errors in performing a task, is traditionally the basis on which successful completion of a task is assessed. It is possible to create integrated curriculum based on hands-on sessions on simulators and objectively assess echocardiography skills using hand motion metrics, including the number of rapid movements or transitions and the total length travelled by the TEE probe. This kinematic data can then be used to assess expertise [34]. These studies showed significant improvement in technical skills of learners who underwent simulation-based educational curriculum by analyzing the novice learners' technical proficiency and comparing to an expert board-certified echocardiographer. Such objective analysis can also aid in identifying participants who need further training to improve their skills.

Echocardiography based teaching aimed at LMIC can use such technology available in the market with a perspective of significant upfront investment, but a very high return of investment in the future, as such technology can greatly help in training personnel in LMIC.

19.10 Conclusion

Proficiency in echocardiography is essential to correctly diagnose cardiovascular diseases. With the increased use and availability of ultrasound devices and machines, it is imperative that training modalities keep pace with technical advancements. This could lead to early diagnosis of deadly diseases such as RHD and other CVD and aid in the care of critically ill patients through proliferation of POCUS. A variety of simulators are available in the market across various price points, each with its own benefits and limitations, from static simulation to 2D and 3D imaging, as well as AR capability. It is possible to develop curricula that include simulators to train learners in echocardiography. Previously developed curricula have shown to improve cognitive and technical skills in echocardiography and may serve as the basis for more widespread adoption of echocardiography in LMIC.

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20 Developing a Web-Based Curriculum for Radiology Sub-Specialty Training in Emerging Countries

Brian de Francesca, Kofi Asante, Iman Iqbal, and Jacques Kpodonu

Abstract

The most practical solution for the critical shortage of healthcare workers across Africa is to connect remote medical educators from developed countries to learners in the countries of Africa. A well-defined e-learning program should include the creation of digital libraries and knowledge bases that are accessible by all, as well as include the development and implementation of train-the-trainer programs to ensure that the programs are economical and sustainable and will avoid digital colonization. The virtualization of medical training will provide emerging countries with a route to medical workforce upskilling which is faster, affordable, and easily scalable. Such programs will also allow us to remedy the severe imbalance in medical education and care that currently exists in our world.

Keywords

Teleradiology · eLearning · Medical education · Sustainable solutions · Telediagnostics · Remote education · Virtualization

20.1 Overview: The Greatest Problem

One of the most serious problems facing the countries of Africa is the critical shortage of healthcare workers. The demand for healthcare services is far outpacing the supply, and the gap is widening, resulting in millions of avoidable deaths, lifetime disabilities and widespread pain and suffering.

Africa statistics in brief:

17% of the global population (the population is growing) [1]
25% of the global disease burden [2]
50% of deaths are caused by infectious diseases in Africa, compared to only 2% in Europe [3]
Only **2%** of the world's doctors (the supply of doctors is not growing in pace with the populations) [4]

There has been a massive brain drain of medical personnel from African countries and there are limited resources available to replace those who

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_20

have left. Various causes exist for the massive exodus of doctors, ranging from relocating for a better standard of living to fleeing the country during pandemics like Ebola and other crises. There also exists a severe shortage of faculty available to educate new clinical workers. Additionally, the few doctors that are in-country often prefer to live in larger cities, leaving the rural areas with minimal to no access to medical care.

The health care crisis affects every facet of public health within the region, including child and adult mortality, the quality of maternal healthcare, the treatment of human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS) and the treatment of diseases and infections.

The knee jerk response for addressing this problem is to create more medical schools that replicate the medical education curriculum of more developed countries. Following this path will not be effective in addressing the shortage of healthcare workers and improving poor health outcomes in low resource settings because the countries of Africa lack medical faculty to teach at these proposed medical schools; distance education is the solution to this problem.

20.2 What to Avoid

A traditional western model of building solutions does not address the lack of adequate healthcare workforce:

- Building medical schools: There is a chronic lack of healthcare educators in the countries of Africa. Investing in building medical schools without adequate medical faculty to teach and train creates a false sense of addressing the health gap problem.
- Overseas training: Sending nationals overseas for training is not a sustainable, long-term solution, especially considering that many of those sent abroad for education do not return to their home country of origin.
- Importing medical faculty: Attracting sufficiently qualified medical faculty to move to the countries of Africa for extended periods of time to educate local students has been tried and, again, has not proven to be a sustainable, long-term solution. A few expatriate faculty do come for shorter periods of time but that has not shown to be again sustainable.
- Blocking innovation: Replicating current models of education and care delivery from more developed countries does not allow for the exploration and consideration of new and innovative teaching tools, methods, curricula and/or care delivery. The intrenched legacy systems and self-interest of the medical education community in more developed countries, limits their ability to create innovative positive change. The lack of outdated legacy systems across some of the sub–Saharan African (SSA) countries could enable for the leapfrogging that we so often hear and talk about and allow for implementing more modern methods of educating medical professionals and delivering care.

The models of developed countries should not be cut and pasted into Africa because:

- Healthcare education and delivery models currently used in the most developed countries are have shown to be sub-optimal especially during the COVID-19 (SARS-CoV-2) pandemic, where traditional in person classes have not been possible.
- Many current institutional education models take too long to create qualified caregivers and are expensive. A large part of medical school curriculums is out of date and no longer required for doctors to learn (Institutions have not been diligent about pruning irrelevant material over the years) [5].
- Current education models are creating caregivers for jobs that may not exist in the future. For the job categories that will exist in the future, current programs are slow to adapt to new models of teaching, new knowledge, and skills.
- While there are “pockets of excellence” across the healthcare systems of more developed countries, these systems should not be replicated in their entirety; something new and better can be created and implemented in SSA

countries where there are currently no large legacy systems and infrastructures in place.

20.3 The Digital Solution

While traditional medical education models in SSA countries are replicating curricula from developed countries to provide tailored solutions, virtually importing the knowledge and experience from developed countries is practical and may be a workable solution to this serious and growing health gap problem. Healthcare workers can be educated virtually via a combination of pre-recorded and live lectures provided by remote educators from around the world; and not only "some" medical educations, but some of the best medical minds.

The best, brightest and most up-to-date medical educators tend to not travel to teach others because they are remarkably busy with several obligations at home. Additionally, the time and expense of flying between locations makes in-person medical education cost prohibitive and less effective. Similarly, it is difficult for a person to be in two locations at the same time to give a lecture; however, this is possible via eLearning. e-learning allows for high quality and cost-effective medical education to be provided to a broader population of learners over in-person learning.

The creation and sharing of "digital content and knowledge bases" are a new opportunity that enables medical courses course, and others to be taught live, recorded, edited, indexed, archived and curated to be shared broadly within a medical community when needed. These courses can be adapted into smaller chunks of 10–15 min each which fits well with an audience with shortening attention spans.

There is the need to ensure that the baseline knowledge and learning ability of each learner is considered and addressed. This includes continual assessments (pre- and post-testing), access to varying levels of course content, and the creation and curation of a dynamic "knowledge base" that consists of all questions asked by learners with vetted responses from educators. Implementing this tool will allow for a majority of questions typically asked by learners to be consolidated into one place with the right answers. The questions submitted to this knowledge base should be reviewed on a regular basis, and the contend modified to address questions that are continually asked by many of the learners. Digital libraries of content combined with dynamic knowledge bases can provide the world with access to a vast amount of relevant medical knowledge.

20.4 Case Example: Ethiopia

One example of a successful distance learning program was conducted in Ethiopia by the authors in collaboration with Johns Hopkins Medicine. Ethiopia is a country of over 100 million people [6]. As with most of SSA, Ethiopia suffers from a critical shortage of healthcare workers. The government of Ethiopia contacted the author with a clear problem: For a country of over 100 million people, they had only 120 radiologists—when comparative metrics would require them to have 5,000–10,000 radiologists to provide adequate care. Additionally, none of these 120 radiologists were trained in any sub-specialty. Given that the diagnosis is the foundation of care delivery, this critical shortage of radiologists was significantly undermining the delivery of care.

Ethiopia had more radiologists earlier but had sent some abroad for training—never to return. They had tried for several years to attract qualified medical educators to come to Ethiopia to train their radiologists in sub-specialties, but they were never able to attract enough high-quality educators to relocate to nations capital of Addis Ababa, for a prolonged period.

The radiology healthcare gap problem was effectively addressed by creating and delivering a 20-month sub-specialty radiology training program for an initial group of 10 radiologists in Ethiopia. The courses were developed and taught by the Johns Hopkins Medical Faculty in Baltimore Maryland and consisted of both pre-recorded and live case studies. A base line learner knowledge assessment was conducted, as well as pre- and post-testing with every learning instance. These assessments were essential so that we could quantify knowledge transfer. The program was highly successful in transferring relevant knowledge. This same model could easily be replicated in other countries across Africa, as well as for other sub-specialties.

It is important to mention that the development and implementation of this program was not easy and without challenges. The following were some of the challenges encountered, and overcame, along the way:

- There was some disagreement on the number of pre-recorded and live lectures necessary for the program to be effective.
- The development of the course curricula involved many people, which resulted in a considerable number of modifications to the curricula before consensus was finally reached.
- On several occasions, the government shut down the internet.
- Since the government was paying for the program, they required potential students to sign commitment bonds, which some did not agree to do, as they wanted to leave government employment for the private sector as soon as possible.
- A dedicated learning center was established in Ethiopia at the St. Paul's Millenium Hospital where all 10 students would go to participate in the live case studies. Having a central location ensured that both the right technology and connectivity would be available; however, on two occasions the room was broken into and the equipment was stolen.
- Some learners were less diligent in their studies than others, which at times would hold back the entire group.

All of these highlighted challenges were addressed and overcome. There were many valuable lessons learnt from this initiative that will be applied to future programs. Outcomes and more details of the successful implementation of the radiology web-based program were published in "The Journal for Academic Radiology" [7]. This program proved that distance education can be highly effective and economical and has set the foundation for the development of a train-the-trainer program, which will ensure that, going forward, the country of Ethiopia will not be continually dependent on foreign support in these areas.

20.5 A Note on Digital Colonialism

Any e-Learning, telemedicine, or artificial intelligence initiative must include a solid plan for creating and implementing local competence in a sustained and cost-effective manner. The development and implementation of a train-the-trainer program combined with a dedicated digital library and knowledge base will build on the success of the "sub-specialty training program," thereby reducing the cost of delivering future courses while avoiding "digital colonialism."

This digital colonialism occurs when a country is exploited through data and information. There is indeed a danger that distance learning technologies could be used by foreign entities as a vector for digital colonialism: If emerging nations rely on foreign entities to provide the platforms and resources for distance learning, said entities could very well control any computer-mediated experience between teachers and students. In doing so, they would be able to:

- Extract enormous amounts of potentially valuable metadata
- Increase the geographical reach of their digital ecosystems
- Connect with and influence new customers
- Expand into new markets and develop new products or services

When digital colonialism is severe, native populations of emerging nations will be dispossessed from their virtual education systems and its respective infrastructure. Additionally, all profit generated from virtual education activity will be extracted from its country of origin to foreign providers.

Foreign organizations must hence be held accountable for digital colonialism. Of course, in a perfect world these entities would be unable to partake in digital colonialism due to preventative international law and inescapable sanctions. However, until this is the case, it is imperative that emerging countries protect themselves with policies to prevent digital takeovers, initiated by the people. India is a key example of how the populations of emerging nations can create direct involvement in this protective movement. When Facebook provided and controlled the internet access of millions of Indians through its so-called Free Basics service, there was significant backlash created by local demonstrators.

20.6 More Than eLearning: "Project Nobel", A Model for Healthcare Workforce Capacity Building

Currently, the authors of this chapter are in the planning phase of a healthcare workforce capacity building program, Project Nobel. The program will include six related and complementing components, in addition to traditional eLearning methods:

1. Distance education: Courses taught by remote subject matter experts. Specifically, the development and implementation of a robust train-the-trainer program.
2. Telemedicine: The use of remote medical specialist to fill local skill and capacity gaps, to be utilized to improve care access until sufficient local capacity is created.
3. Platform technology: Using in country cloud-based resource sharing platforms to allow the limited in country resources to be shared across the country, increasing utilization, access, and quality.
4. Artificial Intelligence: Artificial Intelligence is finally proving to be viable in the delivery of care. The first areas where this will be most viable, will be in specialties that are heavy on pattern recognition and the running of algorithms such as radiology, pathology, dermatology, and ophthalmology. Given the current shortage of clinical capacity in these areas, the countries of Africa can use proven A. I. to rapidly and cost effectively fill many skills and capacity gaps.
5. Mobile care teams: The development and implementation of mobile field teams of caregivers, combined with remote specialist telemedicine support, will both increase assess and quality of care.
6. Task shifting: The migration of specific tasks from doctors, to nurses to patients and their families has been a proven method of expanding the delivery of care. Task shifting, combined with remote clinical consultations and patient monitoring, can push a significant amount of care delivery from hospitals, into primary care settings and to the home.

The goal of Project Nobel is to create a totally independent and sustainable healthcare workforce capacity building program in each country that meets both immediate and long-term needs. eLearning alone will go far in building capacity, but it does not address current critical skill gaps. eLearning combined with the other components of a program such as "Project Nobel" could be a single best option for addressing the critical shortage of healthcare workers across the countries of Africa.

20.7 Application to Cardiovascular Care (Cardiac Echo Curriculum) and Future Perspectives

There are multiple learnings from the web-based training program, which can be applied to cardiovascular care education in emerging countries. A number of teaching opportunities around cardiovascular imaging practice in such countries would be suitable for a web-based education model. The fundamental steps needed to develop and implement a web-based echocardiography training curriculum using Ver2's web-based radiology program model in Ethiopia is outlined below:

Step 1: Establish Healthcare Needs
To develop a training program that delivers tangible cardiovascular healthcare outcomes and improvements, the program director must outline the healthcare needs which are being addressed.

For example, the underdiagnosis of congenital heart defects (CHD) and rheumatic heart disease (RHD) screening in SSA countries has been reported by Edwin et al. (2016), which showed an increased CHD burden during a two-year study in Ghana [8]. Both CHD and RHD are major contributors to the cardiovascular disease burden in Ghana.

To address these cardiovascular issues, producing a higher number of echocardiography operators in SSA countries could be outlined to support a national CHD and RHD screening program. The echocardiography curriculum could then be focused on this need by devoting more time to CHD and RHD identification within the teaching of basic echocardiography scanning.

Step 2: Establish Training Needs
The program director must outline the training needs of the organization receiving the echocardiography teaching. The best way to outline these needs is to conduct a Training Needs Assessment (TNA), which is critical to developing the training and educational strategy. Multiple TNA framework examples can already be found online. Ultimately, TNAs exist to help healthcare leadership quantify the immediate and long-term skills-resources gaps which they aim to address.

In echocardiography training, there may be both a resource and a skill gap: The resource gap may increase due to a lack of cardiac echocardiography simulators, whilst the skills gap could be identified as the lacking ability to independently perform echocardiography and identify CHD or RHD by nurses and community health workers (CHWs). Assuming nurses and CHWs have the proper subject area knowledge, the TNA could be extended to evaluate the depth and breadth of this knowledge. This is known as a Baseline Knowledge Assessment (BKA). Only once all training needs assessments are complete, steps should be taken to decide what will be taught in the program, how long the program will last, how competencies will be assessed, and how simulation in training can be acquired.

Step 3: Identify an Education Provider Organization
The program director should be encouraged to partner and collaborate with a medical education provider (MEP) that can supply necessary teaching resources. The MEP is to handle the supply of pre-recorded lectures, teachers for live instruction via video, and reading materials.

Step 4: Accreditation
The program director should strive to ensure that the training program is accredited by a medical council encompassing cardiovascular practitioners in each specific country. Such accreditation will ensure that trainees are medico-legally approved and able to practice echocardiography in real-world healthcare settings.

Step 5: Identify an Online-Based Learning Management System
The learning management system (LMS) is an educational platform that should act as an interface between students and the medical education provider. Ver2's LMS platform in the Ethiopian model was able to host and curate a wide range of learning materials for both trainees and teachers.

20.8 Summary

The critical shortage of healthcare workers across the countries of Africa is an issue that will not be solved by building more medical schools, because there is an insufficient number of medical faculty to teach at those schools. The most practical solution is to connect remote medical educators from developed countries to learners in the countries of Africa is to adopt proven eLearning modules and technologies. A well-defined e learning program should include the creation of digital libraries and knowledge bases that are accessible by all, as well as include the development and implementation of train-the-trainer programs to ensure that the programs are economical, sustainable and avoid digital colonialism. Although the virtualization of medical education is yet to mature, the future perspectives of such an e-learning model and its applications to other subjects are hugely exciting and do provide a realistic alternative to traditional, institution-based training which is dreadfully slow and expensive. The virtualization of medical training will provide emerging countries with a route to medical workforce upskilling which is faster, affordable, and easily scalable. Such programs will also allow us to remedy the severe imbalance in medical education and care that currently exists in our world.

Acknowledgements Nadine Halabi (editing).

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Part IV

Strategies for the Implementation of Sustainable Cardiac Surgery Programs

21 Echocardiography for Cardiac Surgeons

Bernard E. Bulwer

Abstract

Cardiac ultrasound or echocardiography is a useful non-invasive imaging technique for the assessment of cardiac structure and function. Cardiac surgeons are uniquely suited to harness this versatile imaging technique both inside and outside the perioperative or transesophageal echocardiography (TEE) setting. With the advent of point-of-care ultrasound (POCUS), access and utility of transthoracic echocardiography (TTE) can now be appropriately focused for rapid assessment of ventricular systolic function, the intracardiac valves, great vessels, and the pericardium. This chapter is an illustrated atlas that covers the fundamentals of echocardiography that cardiac surgeons and trainees can use as foundation for engagement with echocardiography. It begins with a basic introduction to the technique and covers the fundamentals of echocardiographic anatomy as presented on TTE and TEE, the nomenclature and emanation protocols, echo anatomy of the coronary artery territories and the intracardiac valves.

Keywords

Cardiac ultrasonography—echocardiography · Transesophageal echocardiography (TEE) · Transthoracic echocardiography (TTE) · Anatomical (B-mode) images · Doppler ultrasound · Cardiac anatomy · Coronary artery territories · Echocardiographic windows—transducer positions · Echocardiographic imaging planes · Echocardiographic views

21.1 Overview

Echocardiography or cardiac ultrasonography utilizes the properties of ultrasound and the received echoes to generate real-time images that represent cardiac structure and function (Fig. 21.1). Echocardiography is the most versatile cardiac imaging technique, not just in its clinical application in cardiology and cardiac surgery, but because of its unrivalled ease of access, safety, cost, portability, connectivity to smartphones and tablets, and its utility in global health efforts such as screening for major congenital and acquired heart diseases, such as rheumatic and other valvular heart diseases and heart failure.

A detailed expose of cardiac ultrasound physics is beyond the scope of this chapter, but the two fundamental properties of ultrasound used to create anatomical (B-mode) images are: (i) the

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_21

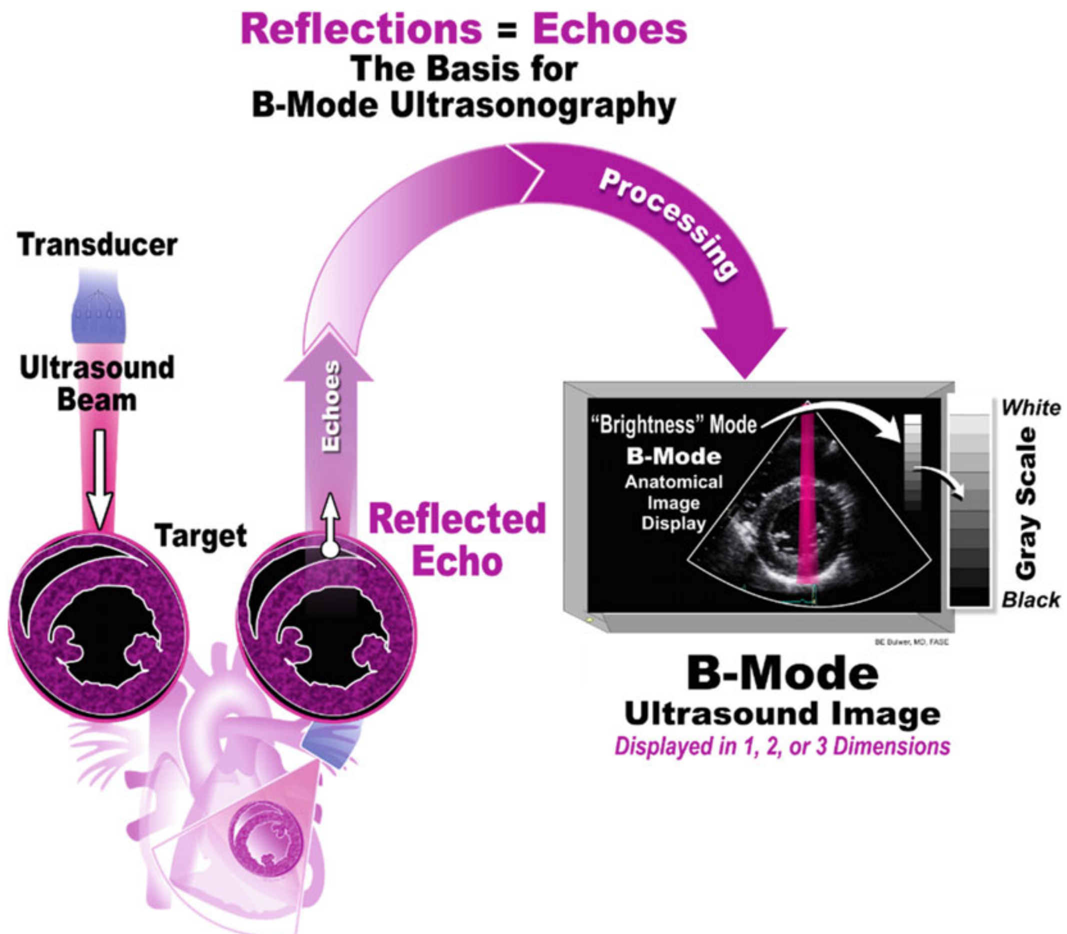

Fig. 21.1 Two major types of echocardiography based on the position of the transducer probe. Transthoracic echocardiography acquires images of the heart mainly through the thorax (left). Transesophageal echocardiography acquires images using a transducer mounted on an endoscope inserted into the esophagus (right). High frequency inaudible echoes are used to create the ultrasound image. To do so, ultrasound is first transmitted from the transducer, reflected from the cardiac structures, exquisitely processed within the instrument, and then graphically dis-played as anatomical images, or as velocity graphs or color-coded velocity maps

amplitude or strength (brightness) of the received echoes based on the differential "echo reflectivity" of tissues, and (ii) the times it takes for the echoes to be received, which representing their anatomical depths or locations (Fig. 21.2). Doppler ultrasound, on the other hand, utilizes the change or shift in the frequency of the echoes (akin to the change in pitch of a siren), to derive information on blood flow velocities, direction, and blood flow patterns (Fig. 21.3).

The same principles apply to transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE) (Fig. 21.4), with protocols established by expert societies (Figs. 21.5, 21.6, 21.27 and 21.28). Echocardiographic views are so named using three variables: (i) the transducer position or window, (ii) the echocardiographic imaging plane (iii) and the region or structures visualized. This applies to both the TEE and TTE examinations. Note that the same structures on TEE can be visualized on TEE, the primary differences being the transducer position and the image display protocols (Figs. 21.5, 21.6, 21.7, 21.8, 21.9, 21.10, 21.11, 21.12, 21.13, 21.14 and 21.15).

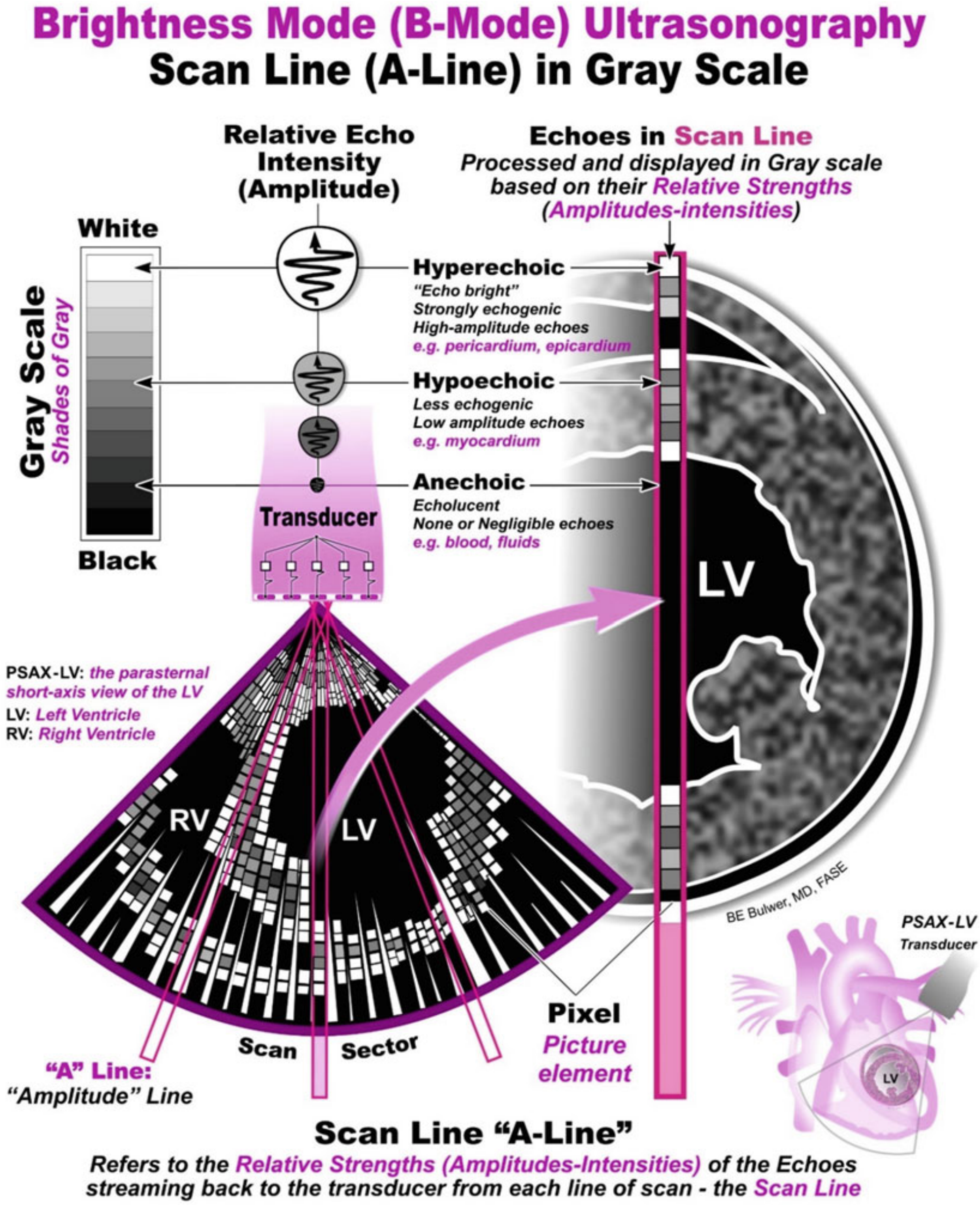

Fig. 21.2 The B-mode images is an anatomical map of gray scale pixels, representing the relative strengths (amplitudes/intensities) of the echoes. Note the gray scale, the relative echo intensities, and their corresponding shade of gray in the B-mode image

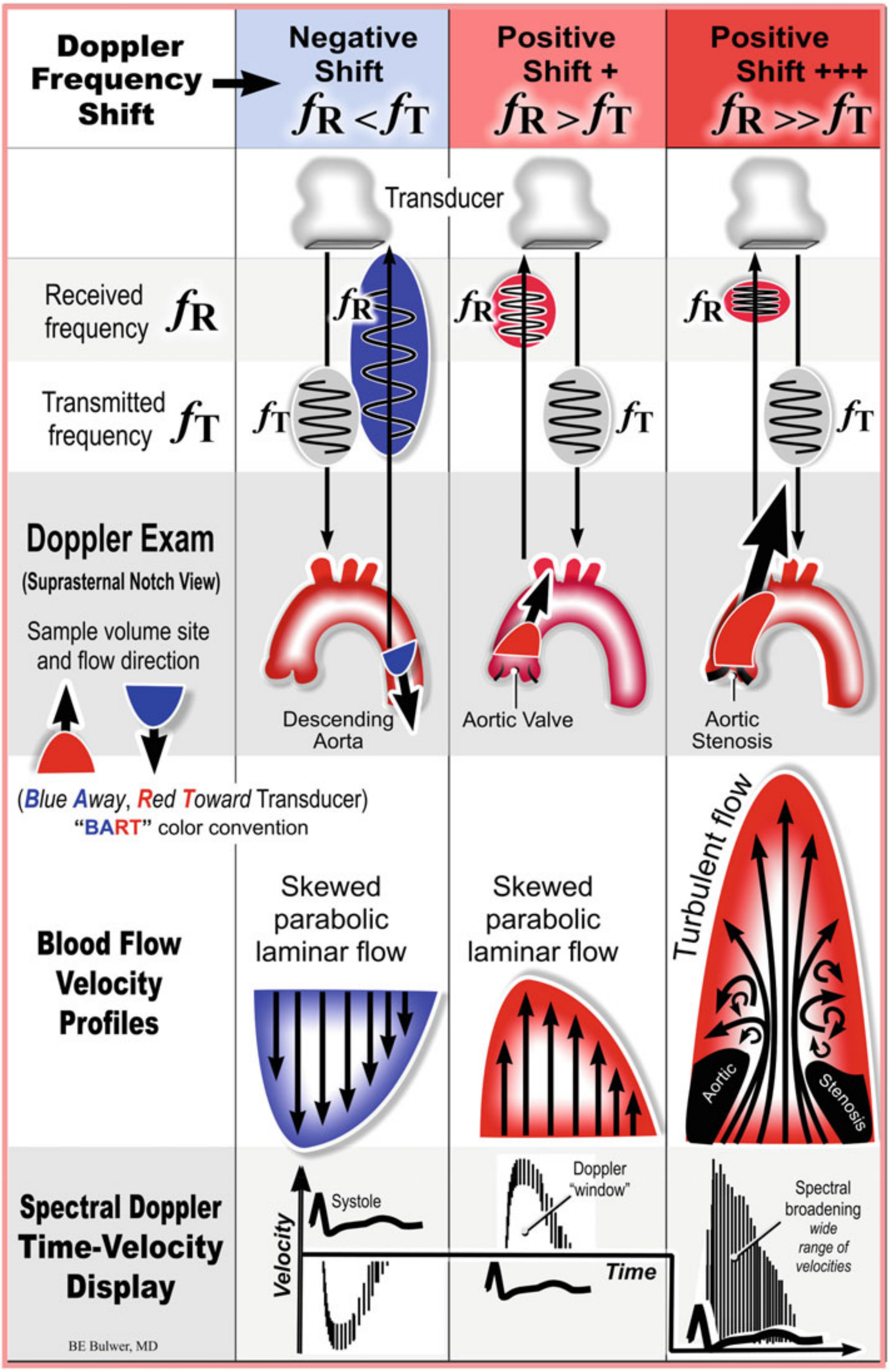

Fig. 21.3 Summary of Doppler examination of flow within the ascending and descending thoracic aorta, using the suprasternal notch (SSN) window. Left column: Note (blue) flow within the descending thoracic aorta away from the transducer, with lower frequency echoes ($f_R < f_T$)—resulting in a negative Doppler shift. Center: Doppler examination of (red) flow moving toward the transducer, with higher frequency echoes ($f_R > f_T$)—resulting in a positive Doppler shift. Right column: With turbulent flow, note the higher and wider range of multidirectional flow, resulting in spectral broadening ("filled-in" window) on the Doppler display

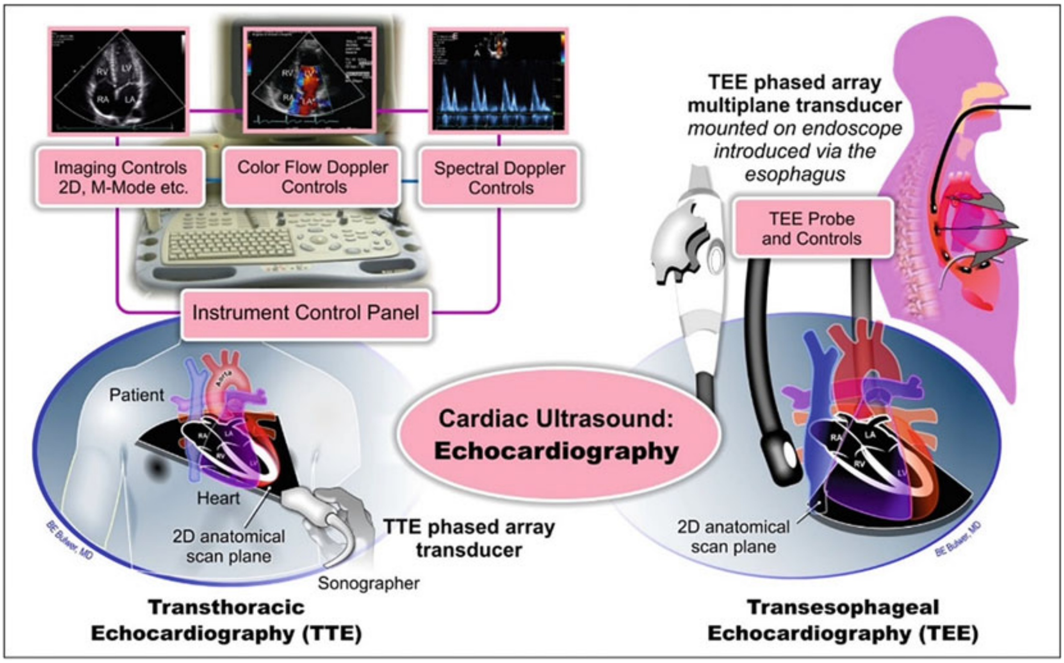

Fig. 21.4 Two major types of echocardiography based on the position of the transducer probe. Transthoracic echocardiography acquires images of the heart mainly through the thorax (left). Transesophageal echocardiography acquires images using a transducer mounted on an endoscope inserted into the esophagus (right). High frequency inaudible echoes are used to create the ultrasound image. To do so, ultrasound is first transmitted from the transducer, reflected from the cardiac structures, exquisitely processed within the instrument, and then graphically dis-played as anatomical images, or as velocity graphs or color-coded velocity maps

Novice users and those less versed in cardiac anatomy may find this initially confusing. However, understanding the anatomical basis of echocardiography fosters communication between cardiac surgeon and perioperative cardiac anesthesiologists or cardiologist during cardiac surgery for valvular pathology, as in the examples shown in reference to the mitral valve apparatus and scallops (Figs. 21.16, 21.17, 21.18, 21.19 and 21.20).

Coronary artery disease (CAD) is the leading cause of morbidity and mortality. Echocardiographic correlations of the coronary artery supply in relation to the ventricular myocardium, both left and right, are important in the assessment and management of patients with coronary artery disease, ventricular remodeling, and ventricular systolic dysfunction (Figs. 21.21, 21.22, 21.23, 21.24, 21.25, 21.26 and 21.27). Ventricular walls that demonstrate abnormal motion and thickening, e.g., hypokinesis, akinesis, or dyskinesis, and ventricular walls that appear aneurysmal, or thinned (or scarred) do so most commonly because of ischemia to their corresponding blood supply.

Therefore, knowledge of the coronary artery territories that correspond to the ventricular walls and ventricular segments is of critical importance in echocardiography. This is the basis for optimal image interpretation of regional wall motion abnormalities in patients with CAD, ventricular systolic dysfunction, and heart failure.

Newer echocardiography imaging techniques, such as tissue Doppler and B-mode speckle tracking-based techniques are now routinely used to assess cardiac motion and deformation.

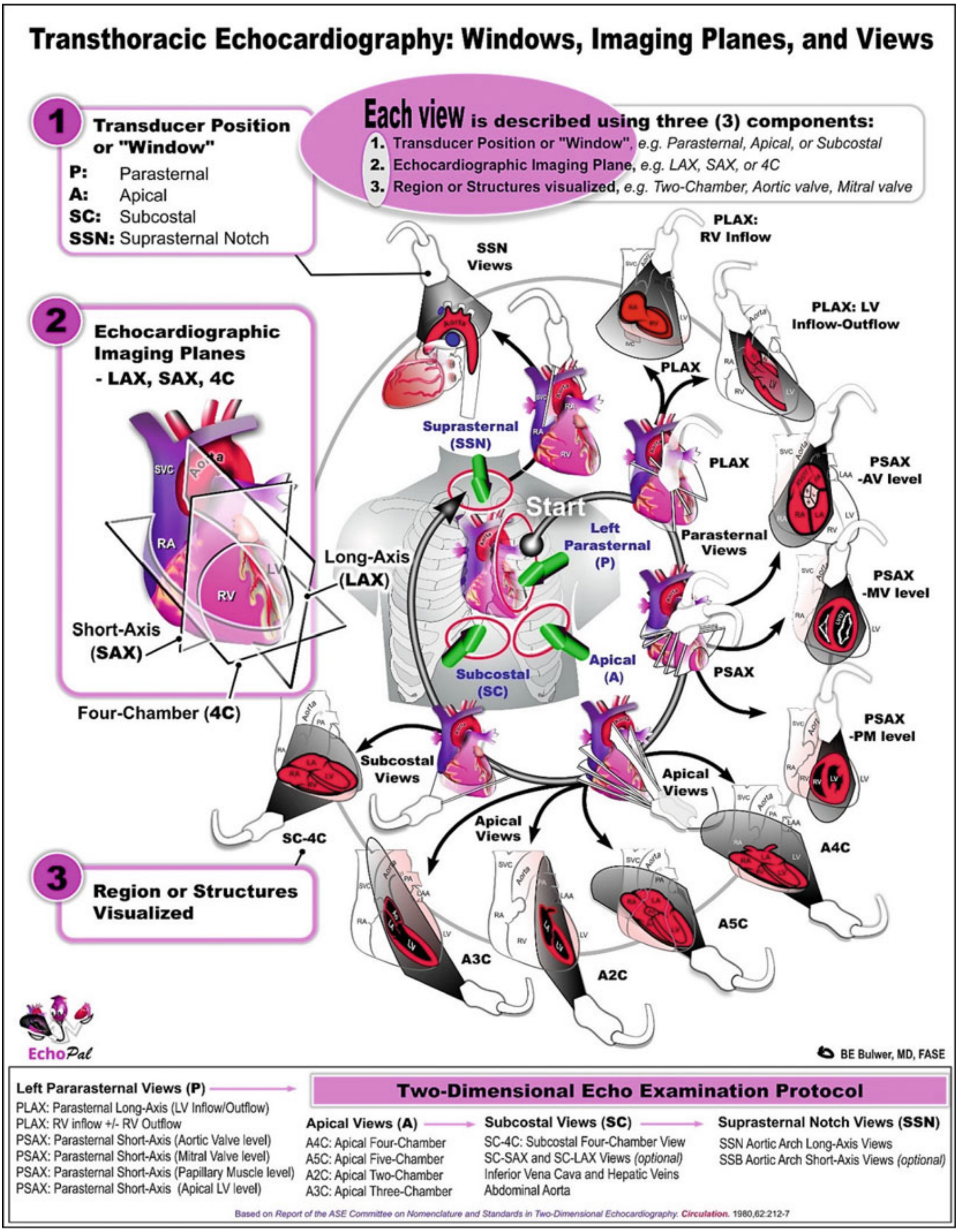

Fig. 21.5 In the comprehensive two-dimensional (2D) transthoracic echocardiography (TTE) protocol, as recommended by the American Society of Echocardiography (ASE), each component echocardiographic view is described using three parameters: (1) transducer position, (2) echocardiographic imaging plane, and (3) region or structures visualized. The adult TTE examination protocol begins at the left parasternal window (P), followed by examination at the subsequent windows (green arrows)

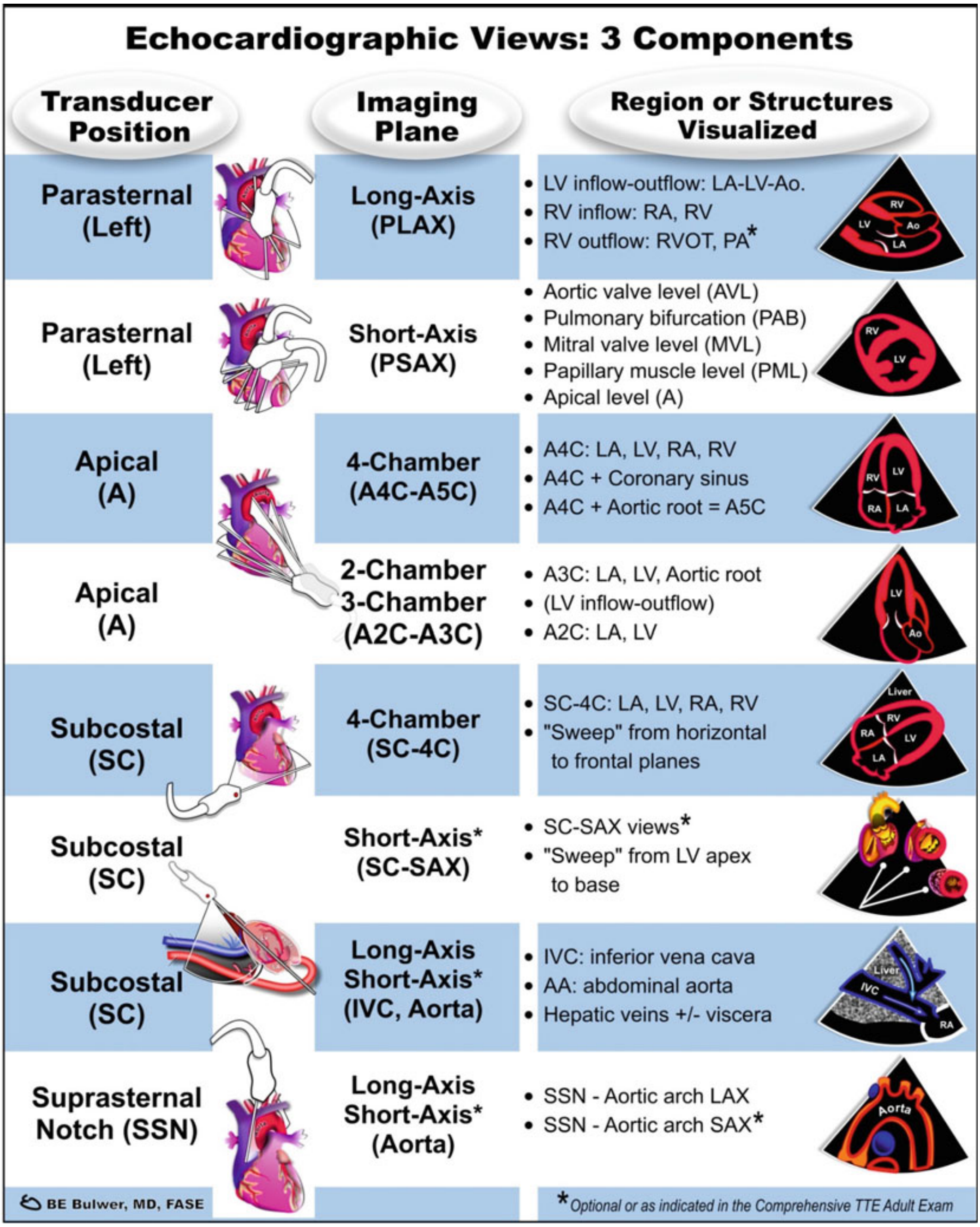

Fig. 21.6 Selected examples of the recommended nomenclature used to describe each standard transthoracic echocardiographic view in the adult two-dimensional (2D) or cross-sectional examination protocol: (1) transducer position (acoustic window), (2) echocardiographic imaging plane, and (3) the region or anatomic structures visualized

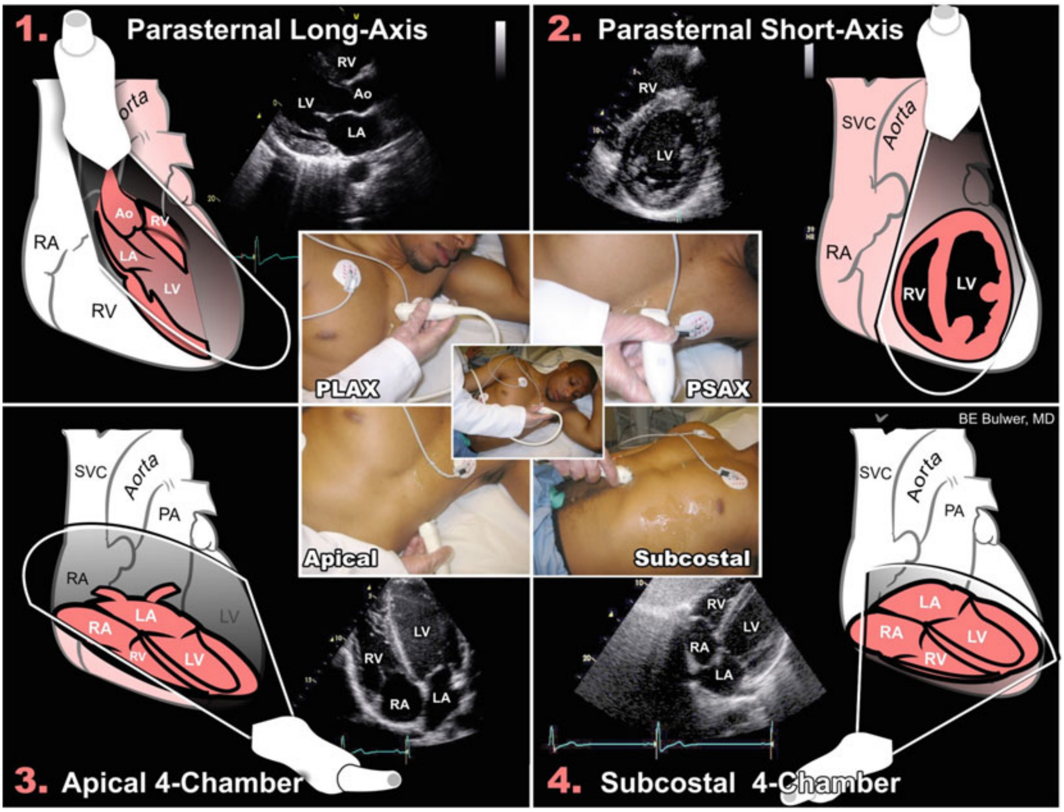

Fig. 21.7 Optimal acquisition of echocardiographic views also requires optimal patient positioning. Panels 1 to 4 are a panoramic overview of patient positioning, transducer windows, and the corresponding echocardiographic view

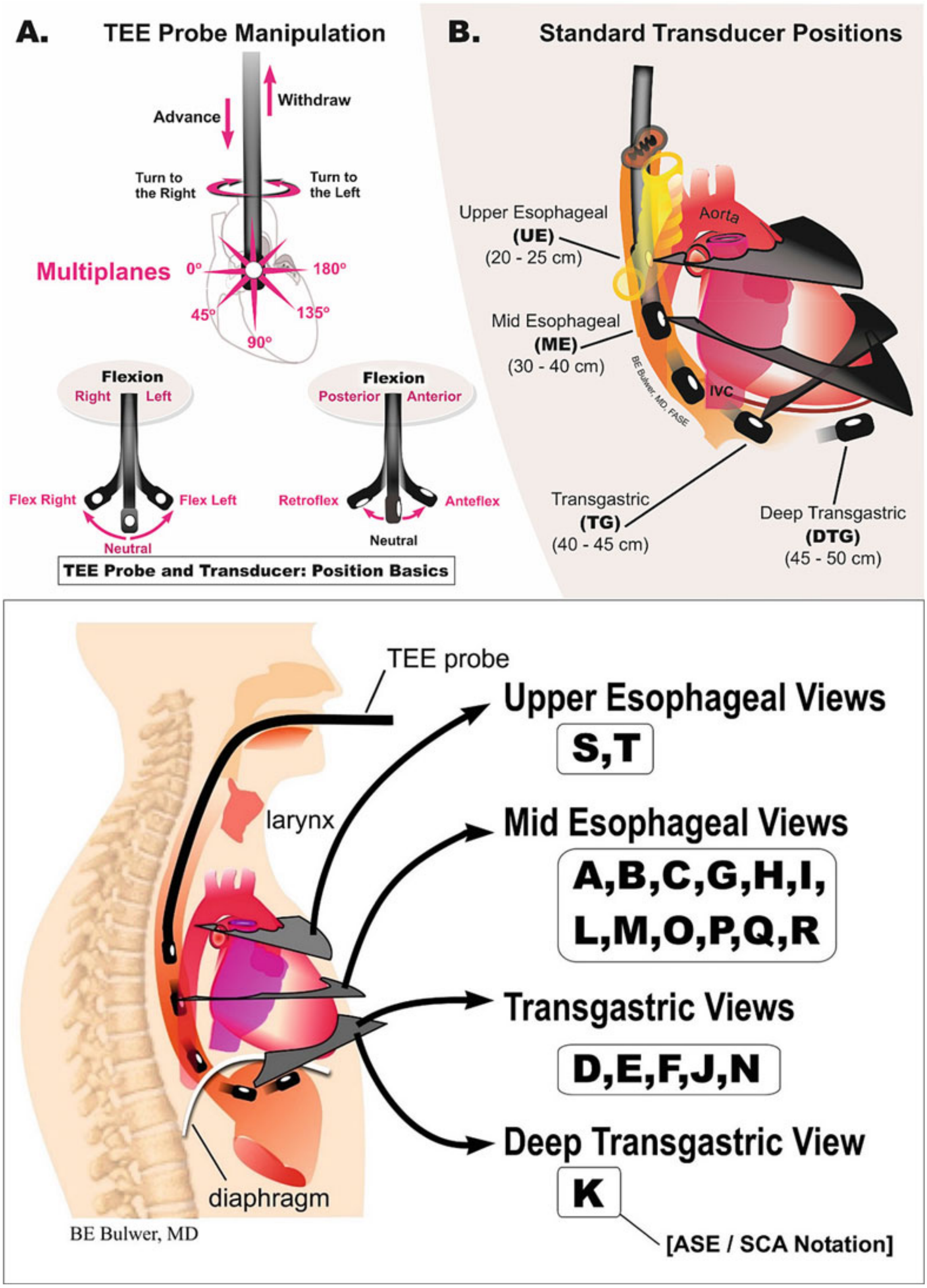

Fig. 21.8 Summary of the recommended nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on 1999 guidelines by American Society of Echocardiography (ASE) and the Society of Cardiovascular Anesthesiologists (SCA)

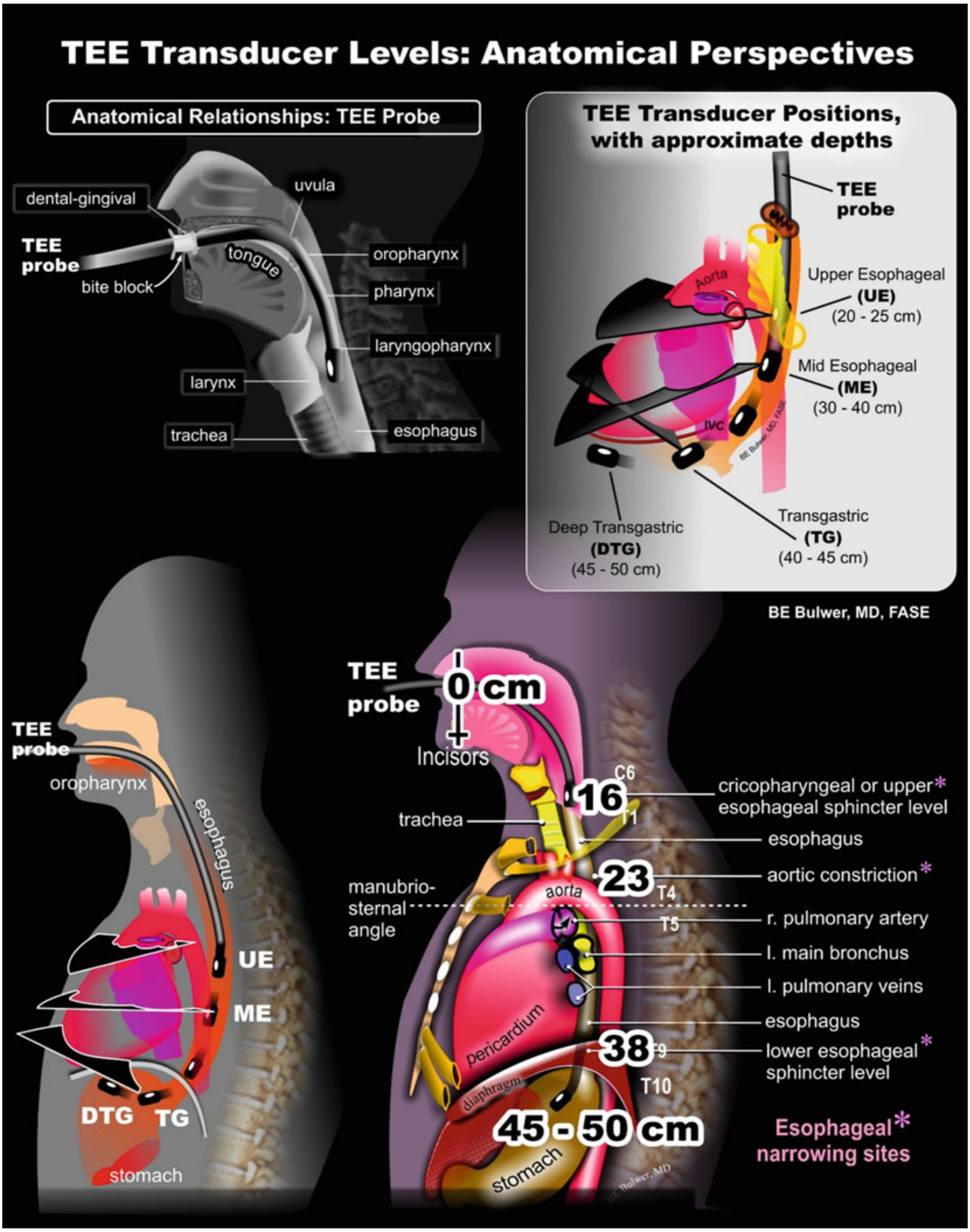

Fig. 21.9 Left lateral erect perspective of the approximate transesophageal echocardiographic (TEE) transducer positions and levels in an average adult male. This procedure is typically performed with the patient under intravenous conscious sedation or similar anesthetic procedure

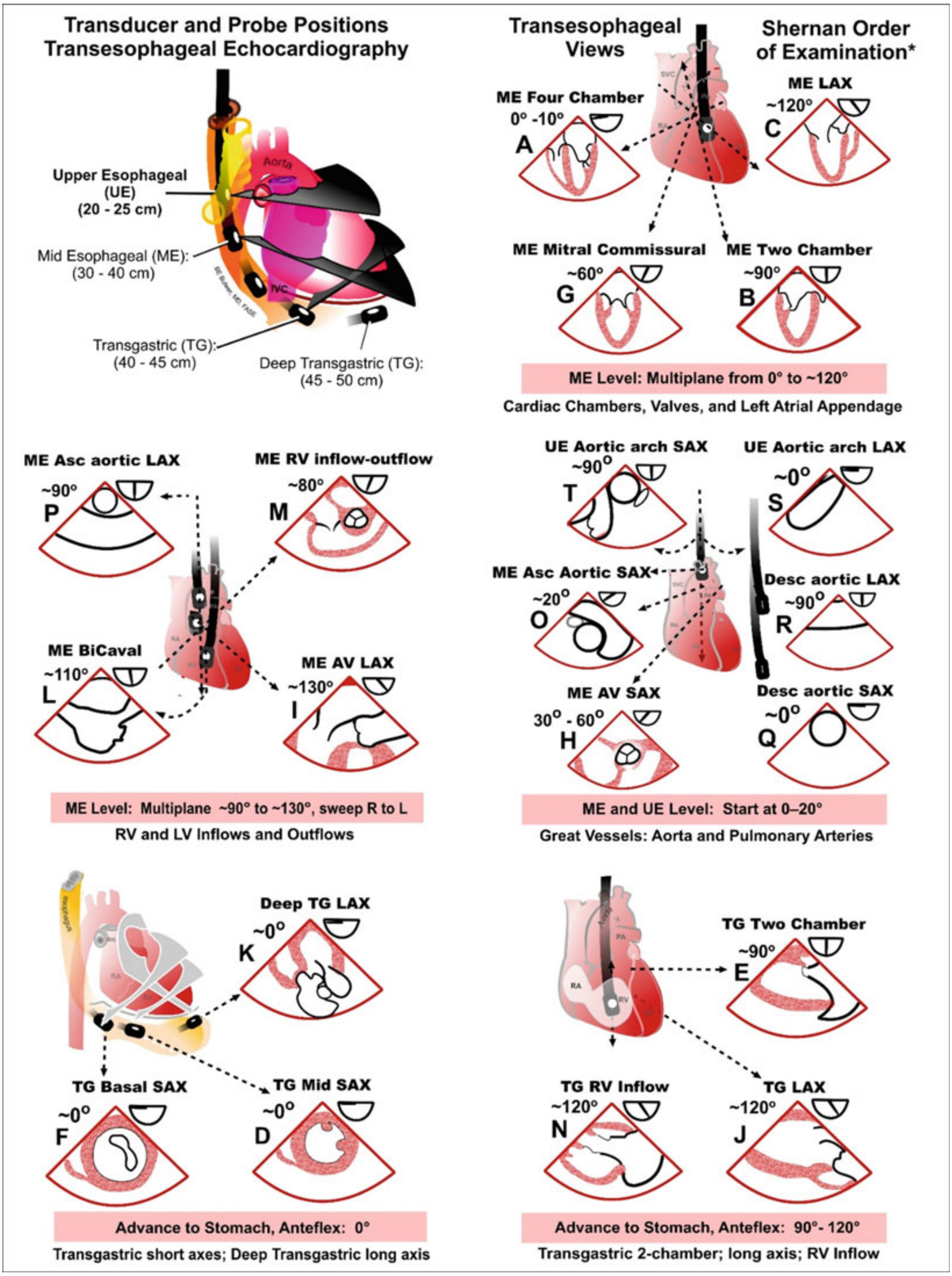

Fig. 21.10 Nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on based on the 1999 ASE/SCA guidelines

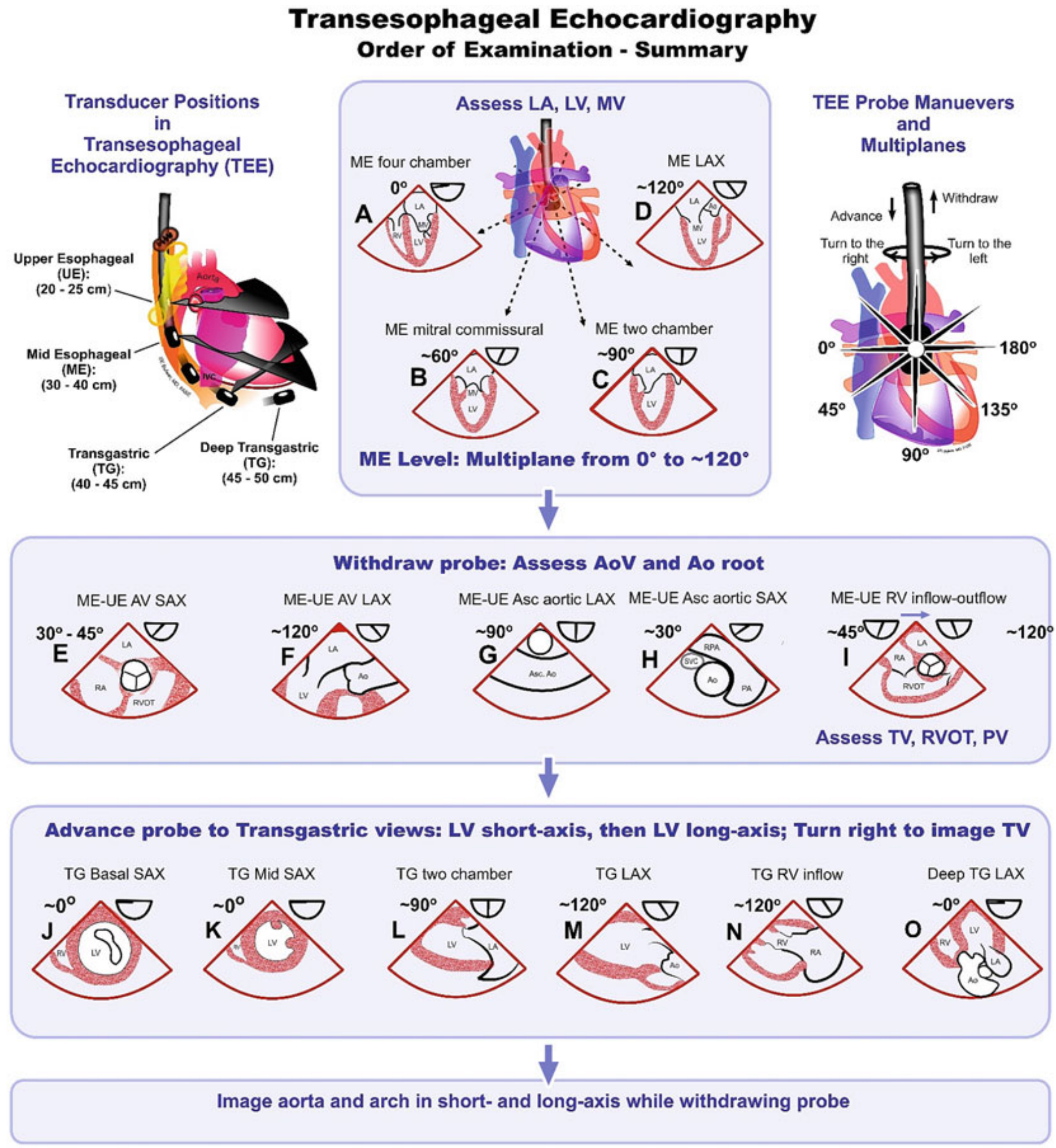

Fig. 21.11 An abbreviated protocol and procedure used to conduct the transesophageal echocardiographic (TEE) examination, TEE transducer probe positions, anatomical structures and regions of interest, based on the 1999 ASE/SCA guidelines

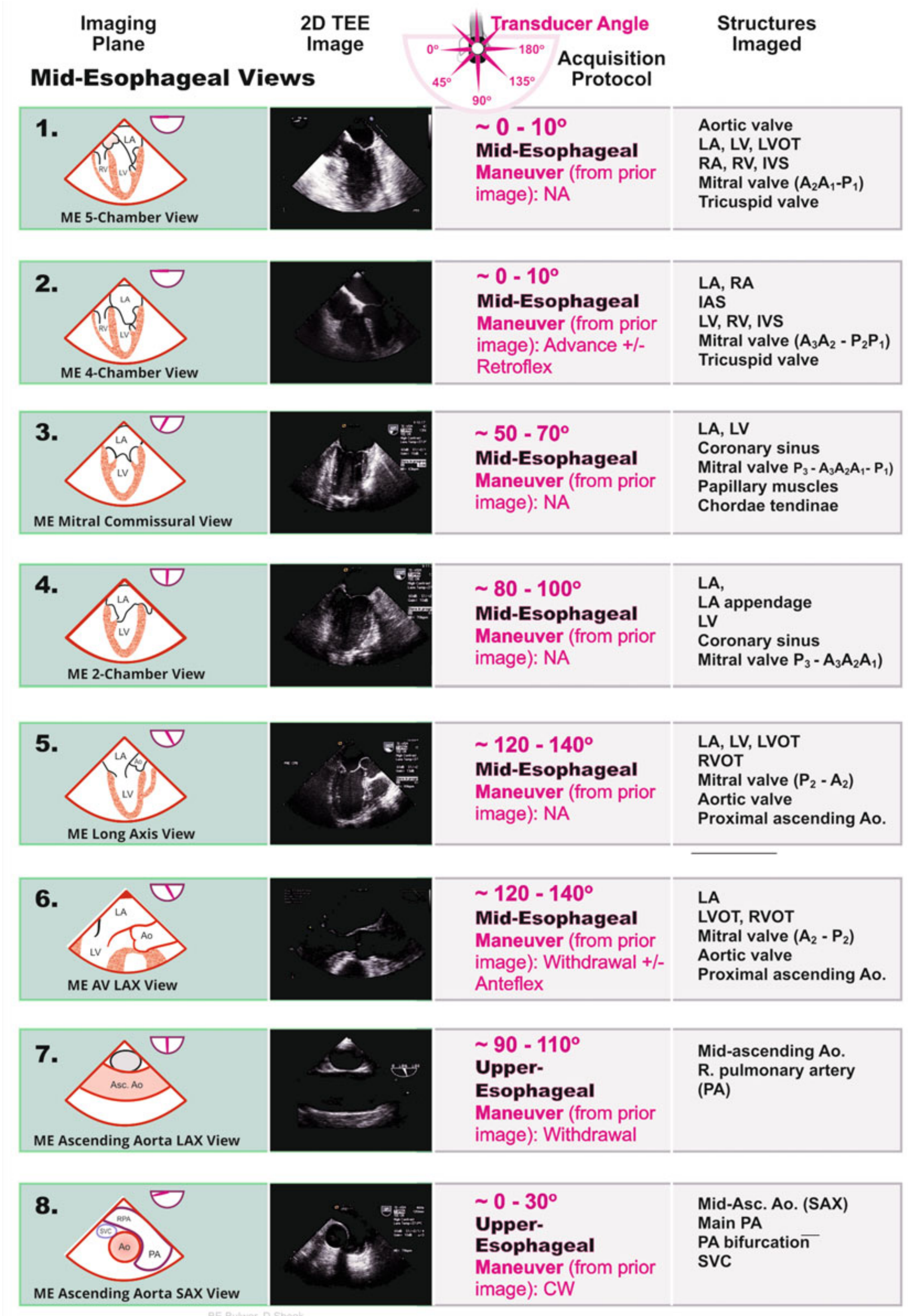

Fig. 21.12 Nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on the 2014 guidelines by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists

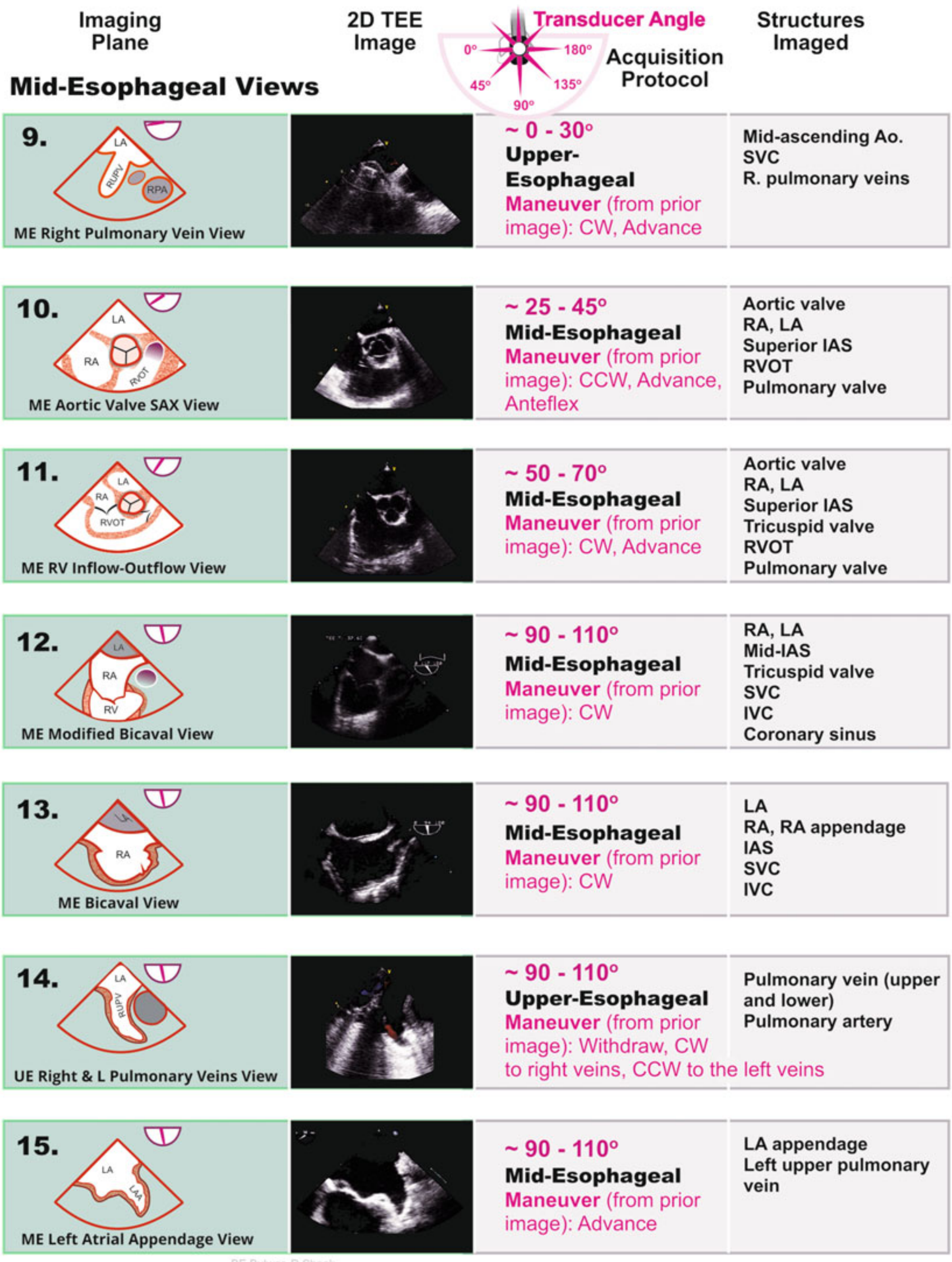

Fig. 21.13 Nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on the 2014 ASE/SCA guidelines

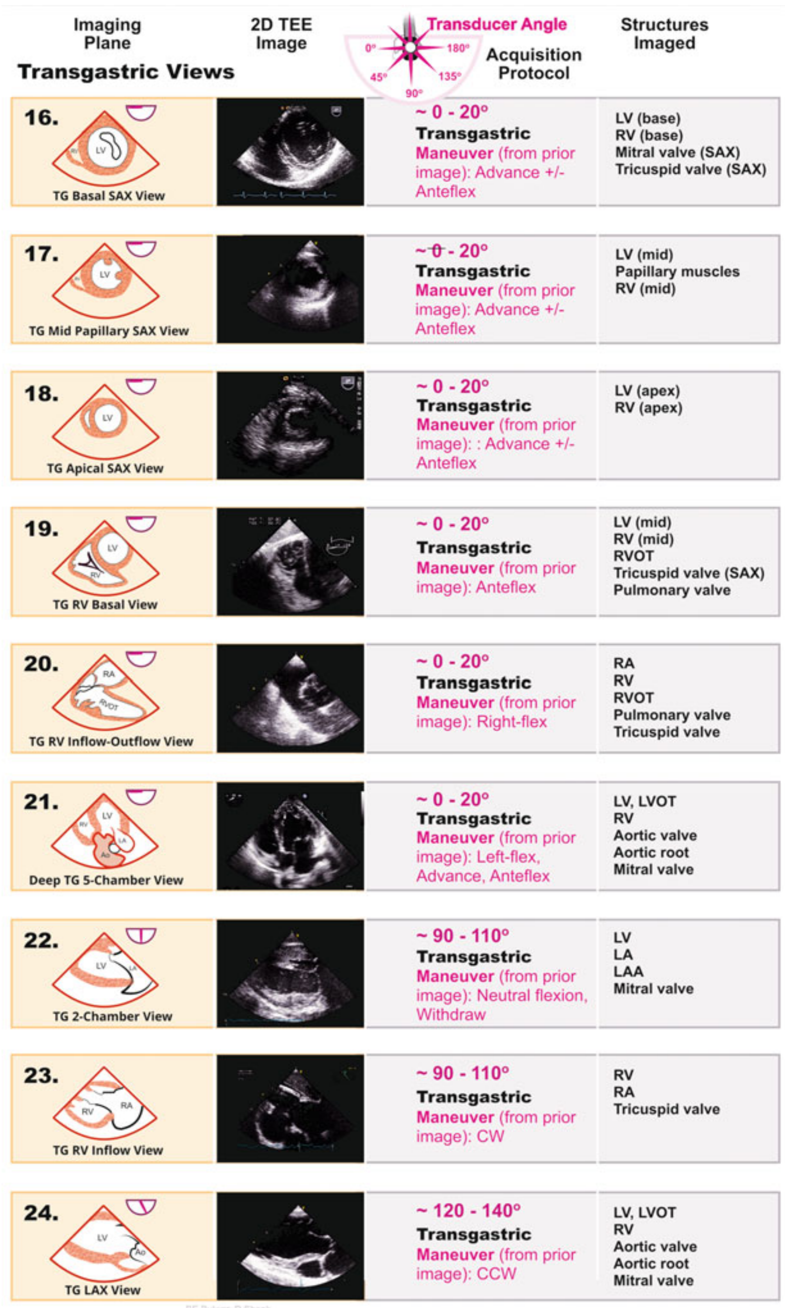

Fig. 21.14 Nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on the 2014 ASE/SCA guidelines

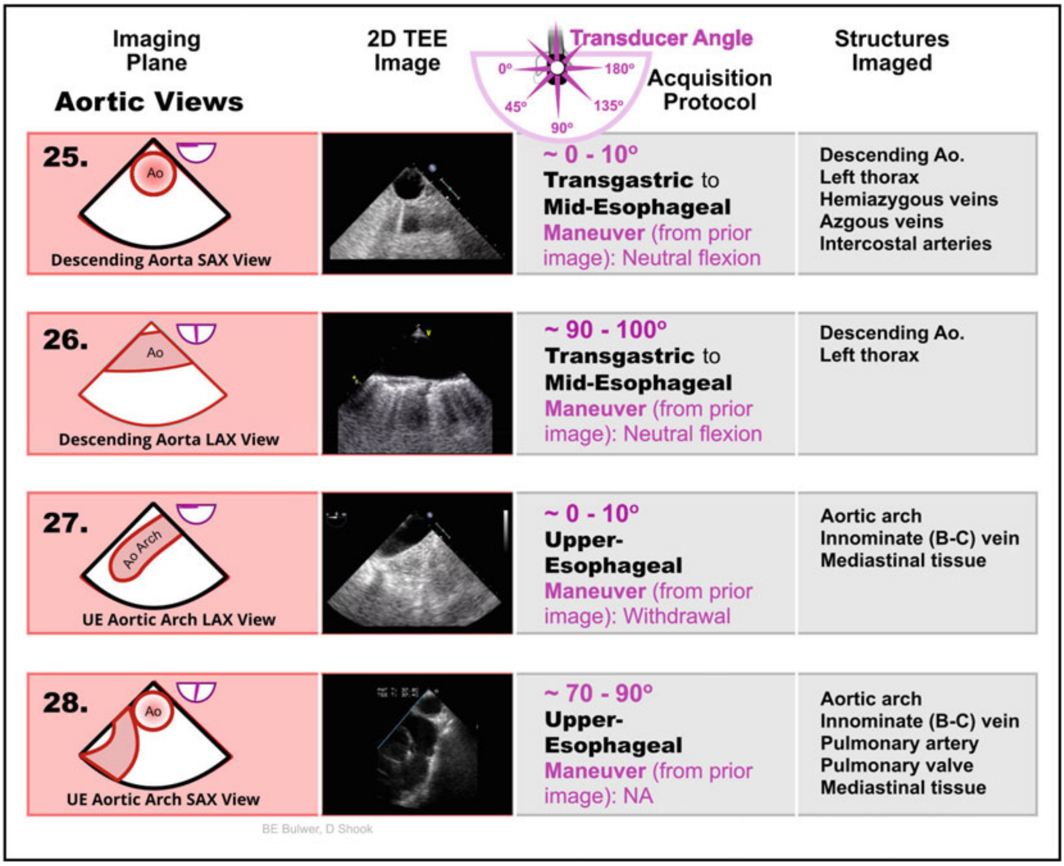

Fig. 21.15 Nomenclature of the transesophageal echocardiographic (TEE) views, TEE transducer probe positions, anatomical structures and regions of interest, based on the 2014 ASE/SCA guidelines

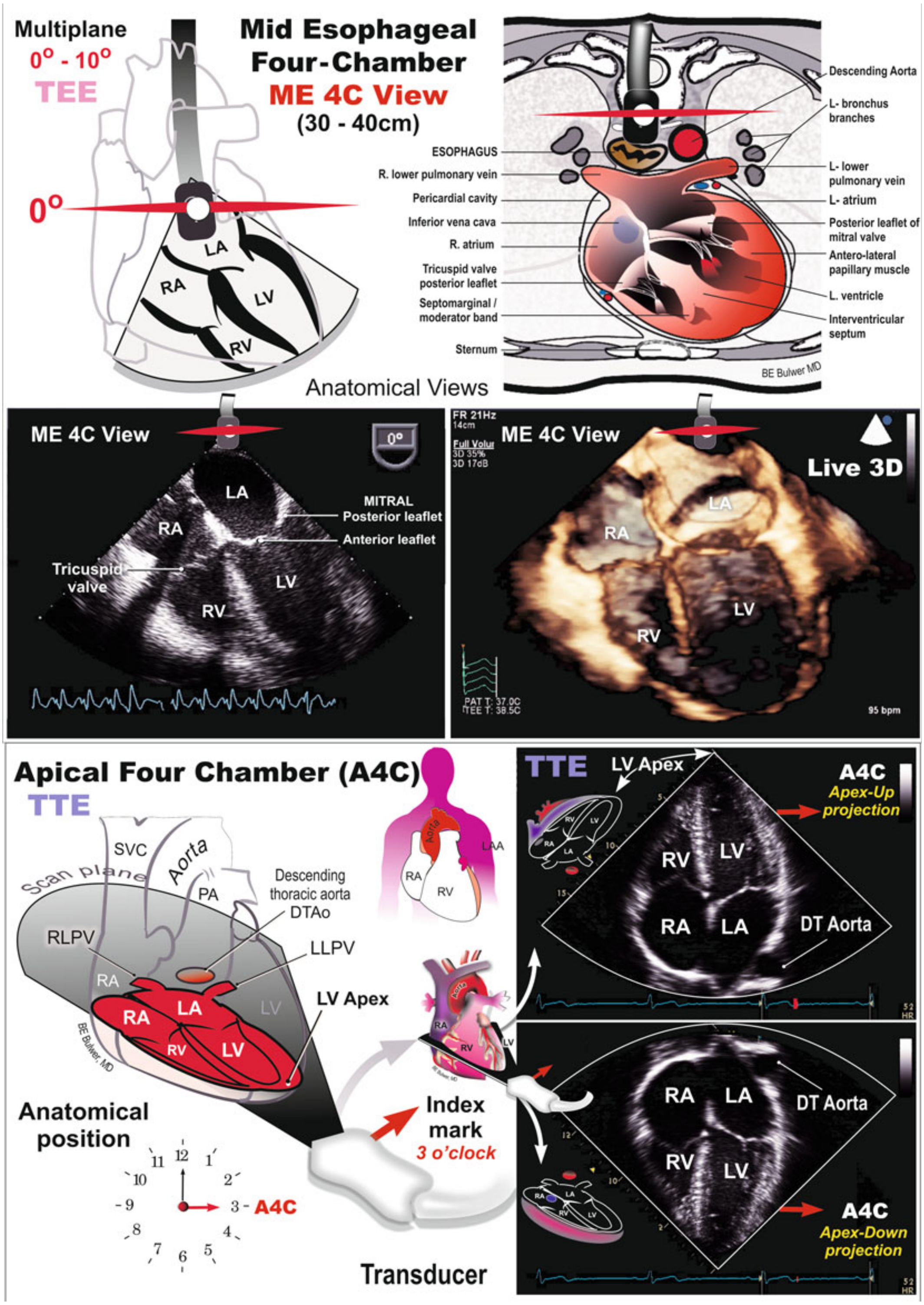

Fig. 21.16 Cross-sectional anatomy of the four-chamber (4C) plane using transesophageal echocardiography (TEE), upper panels, and on transthoracic echocardiography, lower panels

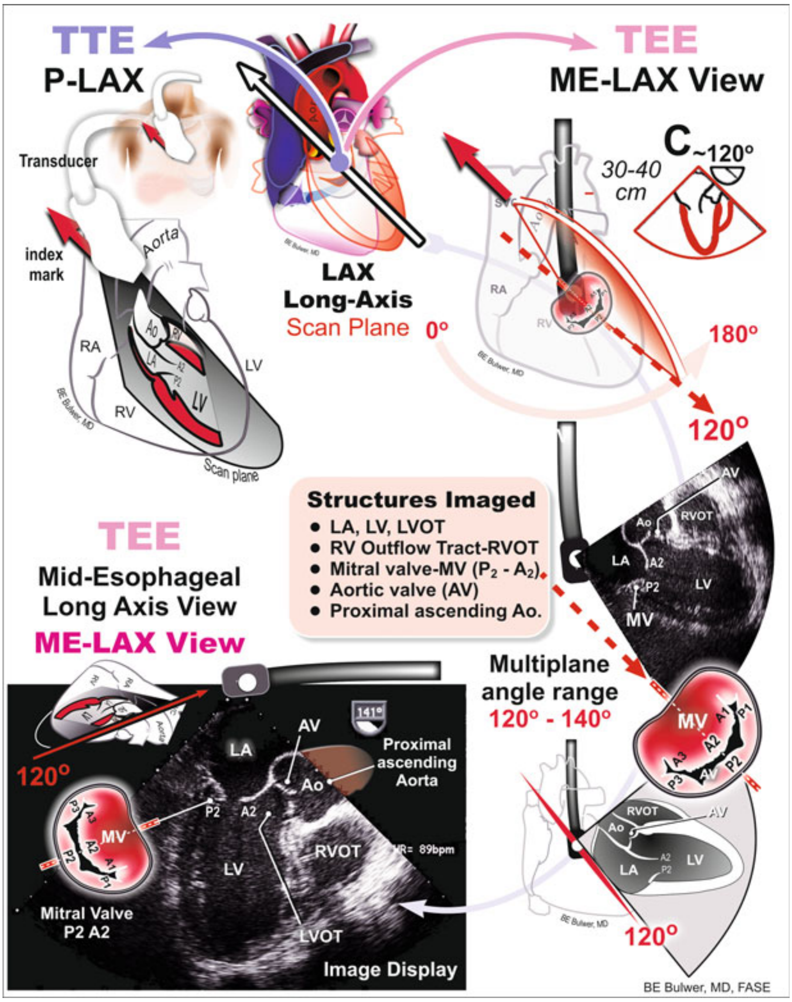

Fig. 21.17 Cross-sectional or two-dimensional (2D) anatomy of the long-axis views of the heart, when viewed on transthoracic echocardiography-TTE (above left) and by transesophageal echocardiography-TEE (above right). Essentially, the same structures are imaged along the LAX plane of the heart. The TTE-PLAX view is acquired using a TTE phased-array transducer placed at the left parasternal window of chest—approximately in the 3rd or 4th left intercostal space. In contrast, the ME-LAX view is acquired from the mid-esophageal position, with the TEE transducer positioned in the esophagus, immediately behind the left atrium (LA), at multiplane 120–140°. The anatomical structures transected are labeled as shown

The intimacy of the cardiac surgeon with cardiac structure and function should logically spell a future where echocardiography should become a standard tool for cardiac surgeons and trainees, both inside and outside the perioperative environment (Figs. 21.28, 21.29 and 21.30).

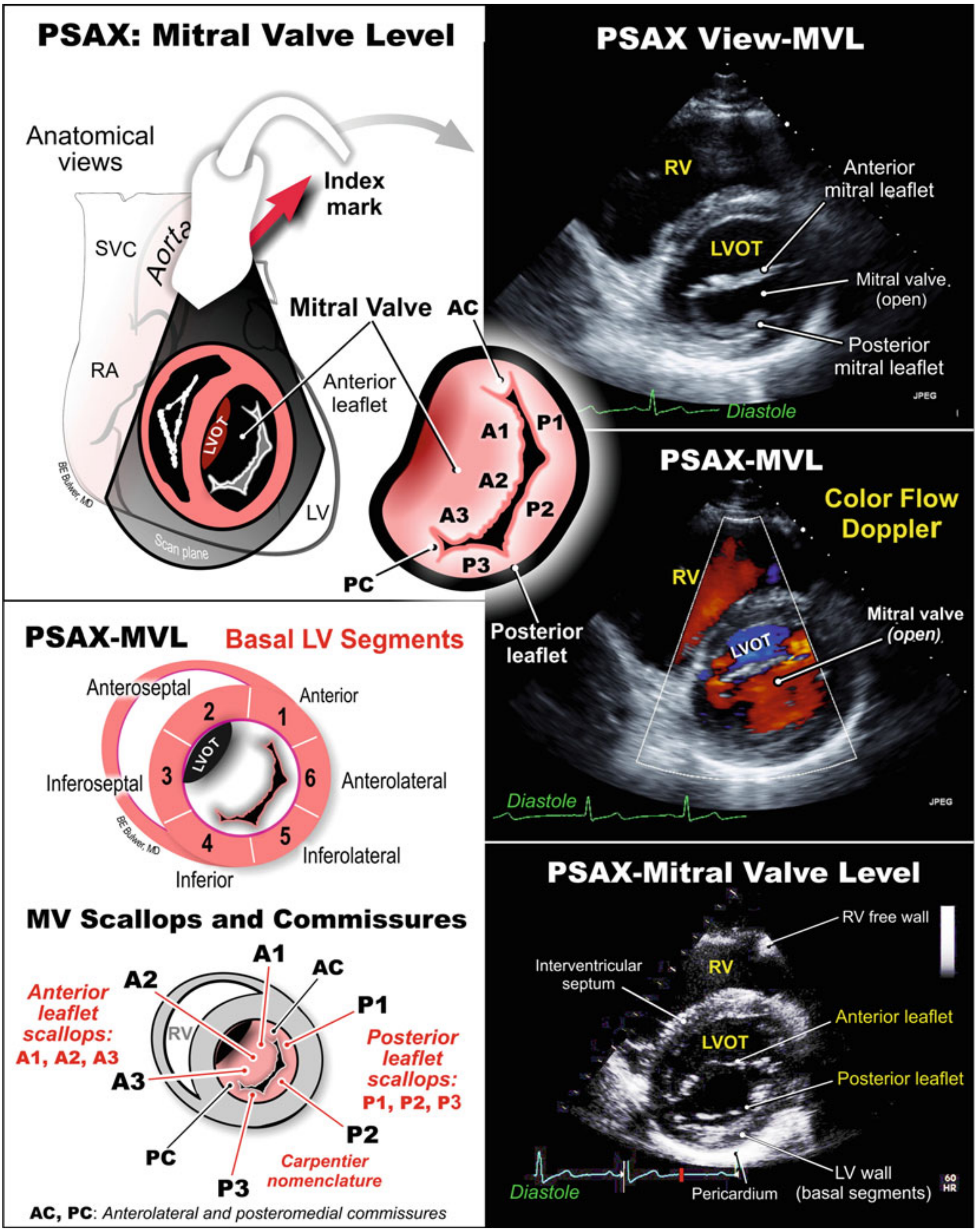

Fig. 21.18 PSAX-Mitral Valve Level: Scan Plane Anatomy. Parasternal short axis view—mitral valve level (PSAX-MVL) on transthoracic echocardiography (TTE). Scan planes depicting the anatomy and orientation of mitral leaflets and scallops (left panels) and the cross-sectional image displays (right panels)

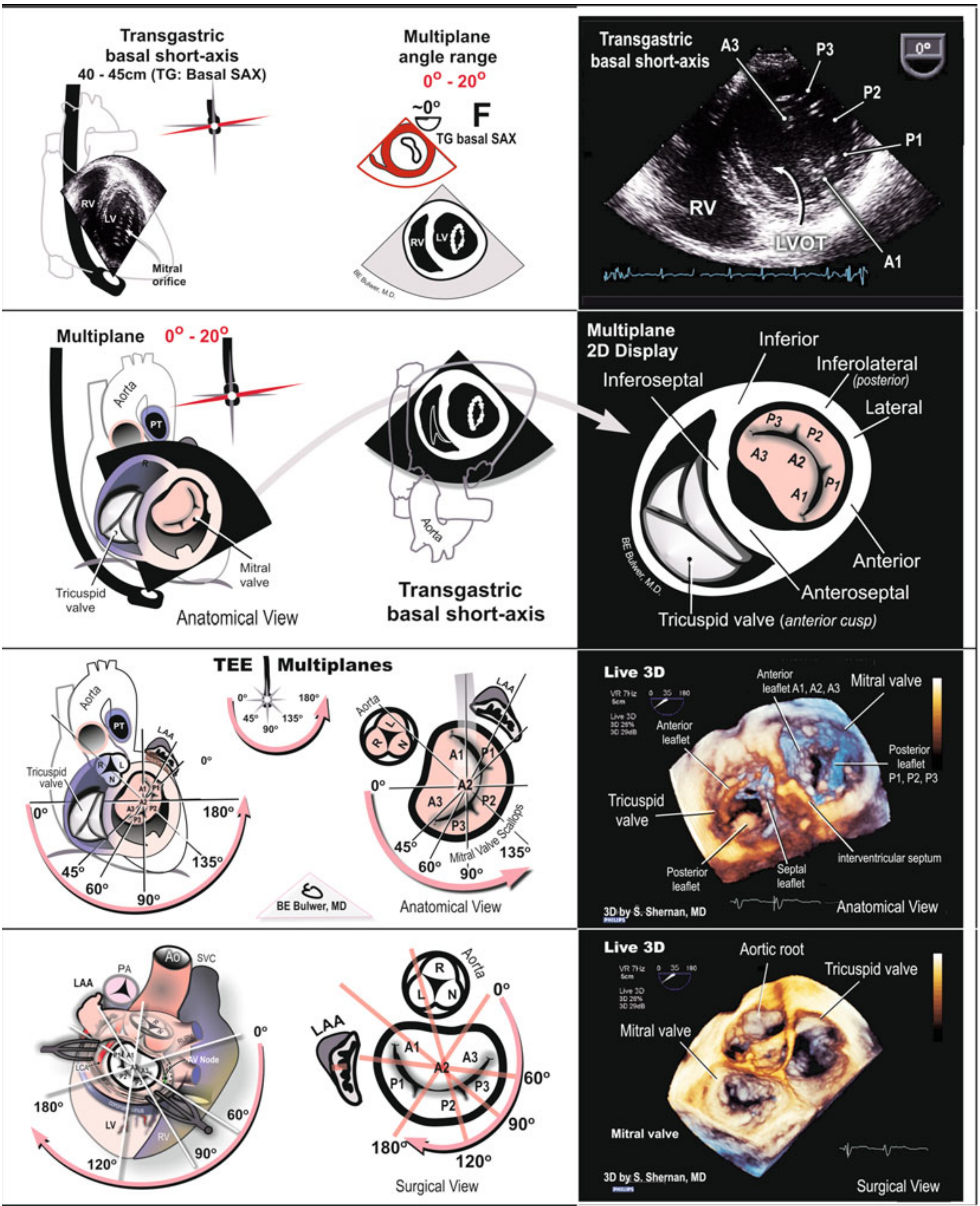

Fig. 21.19 Transgastric Basal Short Axis View: Cross-Sectional Anatomy on 2D- and 3D-TEE Short-axis views of the mitral valve leaflets and scallops on transesophageal echocardiography (TEE). Transgastric TEE views are shown in the above panels, with anatomical and surgical views (lower left), and the corresponding 3D echo anatomy (lower right)

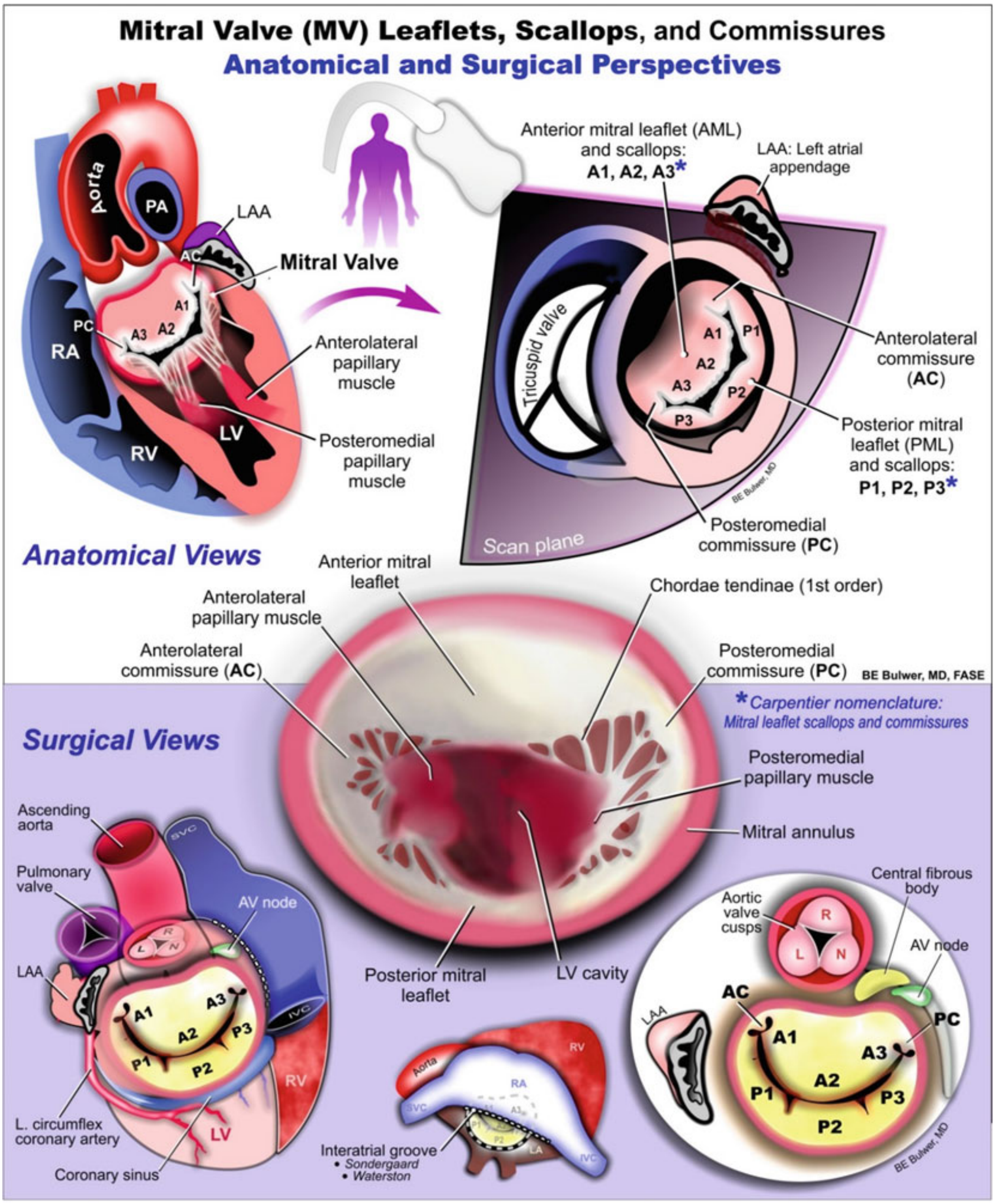

Fig. 21.20 Anatomical and surgical perspectives of the mitral valve (MV) leaflets and scallops (Carpentier classification). A thorough knowledge of mitral valve anatomy is important, especially for communicating findings on TEE and 3D, and in the perioperative setting. Surgically speaking, the MV leaflets are divided into 8 segments. The anterior and posterior leaflets each has 3 scallops, with the additional 2 components being the commissures

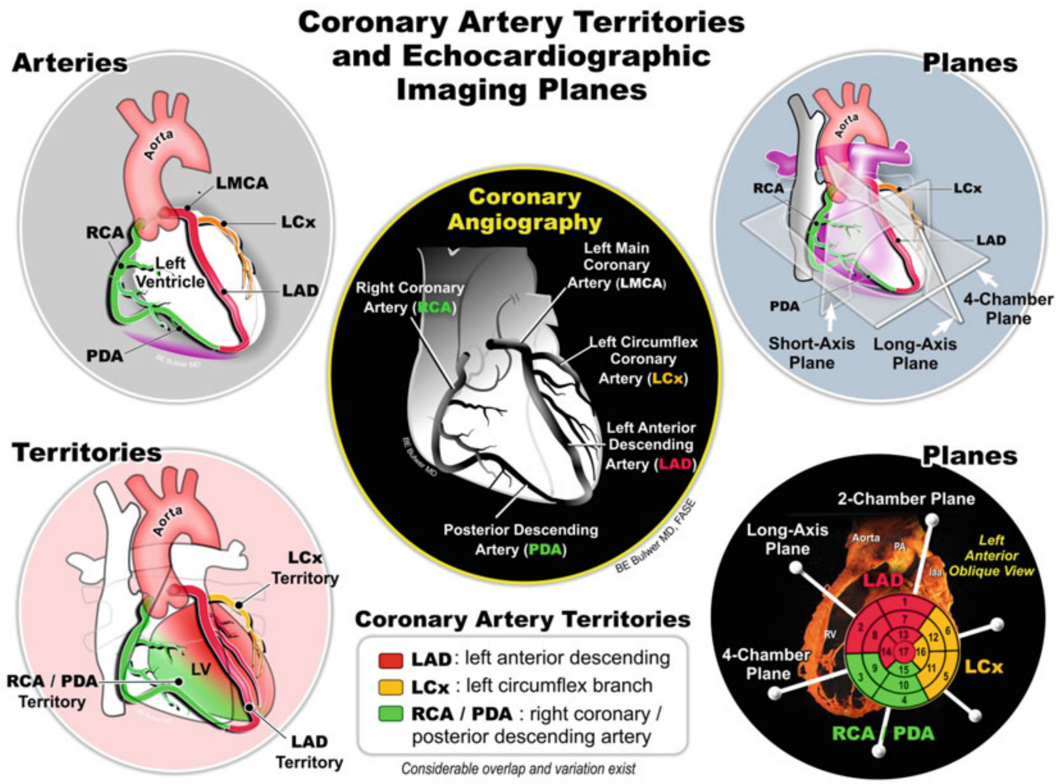

Fig. 21.21 Coronary artery territories and the reference echocardiographic imaging planes. LAA: left atrial appendage; LAD: left anterior descending coronary artery; LCx: left circumflex coronary artery; LMA: left main coronary artery; PDA: posterior descending (branch of the right coronary) artery; RCA: right coronary artery

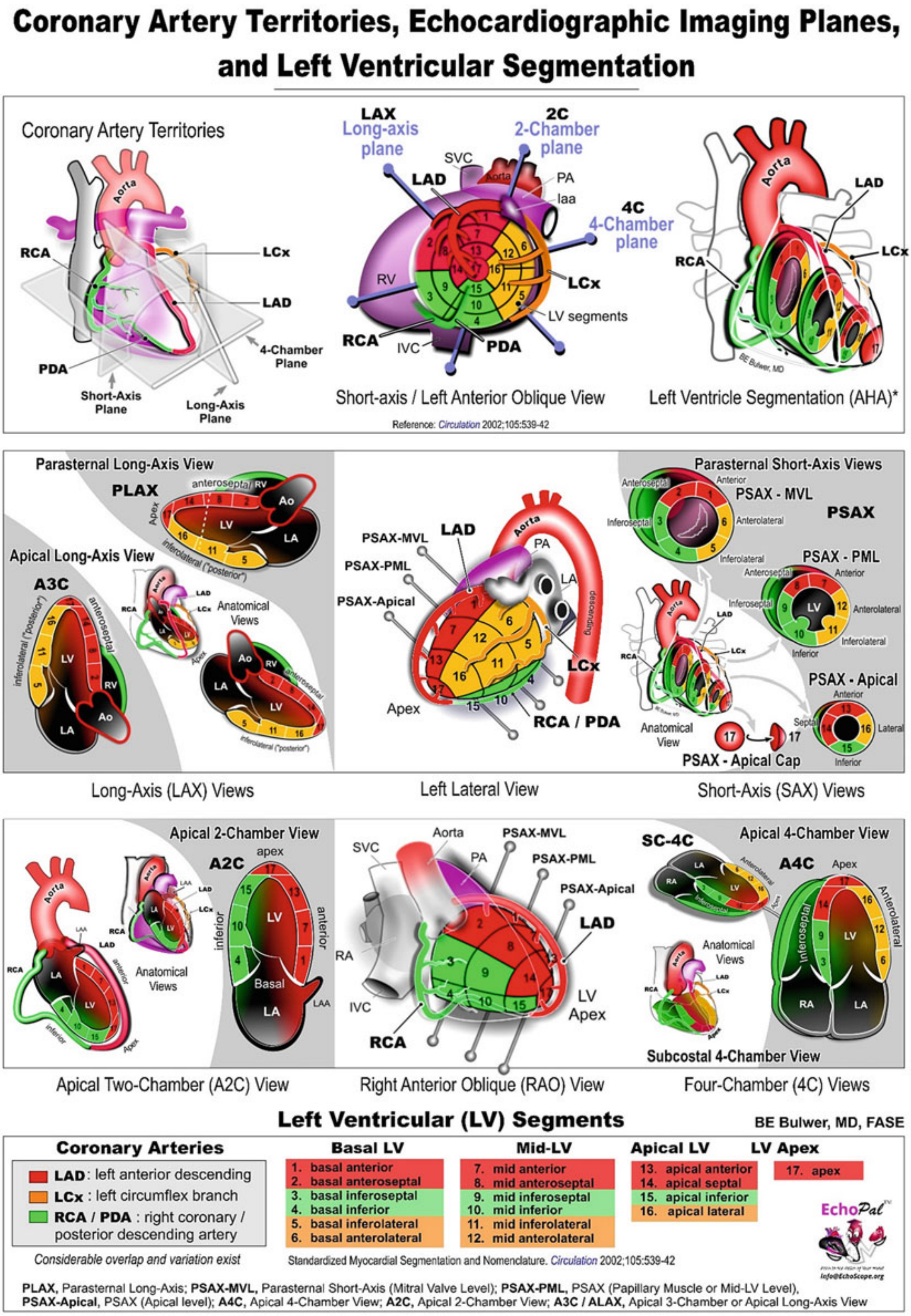

Fig. 21.22 Expanded views of the coronary artery territories and blood supply to the left ventricular walls and segments, and their corresponding two-dimensional (2D) echocardiographic views

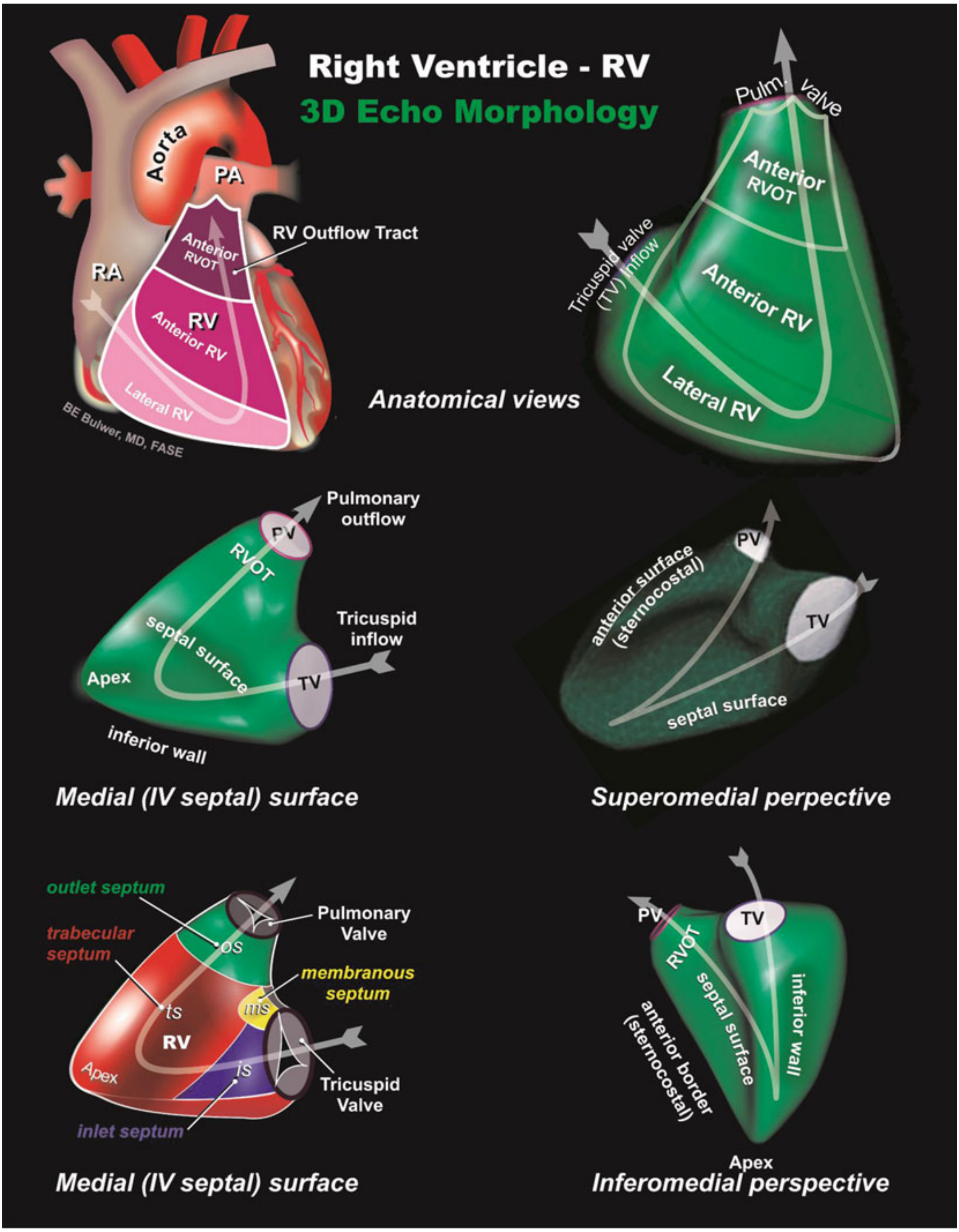

Fig. 21.23 Three-dimensional (3D) echocardiographic perspectives and rendered 3D models of the right ventricle and right ventricular walls

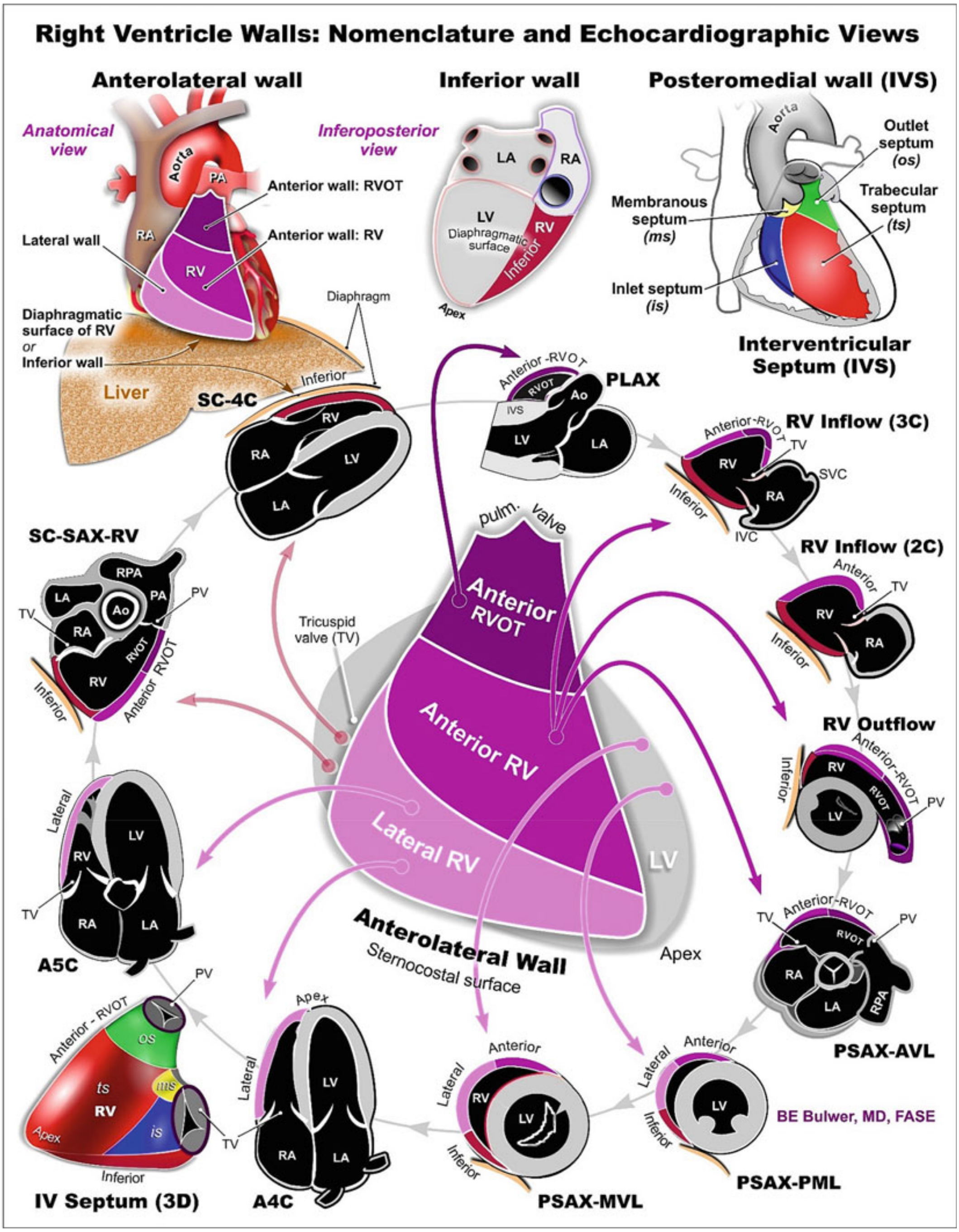

Fig. 21.24 Right ventricular (RV) walls, nomenclature, cross-sectional anatomy, and echocardiographic views

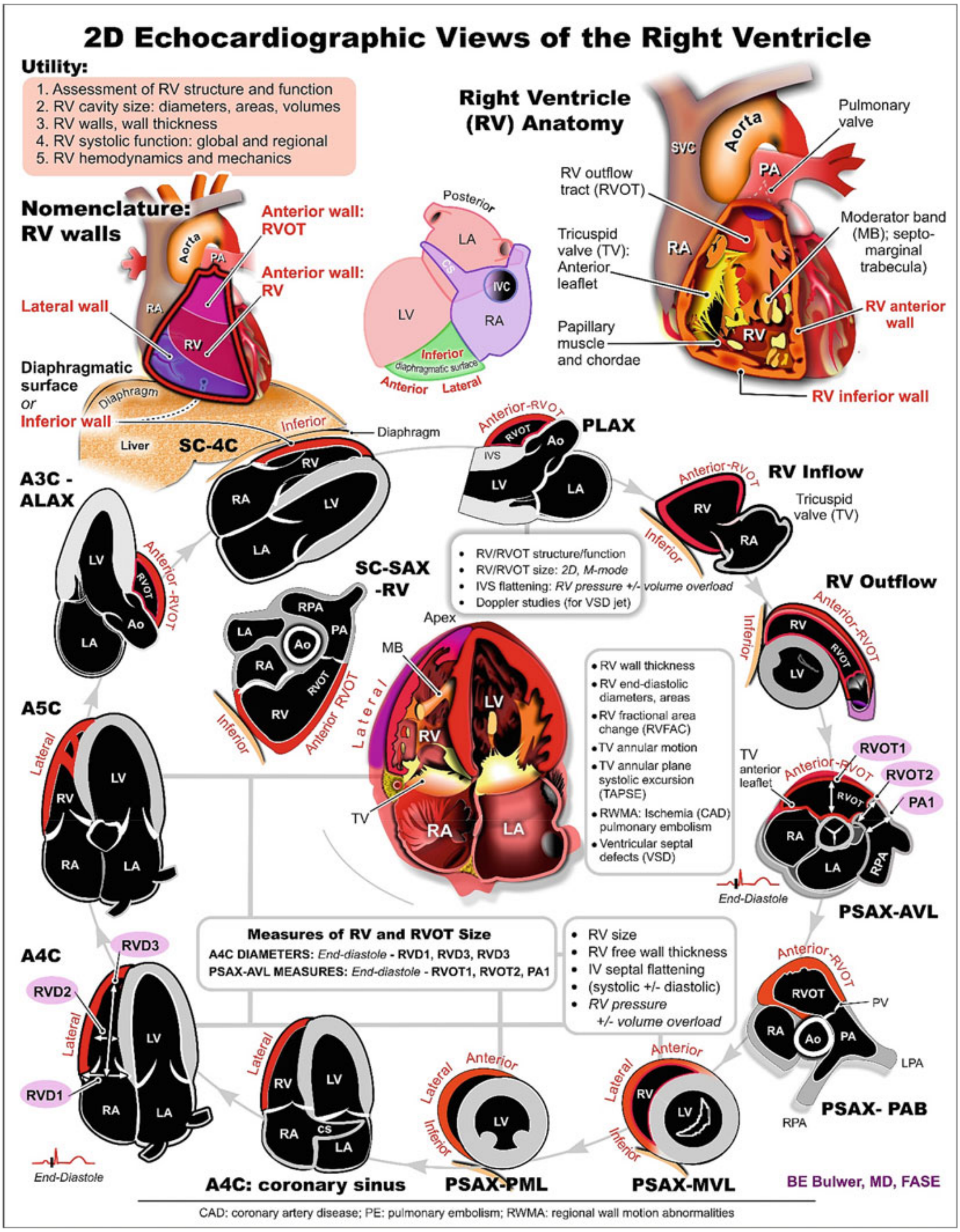

Fig. 21.25 Right ventricular (RV) cross-sectional anatomy, echocardiographic views, and measurements of RV structure and function

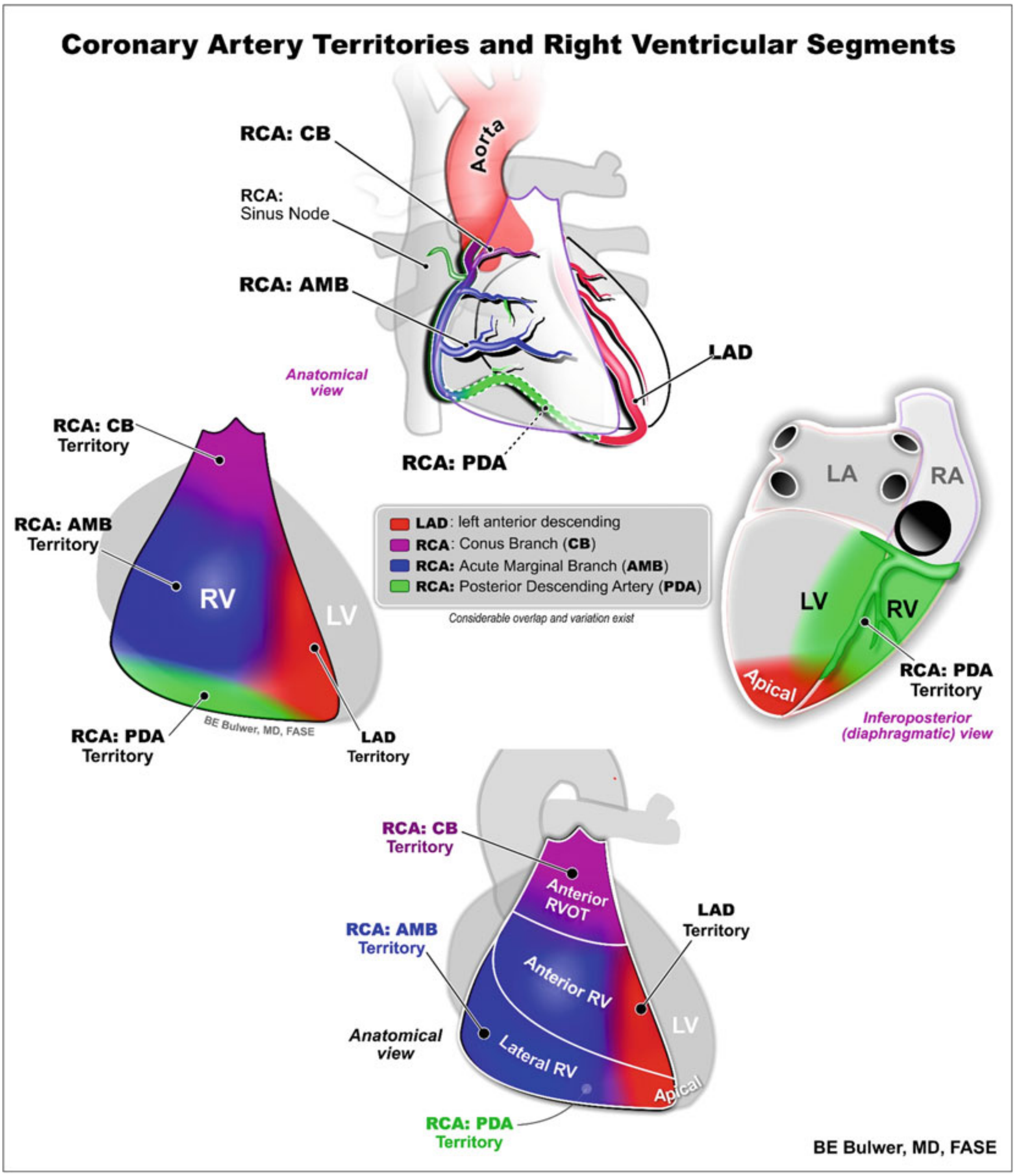

Fig. 21.26 Panoramic views of the coronary artery territories and blood supply to the right ventricle (RV)

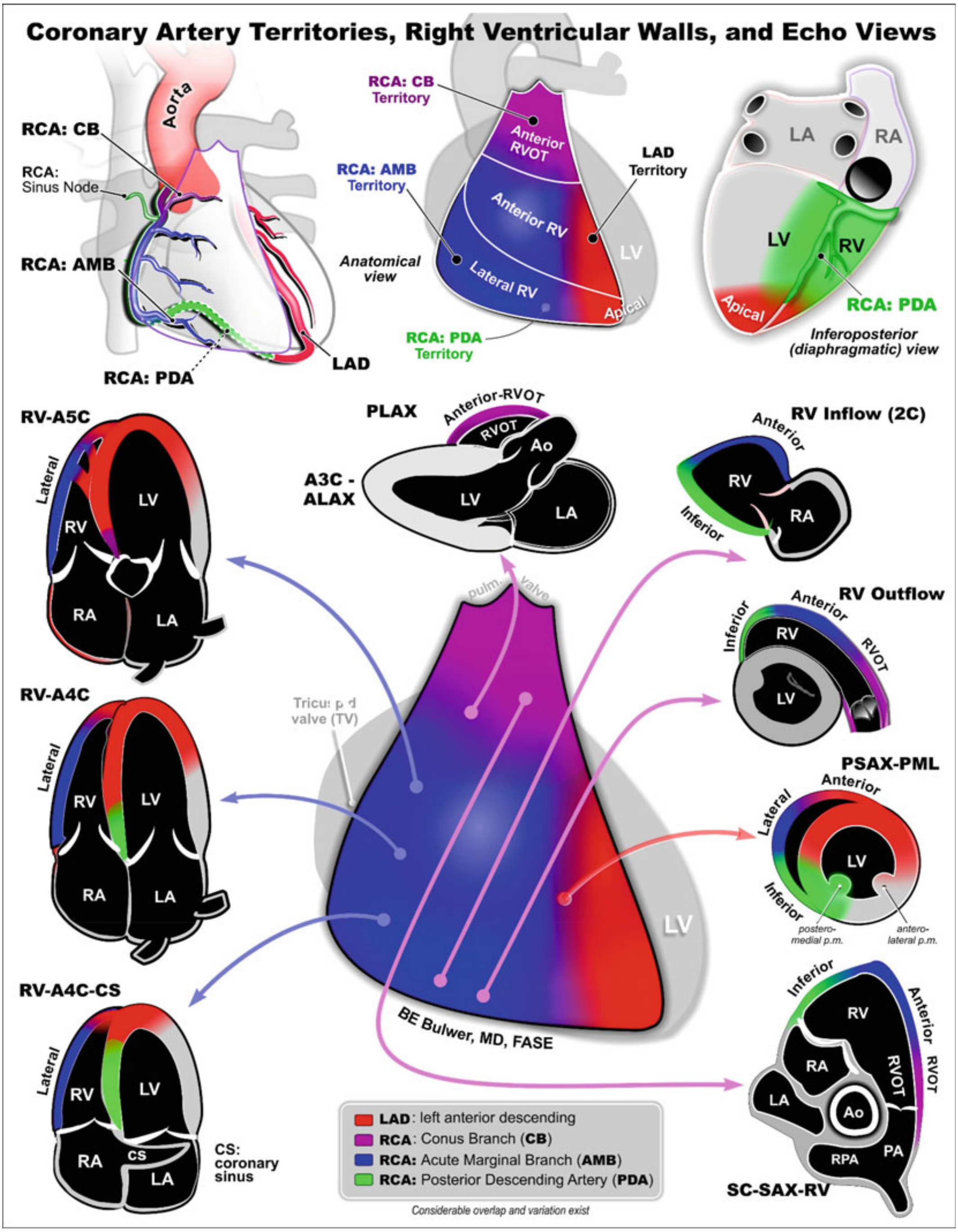

Fig. 21.27 Coronary artery territories, right ventricular (RV) walls, and their corresponding echocardiographic views

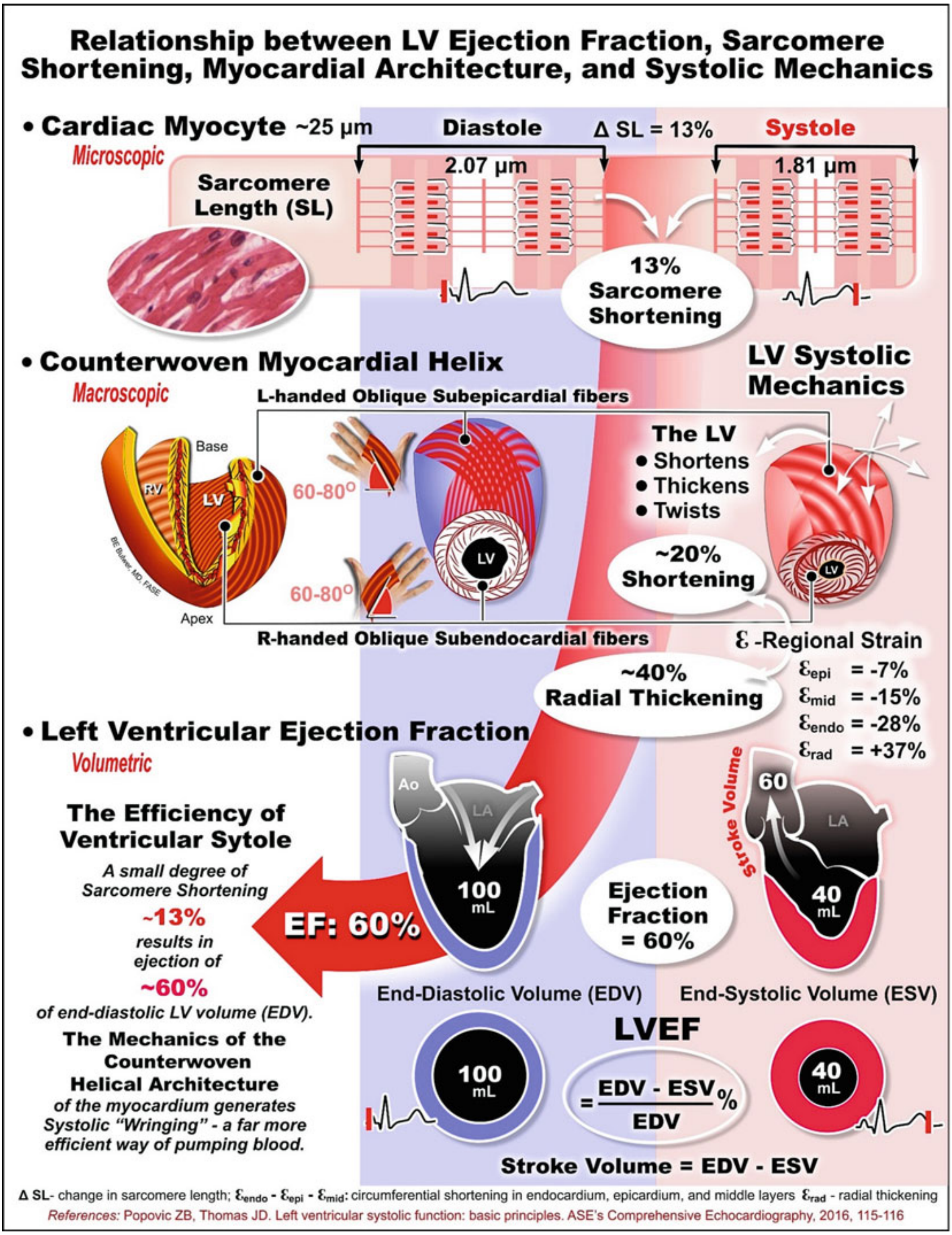

Fig. 21.28 Relationship between the microscopic (cardiac myocyte) systolic sarcomere shortening of ∼13%, coupled with the systolic efficiency of the LV (LV strain [thickening] reaching ∼40%) due to the helical interwoven cardiac myofibers, result in ejection of ∼60% of LV blood volume

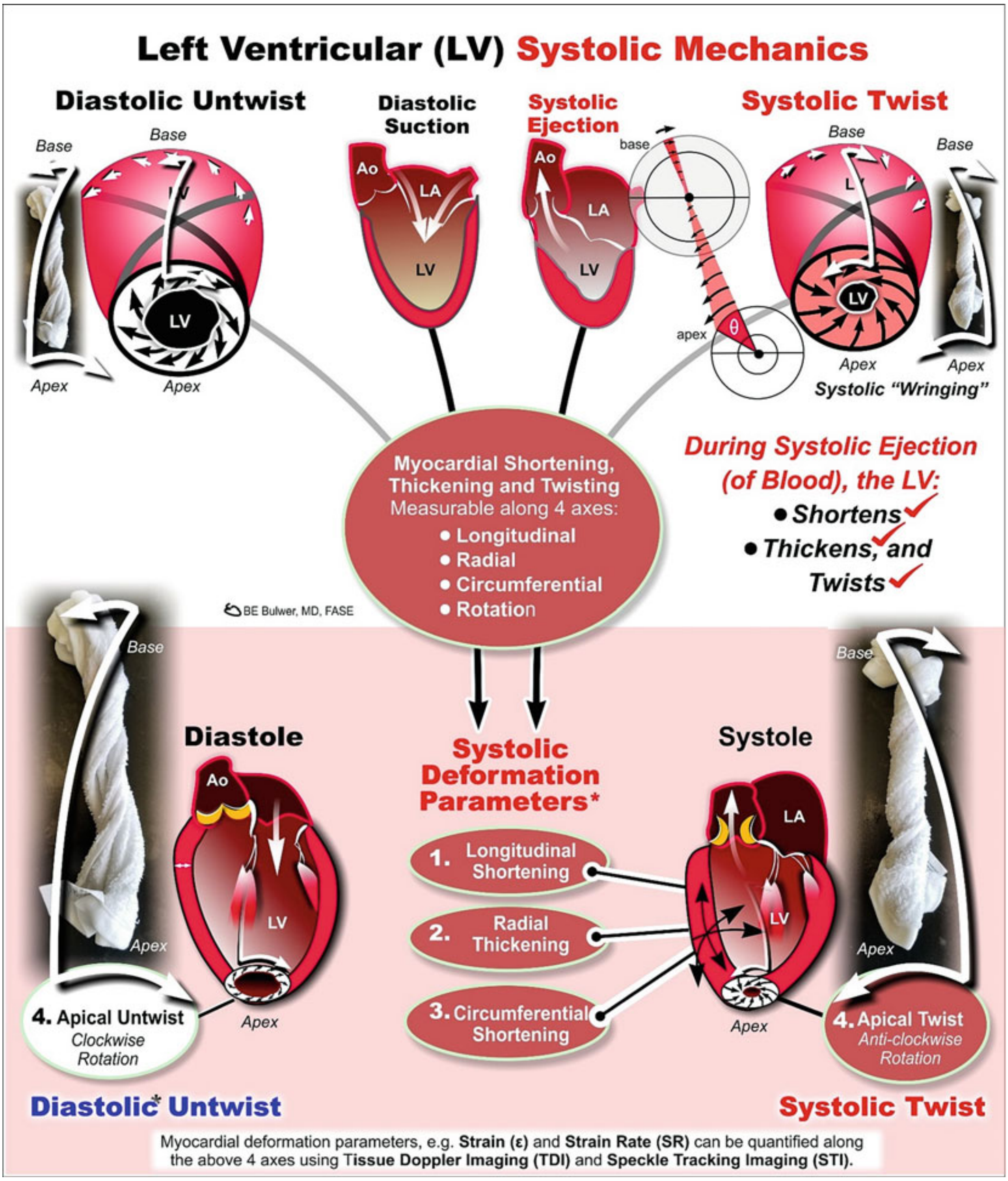

Fig. 21.29 Cardiac mechanics is complex, including gross motion of the ventricular walls, as well as internal deformation—*shortening, thickening,* and *twisting* during systole. Myocardial "deformation" refers to dynamic changes in shape and dimensions of the ventricular walls during the contractile cycle. The extent or magnitude of this change is called **strain**. The rate of this change is called the **strain rate**. Echocardiographic techniques—tissue Doppler imaging (TDI) and speckle tracking echocardiography (STE)—are used to assess myocardial motion (velocities) and deformation (strain and strain rate) along the vectors shown

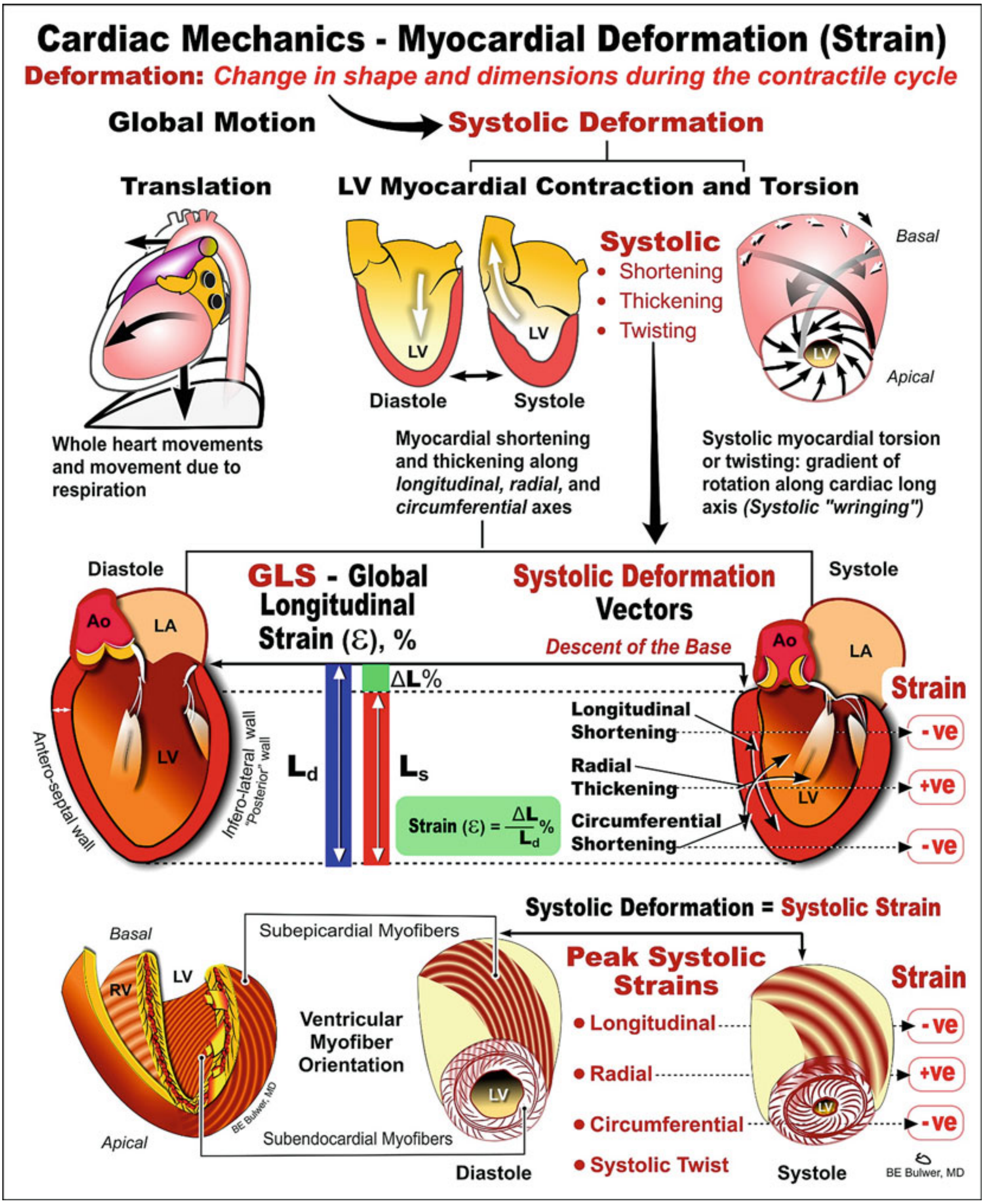

Fig. 21.30 Myocardial "deformation" refers to dynamic change in shape and dimensions of the ventricular walls during the contractile cycle. The extent or magnitude of this change is called **strain**. The rate of this change is called the **strain rate**. Global longitudinal strain, which reflects the degree of LV contractile function along the cardiac long axis, is a widely used parameter. It can be measured by tissue Doppler Imaging (TDI) and speckle tracking echocardiography (STE)

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22 Anesthesia Considerations in Global Cardiac Surgery Capacity Development in Emerging Countries

Patrick N. Odonkor and Samhati Mondal

Abstract

Cardiac surgery is a complex specialty that requires significant investment in medical personnel, medical equipment, and medical facilities along with support from private, international and governmental agencies for successful outcomes. Multiple medical subspecialties are involved, including cardiac surgeons, anesthesiologists, nurses and perfusionists. Cardiac anesthesiologists are involved in the preoperative, intraoperative and postoperative management of cardiac surgical patients. Appropriate preoperative management ensures optimization of cardiac surgical patients prior to surgery and improves patient outcomes and satisfaction. Intraoperative management during cardiac surgical procedures involves a very high level of communication and coordination amongst medical personnel taking care of the patient in the operating room. The anesthesiologist is also involved in postoperative pain control and hemodynamic management. Experienced cardiac anesthesiologists play a very significant role in global cardiac surgery development. Apart from perioperative risk stratification and management, they are also involved in training local medical personnel and ensuring that safe clinical standards are adhered to as cardiac surgery capacity increases.

Keywords

Anesthesia · Cardiac surgery · Preoperative management · Intraoperative management · Postoperative management · Monitoring · Echocardiography · Cardiopulmonary bypass

ABG	Arterial blood gas
ACEI	Angiotensin-converting enzyme inhibitor
ACT	Activated clotting time
ASA	American Society of Anesthesiologists
ASD	Atrial septal defect
ASE	American Society of Echocardiography
BP	Blood pressure
CABG	Coronary artery bypass graft
COP	Cardiac output
COPD	Chronic obstructive pulmonary disease
CPB	Cardiopulmonary bypass
CS	Cardiac surgery
CVP	Central venous pressure
EACVI	European Association of Cardiovascular Imaging

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_22

ECMO	Extracorporeal membrane oxygenation
EEG	Electroencephalography
EKG	Electrocardiography
ESHD	End-stage heart disease
GA	General anesthesia
HbA1c	Hemoglobin A1c
IABP	Intra-aortic balloon pump
ICU	Intensive care unit
IM	Intramuscular
IV	Intravenous
LMIC	Low- and middle-income countries
LV	Left ventricle
LVAD	Left-sided ventricular assist device
MCA	Middle cerebral artery
MCS	Mechanical circulatory support
MIDCAB	Minimally invasive direct coronary artery bypass
NBE	National Board of Echocardiography
OPCAB	Off-pump coronary artery bypass
OR	Operating room
PA	Pulmonary artery
PAC	Pulmonary artery catheter
PEEP	Positive end-expiratory pressure
ROTEM	Rotational thromboelastometry
$rScO_2$	Regional cerebral oxygen saturation
RV	Right ventricle
SCA	Society of Cardiovascular Anesthesiologists
TAVR	Transcatheter aortic valve replacement
TCD	Transcranial Doppler
TEE	Transesophageal echocardiography
TEG	Thromboelastography
TMVR	Transcatheter mitral valve replacement
TOE	Transoesophageal echocardiography
TTE	Transthoracic echocardiography
VAD	Ventricular assist device
VS	Vasoplegic syndrome

22.1 Introduction

Cardiac surgery (CS) is not readily available in low- and middle-income countries (LMIC) due to existing worldwide disparities in availability and quality of CS care. These disparities occur both within and between world regions. Access to high-quality, safe, efficient and reliable CS centers in LMICs can be achieved with significant commitment to and investment in medical personnel, medical equipment, medical facilities and other essential resources. Sources for this support include private, international and governmental agencies around the world [1]. There are currently no well-recognized methods for the establishment of CS centers in LMICs. During the initiation phase of CS centers, professional and technical support for local medical teams is usually provided by medical personnel from well-established CS centers. In some instances, medical support teams consisting of cardiac surgeons, anesthesiologists, nurses and perfusionists from established CS centers have been sent to emerging countries to facilitate the establishment of CS centers. As the local medical team gains experience in the new environment and the workload increases, this external support is gradually withdrawn [2]. CS is complicated and requires a high level of coordination among multiple medical subspecialties to be successful. There is very little margin for error. To minimize potential for errors, complications and poor outcomes during the establishment of a new CS center, initial cases should be relatively straightforward cases in low-risk patients.

As with healthcare in general, disparities in the quality and availability of experienced physicians providing anesthetic care for surgical procedures exist within and between world regions. Reliable perioperative anesthetic care is critical for the establishment of successful CS centers in emerging countries. The anesthesia management team for CS should be led by an experienced cardiac anesthesiologist. Equipment for delivery of anesthetic care, such as anesthesia machines, airway equipment, vascular access devices and hemodynamic monitoring equipment like echocardiography machines, should be readily available with a reliable pathway for replenishment of supplies. Support services for delivery of anesthetic care, such as anesthesia technologists, equipment maintenance technicians and echocardiography technologists, should also be available. A cardiac anesthesiologist should be involved in the supervision and training of other anesthesiologists, anesthesiology residents or nurse anesthetists, thereby developing a framework for maintaining staffing requirements as capacity for CS increases with time. Anesthetic management starts from the preoperative period, continues through the intraoperative period and extends into the postoperative period.

22.2 Preoperative Anesthetic Management

Patients undergoing CS are at high risk for perioperative morbidity and mortality due to high prevalence of significant comorbidities, advanced age and the complex nature of CS procedures. For elective CS, anesthetic management starts with the preanesthetic evaluation, which is usually performed in a preanesthetic clinic. Active participation by a consultant anesthesiologist in the preanesthetic clinic leads to an improvement in patient satisfaction and outcomes [3]. Components of the preoperative anesthetic consultation include acquisition of a comprehensive medical history and preoperative medication review. A physical examination is performed along with review of diagnostic laboratory and cardiopulmonary function test results. During this visit, a perioperative anesthetic management plan is developed and shared with the patient for education and alleviation of anxiety. Informed consent is also obtained. Last-minute cancellations of elective surgical procedures can be avoided by performing timely preanesthetic assessments. Decisions to postpone surgery for patient optimization must also consider the potential harm from delaying surgery. Use of perioperative risk prediction models in CS such as Euroscore II [4] and the Society of Thoracic Surgeons cardiac risk models [5–7] improve perioperative management decision making and facilitate appropriate planning and allocation of critical care resources. For urgent and emergent cases, there is less time available for any potential preanesthetic interventions.

22.2.1 Preoperative History

In regions of the world where primary healthcare may not be readily available, scheduling the preanesthetic evaluation several days ahead of the day of surgery facilitates timely detection and multidisciplinary management of pre-existing medical conditions. It is also important to screen for conditions that are unique to the region where surgery is being performed such as poor general health, nutritional deficiencies, and endemic infections such as malaria. Preoperative identification of pre-existing medical problems and risk stratification guide the formulation of anesthetic management plans that improve clinical outcomes. Some of the more commonly encountered pre-existing medical conditions in CS patients are diabetes mellitus, systemic hypertension, atherosclerotic disease of the carotid arteries, pulmonary diseases, renal insufficiency and anemia.

22.2.1.1 Diabetes Mellitus

Risk stratification can be done in diabetic patients by measurement of preoperative hemoglobin A1c (HbA1c) levels. Elevated levels have been shown to be a strong predictor of morbidity and mortality in patients having coronary artery bypass graft (CABG) surgery [8]. Apart from attempting to achieve blood sugar control prior to surgery, diabetic patients should also be screened for potential complications in other organ systems such as the renal insufficiency.

Hyperglycemia is known to be an independent risk factor for the development and progression of chronic kidney disease [9].

22.2.1.2 Systemic Hypertension

Poorly controlled hypertensive patients are at increased risk for cardiovascular complications such as ischemic heart disease, congestive heart failure, stroke and renal failure. Hypertensive patients should be screened in the preanesthetic clinic for target organ damage arising from pathophysiologic changes in the cardiovascular system. Perioperative management should be individualized. Patients presenting in the pre-anesthetic clinic with uncontrolled hypertension are at increased risk for hypoperfusion and organ damage during perioperative hypotensive episodes [10].

22.2.1.3 Atherosclerotic Disease of the Carotid Arteries

There is currently no consensus on the management of patients with atherosclerotic disease of the carotid arteries who present for CABG surgery. Patients presenting with severe bilateral carotid stenosis and patients with a history of stroke or transient ischemic attack are at increased perioperative risk for stroke. Carotid revascularization with carotid endarterectomy or carotid artery stenting prior to CS may be beneficial in this group of patients. There is no evidence that prophylactic carotid revascularization in patients with unilateral asymptomatic carotid stenosis prevents perioperative stroke after CS. An individualized approach to perioperative management of carotid stenosis involving a multidisciplinary team of cardiologists, neurologists, endovascular specialists, and vascular and cardiac surgeons is recommended. Decisions about performance of a simultaneous or staged vascular and CS procedure are dependent on local expertise. Perioperative stroke associated with CS may arise from thromboembolism, hemodynamic instability, inflammatory conditions or lower levels of antiplatelet therapy [11, 12]

22.2.1.4 Pulmonary Disease

Commonly encountered pre-existing pulmonary disease in CS patients include chronic obstructive pulmonary disease (COPD), bronchial asthma, restrictive lung diseases and infectious lung diseases. Factors associated with increased postoperative pulmonary risk include age >50 years, body mass index >40 $kg.m^{-2}$, American Society of Anesthesiologists (ASA) physical status >2, obstructive sleep apnea, preoperative anemia, preoperative hypoxemia, emergency or urgent surgery and ventilator duration >2 h [13]. They may cause postoperative pulmonary dysfunction, prolonged mechanical ventilation, prolonged hospitalization and increased risk for poor outcomes. Preoperative physical therapy and optimization of pulmonary function prior to surgery may be used as prophylactic interventions for lung protection. Infections should be treated prior to surgery. Planning for the use of other interventions such as early extubation and use of noninvasive ventilation, bronchodilators and steroids may reduce perioperative risk for poor outcomes [14].

22.2.1.5 Renal Insufficiency

Patients having CS are at increased risk for renal insufficiency due to the nature of the surgical procedure, hemodynamic changes, hemodilution, thromboembolic events and the use of cardiopulmonary bypass (CPB). Preoperative diagnosis and risk stratification for renal insufficiency facilitates perioperative management to improve outcomes after CS. Renal protective strategies include delay of elective surgery to optimize renal function and avoidance of exposure to nephrotoxic agents. There is limited evidence that withholding angiotensin-converting enzyme inhibitors (ACEI) and angiotensin receptor blockers in the preoperative period is associated with reduced incidence of acute kidney injury and that correction of preoperative hypoalbuminemia may be renoprotective in off-pump CS [15]. Avoidance of perioperative hyperglycemia also decreases risk for chronic kidney disease [9].

22.2.1.6 Anemia

Anemia is not uncommon in the population of patients presenting for cardiac surgery. Patients with anemia are at high risk for perioperative blood transfusion. Elective surgery should be postponed in anemic patients and should be evaluated for the underlying cause and corrected appropriately to minimize perioperative transfusion requirements as part of a blood conservation strategy [16]. Interventions for the management of anemia are determined by the underlying cause and include iron, erythropoietin, vitamin B12 and folate supplementation. Gastrointestinal and other potential hemorrhagic lesions should be ruled out aggressively prior to CS procedures because of the risk for significant hemorrhage from anticoagulation during CPB. Coagulation abnormalities should also be evaluated carefully and managed appropriately, since CPB itself may be associated with significant coagulation deficits. Warfarin and direct oral anticoagulants should be withheld for an appropriate number of days prior to elective surgery whereas in emergent cases anticoagulation effects may be antagonized with agents such as vitamin K, prothrombin complex concentrate or transfusion of fresh frozen plasma, depending on clinical presentation. Preoperative risk factors associated with bleeding and blood transfusions include advanced age, low red blood cell volume, congenital and acquired coagulation abnormalities, and performance of urgent or complex surgical procedures associated with prolonged CPB. Perioperative blood conservation strategies should be used to mitigate the need for allogeneic blood transfusion [16, 17].

22.2.2 Preoperative Medications

The patient's medications should be reviewed during the preanesthetic evaluation. Current recommendations for the discontinuation and resumption of anticoagulants and platelet inhibitors in CS patients are based on preoperative ischemic risk and on intraoperative and postoperative bleeding risk [18, 19]. Patients at high risk for preoperative ischemia should continue taking their antithrombotic medications and resume taking them as soon as possible after surgery. Bridging therapy with heparin may be considered where appropriate in patients who are on chronic anticoagulant therapy. Recommendations for perioperative management of patient medications should be made in consultation with the physician prescribing them and should be explained to the patient. Whereas some agents such as ACEIs and antiplatelet agents may be held prior to elective surgery, others such as antianginals, beta blockers, analgesics and anxiolytic agents should be continued until the day of surgery. In geographic regions where a significant proportion of patients may be on local herbal supplements, it is important for the anesthesiologist to determine what the active components of these supplements are and their potential effects on aspects of perioperative management such as coagulation and drug interactions.

22.2.3 Physical Examination

Physical examination of the patient must be performed during the preoperative clinic visit. The airway is assessed for ease of intubation and for dental abnormalities that could potentially be a source for bacterial infection especially in patients undergoing valve replacement procedures. Access sites for invasive arterial and venous sheaths should be evaluated along with skin integrity to rule out any potential infectious lesions. Pre-existing physical disabilities such as weakness in extremities, visual impairment and neck stiffness should be carefully documented. The patient should also be assessed for potential esophageal lesions that may affect the performance of transesophageal echocardiography (TEE).

22.2.4 Preoperative Laboratory Evaluation

Most patients presenting for cardiac surgery have already undergone cardiac diagnostic studies such as electrocardiography (EKG), echocardiography and cardiac catheterization. The results of these studies should be available to the anesthesiologist and should be used as a guide for formulating a plan for anesthetic management. All available blood tests should also be reviewed and should include a complete blood count, coagulation profile and a basic metabolic panel. Additional tests such as liver function tests, thyroid function tests and pulmonary function tests should be available where indicated. Radiological tests such as chest X-rays and CT scans are also usually available for review. Abnormal results should be addressed appropriately prior to surgery.

All patients should have cross-matched blood available prior to surgery. The type and quantity of required components depend on the results of the complete blood count and coagulation profile and the type of surgery being performed. At minimum, there should be 2 units of packed red blood cells available. Prior to starting the surgical procedure, the anesthesiologist should also verify the ability of the local blood bank to meet unforeseen demands for more blood components, should the need arise.

22.3 Intraoperative Anesthetic Management

In general, most patients already have peripheral intravenous (IV) access established and have received premedication prior to arrival in the operating room (OR). Hemodynamic monitors should be applied to the patient prior to induction of general anesthesia (GA) in the OR. Baseline TEE study should then be performed as surgery begins. After appropriate anticoagulation has been established, arterial and venous cannulations should be performed for the establishment of CPB. At the end of surgery, the patient should be weaned off CPB, anticoagulation should be reversed and the patient's chest should be closed prior to transport to the intensive care unit (ICU).

22.3.1 Premedication

Premedication is necessary to allay anxiety and to manage painful conditions prior to induction of anesthesia. These goals may be achieved by careful administration of oral, IV or intramuscular (IM) benzodiazepines (midazolam, diazepam) or opioid analgesics (fentanyl, morphine). Doses should be individualized based on the patient's medical condition. It is also important to confirm that the patient has adhered to instructions for preoperative medication administration.

22.3.2 Monitoring

Monitoring provides real-time clinical data about the patient during surgery. The anesthesiologist should understand the limitations of the monitored variables and use them appropriately to guide therapeutic interventions. Because of the complexity of CS cases, which typically involve the use of CPB, patients having CS are at higher risk for intraoperative complications than patients having less complicated forms of surgery. There is significant variability in intraoperative and postoperative monitoring among various CS centers during similar CS procedures [20, 21].

22.3.2.1 Standard Monitors

All patients are monitored with standard ASA monitors for oxygenation, ventilation, circulation and temperature. Monitoring should be initiated on arrival in the operating room with pulse oximetry, 5-lead EKG, noninvasive blood pressure (BP) and body temperature measurements. Arterial cannulation for invasive BP measurement and central venous cannulation with or without pulmonary artery catheter (PAC) insertion may be initiated before or after induction of GA. Once the airway has been secured, capnography, concentrations of delivered anesthetic gases and respiratory hemodynamics such as tidal volume and airway pressures should also be monitored, along with neuromuscular blockade monitoring.

22.3.2.2 Blood Pressure Monitoring

Systemic BP may be monitored invasively by placing a catheter in the radial, brachial, axillary and femoral arteries. Arterial catheterization also makes it possible to draw blood for gas analysis and is usually left in place for postoperative management.

The internal jugular, subclavian or femoral veins may be catheterized during CS for monitoring central venous pressure (CVP) and also provide large bore venous access to allow rapid fluid and vasoactive medication administration. Venous catheterization should be done safely with real-time ultrasound guidance for vein localization to minimize complications [22]. A multi-lumen central venous catheter or an introducer sheath may be inserted.

Pulmonary artery (PA) pressure may be monitored with a PAC that is positioned through an introducer sheath. There are no standardized guidelines for the use of PACs during CS. The PAC provides real-time information on PA pressure, CVP, pulmonary capillary wedge pressure, blood temperature, cardiac output (COP) and mixed venous oxygen saturation. PACs may be used to guide therapy both intraoperatively and during postoperative management. It is probably more useful in the management of high-risk patients with heart failure, pulmonary hypertension, multiple comorbidities, and in patients having high-risk procedures such as multiple valve surgery and aortic arch surgery. Although intraoperative use of the PAC has not been shown to improve perioperative outcomes, it is still widely used based on local preference. TEE may be used as a supplemental or alternative hemodynamic monitoring tool along with or in place of the PAC intraoperatively. TEE may however not be readily available during postoperative management [23–27].

22.3.2.3 Cardiac Output Monitoring

Cardiac output (COP) is equal to the product of stroke volume and heart rate. Maintenance of an adequate COP is dependent on cardiac preload, contractility and afterload. The gold standard for measurement of COP is the thermodilution method with a PAC. It can also be assessed by TEE. There are, however, other minimally invasive or noninvasive methods for measurement of COP. Minimally invasive methods are obtained from pulse wave analysis of arterial catheter pressure waveforms and esophageal Doppler analysis of blood flow in the descending aorta. Noninvasive methods include pulse wave analysis, measurement of pulse wave transit time, and thoracic electrical bioimpedance and bioreactance. Safe use of these newer monitors requires a thorough understanding of their measurement principles and their limitations [28].

22.3.2.4 Temperature Monitoring

A Foley catheter with temperature sensing capability is used to monitor urine output and core body temperature. In patients with end-stage renal disease and where urine output is not expected, a rectal temperature probe may be substituted for bladder temperature. Significant drops in core body temperature at the end of surgery may cause coagulopathy and myocardial ischemia.

A nasopharyngeal or tympanic membrane temperature probe or PAC may be used as a monitor for cerebral temperature. Cerebral hyperthermia may occur during CPB and is associated with cerebral injury. Cerebral hyperthermia may be prevented by keeping the CPB circuit oxygenator arterial outlet blood temperature below 37 degrees Celsius. When setting the temperature, the perfusionist should assume that oxygenator arterial blood temperature underestimates cerebral perfusate temperature during rewarming on CPB. While on CPB, temperature gradients between the arterial outflow and venous inflow to the oxygenator should be kept below 10 degrees Celsius to minimize risk of gas embolism [29, 30].

22.3.2.5 Brain Monitoring

Neurological complications after CS include stroke, which may be major or minor, and cognitive changes, which may be subtle or overt. Postoperative neurocognitive dysfunction is the most frequently reported form of brain injury after CS [31]. These neurological injuries may occur secondary to arterial thromboembolism, global hypoperfusion, alterations in neurochemical or immune activity or other factors. Strategies that may reduce the occurrence of neurological complications include the avoidance of cerebral hyperthermia, minimization of cerebral thromboembolism and optimization of cerebral oxygen delivery by avoiding drops in cerebral perfusion pressure while maintaining appropriate hematocrit levels. Several monitors of brain function have been used during CS to minimize perioperative neurological complications.

Cerebral oximetry monitors regional cerebral oxygen saturation ($rScO_2$) in the frontal cortex of the brain by near-infrared spectroscopy. It is not a global cerebral monitor. Monitoring $rScO_2$ has not been definitively proven to reduce the incidence of neurological complications after CS; however, reductions in $rScO_2$ may detect CPB cannula malposition during aortic surgery [32].

The middle cerebral artery (MCA) carries about 40% of blood flow to the brain and can be monitored by transcranial Doppler (TCD) ultrasonography. Blood flow to the brain may be affected by patient neck position, cannulation of the aortic arch and its branches, and fluctuations in blood flow rates and pressure in the CPB circuit. TCD may also be used to detect the presence of thromboembolism of gaseous or particulate materials originating from the CPB circuit. TCD monitoring is not widely used in CS because there is a high incidence of artifacts and difficulty in maintaining appropriate probe position. Somatosensory evoked potential monitoring is also not widely used in CS because it is affected by several factors prevalent during CS, such as hypothermia, nonpulsatile flow and acid–base disturbances. Motor evoked potentials may however be used during thoracic aortic surgery [31].

Patients having CS are at increased risk for intraoperative awareness and recall because of a higher incidence of multiple comorbidities and hemodynamic instability arising from use of anesthetic agents and surgical manipulation of the heart. Awareness and recall can be minimized by monitoring end-tidal concentrations of volatile anesthetic agents to ensure that adequate amounts of anesthetic agents are being administered. Raw or processed electroencephalography (EEG) monitors of anesthetic depth such as the BIS (Covidien) or SedLine (Masimo) may also be used to monitor depth of anesthesia to reduce the incidence of awareness and recall [33, 34].

22.3.3 Induction and Maintenance of Anesthesia

CS is typically done under GA. A balanced technique with an IV induction agent (propofol, etomidate), an anxiolytic agent (midazolam, diazepam), an opioid analgesic (morphine, fentanyl, sufentanil, alfentanil), a non-depolarizing muscle relaxant (rocuronium, vecuronium) and a volatile anesthetic agent (sevoflurane, desflurane, isoflurane) is usually performed. Total IV anesthetic techniques (propofol, remifentanil) may also be used.

After securing the airway, obtaining vascular access and placing hemodynamic monitors, the patient should be carefully placed in the supine position with arms tucked at the side and neck carefully positioned to expose the jugular notch to facilitate sternotomy. Potential nerve injuries during CS may occur secondary to extreme stretch, pressure, heat or cold and may affect the brachial plexus, as well as the phrenic, recurrent laryngeal, intercostal, saphenous, and lateral femoral cutaneous nerves [35].

A first- or second-generation cephalosporin (cefazolin, cefuroxime) administered within 1 h of surgical incision and continued up to 48 h after surgery provides antimicrobial prophylaxis. Intraoperative redosing is recommended if the duration of the surgical procedure is greater than two half-lives of the agent used or when excessive blood loss is anticipated. Clindamycin or vancomycin may be used in patients with beta-lactam or penicillin allergy. Vancomycin should be used in patients with prior exposure to methicillin-resistant *Staphylococcus aureus* bacteria. Mupirocin should be administered preoperatively to eliminate staphylococcal nasal colonization. Additional gram-negative bacterial coverage may be obtained perioperatively with an aminoglycoside such as gentamicin [18, 36, 37].

22.3.4 Intraoperative Anesthetic Management Prior to Cardiopulmonary Bypass

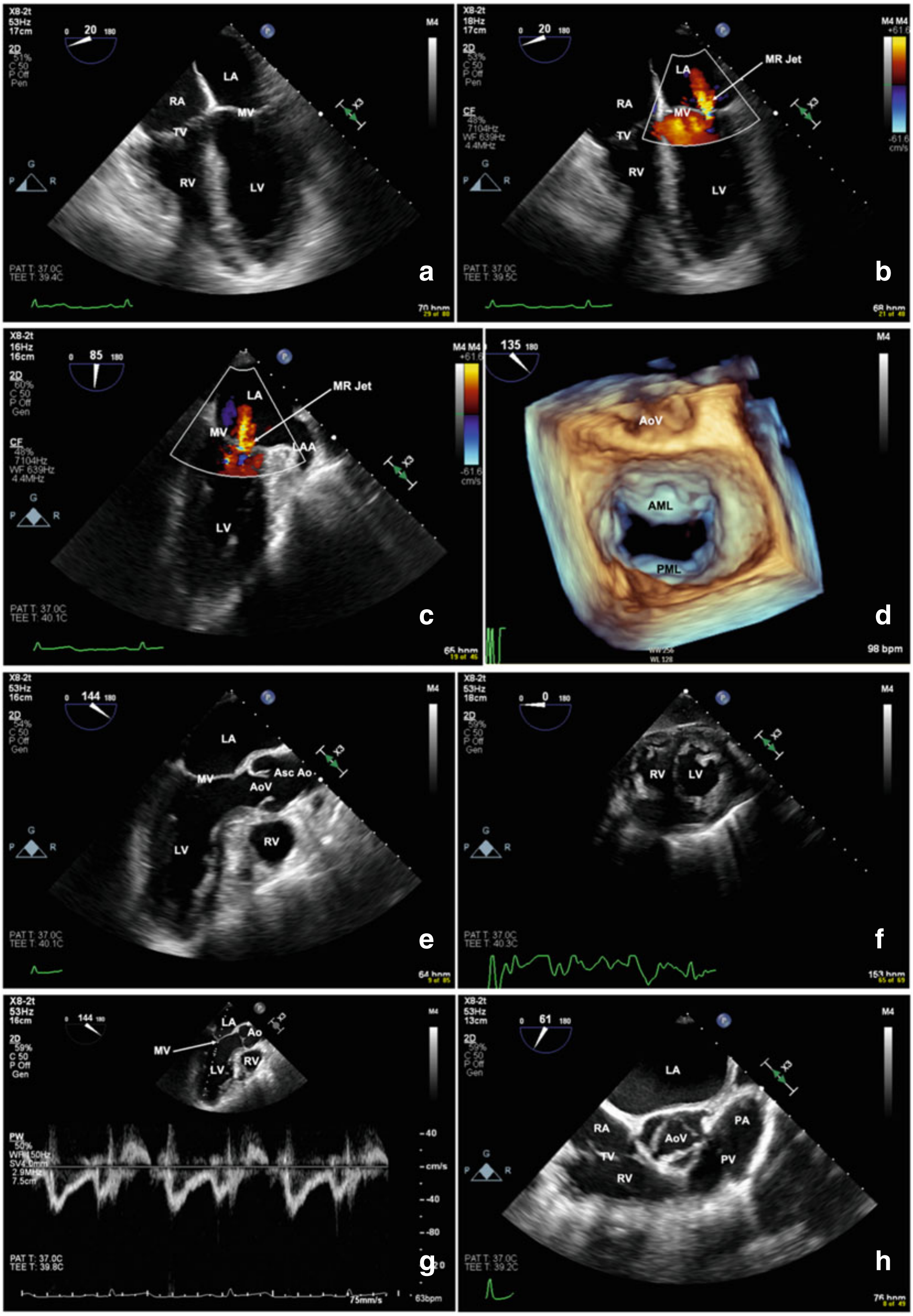
Goals of intraoperative anesthetic management during the pre-bypass period include the maintenance of stable hemodynamics and optimized oxygen delivery to tissues. Goal-directed therapy uses physiologic variables such as cardiac output, mixed venous oxygen saturation and stroke volume variation to guide administration of IV fluids, inotropes and vasopressors, and has been shown to improve recovery times with respect to ventilator dependency, ICU and hospital length of stay in high-risk CS patients [38]. Arterial blood gas (ABG) analysis monitors patient physiology while activated clotting time (ACT) monitors response to heparin prior to CPB. Blood conservation strategies include acute normovolemic hemodilution and the administration of antifibrinolytic agents such as lysine analogs (epsilon-aminocaproic acid or tranexamic acid) to minimize blood loss and blood transfusion requirements. Aprotinin is not used in the US due to safety concerns with respect to kidney injury and mortality. Magnitude of hemodilution occurring with initiation of CPB can be minimized with retrograde autologous and venous antegrade priming of CPB circuits, and use of mini circuits for CPB [16, 39, 40]. Intraoperative point-of-care tests such as rotational thromboelastometry (ROTEM; TEM International, Munich, Germany), thromboelastography (TEG; Haemonetics Corp., Braintree, MA, USA) or impedance platelet aggregometry (Multiplate; Roche Diagnostics, Rotkreuz, Switzerland) should be incorporated into an integrated transfusion algorithm to reduce intraoperative transfusion requirements and improve clinical outcomes [41, 42].

22.4 Intraoperative Transesophageal Echocardiography

Transesophageal echocardiography (TEE) has recently become an integral part of intraoperative management during anesthesia for CS. Intraoperative TEE may be used as a diagnostic or monitoring tool. In most cases, preoperative diagnosis of cardiac disease is made either by transthoracic echocardiography (TTE) or TEE, and the decision to undergo CS has been made prior to coming to the OR. Hence, the diagnostic value of intraoperative TEE is somewhat limited. Nevertheless, there are instances of diagnostic dilemma and instances where preoperative imaging may have missed a potentially operable finding that is diagnosed during intraoperative TEE, thereby changing the surgical plan based on intraoperative TEE findings. This adds to its diagnostic value. Post-bypass, TEE helps to evaluate prosthetic valve function for prosthetic valve stenosis or regurgitation, as well as paravalvular leaks. Valves that have been surgically repaired may also be evaluated. Additionally, TEE may be used to monitor the aorta for changes associated with atherosclerotic plaque and to diagnose post-bypass aortic dissection.

The role of TEE as a monitoring tool is invaluable during CS. A comprehensive TEE assessment evaluates global left ventricle (LV) and right ventricle (RV) systolic and diastolic function, valvular abnormalities, diseases of the aorta, pericardial or pleural effusions, and thrombi. Moreover, hemodynamic monitoring pre- and post-bypass can be reliably done by TEE. Examples of images obtained during a comprehensive TEE examination are shown in Fig. 22.1.

The American Society of Echocardiography (ASE) and the Society of Cardiovascular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◀ **Fig. 22.1** **a** Mid-esophageal four-chamber view. *LA, left atrium. LV, left ventricle. MV, mitral valve. RA, right atrium. RV, right ventricle. TV, tricuspid valve*. **b** Color flow Doppler of mitral regurgitant jet on mid-esophageal four-chamber view. *LA, left atrium. LV, left ventricle. MR Jet, mitral regurgitant jet. MV, mitral valve. RA, right atrium. RV, right ventricle. TV, tricuspid valve*. **c** Color flow Doppler of mitral regurgitant jet on mid-esophageal two-chamber view. *LA, left atrium. LAA, left atrial appendage. LV, left ventricle. MR Jet, mitral regurgitant jet. MV, mitral valve*. **d** Three-dimensional (3D) TEE en face view of the mitral valve. *AoV, aortic valve. AML, anterior mitral leaflet. PML, posterior mitral leaflet*. **e** Mid-esophageal long-axis view of the aortic valve. *AoV, aortic valve. Asc Ao, ascending aorta. LA, left atrium. LV, left ventricle. MV, mitral valve. RV, right ventricle*. **f** Transgastric short-axis view. *LV, left ventricle. RV, right ventricle*. **g** Pulsed wave Doppler showing flow across mitral valve. *Ao, aorta. LA, left atrium. LV, left ventricle. MV, mitral valve. RV, right ventricle*. **h** Mid-esophageal short-axis view of the aortic valve. *AoV, aortic valve. LA, left atrium. PA, pulmonary artery. PV, pulmonic valve. RA, right atrium. RV, right ventricle. TV, tricuspid valve*

Anesthesiologists (SCA) have collaborated to publish guidelines for appropriate use of intraoperative TEE [43]. Recognizing that performance, interpretation and clinical application of TEE require expertise and involve risk, these societies recommend use of TEE in the perioperative period by expert echocardiographers who have spent a significant amount of time training prior to performing and interpreting intraoperative TEE.

Indications for intraoperative TEE [44]:

1. TEE as a monitoring and diagnostic tool during CS procedures
2. Diseases involving cardiac structures, valves or the aorta where TTE is inconclusive or has a high likelihood of being inconclusive and performing TEE can make a significant difference in management strategy
3. TEE as a guiding tool in transcatheter-based CS procedures
4. Critically ill patients for whom TEE can direct further management during non-cardiac surgery (e.g., cardiac evaluation during perioperative hemodynamic instability)

Absolute contraindications to TEE [44, 45]:

1. Perforated esophagus
2. Esophageal stricture
3. Active GI bleeding
4. Esophageal and gastric tumors
5. Esophageal diverticulum

Relative contraindications to TEE [44, 45]:

1. Esophageal varices
2. Recent history of (H/O) GI bleed
3. H/O radiation to neck or mediastinum
4. H/O surgery on stomach or esophagus
5. Cervical arthritis or trauma
6. Esophagitis

Potential complications arising from the use of TEE [44, 45]:

1. Trauma
2. Bleeding
3. Perforation of esophagus
4. Dental and lip injury
5. Cervical radiculopathy caused be excess neck manipulation
6. Odynophagia, dysphagia
7. Bronchospasm, laryngospasm
8. Heart failure, arrythmias
9. Endotracheal intubation
10. Endotracheal tube malposition

22.4.1 Training Requirements for TEE Certification

22.4.1.1 National Board of Echocardiography [46]

The National Board of Echocardiography (NBE) was established in 1998 for the purpose of recognition and standardization of echocardiography skills among medical practitioners in North America. NBE diplomate status is awarded to applicants who satisfy all the criteria required for NBE certification, including clinical training and passing an examination with a requirement for recertification after a defined interval. Criteria for certification in advanced perioperative TEE

Table 22.1 Criteria for certification in advanced perioperative TEE (PTEeXAM) or adult echocardiography (ASCeXAM) by the NBE

Certification Requirements	Required Documents
1. Successful completion of the PTEeXAM or ASCeXAM	Documented proof of passing PTEeXAM or ASCeXAM
2. Current license to practice medicine	Copy of medical license with expiration date
3. Current medical board certification: Applicant must be board certified by a board that holds membership in the American Board of Medical Specialties, the Advisory Board for Osteopathic Specialties, the American Association of Physician Specialists, or the Royal College of Physicians and Surgeons of Canada	Copy of highest board certification
4. Specific training experience • **If applicant completed the PTEeXAM:** Applicant must have specific training and experience in the perioperative care of surgical patients with cardiovascular disease – *Fellowship pathway* – Candidate must have minimum 12 months of clinical fellowship in cardiovascular anesthesia or cardiothoracic disease where candidate has the opportunity to interact with and manage CS patients. This should be one year of training in addition to standard anesthesia residency – *Practice experience pathway* – Candidate must have exposure to taking care of CS patients for 24 months or more • **If applicant completed the ASCeXAM:** Applicant must have 24 months of training dedicated to adult cardiovascular diseases	*For the PTEeXAM fellowship pathway:* Copy of fellowship certification or a notarized letter from the program director certifying completion of fellowship with required number of TEEs *For the PTEeXAM practice experience pathway:* Notarized letter from the program director or the hospital certifying completion of fellowship with required number of TEEs *For the ASCeXAM:* Copy of fellowship certification or a notarized letter from the program director certifying completion of fellowship with required number of performed and interpreted echoes and date of completion of training
5. Specific training in TEE: Applicant must have performed, interpreted, and reported on 300 TEEs involving a wide variety of CS conditions under appropriate supervision. Among these 300 TEEs, at least 150 must have been personally performed by the applicant under appropriate supervision	Notarized letter from the program director or hospital certifying completion of fellowship with required number of TEEs

(PTEeXAM) or adult echocardiography (ASCeXAM) by the NBE are shown in Table 22.1.

22.4.1.2 European Association of Cardiovascular Imaging [47]

The European Association of Cardiovascular Imaging (EACVI) also has an adult transoesophageal echocardiography (TOE) certification program. Certification requirements include an online theoretical examination in the English language in multiple choice format. It consists of 50 echocardiographically displayed questions and 75 theoretical questions. There is a practical component to the requirements which consists of submission of a logbook of 125 TOE cases for initial certification and 75 cases for recertification.

22.5 Cardiopulmonary Bypass

Cardiopulmonary bypass (CPB) is a form of extracorporeal circulation used during the performance of most CS procedures. Safe conduct of CPB requires seamless communication between the surgeon, anesthesiologist and perfusionist. Anticoagulation for CPB is usually achieved with unfractionated heparin, which is subsequently reversed with protamine after weaning from CPB. An ACT target >350 s and heparin concentration level >2.0u/mL have been used safely during anticoagulation for CPB without any reported complications [48]. Altered heparin responsiveness may lead to failure to achieve the target ACT. This may be seen in patients with congenital or acquired antithrombin III deficiency, patients with recent exposure to heparin or nitroglycerin, and patients with high fibrinogen levels and thrombocytosis. Antithrombin III deficiency may be treated with recombinant antithrombin III or fresh frozen plasma. For patients in whom heparin is contraindicated, the direct thrombin inhibitors argatroban and bivalirudin are first-line alternative anticoagulants. They, however, have no specific reversal agent and may be associated with excessive bleeding [49, 50].

After heparinization, arterial and venous cannulation are established for CPB. Initiation of CPB leads to changes in physiology with respect to blood flow and ventilatory requirement. Other changes occur secondary to hemodilution, hypothermia and activation of the systemic inflammatory response, resulting in alterations in pharmacokinetics and pharmacodynamics of intravenous and volatile anesthetic agents [51]. Administration of anticoagulants and anesthetic agents on CPB, along with monitoring and manipulation of hemodynamics variables, is usually a collaboration between the perfusionist and anesthesiologist. There is no consensus on delivery of anesthetics on CPB, which is manifested by regional variations in clinical practice around the world [52]. Some of the recommended parameters in the CPB circuit that should be monitored on CPB include blood flow rate, CPB circuit pressure, oxygen saturation and blood temperature in the oxygenator arterial outlet and venous inflow, fresh gas flow rate to the oxygenator, cardioplegia delivery line pressure and temperature, and exhaust concentration of volatile anesthetic agents where available. Circuit blood should be analyzed for hemoglobin or hematocrit, electrolytes and ABG every half hour. Patient parameters that should be monitored on CPB include systemic BP, CVP, EKG, cerebral and body temperature, neuromuscular blockade, urine output, anesthetic depth and $rScO_2$ [51].

22.5.1 Weaning from Cardiopulmonary Bypass

At the end of the surgical procedure the patient should be weaned from CPB with TEE monitoring of myocardial and valvular function and intravascular volume status. Weaning from CPB requires close coordination between the surgeon, anesthesiologist and perfusionist. Standardization of weaning protocols, with the implementation of checklists and interventions that enhance teamwork and communication, improves patient safety, reduces errors and improves outcomes [53, 54].

Predetermined hemodynamic and physiological goals can usually be achieved safely with appropriate use of IV fluids, inotropes and vasoactive drugs [54–56]. Timely initiation of drug therapy should occur in association with appropriate fluid resuscitation. There is no widespread consensus about choice of inotrope and vasoactive agent. There is significant institutional variation with their use. Commonly used pure vasoconstrictors are phenylephrine, vasopressin and angiotensin II. Inotropic agents that also have vasopressor effects are norepinephrine, epinephrine and dopamine, whereas those with vasodilatory effects are dobutamine, milrinone, levosimendan and isoproterenol. Their therapeutic use should be individualized.

After the patient has been weaned from CPB, arterial and venous decannulation should be done. Systemic anticoagulation should then be pharmacologically reversed (e.g., protamine to reverse heparin), followed by chest closure when adequate hemostasis has been achieved.

22.5.2 Intraoperative Problems After Cardiopulmonary Bypass

After the patient has been completely weaned from CPB, TEE and hemodynamic monitors should be used to evaluate potential post-bypass problems such as cardiac dysfunction, hemodynamic dysfunction, excessive hemorrhage, metabolic derangements and pulmonary dysfunction. These problems may occur alone or in variable combinations.

22.5.2.1 Problems with Cardiac Function

Cardiac function after CPB is reliably evaluated with TEE. Myocardial dysfunction may occur in the LV, RV or both ventricles and may be caused by poor myocardial preservation on CPB, thrombosed or kinked coronary graft, or air embolism into a coronary vessel. Other causes include myocardial stunning, ischemia–reperfusion injury or mechanical problems arising from the surgical procedure such as valvular dysfunction and systolic anterior motion of the mitral valve causing left ventricular outflow obstruction. Post-bypass ventricular dysfunction is more likely to occur in patients with pre-existing ventricular dysfunction.

Initial therapy is with inotropes and vasoactive drugs. CPB should be reinstituted if there are potentially reversible surgical causes of cardiac dysfunction and in patients with inadequate response to drug therapy. There is significant institutional variation in the post-bypass use of inotropic and vasoactive agents. Epinephrine, dopamine, dobutamine, and milrinone are some of the commonly used inotropic agents. In the presence of RV dysfunction or pulmonary hypertension, a pulmonary vasodilator such as milrinone, inhaled nitric oxide or inhaled epoprostenol may be administered. Dysrhythmias may also adversely affect cardiac function and can be managed with temporary epicardial pacing, cardioversion or antidysrhythmic agents such as amiodarone or beta blockers.

A subset of high-risk patients remain in cardiogenic shock after separation from CPB and are unable to maintain adequate COP, tissue perfusion and oxygenation despite maximal therapy with pharmacological agents. Temporary mechanical circulatory support (MCS) may be provided for these patients with extracorporeal membrane oxygenation (ECMO), intra-aortic balloon pump (IABP) and/or ventricular assist devices (VADs). Requirement for pharmacologic support and MCS during weaning from CPB is independently associated with increased morbidity and mortality [57]. There is no widespread consensus or standardized guideline about the use of MCS after CPB. Timing for initiation of MCS and the type of MCS used during the weaning period are also variable and dependent on patient presentation, available institutional resources and institutional experience. In general, therapy should be initiated sooner rather than later and prior to the onset of significant metabolic derangement or end-organ dysfunction. ECMO use may be associated with significant complications arising from coagulopathy, impaired blood flow and thromboembolism. ECMO management requires significant resources and is associated with high cost [58]. IABP use is less resource-demanding with lower complication rates and may be used for hemodynamic support in ischemic or non-ischemic cardiogenic shock and also for LV or RV support [59–61]. There are commercially available short-term VADs such as the Impella system (Abiomed, Danvers, MA, USA), CentriMag (Thoratec, Pleasanton, CA, USA) and the TandemHeart (TandemLife, Pittsburgh, PA, USA) [62, 63]. These devices may be used to provide temporary MCS for both the LV and RV.

22.5.2.2 Hypotension and Hypertension

Hypotension after CPB may be caused by inadequate preload, impaired contractility or decreased afterload. Bradycardia and other rhythm disturbances such as supraventricular tachydysrhythmias may also cause hypotension. These underlying causes of hypotension may occur in isolation or in combination. Preload can be assessed by TEE, CVP or PA wedge pressure. Low preload can be corrected by careful administration of IV fluids. Excessive administration of IV fluids may cause pulmonary edema in patients with reduced left ventricular function or diastolic dysfunction.

Impaired contractility may occur in the LV, RV or both ventricles and is discussed in the previous section. Dysrhythmias that cause hypotension may require temporary pacing via epicardial leads, cardioversion or pharmacologic intervention.

Vasoplegic syndrome (VS) causes hypotension in 5–25% of patients after CPB [64]. It is characterized by a high or normal cardiac index and low systemic vascular resistance that is typically poorly responsive to therapy with goal-directed IV fluids and vasopressors. Vasopressors that may be used in the treatment of VS include phenylephrine, norepinephrine, vasopressin, dopamine, angiotensin II, vitamin C and methylene blue. Risk factors for the development of VS include preoperative use of an ACEI and IV heparin [65].

Protamine administration for reversal of heparin effect may be complicated by a rash, hypotension, an anaphylactic reaction and pulmonary hypertension [66]. Risk factors for protamine reactions are prior exposure to protamine or NPH insulin, allergy to shellfish and prior vasectomy.

Post-bypass hypertension may be due to systemic vasoconstriction and may occur in patients with pre-existing hypertension or hypothermia or in association with other humoral factors related to CPB. Hypertension may also be a response to pain due to light anesthesia. Systemic hypertension can be treated with vasodilators such as nitroglycerin, sodium nitroprusside, and calcium channel blockers. Light anesthesia should be managed by administering anesthetic agents and analgesics.

22.5.2.3 Excessive Hemorrhage

Excessive hemorrhage in the post-bypass period may be due to incomplete surgical hemostasis or coagulopathy. Distinguishing between the two is critically important and reduces the incidence of inappropriate blood transfusions and delays in return to the OR for surgical re-exploration. Excessive hemorrhage results in reduced preload and hypotension and may also cause cardiac tamponade. It leads to a sequence of complex events including increased transfusion of banked blood products, mediastinal re-exploration and infections, which are all associated with poor outcomes.

Incomplete surgical hemostasis may present as bleeding around suture lines, surgical graft sites and sternal wound sites. Patients of advanced age and those undergoing emergency surgery, redo sternotomies, multiple valve procedures and other complex surgical procedures such as aortic arch surgery are more likely to experience post-surgical bleeding from incomplete surgical hemostasis. Incomplete surgical hemostasis may occur in association with post-bypass coagulopathy.

Post-bypass coagulopathy is multifactorial in origin and may arise from activation of the coagulation cascade by prolonged contact of blood with the CPB circuit, inflammation, platelet dysfunction or fibrinolysis [67]. It may also occur secondary to residual heparin effect or preoperative undiagnosed or untreated coagulopathy [68]. Coagulopathic patients should be evaluated by point-of-care tests in the OR to guide therapeutic interventions and transfusion requirements.

22.5.2.4 Metabolic Abnormalities

Metabolic abnormalities that can occur in the post-bypass period include acid–base imbalance and abnormalities in serum glucose and electrolyte concentrations. Metabolic acidosis may arise from inadequate tissue perfusion or may be seen in patients with medical conditions like renal insufficiency. RV dysfunction and pulmonary hypertension are adversely affected by acidosis. Hyperglycemia may occur in both diabetic and non-diabetic patients during CS. Insulin should be administered with a blood sugar target of <180 mg/dL. Serum Potassium, Magnesium and Calcium concentration should be monitored and supplemented when levels are low. Hyperkalemia may be related to administration of cardioplegia or may be seen in patients with acidosis and renal failure. Abnormal serum potassium and magnesium levels may increase predisposition to cardiac dysrhythmias. Abnormal serum calcium levels may cause abnormalities with coagulation and myocardial function.

22.5.2.5 Pulmonary Dysfunction

Exposure to CPB, hypothermia, blood transfusions and anesthetic agents during CS may all lead to the development of noncardiogenic pulmonary edema, although pulmonary edema may also be cardiogenic in origin. Management of noncardiogenic pulmonary edema is usually supportive with the administration of diuretics and mechanical ventilation. In cardiogenic pulmonary edema, the underlying cardiac cause should also be appropriately managed.

Problems with ventilation after CPB may also occur secondary to atelectasis, pleural fluid collection or bronchospasm. Prior to separation from CPB, the lungs should be reinflated under direct visualization to minimize atelectasis while avoiding overdistention after evacuation of all pleural fluid collections. A strategy of lung-protective ventilation with use of low tidal volumes (6–8 $mL \cdot kg^{-1}$ predicted body weight) and positive end-expiratory pressure (PEEP = 5 cmH_2O) is associated with reduced risk of organ dysfunction and prolonged ICU stay [13, 69].

Bronchospasm during the post-bypass period may occur in patients with reactive airway diseases such as bronchial asthma and COPD. It may also be caused by hypersensitivity reactions to blood transfusions and medications. Severe cases of bronchospasm should be managed with bronchodilators, corticosteroids antihistamines and epinephrine. Severe pulmonary dysfunction associated with acute respiratory failure that does not resolve with therapy may require ECMO for ventilatory support.

22.6 Transport to ICU

At the end of surgery, the patient is transported from the OR to the ICU for handoff. There is high risk for hemodynamic instability and adverse events during transport. Most patients remain intubated at the end of CS, but straightforward cases without complications may be extubated in the OR. A typical CS patient is transported with monitors, IV infusions, and bag valve or mechanical ventilation. Other life support systems such MCS devices may also be required. The transport team usually consists of the cardiac anesthesiologist, a surgical team member and other individuals who help with moving the bed and other equipment. Technicians familiar with MCS equipment should be present during transport.

Continuous monitoring of BP, EKG and pulse oximetry should be done during transport to the ICU. Intubated patients should also be monitored with capnography. A short-acting IV anesthetic agent (propofol, dexmedetomidine) may be administered for sedation. The anesthesiologist should be ready to manage any significant changes in hemodynamics appropriately with IV fluids, inotropes, vasopressors or vasodilators while ensuring adequate mechanical ventilation. Equipment for securing the airway should be available for reintubation if accidental dislodgement of the endotracheal tube occurs. Potential problems that can occur with MCS devices include dislodgement of vascular access cannulae and equipment malfunction from technical issues. Individuals who are familiar with the equipment being used and who can manage problems associated with their use should always be present.

The receiving team in the ICU should be ready prior to patient transport. Communication of accurate and complete information from the OR team to the ICU team is critical. There is high potential for errors and incomplete transfer of information to the ICU team. CS centers should develop their own standardized structured protocol with clearly defined roles and sequence of events for OR to ICU handoff based on availability of local resources. Implementation of such a standardized protocol with a checklist reduces the incidence of adverse events and improves outcomes [70, 71]. Members of the handoff team should include an ICU receiving nurse, an ICU intensivist, a member of the surgical team and the cardiac anesthesiologist. The handoff team should be free of all distractions during handoff. In order to facilitate this, other members of the ICU team should be available to help receive the patient, transfer monitors and cross-check patient infusions and chest tube output.

22.7 Pain Control

Multimodal postoperative pain management after CS has an opioid-sparing effect which leads to a reduction in undesirable opioid effects such as sedation, respiratory depression, nausea, vomiting and ileus. Concomitant administration of non-opioid analgesic agents such as gabapentinoids, steroids, acetaminophen, lidocaine, dexmedetomidine and ketamine have been associated with reduced dosing of opioids [72]. Non-steroidal anti-inflammatory drugs and selective cyclo-oxygenase-2 inhibitors should not be routinely administered after CS because they may be associated with bleeding, renal dysfunction and thromboembolic events. The use of neuraxial anesthetic techniques have not been widely adopted in CS because of concerns about high risk for hemorrhagic complications and hemodynamic instability. There are now multiple ultrasound-guided regional anesthetic blocks that have been used relatively safely in the CS population as part of a multimodal analgesic management regimen and can lead to faster functional recovery and discharge after minimally invasive CS procedures [73]. Successful use of these blocks can also potentially reduce opioid requirements during the perioperative period.

22.8 Enhanced Recovery After Cardiac Surgery

Enhanced recovery after surgery is a global multimodal and multidisciplinary effort which uses evidence-based protocols to standardize perioperative care with a goal of improving clinical outcomes after surgery and reducing cost [74]. It was initially implemented in colorectal surgery but has now been introduced in many other surgical subspecialties. Cardiac surgery is a complex field involving multiple complicated surgical procedures in complicated patients with multiple pre-existing comorbidities being managed by multiple subspecialties. Standardization of care in this patient population is not straightforward. There are, however, published evidence-based guidelines for perioperative care in CS that may ultimately lead to greater standardization in global practice associated with improved clinical outcomes, quality of care, safety and cost [75].

22.9 Future Perspectives

The practice of CS is evolving rapidly around the world with advances and innovations in technology. Minimally invasive and transcatheter-based surgical procedures are gaining popularity and have been performed safely in many patients who may otherwise have been considered very high-risk for open CS due to age or pre-existing medical conditions. Minimally invasive direct coronary artery bypass (MIDCAB) has been shown to be efficacious in selected patient populations and is associated with less perioperative trauma and faster recovery. Similarly, off-pump coronary artery bypass (OPCAB) has been performed in many patients with multiple vascular occlusions where MIDCAB would not have been the best course of action [76].

Other noninvasive CS procedures that are being performed with increasing frequency include transcatheter-based procedures that are typically performed in hybrid ORs under fluoroscopic and TEE guidance. These procedures include transcatheter aortic valve replacement, clipping of mitral valve leaflets (MitraClip), transcatheter mitral valve replacement, left atrial appendage occlusion device placement (Watchman or Lariat), and closure of atrial septal defects and paravalvular leaks with a transcatheter-based occlusion device (Amplatzer devices).

Life expectancy in patients with end-stage heart disease (ESHD) is increasing because of advances in medical therapy. Patients with ESHD who have failed all conservative management and are awaiting heart transplant often need a left-sided VAD as a bridge to transplant. Some of these patients live the rest of their lives with the VAD (destination therapy). Newer models of VADs can also be placed using a minimally invasive approach which has the advantages of sparing the sternum, better right heart function, and earlier recovery after VAD placement.

Most of these advances and innovations in CS are not yet readily available in emerging countries, but it is not unreasonable to expect them to be performed in these regions of the world as global cardiac surgery capacity increases.

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23 Cardiopulmonary Considerations for Cardiac Surgery in Low and Middle Income Countries

Deborah McSparren, Joy Evangelin, Ya Wen Zhang, Emily Morrow, Rene J. Dekkers, David Watson, Jacques Kpodonu, and Kyle Spear

Abstract

To accomplish a successful cardiac surgery, cardiopulmonary bypass (CPB) is often utilized to give the surgeon a bloodless field while keeping the patient hemodynamically stable. The perfusionist is responsible for running the heart-lung machine and other devices such as: cell savers, anticoagulation and blood gas management or mechanical circulatory support. Critical times during CPB include going on, cross clamp on and off, cardioplegia delivery, and termination. Troubleshooting is a component that is often overlooked but can be detrimental to delivering the best patient care. To help eliminate these errors, checklists and protocols are put into place to make sure standardized measures are taken pre/intra/post CPB. Safety techniques like deep hypothermic circulatory arrest is performed for certain cardiac surgeries to prevent end organ damage. Perfusion technology is constantly evolving; however, this chapter looks to help build a solid foundation for understanding CPB and supporting devices.

Keywords

Cardiopulmonary bypass · Anticoagulation · Mechanical circulatory support · Cardiac surgery, hypothermia · Heart-lung machine

23.1 Brief History of CPB

The development of cardiopulmonary bypass was a major development in cardiac surgery and clinical medicine. Cardiopulmonary bypass allows a surgeon to correct cardiac defects while bypassing the heart and lungs. A machine takes over their function, oxygenating the blood and pumping the oxygenated blood throughout the body [1].

John Gibbon first became interested in the concept of taking deoxygenated blood from a patient with a pulmonary embolus and injecting oxygenated blood to help survival in 1931. Through the next two decades, he worked on developing a heart-lung machine [1]. Based on Gibbon's theories, several people tried to develop their own heart-lung machine and operate on patients with cardiac defects throughout the 1950s [1]. This machine would have to anti-coagulate the blood and reverse it, pump blood without destroying the red blood cells and oxygenate the

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_23

blood and remove carbon dioxide all while the heart and lungs were at rest [2]. For anticoagulation, Gibbon used heparin which was discovered in 1916 and went into clinical trials in the 1930s and heparin could be reversed with protamine [1]. For the pump, there were already pumps in the dairy and food industry that could be adapted [2]. For oxygenation, directly introducing oxygen caused issues like air, thrombosis and hemolysis. To resolve these issues, Gibbon introduced oxygen with a series of roller pumps which controlled the rate of delivery [3]. Gibbon successfully operated on a patient in 1953 to repair an ASD using his heart-lung machine design. However, his next couple of patients expired making the development of the technology an arduous task for which he took a break to further develop and improve his heart-lung machine [1].

Around the same time in the 1950s, five medical centers were involved in trying to develop a heart-lung machine [2]. Dr. C. Walton Lillehei and Dr. John W. Kirklin created two separate cardiac surgery programs partially based off of Gibbon's research. Lillehei operated on 45 children with 28 surviving over a two-year period and Kirklin operated on 8 children with 50% survival rate [3]. Research during this time continued to develop different and improving oxygenators, pumps and heat exchangers to improve cardiac surgery outcomes. In 1966, Dr. Richard DeWall developed a hard-shell bubble oxygenator with an integrated heat exchanger that was disposable which set the standard for years to come in cardiac surgery [1]. As a result of all this research and evolving technology, approximately 500,000 cardiac surgeries are performed each year with mortalities as low as 1% for some surgical types.

23.2 CPB Hardware Including Oxygenator and Pump

For cardiac surgery to be effective, blood must be diverted from the heart and the lungs and be returned to the systemic arterial system. To achieve this, a cardiopulmonary bypass machine is used to replace the function of both the heart and lungs during the operative procedure. Many different types of hardware are used to achieve this goal.

Cannulas

Cannulas are placed in the heart to direct blood towards the cardiopulmonary bypass machine and also to return oxygenated blood back to the patient. There are many different size cannulas, each having their own configuration. Venous cannulas are typically either single stage or two stage [4]. Two stage cannulas sit in the RA and the IVC and often times provide superior drainage over a single stage cannula. Venous cannulas can also be angled or straight and most are made of wire reinforced plastic to prevent kinking.

Arterial cannulas also come in many different types and sizes and are made to be inserted into the ascending aorta, axillary artery or femoral artery [4]. The arterial cannula returns blood that has been oxygenated by the cardiopulmonary bypass machine back to the patient's arterial system. Arterial cannulas provide the highest resistance within the cardiopulmonary bypass circuit therefore, arterial line pressures are typically measured to reduce hemolysis.

Blood pumps

Blood pumps within the cardiopulmonary bypass circuit are either positive displacement pumps (roller) or rotary pumps (centrifugal) [4]. Roller pumps work via positive displacement and their output is determined by the size of the raceway and the size of the tubing. Tubing is compressed within a raceway by the roller pump creating both positive pressure to propel the blood forward and negative pressure used for suction. Roller pumps can cause high shear stress to blood resulting in hemolysis and activation of platelets and white blood cells [4].

Centrifugal pumps consist of a disposable pump that is attached magnetically to a motor. These pumps offer very small priming volume and cause less hemolysis due to the lack of shear stress. Unlike roller pumps, centrifugal pumps are non-occlusive and are afterload dependent. However, centrifugal pumps are more expensive than roller pumps. Centrifugal pumps also require a blood flow meter to provide an accurate blood flow reading.

Oxygenators

An integral part of the cardiopulmonary bypass machine is the oxygenator which replaces the function of the lungs during the operation. CO_2 is removed from venous blood and also an increase in PO_2. Currently oxygenators used for cardiac surgery are hollow fiber membrane oxygenators. The fibers of the cardiopulmonary bypass oxygenator are made from polypropylene [4]. With hollow fiber oxygenators, blood flows around the fiber bundle and oxygen flows through the fibers of the oxygenator. These oxygenators are typically used for a time period of hours (less than 6), sufficient time for the cardiac operation to be completed and to reduce the incidence of plasma leakage. For longer term oxygenation, like extracorporeal membrane oxygenation (ecmo), oxygenators are made from polymethylpentene. These fibers resist plasma leakage and therefore are a better option longer periods of support.

23.3 Hemodilution and Priming Solutions

Historically, studies have shown that hemodilution is effective in reducing morbidity associated with CPB. The type of priming solution and volume of prime vary between institutions. Broadly they are classified as

- Crystalloid solutions (Lactated Ringers, Plasmalyte, Normal Saline)
- Colloid solutions (Albumin, Plasma)

Modern priming solutions have osmolarity and electrolyte content which are very similar to plasma. Most commonly used priming solutions are crystalloid, although some practices, add a colloid to their prime for longer pump runs to reduce excessive edema [1]. Some institutions have a standard priming volume for all adult patients whereas, others vary their priming volume based on patient weight or body surface area (BSA). The degree of hemodilution can be determined based on patient weight, preoperative hematocrit (HCT), amount of fluid administered pre CPB and the priming volume.

$$\text{Predicted Hct on } CPB = \frac{\text{Patient RBC Volume before CPB}}{\text{Patient estimated blood volume} + CPB \text{ volume} + pre\ CPB\ IV \text{ fluid volume}}$$

- I unit of RBC/whole blood = 150 ml RBC volume
- Estimated blood volume = patient weight*0.08 for infants, 0.075 for children and men, 0.07 for women.

Hemodilution has a positive effect on perfusion by reducing blood viscosity and improving regional blood flow thereby increasing oxygen delivery to the tissues. Most centers try to achieve a HCT <30% on CPB to ensure end organ perfusion. This can be achieved with a priming volume of 1000 ml-1500 ml in adults. Patients with a high pre-bypass Hct or higher blood volume may require pre-pump phlebotomy or additional dilution on CPB [1]. Conversely, a technique known as retrograde autologous priming (RAP) is employed in some centers to reduce hemodilution. Hypothermia also plays a role in determining the level of hemodilution on CPB. Studies show that HCT <20% may be associated with abnormal distribution of flow to organs.

Hemodilution can lead to a decrease in the plasma colloid oncotic pressure due to dilution of plasma proteins. Some institutions use a colloid solution (like 5% or 25% albumin) in the prime to attenuate these changes. Studies have shown no significant differences between the two groups post operatively [1].

Additionally, following components may be added to the prime depending on the institution [1].

- Heparin 10–25 mg—to provide additional safety to systemic heparinization
- Mannitol 25–50 mg—helps prevent tissue edema and induces osmotic diuresis

- Corticosteroids-prevents activation of inflammatory process during CPB
- Calcium 200 mg/L of prime-used in pediatric patients to prevent chelation of circulating calcium if citrated blood is added to prime.

23.4 Conduction of CPB

The conduct of cardiopulmonary bypass (CPB) involves staff from different disciplines who function together as a team. These members include the surgeon, anesthesiologist, perfusionist and nursing that must effectively use communication throughout the case for a successful outcome for the patient [1].

Satisfactory CPB means that the circuit has effectively taken over for the heart and lungs in order for the surgeon to perform the surgery on the heart. To do this the circuit must first be assembled, consisting of disposable items and reusable equipment. The patient's chart must also be reviewed to choose the appropriate equipment based on the patient's needs, i.e., different size circuits are used based on patient size in pediatric cardiac surgery but in adult cardiac surgery the circuit is usually standardized [1]. Once the circuit is assembled, the perfusionist then primes it with a crystalloid solution to remove all air. If there is air present on the arterial side then the patient could get an air embolism or if air is present on the venous side, the perfusionist may experience an air lock so it is crucial that all air is removed, including micro-air, from the circuit [5].

Once the circuit is primed and the surgeon is ready, heparin is then administered as an anticoagulant based on the patient's size. The surgeon can then cannulate the patient, arterial and venous, to connect to the circuit. Once an adequate activated clotting time (ACT) is achieved, a goal of 480 s at many institutions, the perfusionist can then initiate bypass [6]. The perfusionist opens up the venous and arterial clamps, initiates adequate flow and oxygenation for the patient and anesthesia stops ventilating [6]. Adequate flow is usually based on a cardiac index of 2.2 to 2.4 L/min/m^2 [1]. While initiating bypass, many factors need to be assessed to achieve flow and oxygenation and if there are any issues then the perfusionist needs to troubleshoot the problem [6].

Once full flows are obtained then the surgeon can now cross clamp to continue the surgery. Cross clamping causes the heart to be ischemic and cardioplegia is given, either antegrade or retrograde or both into the coronary arteries, for myocardial protection. The cardioplegia solution contains potassium and is usually cold to achieve an electromechanical arrest and reducing myocardial oxygen consumption [5]. After this occurs, the surgeon can now perform the surgery. During the bypass period, the perfusionist must monitor and adjust as necessary many physiologic and circuit variables including blood pressure, temperature, arterial blood gases with oxygenation, EKG, coagulation status and renal function in the form of urine output among many other variables [5].

Towards the end of the surgery, the perfusionist will be instructed to warm up the patient to normothermia. Once the surgery is complete, the surgeon removes the cross clamp, reintroducing warm blood to the heart and reestablishing sinus rhythm or at least an acceptable EKG. At this point the perfusionist will prepare to wean off bypass and anesthesia will start to ventilate again. To do this, a partial clamp is placed on the venous line and arterial flow is reduced while the arterial pressure is brought to an acceptable level. Once flow is at low levels and the patient's pressure has normalized, the perfusionist will clamp the venous and arterial lines to terminate bypass. The remaining blood in the circuit will either be given directly to the patient through the arterial line or salvaged in the cell saver [6].

23.5 Troubleshooting During CPB and Management

CPB emergencies can be categorized into two broad categories based on the origin of the event they are patient emergencies and equipment emergencies. Although uncommon, CPB emergencies may happen suddenly and requires a team approach to achieve the best patient outcome. Team communication is crucial when encountering CPB emergencies and the communication must be promptly initiated by the perfusionist. Perfusionists utilize safety checklist in every case to ensure perfusion-related problems are prevented wherever possible, and backup equipment is available and functional for when they are needed. Perfusionists should always have a high index of suspicion for CPB-related emergencies when monitoring equipment and patients, to ensure problems are diagnosed early and managed quickly when they do occur

Patient emergencies during CPB

1. Malposition of arterial cannula

Malposition of the arterial cannula into the arterial wall may lead to dissection of the aorta when initiating CPB. This happens in 0.06% of cases [7]. This can be detected by checking the pressure and pulsatility of the arterial tubing prior to the initiation of CPB. In addition, whenever possible, the position of the aortic cannulae should be visualized on TEE for second confirmation. If the malposition was not detected prior to the commencement of CPB and an aortic dissection is created, CPB must be discontinued. A protocol for surgical repair of aortic dissection must then be followed.

Another common malposition of the arterial cannula occurs when aortic cannula tip is very close to the opening of the innominate artery or the left carotid artery, leading to the hyperperfusion of the head [7]. Hyperperfusion of the head may lead to cerebral edema, even arterial rupture. Symptoms of hyperperfusion of the head are facial flushing, pupillary dilation, and conjunctival edema. Hyperperfusion of the head may also involve hypoperfusion of the lower body. This may exhibit as low MAP measured on left radial and femoral arterial lines. When this occurs, surgeon will need to reposition the aortic cannula and attempt to reduce cerebral edema with medication (Mannitol) and reverse Trendelenburg position [7].

2. Reversed cannulation

Reversed cannulation happens when the arterial line of the CPB circuit is connected to the venous cannula, and the venous line is connected to the arterial cannula. One will suspect this misconnection of the tubing to cannula when observing very low arterial pressure and very high central venous pressure despite being on full CPB flow [7]. When vacuum is used for venous drainage assistance with reversed cannulation, there is a high risk of entrainment of air in the aortic cannula, which may lead to massive air embolism in the patient if not handled properly. The management of this emergency requires cessation of CPB, putting patient in Trendelenburg position, de-airing cannulas, reverse the tubing-cannula connections and initiate massive air embolism protocol if required [7].

3. Obstruction to venous return

Obstruction of the venous return will lead to a sudden drop in the level of venous reservoir, leading perfusionist to drastically turn down the forward flow. This will manifest in patient in the form of low MAP. In addition, with the sudden reduction in venous return, there is a higher chance of emptying the venous reservoir. In order to maintain flow, crystalloid fluid may be added to the reservoir to maintain flow temporarily until the root cause is found.

One of the reasons for a sudden obstruction of venous return may be the presence of air lock in the venous tubing [7]. As large air bubbles accumulate in the venous drainage cannula or tubing, an air lock is created, due to the lower pressure gradient and the surface tension in the air-blood interface. Air lock can be “walked out” by sequentially elevating the tubing until the air enters the venous reservoir. However, the source of venous air must be investigated to prevent further air lock from forming.

Another common cause of sudden reduction of venous return is due to the mechanical positioning of the heart by the surgeon. As heart is lifted and repositioned for better surgical exposure, the venous cannula may be malpositioned or kinked. This should be communicated with the surgeon immediately for repositioning [7].

4. Massive air embolism

Massive air embolism is when gaseous emboli reach the patient via the arterial line. This event is associated with high risk of stroke, myocardial infarction and death. This emergency happens in 0.01% of cases with a high percentage experiencing adverse patient outcome [7].

Some causes that may lead to massive air embolism in the patient include empty venous reservoir level, leaks in the negative pressure part of the CPB circuit, entrainment of air around the aortic cannula, inadequate de-airing when preparing the circuit or when connecting tubing with cannula, reversed roller pump direction, pressurized cardiotomy reservoir, runaway pump head and various septal defects that channels air from right to left side of the heart [7].

To manage massive air embolism, it requires a team effort to follow the massive air embolism emergency protocol [7]. Often times, perfusionist is the person noticing air in the circuit, and will stop CPB and clamp out the venous and arterial lines. The perfusionist will communicate with the rest of the OR team. Patient will then be put in a reverse Trendelenburg position and the source of air must be located and resolved. The arterial tubing and cannula must then be properly de-aired before re-establishing CPB. The surgeon will request to cool the patient if suspect massive air embolism has gone into the patient and retrograde perfusion through the SVC will be initiated as per protocol.

Equipment emergencies during CPB

1. Failure of oxygen supply

Failure of the oxygen supply will result in hypoxemia in the patient, as venous blood can no longer be oxygenated before returning to the patient. The perfusionist will notice that the arterial blood is turning darker, patient SvO2 will steadily drop, and the oxygen analyzer will show lower percentage of oxygen in the air-oxygen mixture by the blender. It is part of the safety checklist to ensure that there is a full oxygen tank nearby and available to provide oxygen supply in case of central oxygen supply failure. The priority is to re-establish oxygen supply and then investigate the cause of oxygen supply failure.

2. Pump failure

Pump failure may be due to electrical or mechanical reasons. A runaway pump is where pump flow can no longer to controlled and often requires the module to be shut down and reset. All CPB pumps should have hand cranks available. If the pump is operated by electromagnetic signals, then a second motor drive should be available to restore flow. The priority in this case is to re-establish flow to the patient. Then the root cause should be investigated.

3. Oxygenator failure

Oxygenator failure may take the form of oxygenation defect, mechanical obstruction, exterior leakage of blood, or water-to-blood leak in the heat-exchanger [7]. Oxygenator must be replaced during the operation. This requires the perfusionist to communicate and work with other OR team members to ensure the least of amount of time for the disruption of perfusion to the patient. This requires good planning, communication, and preparation of backup equipment readily available in the OR.

4. Clotted oxygenator or circuit

Clots found in the oxygenator will interfere with the gas exchange capability of the oxygenator. Clots found in other parts of the circuit will predispose patient to embolic risks and obstructing flow in the circuit. The causes of a clotted oxygenator are often related to inadequate heparinization prior to the commencement of CPB or inadvertent administration of protamine during CPB [7]. The management of this emergency requires the perfusionist to change out the oxygenator and tubing where clots are present. The root cause must be investigated before re-establishing CPB.

23.6 Deep Circulatory Arrest

In humans, hypothermia is defined as body temperature below 35° C or a state in which the body temperature of a homeothermic mammal is below normal [8]. The four categories of hypothermia are

- Mild hypothermia (32 °C to 35 °C)
- Moderate hypothermia (26 °C to 31 °C)
- Deep hypothermia (20 °C to 25 °C)
- Profound hypothermia (<20 °C)

The rationale for hypothermia in cardiac surgery is to

- Reduce metabolic rate
- Reduce oxygen consumption
- Preservation of phosphate stores
- Lower pump flows

Hypothermia has a positive effect on gas transfer by increasing the affinity of hemoglobin to oxygen, decreases carbon dioxide production (by reducing metabolism) and increases the solubility of oxygen and carbon dioxide.

Systemic temperatures of 20 °C–22 °C (deep hypothermic circulatory arrest (DHCA)) less are used to allow cessation of circulation for periods up to 40–60 min often without detectable organ injury [1]. In pediatric population, DHCA is used to achieve an exsanguinous surgical field during complex congenital repairs. In adults, DHCA is primarily used in surgeries like aortic arch repair, cerebral aneurysm resection etc. which require occlusion of cerebral vessels. Brain is the organ which is at the greatest risk of injury. Studies have shown that at 20 °C, circulatory arrest period of 30–45 min is typically tolerated [1]. The rate of cooling is important to prevent organ damage.

Cooling phase

- Maintain a gradient of 10 °C to 12 °C between the perfusate and patient
- Employ pH stat during initial cool down
- Pack head with ice
- Reduce flows as needed
- Monitor temperature (nasopharyngeal, arterial, venous)
- At required temperature (<22 °C), shut off pump stopping all circulation
- Allow patient volume to drain into reservoir (exsanguination allows vascular decompression as well as reduces blood stasis)

Adjuncts to increase safe ischemic time:

- Target temperature (<22 °C)
- Antegrade cerebral perfusion (ACP)
- Steroids
- Intermittent low flow

Antegrade cerebral perfusion (ACP): Once systemic circulation is stopped, ACP can be initiated via the same axillary cannula at a rate of 10 ml/kg/min and occluding the innominate artery. This technique provides adequate cerebral protection with an intact Circle of Willis. Studies have shown that when ACP is used as an adjunct, it extends the safe duration of ischemic time [1]

Rewarming phase

- Re-establish circulation
- Maintain a temperature gradient of 8 °C to 10 °C between perfusate and patient)
- Employ alpha-stat to blow off excess carbon dioxide
- Vasodilation as needed to ensure global reperfusion
- Treat acidosis with sodium bicarbonate
- Rewarm adequately to achieve a systemic temperature of 37 °C

Complications of DHCA

- Stroke
- Cognitive degeneration
- Seizure
- Choreoathetosis (1–20% of children due to basal ganglia injury)

23.7 Non-cardiac Use of CPB

There are many practical applications of CPB in surgical areas aside from cardiac surgery these applications include neurosurgery, urologic surgery, thoracic surgery, vascular surgery and liver transplantation.

The first area of CPB application is to achieve profound hypothermia using CPB, so that circulatory arrest can be established. Hypothermia circulatory arrest is utilized in surgeries that repair vascular abnormalities. Examples of surgeries that utilizes CPB to establish circulatory arrest include repair of intracranial vascular aneurysm and vena cava tumor resection [4].

The second main area of the application of CPB is in thoracic surgery an example would be resections various malignant tumor in the thorax. The rationale of the use of CPB is that the technique allows blood to bypass the lungs where the operation is performed. Depending on the surgery type, full CPB may not be required, and veno-venous bypass is established that would reduce the requirement of heparization significantly [4]. The advanced thoracic surgical techniques have steered more surgeries away from the use of CPB technique however, for major reconstruction, CPB remains to be an essential component of surgical care. To this date, full CPB is used in bilateral/unilateral pulmonary endarartectomy and double lung transplantation.

The third area of CPB application is in the form of isolated left heart bypass and veno-venous bypass. Isolated left heart bypass can be used to facilitate catherization laboratory interventions on patients who are not surgical candidates. Veno-venous bypass has its greatest application in liver transplantation; approximately 5% of the liver transplantation procedures require the use of veno-venous bypass that shunts blood from lower extremities to the right atrium [4].

The last major area of CPB application is in the treatment of rare conditions, such as accidental hypothermia and treating cancer patients using regional perfusion technique. In the case of accidental hypothermia, CPB is used to gradually perfuse and warm patient in a controlled fashion. CPB can support patient's cardio-pulmonary function and balance metabolic parameters as patient slowly warms up and may develop ventricular fibrillation [4]. In the case of cancer patients, a modified CPB circuit can be used to administer high concentration of chemotherapy agents at an ideal temperature (high perfusing temperature has synergistic effect on the chemotherapy drugs) to a specific region of the body. The complete isolation of the limbs can be accomplished by cannulating small artery and vein, and then applying tourniquet proximal to the vessels [4].

23.8 Heparin-Protamine Axis

During cardiac surgery, the cardiopulmonary bypass (CPB) machine is utilized to create a clear field for the surgeon while keeping the patient hemodynamically stable. When the blood comes into contact with a foreign substance, the circuit for example, a systemic inflammatory response is activated. Thereby initiating the extrinsic and intrinsic coagulation systems, leading to clot formation without sufficient anticoagulation to inhibit this response [9]. The most common drug utilized to attain anticoagulation is heparin. Unfractionated heparin binds with antithrombin III inhibiting clot formation [10]. Maintaining anticoagulation is necessary throughout the bypass run to ensure the prevention of thrombin formation

The activated clotting time (ACT) is the gold standard test for measuring anticoagulation. This test measures the time it takes for whole blood to clot, primarily by activation of the intrinsic coagulation pathway [11]. There are currently no definitive guidelines on how much heparin will determine anticoagulation for CPB or what number of seconds will ensure inhibition of clot formation. While traditionally the minimum number of seconds needed for anticoagulation is 480 s, some studies suggest a minimum of 400 s will warrant safe CPB [12]. Also, many institutions will dose heparin based on weight in kilograms, either 300 or 400 IU/kg [12]. Another alternate method is the Hepcon Hemostasis Management System (HMS): this device will calculate the heparin dose based on patient blood volume and utilizes a heparin dose response curve to signify anticoagulation. It is still unclear which method better achieves adequate anticoagulation [12].

The benefit to using heparin as the anticoagulant drug of choice is the ability of protamine to achieve a reversal effect. The amount of protamine needed for neutralization is determined by how much total heparin was administered during the bypass run. A simple way of calculating how much protamine is needed is administering between 1 to 1.5 mg for each milligram of heparin that has been given [13]. There are some devices such as the Hemochron RxDx or the HMS that can predict the amount of protamine needed to reach baseline ACT levels [13]. Developed by Bull et al., some institutions will use the Heparin Dose Response Curve. Towards the end of the bypass run, a heparin concentration is calculated that provides a protamine dose needed to neutralize the amount of heparin in the patient's blood [13]. With the help of the ACT, the heparin dose response curve can be utilized. After 3–5 min from when protamine is fully administered, an ACT is performed to ensure baseline coagulation levels and full heparin reversal.

23.9 Perioperative Cell Salvage

The risks of homologous blood transfusion during cardiac surgery are well documented. One of the simplest ways to provide intraoperative autologous blood collection is with an auto transfusion device (cell saver). Blood is collected via a double lumen tube and simultaneously anticoagulated with either heparin or citrate-phosphate-dextrose [14]. Blood is collected into a filtered reservoir, washed in a centrifugal bowl and reinfused back to the patient. The finished product is red cells suspended in normal saline with a hematocrit between 45% and 60% [14]. One potential problem with overuse of this device is dilutional coagulopathy. If large quantities of shed blood are collected and processed, washout of clotting factors, plasma proteins and platelets will occur requiring replacement [14].

23.10 Brief: Off Pump CABG Role of a Perfusionist

In patients with coronary artery disease (CAD), blood vessels that supply oxygen to the heart are blocked therefore needing surgical intervention. For this type of operation, a patient's great saphenous vein or radial artery is taken and used to perfuse blood passed the blockage site. This allows for optimal gas exchange to keep the heart tissue functioning to its best ability. Typically, the cardiopulmonary bypass machine is needed to give the surgeon a clear field and a quiet heart. While not routinely done, an off pump coronary bypass graft operation can be performed on select patients. Patients who may benefit from this include those with heavily calcified aortas, liver cirrhosis, or compromised pulmonary or renal function [15]. In this case, the cardiopulmonary bypass machine is not utilized. Instead, the heart remains beating and stabilizers are placed to keep a section of the heart immobile [16]. As a perfusionist, it is important to always be prepared to go on bypass if necessary.

Some alternate devices that will still need to be managed by the perfusionist include the cell saver and potentially the carbon dioxide (CO2) blower. The cell saver processes whole blood, washes it with normal saline and saves the red blood cells collected from the field. This is often processed throughout or at the end of the case and given to anesthesia to increase patient blood volume and hematocrit. Hopefully this is enough to reduce the use of blood products. A limiting factor of the cell saver is that it does not keep the patient's clotting factors [17]. The surgeon can utilize the CO_2 blower, especially in this case, to dissolve blood that is in his surgical viewpoint. A benefit of carbon dioxide is that it has a 20-fold higher solubility coefficient in blood as compared to oxygen. Therefore, using this technique can minimize air embolism of the patient.

This method is found to be simple and safe and should be used when performing an off-pump CABG [18].

23.11 IABP, VADS, ECMO

Intra-Aortic Balloon Counterpulsation

Introduction

The clinical objectives in utilizing any form of ventricular support are to restore adequate blood flow while preserving end-organ function. Whether a patient in cardiogenic shock resulting from acute heart failure (postcardiotomy) or in congestive heart failure, the indications for the support are hemodynamic compromise, reduction in myocardial contractility and low-output syndrome.

Intra-aortic balloon pump (IABP) counterpulsation has been the most widely used left ventricular assist device for nearly five decades. The first clinical application of a successful treatment with IABP was reported in 1967 [19]. Intra-aortic balloon pumping was advocated successfully in a 45-year-old female who had sustained a myocardial infarction and was hypotensive, comatose and anuric in severe cardiogenic shock [20].

The goal of IABP is to support a failing heart by increasing the myocardial oxygen supply and decreasing myocardial oxygen demand. To do so, the balloon inflates in diastole, augmenting coronary perfusion, and deflates in early systole (counterpulsation).

IABP Theory

Intra-aortic balloon pump counterpulsation is the most common form of mechanical circulatory support used in patients with myocardial ischemia and cardiogenic shock. Intra-Aortic balloon counterpulsation can provided cardiac and circulatory support for patients exhibiting marginal to severe cardiac compromise. IABP is mainly used in high-risk patients with acute myocardial infarction, especially when complicated by cardiogenic shock.

Augmentation of diastolic pressure during balloon inflation contributes to the coronary circulation and the presystolic deflation of the balloon reduces the resistance to systolic output. Consequently, the myocardial work is reduced.

Indications of use:

1. Cardiac Failure
2. Refractory unstable angina
3. High risk catherization procedures
4. Perioperative treatment of complications due MI

Contraindications to IABP

1. Severe aortic insufficiency
2. Aortic aneurysm
3. Aortic dissection
4. Limb ischemia
5. Thromboembolism

IABP Instrumentation and Techniques:

1. Flexible dual lumen catheter
   a. Shuttle helium gas to and from the balloon
   b. Pressure monitoring line
   c. Balloon should be catheters sized to patient size
   d. Polyethylene or PU balloon mounted at the distal tip of a large bore catheter

2. Balloon Catheter Insertion

Insertion is carried out percutaneously using the Seldinger technique and in some case under mild anticoagulation with heparin.

Common practice dictates the intra-aortic balloon catheter be inserted via the femoral artery and the tip of balloon is positioned 2 cm below the left subclavian artery. The proximal balloon end should be lying above the renal vessels. Incorrect balloon position results in reduced diastolic augmentation or vascular morbidity due to direct intimal injury or plaque distortion and embolization or finally direct occlusion of the arterial lumen. Position should be verified by x-ray or TEE.

3. Portable IABP console capable of transferring helium gas to and from the balloon synchronized to the cardiac cycle.

IABP Triggering Modes and Timing

There are 6 Triggering modes which can be used to trigger the balloon console.

1. ECG—using QRS wave form to detect trigger point
2. Arterial pressure wave form—arterial internal balloon or radial arterial wave forms
3. Fiberoptic cable—internal within balloon catheter
4. Internal Trigger Mode
5. Pacer Mode
6. Pacer V/Pacer A-V

For the IABP to function properly, its inflation-deflation cycle must be synchronized to the appropriate events in the cardiac cycle. The central lumen of the double-lumen IAB catheter allows monitoring of the pressure in the descending aorta during the cardiac cycle. This arterial line provides data to the IABP console. Timing of the IABP is always performed using the arterial waveform as the guide.

The IABP console continuously monitors the patient's arterial pressure. When it recognizes the dicrotic notch (the onset of diastole), it triggers rapid balloon inflation; pressure within the aortic compartment increases and an increase in coronary artery perfusion occurs. The pressure during diastolic augmentation is often considerably higher than both the normal diastolic pressure and even the peak systolic pressures. High diastolic augmentation pressure is one of the indicators of effective IABP function [21].

Balloon deflation is timed to occur with the onset of systole. When the IABP console identifies the beginning of the patient's R wave, the balloon is rapidly deflated, lowering the pressure in the proximal aorta. In the second waveform of the illustration, the *assisted aortic end-diastolic pressure* is lower than the previous pressure waveform's *unassisted aortic end-diastolic pressure*. The lowering of the end-diastolic pressure from balloon deflation is another physiologic indicator of proper IABP function.

Summary

The use of the IABP counter pulsation has shown efficacy due to the increase in diastolic pressure during balloon inflation augments the coronary circulation. Also, pre-systolic deflation of the balloon reduces the resistance to systolic output, thus a decrease in myocardial work. The efficacy of the IABP is reflected by the positive outcomes of the high number of patients who are weaned from the device. The success rate is higher for patients, in whom the device is deployed early.

Ventricular Assist Devices

Introduction

Heart failure (HF) is a major public health issue associated with significant morbidity, mortality, and healthcare expenditures. Mechanical circulatory support devices (MCS) such as left ventricular assist devices (LVADs) provide an alternative to heart transplantation for patients with advanced HF.

Definition of Left Ventricular Failure

Cardiac Output <2.0 Lpm/m2
Systolic Blood Pressure <80–90 mmhg
Left atrial pressure >20 mmhg

MCS Classification

1. Acute Devices

   * Post-Cardiotomy support <24 h
   * Recoverable Post-Cardiotomy 24–48 h
   * Transition to Chronic VAD

2. Durable Devices

   * Bridge to Transplantation
   * Destination Therapy

I. Acute Ventricular Assist Device

A. Centrifugal Blood Pumps
B. Catheter based Technology

Post Cardiotomy Support

- 2–6% post-cardiotomy ventricular failure despite improvements in myocardial protection techs and tech successful operation

- .5–1% CPB failure to wean despite max inotropic support in conjunction with IABP

Acute Device selection criteria

- Extended Bypass time
- Unable to wean from bypass
- Most in a state of coagulation imbalance
- Bank blood, FFP and Platelets
- Intractable ventricular tachycardia
- Neurological status in question

Historical Timeline for Centrifugal Pump Ventricular Support

- 1960 Saxton and Andrews
- First report of use of a centrifugal pump
- 1963 Spencer
- First successful post cardiotomy LVAD
- 1966 Dorman et al.
- Impeller centrifugal pump
- 1978 Golding et al.
- Clinical use of Medtronic LVAD
- 1980 Magovern
- Clinical use of Bio-Medicus LVAD

Cannulation Techniques

Traditional Approaches [22]

- Interatrial Groove
- Left Atrial Appendage
- Left Ventricular Apex
- Dome of Left Atrium
- Right Superior Pulmonary Vein
- Femoral Cannulation

A. Centrifugal Blood pumps

1. Centrimag Blood Pump

Overview

The Centrimag Blood Pump is electronically driven, based on bearing-less motor technology. The centrifugal pump allows pumping without mechanical bearings and seals. The Blood pump has a magnetically levitated rotor to attempt to decrease the incidence of heat and thrombus formation.

Pump Speed Range 0–5,500 revolutions per minute (RPM)

Pump Flow Range 0.0–10.0 L per minute (LPM)

2. The Tandem Heart

Overview

Tandem Heart Blood pump is a left atrial-to-femoral artery bypass system comprising a trans-septal cannula, arterial cannula, and a centrifugal blood pump. The pump can deliver flow rates up to 4.0 L/min at a maximum speed of 7500 rpms.

Impella Ventricular Assist Device

Overview

The Impella ventricular assist blood pump is a percutaneous catheter-based micro axial blood pump providing temporary hemodynamic support to the heart. The device pumps blood from the left ventricle into the ascending aorta and systemic circulation at the upper rate of 2.5 L/min to 5 L/min. It can be placed via a retrograde approach across the aortic valve using a femoral arterial access.

Durable Ventricular Assist Devices

MCS with durable ventricular assist devices has shown to be an efficacious treatment modality for patients with end stage heart failure refractory to medical treatment. With the annual volume of heart transplants in the U.S. plateauing around the 3000-mark, implanting BTT (bridge to transplant) vads became inevitable. The numbers of patients supported by Vads continues to grow, those indicate a DT are around 50%, whereas BTT constitutes 26% [23]. The REMATCH trail in 2001 by ROSE et al. demonstrated the use of Vads as a durable Destination Therapy (DT) with superior outcomes when compared to long-term medical treatment.

Current FDA approved devices

1. Heartmate II VAD (Abbott)
   FDA approved for BTT 2008
   FDA approved for DT 2010

The HeartMate II is a continuous flow, second generation left ventricular assist device (LVAD). This pump has been implanted for bridge to transplant and destination therapy indications. This is valve-less axial blood pump contains a rotor spinning on a ruby bearing.

The pump operates in the range of 6000–15000 rpms and the maximum flow range is 3–10 L/min. It is both preload and afterload sensitive.

2. Heartmate III VAD (Abbott)
   FDA approved for BTT 2017
   FDA approved for DT 2017

A new generation centrifugal flow pump, which incorporates a fully magnetically levitated rotor, wider blood-flow paths and the has the ability to provide artificial pulsatility, in order to decrease the incidence of thrombus formation. The Heartmate III is both preload and afterload sensitive.

The motor technology of this LVAD incorporates a contactless bearing technology and consists of the rotor with passive magnets for drive and bearing. The application of rotary blood pumps with magnetically levitated rotors, as opposed to pumps with mechanical bearings, improves the feasibility and safety of implanting such LVADs as alternative-to-transplant, applicable for a time span of 10 to 15 years.

The pump operates at rotor speed in the range of 3,000 to 9,000 rpms, and the maximum flow rate is 10 L/min.

Principles and Indications for Extracorporeal Membrane Oxygenation—ECMO

Introduction

ECMO uses a pump to take over the work of the heart and an oxygenator (artificial lung) to take over the work of the lungs. Extracorporeal membrane oxygenation (ECMO) is mechanical support in the form of prolonged cardiopulmonary bypass, achieved by using a modified bypass circuit and peripheral cannulation techniques. This support technique is used in patients who present with lung injury or compromised lung function that is unresponsive to optimal ventilator management. The classic indication for VA-ECMO is cardiogenic shock, defined by decreased cardiac output and myocardial contractility resulting in tissue hypoperfusion. It should be considered in patient populations with potentially reversible respiratory failure has been identified.

Some lung (pulmonary) conditions in which ECMO may be used include:

- Acute respiratory distress syndrome (ARDS)
- Blockage in a pulmonary artery in the lungs (pulmonary embolism)
- Coronavirus disease 2019 (COVID-19)
- Flu (influenza)
- Pneumonia
- Respiratory failure
- Trauma

Risks

The most common risks that may occur with ECMO include:

- Bleeding
- Blood clot (thromboembolism)
- Blood clotting disorder (coagulopathy)
- Infection
- Loss of blood in hands, feet or legs (limb ischemia)
- Seizures
- Stroke (part of the brain is damaged by loss of blood or by a blood vessel that bursts)

Historical Timeline for Adult ECMO

1972—First survivor (NEJM)—young patient with post-traumatic
respiratory failure

1979-VA ECMO (ECMO with ventilation) vs ventilation alone -> high mortality in ECMO group

1986—Gattinoni's case series, VV, used for CO2 removal, increased survival but large blood loss/day

1989—ELSO established

Note: ELSO maintains a registry of clinical characteristics and outcomes of patients supported with ECMO.

Types of ECMO

- VV = Veno-Venous
- VA = Veno-Arterial: peripheral or central

VV ECMO

Veno-Venous (VV) ECMO provides respiratory support but does not provide circulatory support. Blood is drained from the central venous system, either from the superior or inferior vena cava, oxygenated, and reintroduced into the right atrium. From the right atrium, the oxygenated blood flows to the right ventricle and is pumped by the native heart through the pulmonary artery, dysfunctional lungs, and pulmonary vein. Blood flow continues to the left atrium and left ventricle where it is pumped through systemic circulation.

Indications for Use

1. Pneumonia
2. ARDS
3. Status asthmaticus
4. Airway obstruction
5. Aspiration
6. Bridge to lung transplantation
7. Drowning
8. Covid 19 Virus

Advantages

- normal lung blood flow
- oxygenated lung blood
- pulsatile blood pressure
- oxygenated blood delivered to root of aorta
- must be used when native cardiac output is high

Disadvantages

- no cardiac support

VA ECMO

Veno-Arterial (VA) ECMO provides respiratory and circulatory support. Deoxygenated blood is drained from a central vein into ECMO circuit, oxygenated, and returned to arterial circulation. VA Ecmo provides support to both the lungs and the heart.

Indications for use

1. Support for cardiac failure (± respiratory failure)
2. Graft failure post heart or heart lung transplant
3. Non-ischemic cardiogenic shock
4. Failure to wean post CPB
5. Bridge to LVAD
6. Drug overdose

Disadvantages

- Relative lung ischemia
- Non-pulsatile blood flow

23.12 Checklists

The American Society of Extracorporeal Technology (AmSECT) has compiled a list of Standards and Guidelines in order to help institutions provide basic levels of care. One of the standards prioritized in this list is having a checklist for each cardiopulmonary bypass case and including that checklist as part of the patient's chart [24].

One of the main responsibilities a perfusionist has is to provide safe cardiopulmonary bypass by means of an extracorporeal circuit every time a patient goes on bypass. A simple and effective way to help ensure this is to incorporate checklists into the perfusionist's duties. This should be done as needed throughout a case, however common times to consider using a checklist are preoperatively, intraoperatively, and postoperatively [24, 25].

Checklists are a common tool used by multiple industries. Their proper use and application can facilitate several desirable outcomes. The appropriate use of checklists helps users remember to perform each needed step, to do so correctly, and it provides continuity in task performance among colleagues. An additional

Figure 1: AmSECT's Perfusion Checklist

Patient ID ______________________

Check each item when completed, sign and date. If not applicable, draw line through**. Bold italicized items for expedited set-up.**

PATIENT

- ***Patient identity confirmed***
- ***Procedure confirmed***
- ***Blood type, antibodies confirmed***
- ***Allergies checked***
- Blood bank number confirmed
- Medical record number confirmed
- Chart reviewed

STERILITY/CLEANLINESS

- ***Components checked for package integrity/expiration***
- Equipment clean
- Heat exchanger(s) leak-tested

PUMP

- ***Occlusion(s) set***
- ***Speed controls operational***
- ***Flow meter in correct direction and calibration***
- ***Flow rate indicator correct for patient and/or tubing size***
- ***Rollers rotate freely***
- Pump head rotation smooth and quiet
- Holders secure
- Servoregulated connections tested

ELECTRICAL

- ***Power cord(s) connection(s) secure***
- ***Servoregulation connections secure***
- Batteries charged and operational

CARDIOPLEGIA

- ***System debubbled and operational***
- System leak-free after pressurization
- Solution(s) checked

GAS SUPPLY

- ***Gas line(s) and filer connections secure***
- ***Gas exhaust unobstructed***
- ***Source and appropriate connections of gas(es) confirmed***
- ***Flow meter / gas blender operational***
- Hoses leak-free
- Anesthetic gas scavenge line operational

COMPONENTS

- ***System debubbled and operational***
- ***Connections / stopcocks / caps secure***
- ***Appropriate lines claimed / shunts closed***
- ***Tubing direction traced and correct***
- ***Patency of arterial line / cannula confirmed***
- No tubing kinks noted
- One-way valve(s) in correct direction
- Leak-free after pressurization

SAFETY MECHANISMS

- ***Alarms operational, audible and engaged***
- ***Arterial filter / bubble trap debubbled***
- ***Cardiotomy / hardshell venous reservoir(s) vented***
- ***Vent(s) tested***

Fig. 23.1 AmSECT's perfusion checklist

Venous line occluder(s) calibrated and tested
Devices securely attached to console

ASSISTED VENOUS RETURN

Cardiotomy positive-pressure relief valve present
Negative- pressure relief valve unobstructed
Vacuum regulator operational

MONITORING

Circuit / patient temperature probes placed
Pressure transducers / monitors calibrated and on proper scales
Inline sensors calibrated
Oxygen analyzer calibrated

ANTICOAGULATION

Heparin time and dose confirmed
Anticoagulation tested and reported

TEMPERATURE CONTROL

Water source(s)connected and operational
Temperature range(s) tested and operational
Water lines unobstructed

SUPPLIES

Tubing clamps available
Drugs available and properly labeled
Solutions available
Blood products available
Sampling syringes / laboratory tubes available
Anesthetic vaporizer correct
Vaporizer operational and filled

BACKUP

Hand cranks available
Duplicate circuit components / hardware available
Emergency lighting / flashlight available
Backup full oxygen tank with flow meter available
Ice available

EMERGENT RESTART OF BYPASS

Heparin time and dose confirmed
Components debubbled
Gas flow confirmed
Alarms reengaged
Water source(s) connected

TERMINATION CHECKLIST

Venous assist off / cardiotomy / venous reservoirs vented
Shunt(s) closed
Vent(s) clamped / removed

POSTBYPASS CHECKLIST

Announce bypass terminated
Arterial and venous lines clamped
Arterial circuit bubble-free before transfusing perfusate
Pump suction(s) off

Comments:

Signature: ____________________________

Date: ________________ Time: ____________

These perfusion checklists, or a reasonable equivalent, should be used in perfusion practice. This is a guideline, which Perfusionists are encouraged to modify to accommodate difference in circuit design and variations in institutional clinical practice. Users should refer to manufacturers' information, including Instructions for Use, for specific procedures and/or precautions. AmSECT disclaims any and all liability and responsibility for injury and damages resulting from following this suggested checklist. Origination 1990; revision 2004 by AmSECT Quality Committee.

Fig. 23.1 (continued)

benefit is that using a checklist gives the perfusionist additional confidence that they are adequately prepared for the needs of the patient [25].

A perfusionist's checklist should coincide with his or her responsibilities, and either directly or indirectly answer certain overarching questions. Some of which include:

- Has the patient been identified?
- Does the patient have special needs?
- Has the circuit been correctly set up, primed, and tested for use?
- Have the appropriate monitoring devices been attached?
- Have the needed supplies for bypass been gathered?
- Are backup supplies and equipment available in the event that equipment or power fails?
- Is the patient sufficiently anticoagulated before bypass?
- Once on bypass, is the patient being adequately supported?
- When not on bypass, is the circuit and perfusionist ready to go on bypass if the patient's vitals begin to deteriorate?

While checklists should be customized to the needs of the institution where it is implemented, several examples of checklists can be found in literature. A checklist commonly referenced was created by AmSECT and made available to the public (Fig. 23.1) [24]. Tasks performed by perfusionists are vital to patient safety. Using a tangible checklist that becomes part of the patient record, which requires an active acknowledgement of specific actions being completed is an effective way to ensure that performance is not compromised by tasks being left incomplete or being completed in a suboptimal manner [6].

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24 PEN-Plus Strategies I: Decentralizing and Integrating Preoperative Medical Management, Cardiac Surgery Screening, and Referral

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Abstract

Cardiac surgery is an essential health service required to prevent mortality and morbidity among patients with valvular and other cardiac disease. Access to cardiac surgery has historically been limited in low and lower-middle income countries (LLMICs), especially among the rural poor. Decentralization of noncommunicable disease (NCD) care from national tertiary care hospitals to local district hospitals can help achieve equity and increase access to cardiac surgery. Within the described PEN-Plus model for NCD management, nurses at the district hospital level are trained to diagnose heart disease by simple physical examination and echocardiography, and manage heart disease using a locally validated

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_24

protocol, with the assistance of cardiologists from large tertiary care hospitals. This decentralized model provides medical preoperative management and identifies patients eligible for cardiac surgery earlier in their natural history of disease. Case selection can be challenging in LLMICs, but must take into consideration the risks vs benefits of the cardiac surgery for each patient, age of the patient, disease severity, complexity of proposed surgery, local capacity in the operating room and intensive care unit, and likelihood of good surgical outcomes, all with an emphasis on equity. Decisions regarding types of interventions must be made with a patient-centered approach, taking into account not only medical information, but also social and cultural considerations. Cardiac surgery programs must have a national coordinator who is in close communication with local NCD nurses, national cardiologists, and cardiac surgery teams. This coordinator should maintain a dynamic database of patients eligible for surgery, as well as patients who have been operated on and require follow-up and anticoagulation.

Keywords

Cardiac surgery screening · Cardiac surgery referral · Mechanical valve replacement · Bioprosthetic valve replacement · Noncommunicable diseases · Heart failure diagnosis · Heart failure management · PEN-Plus · Decentralized care · Preoperative medical management · Equity · Access to cardiac surgery · Cardiac surgery coordinator · Anticoagulation

24.1 Introduction

On the path to Universal Health Coverage, the importance of interventions to address noncommunicable diseases (NCD) is becoming increasingly recognized [1, 2]. Cardiac surgery is a key intervention to prevent mortality and morbidity among patients with valvular and congenital cardiac conditions. However, access to cardiac surgery has been severely limited historically in low- and lower-middle income countries (LLMICs) [3]. In the few countries that have been able to establish cardiac surgical programs, these programs are often located at referral centers in capital cities. Cardiology services such as echocardiography, anticoagulation, and heart failure management are frequently unavailable outside of these tertiary referral centers as well. Although cardiac surgery is unaffordable even for the middle classes in LLMICs, patient selection itself is biased against the rural poor because they are unlikely to get diagnosed and referred for cardiac surgery in a timely fashion [4].

As a result, patients presenting for cardiac surgery often preferentially come from more urban or wealthy areas. For example, among cardiac surgery cases over a 30-year period in a cardiac center in Ethiopia, >90% of patients were from urban areas despite >80% of the population being rural [5]. There are equity concerns that argue for decentralization of interventions to reach the rural poor [6]. However, barriers to expansion of and access to cardiac surgery in LLMICs include limited availability of accurate and timely diagnosis of cardiac conditions and concerns regarding quality of follow-up [7, 8]. Challenges in tracking complications and monitoring anticoagulation among impoverished patients from rural areas may increase negative postoperative outcomes and even lead cardiac surgical programs to avoid operating on these individuals.

In order to overcome these issues and to address gaps for the rural poor, some countries have begun to implement integrated strategies to decentralize complex NCD management to intermediate care facilities such as district hospitals [9, 10], including early case detection for structural heart disease and post-surgical follow-up programs. These strategies rely on mid-level providers, build on the WHO's Package of Essential Noncommunicable (PEN) disease interventions for primary healthcare centers [11], and have been termed PEN-Plus [12]. The PEN-Plus model has been proven to have beneficial outcomes and be cost-effective in the scale up of cardiac surgery in LLMICs [13]. Here, we discuss the role of PEN-plus strategies based on our experience, in screening, referral, and post-operative follow-up and anticoagulation. Subsequently, we discuss a framework for establishing a decentralized model for cardiac surgical pre-operative management, screening, and referral in highly constrained health systems, with the intent of reaching patients that have been most marginalized historically. We will discuss how cardiologists and other members of the surgical team evaluate patients referred through PEN-Plus clinics and make the determination for cardiac surgery.

24.2 PEN-Plus Model for Decentralizing NCD Care Including Heart Failure and Cardiac Surgical Screening

In order to achieve more equitable access and ensure success of cardiac surgical programs, implementation of integrated NCD clinics is critical to reach the rural poor and to work synergistically with cardiac surgical centers. Decentralization of NCD chronic care utilizing strategies such as PEN-Plus create the necessary infrastructure to allow for impoverished patients living rurally to be diagnosed appropriately with cardiac conditions, receive initial appropriate medical treatment pre-operatively, and assure timely referral for surgical candidates [8]. Additionally, to ensure good long-term outcomes for patients after cardiac surgery, a strong chronic care system is required.

The PEN-plus model allows for decentralization and integration of chronic care services for severe NCDs by developing specialized nurse-led, physician and specialist-supervised, outpatient advanced NCD clinics associated with rural district hospitals (Fig. 24.1) [9]. Conditions addressed include heart failure due to advanced rheumatic and congenital heart disease, hypertensive heart disease, and other cardiomyopathies. This ‘PEN-Plus’ approach, which is complementary to the existing WHO PEN strategy [11], has been shown to be an effective way to address the NCD burden for the rural poor, who often are unable to reach referral centers for initial care [13–15]. Care is decentralized to health centers for basic NCD care, which can refer patients to rural district-hospital clinics for more advanced NCD care, allowing for identification of patients earlier in the natural history of disease.

In this model, NCD clinics are run by nurses, who after initial training, receive monthly mentorship by a cardiologist during outreach visits. Complete diagnostic and therapeutic algorithms are available online, [9] but are briefly summarized here for heart failure management (Protocol 24.1). Diagnostic protocols incorporate simple physical examination and echocardiography to exclude heart failure as cause of symptoms or to assign patients into broad heart failure categories: cardiomyopathy, hypertensive heart disease (HTN-HD), pure mitral stenosis (MS), other valvular diseases (including rheumatic heart disease (RHD), and congenital heart disease), and isolated right heart failure (including constrictive pericardial disease). Nurses perform a simplified echocardiographic protocol using the parasternal long-axis and subcostal views to evaluate for certain key diagnostic features such as depressed left ventricular systolic function, presence of MS, or presence of a large pericardial effusion to assign a preliminary diagnosis [16].

After diagnosis, nurses assess symptom severity with New York Heart Association (NYHA) functional classification, fluid status, and for signs of decompensated disease. They then initiate appropriate protocol-based treatment specific for each diagnostic category using medications from the national formulary, based on guideline-directed care. Patients thought to have valvular or congenital heart disease are started on prophylactic penicillin and are prioritized for cardiology evaluation for possible expedited cardiac surgery referral. Family planning services are essential for women of reproductive age. Cardiologists provide outreach visits monthly to evaluate patients and perform confirmatory echocardiography, and evaluate patients for which surgery is indicated, and help expedite referral of surgical patients [9, 16]. Preoperative evaluation includes detailed history, physical

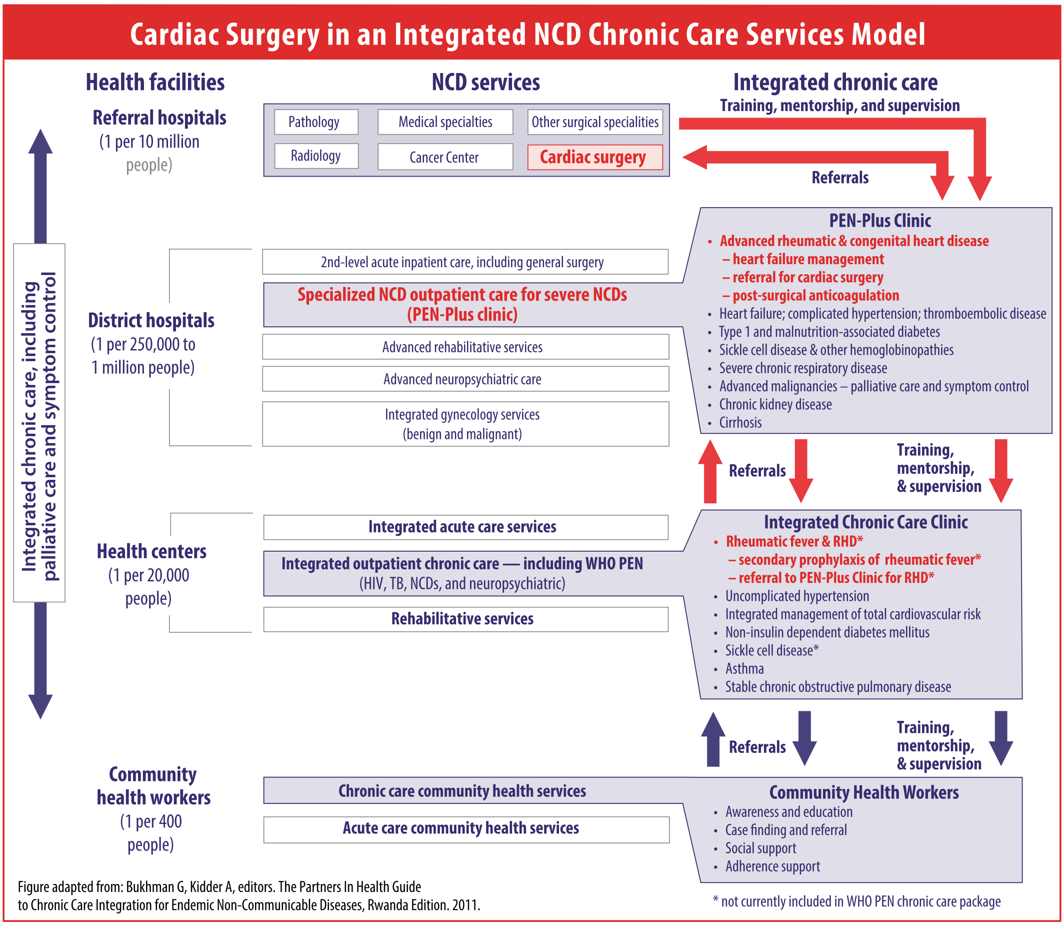


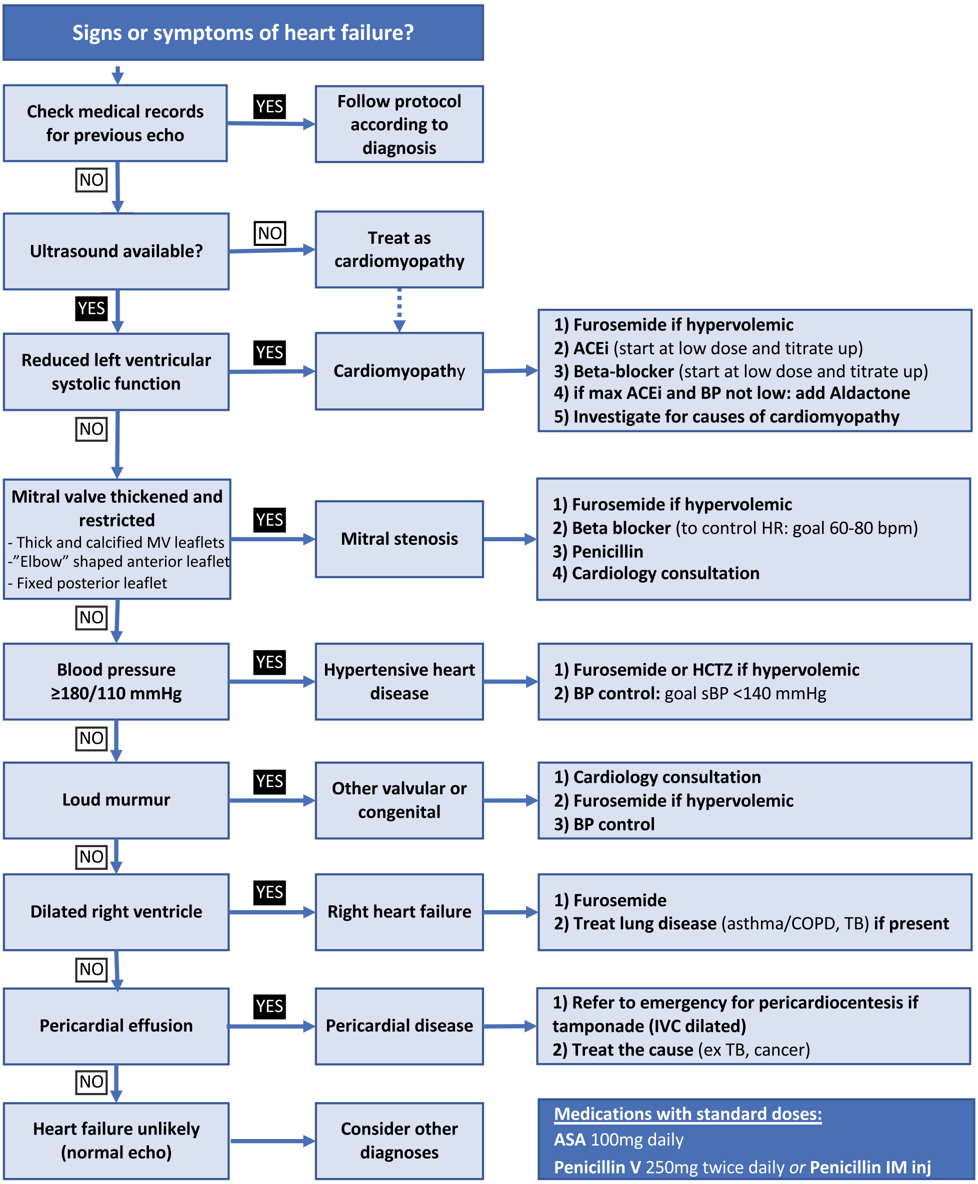
Fig. 24.1 PEN-Plus Clinics in an Integrated NCD Chronic Care Service Model (Figure adapted with permission from: Bukhman G, Kidder A, editors. The Partners In Health Guide to Chronic Care Integration for Endemic Non-Communicable Diseases, Rwanda Edition. 2011.)

exam, laboratory studies and imaging (as shown in Table 24.1) [9]. Social evaluation (including housing, education, and employment needs) is fundamental to evaluation, as not to preclude socially complex patients, but to appropriately identify patients that may require additional social support in the post-operative period.

24.3 Preoperative Evaluation and Planning

Case selection for surgical intervention can be challenging in settings with limited resources and limited number of surgical slots. Equity should be prioritized. Initial focus of early-development cardiac surgery programs should emphasize low-risk cases to build expertise and to allow time for longitudinal process improvement as well as quality assurance. However, given that many patients in rural impoverished settings present late in their disease course [17], systematic exclusion of high-risk cases should be avoided. Program leadership and clinicians should agree upon principles to guide appropriate case selection. In settings where cardiac surgery is very limited, patients under 40 years of age should be

Protocol 24.1 Initial Diagnosis and Management of Heart Failure PEN-Plus clinics at district hospital level ▶



Medication	Starting dose	Goal dose for cardiomyopathy	Contraindication
Beta-blocker: atenolol Beta-blocker: carvedilol	12.5 mg daily 6.25 mg BID	25 mg twice daily 25 mg BID	Heart rate <55, caution in pregnancy
Diuretic: furosemide Diuretic: hydrochlorothiazide (HCTZ)	20 mg daily 12.5 mg daily	- -	Cr >2.3 sBP <100 mmHg
ACE inhibitor: captopril ACE inhibitor: lisinopril	12.5 mg TID 5 mg po daily	50 mg TID 40 mg po daily	Cr >2.3, sBP <100, pregnancy
Spironolactone	12.5 mg daily	25 mg daily	Cr >2.3 or K >5.5, pregnancy
Calcium Channel Blocker: amlodipine Calcium Channel Blocker: nifedipine XL	2.5 mg daily 20 mg daily	goal sBP <140 mmHg	sBP <100 mmHg
Hydralazine	25 mg TID	75 mg TID	sBP <100 mmHg
Isosorbide dinitrate (ISDN)	10 mg TID	40 mg TID	sBP <100 mmHg or headache

Table 24.1 Typical preoperative evaluation for cardiac surgery

History
Heart Failure symptom class
Careful examination for possible tuberculosis
Social evaluation (including housing, education and employment needs)
Reproductive History
Physical examination
Evaluation for obvious comorbidities
Careful evaluation of the liver
Evaluation for malnutrition
Dental evaluation
Laboratory Studies
Full blood cell count with differential
HIV
Hepatitis C
Liver function tests
Creatinine, glucose, electrolytes
Urinalysis
Blood smear for malaria
Imaging
Chest X-ray
Echocardiogram

prioritized. Patients that have advanced disease with compromised end-organ function, such as renal failure or hepatic failure, are unlikely to have good surgical outcomes and should be deferred. Where cardiac surgery is intermittently offered by visiting humanitarian teams, case selection will also face the challenge of deciding who, among eligible seek patients, can wait safely until the next visit of the team. Patients should be evaluated with objective measures to determine their risk of adverse outcomes from surgery, such as The Society of Thoracic Surgeons risk score [18]. Surgery should not be pursued for patients with high risk scores that are likely to die from surgery or are at high-risk for adverse outcomes. Palliative care should be a fully integrated part of chronic care services for those who are felt not to be surgical candidates. Systems are necessary to manage symptoms, and provide anticipatory guidance and psychosocial support [9].

Some patients, for example those with complex congenital lesions, may require multiple staged surgeries for a full repair. In these patients, palliative procedures may be the best available option. Surgery should be made available sooner for patients with emergent, near-end stage disease and for patients who have surgically amenable cardiovascular diseases like shunts, that might not allow them to survive or avoid irreversible complications (i.e. pulmonary arterial hypertension) if care is delayed to the next available surgical date. Complex or advanced cases, however, need to be distributed between available surgical dates to not overburden the existing health system, striking a cautious balance of addressing the critically ill while also promoting optimal outcomes and increased patient survivability. To prevent the need for subsequent surgical interventions in patients with multi-valve disease, dual and sometimes triple valve operations have become the standard for patients, such is often the case in rheumatic valvular disease to address all valvular lesions at the time of the initial operation.

Multidisciplinary teams need to be established that include clinicians, cardiac surgery coordinators, as well as social workers and community health workers. Community health worker and social worker involvement is also critical to educate patients and their families and support them throughout the surgical process.

Comprehensive cardiac surgical care delivery is facilitated by establishing a national cardiac surgical coordinator who can work directly with cardiologists who oversee NCD rural clinics, and cardiac surgery program directors at surgical centers, as well as visiting cardiac surgical teams, if available. Implementation of a database of cardiac surgical candidates is necessary to facilitate surgical intervention and ensure close tracking/monitoring of patients. For RHD surgical candidates, such a database should be extracted from a comprehensive RHD Registry, which is an essential component of a National Rheumatic Fever and RHD prevention and control program [19]. Once the cardiologist and NCD team determines that a patient is a suitable surgical candidate, the patient is then added to a national cardiac surgical waiting list. Cardiac surgical centers or visiting cardiac surgical teams are then able to readily review the list to confirm patient selection and appropriately prepare. This also includes review of hospital level capacity and intensive care unit capacity to ensure sufficient beds are available to care for patients postoperatively.

24.4 Procedural Considerations

Decisions regarding type of intervention must take a patient-centered approach, considering not only the medical information, but also the available social and cultural context in which the patient lives. For example, the decision of mechanical versus tissue prostheses is often challenging. While mechanical valves last the lifetime of a patient and are often recommended primarily for patients, especially younger patients, to prevent the need for reoperation later, they require patients to take anticoagulants that are teratogenic. However, tissue prostheses degenerate quickly in younger patients and access to a second surgery is not guaranteed in resource-restricted settings. Therefore, extensive discussions with female patients of child-bearing age are important to determine their desire to have more children. Proper anticipatory guidance to help guide the difficult decision between mechanical and bioprosthetic valves among this patient group is crucial. Pre-operative counseling for female patients of childbearing age must consider their socio-cultural context, the societal pressure to have children, risk of social exclusion, as well as the loss of future income and social support for the family if they make the difficult choice to not have children in order to pursue a more durable mechanical valve. If future children are desired, then a tissue prosthesis should be used to honor the patient's wishes, with the understanding that the valve is unlikely to last the lifetime of the patient.

Additionally, commonly, patients may be from such a remote part of the country, that warfarin follow-up is considered difficult. In these cases, tissue valves would also be the safer option, though perhaps not the most durable. However, it has also been shown that anticoagulation can be improved with home INR self-testing in educated patients. Close follow up can also be provided utilizing phone call or SMS text messages [20]. In the majority of cases, mechanical valves are preferred, provided warfarin follow-up is available. Good outcomes have been demonstrated with post-surgical anticoagulation in the setting of PEN-Plus programs [21].

While valve repair is feasible in many instances, it is typically avoided for complex or advanced disease given the high recurrence rate in this setting. Although it has the advantage of preserving more of the normal function of the valve, patients with valve repair often require a second operation in their lifetime. If cardiac catheterization laboratories are available, then interventional cardiologists should also be part of multidisciplinary teams in order to discuss which cases may be appropriately treated with a percutaneous approach such as balloon valvuloplasty or low risk procedures for congenital heart disease. However, catheterization laboratories require sufficient volume to maintain skills, and procedures such as balloon valvuloplasty will need cardiac surgery back-up in case of complications. Thus, this is likely only an option once programs are at a later stage of development. Furthermore, many patients with rheumatic valvular lesions do not have pure mitral or tricuspid stenosis amenable to valvuloplasty, and thus require surgical intervention.

Acknowledgements The authors would like to thank the cardiac and heart failure patients, the Rwandan Ministry of Health and the Rwanda Biomedical Center for its commitment to health care as a fundamental human right. We also thank the leadership and staff of Inshuti Mu Buzima (Rwanda) and Partners In Health (Boston, MA) whose programmatic accompaniment of the public health sector in Rwanda led to this work. We also thank Drs. Corrado Concedda, Jim Rawn, Nathan Ruhamya, Gapira Ganza, Patricia Come and the four international humanitarian cardiac surgical teams (Open Heart International (Australia), Chain of Hope (Belgium), Team Heart, Inc (Boston, MA), Healing Hearts Northwest (Spokane, WA) —who all played an instrumental role in providing care, implementing training and the assisting with infrastructure development early in the course of Rwanda's national cardiac surgery program.

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25 PEN-Plus Strategies II: Decentralizing and Integrating Postoperative Management and Anticoagulation

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Abstract

Countries building sustainable, cardiac surgical care must ensure that the local health system has the capacity to support routine postoperative follow-up and generate the infrastructure required to provide timely diagnosis and management of common postoperative complications. Following valvular cardiac surgery, most patients will need management of residual symptoms of heart failure, adjustment and monitor of anticoagulation, administration of lifelong penicillin prophylaxis and guidance on how to navigate family planning. Anticoagulation has historically been seen as an insurmountable challenge in the rural poor; however, in this chapter, we present the PEN-Plus model for decentralized postoperative management—and provide insight into how its application can guide the way forward to support sustain-

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_25

able post-surgical capacity and appropriate patient follow-up in resource-constrained settings. Warfarin, for example, is a standard anticoagulant prescribed following most routine cardiovascular procedures, and its management requires careful consideration in under-resourced settings. Given its teratogenicity and associated untoward effects, if not managed properly, warfarin can present life threatening complications. As such, district hospitals must be equipped with the capacity to diagnose anticipated complications, to treat mild cases and to refer more severe cases of bleeding, valve thrombosis, or thromboembolic events toward tertiary levels of care in a timely and efficient manner. Patients must be counselled on the attendant risks of anticoagulation, and be provided education on how to maintain a consistent diet. Health systems must ensure that district hospitals have a reliable supply of both warfarin and INR testing supplies. Providers must be trained to diagnose and manage common ongoing complications including endocarditis, sternal wound infection and dehiscence, pericardial and pleural effusions, atrial fibrillation, valve thrombosis, valve dehiscence and hemolytic anemia. Furthermore, health systems need to set up comprehensive support systems for patients, including cardiac rehabilitation, nutritional, socioeconomic and mental health supports.

Keywords

Cardiac surgery · Mechanical valve replacement · Noncommunicable diseases · PEN-Plus · Decentralized care · Heart failure management · Anticoagulation · Rheumatic heart disease · Endocarditis, pericardial effusions · Pleural effusions · Sternal wound infection · Sternal wound dehiscence · Atrial fibrillation · Valve thrombosis · Valve dehiscence · Hemolytic anemia · Cardiac rehabilitation · Nutritional support, socioeconomic support · Mental health support

25.1 Introduction

Access to adequate postoperative care is a major barrier to expansion of cardiac surgery in developing countries, particularly in settings with a high burden of rheumatic heart disease where adherence to, and monitoring of, lifelong anticoagulation after mechanical prosthesis is crucial [1–3]. In some established cardiac surgical centers in Sub-Saharan Africa, postoperative follow-up is only provided by cardiologists at urban tertiary referral hospitals [4], thereby restricting access to essential care for poor patients living in rural areas. Outcomes from some of these centralized programs have revealed high rates of anticoagulation non-adherence and loss to follow-up [1, 4–6]. Here, we present the PEN-Plus model for decentralized postoperative management in rural district hospital non-communicable disease (NCD) clinics [7].

PEN-Plus supported countries like Rwanda have developed a decentralized nurse-led post-cardiac surgery follow-up program in rural NCD clinics with promising outcomes [8]. These clinics are operated by nurses trained in the basic management of severe chronic NCDs, including postoperative issues such as anticoagulation management and common complications. NCD nurses are supported by national cardiologists who visit the clinic monthly and are available by phone for consultation. The clinics are equipped with a portable echocardiographic machine and point-of-care INR testing and supplied with warfarin and basic heart failure medications. This model could potentially be adapted in other developing countries as a strategy to facilitate expansion of access to cardiac surgery for the rural poor both by increasing case finding and assuring good postoperative outcomes.

Within the PEN-Plus model, patients require close follow-up at both the tertiary referral hospital by a cardiologist and at their local district hospital in the NCD clinic. It is important to have clear medical records between both systems, either electronic or on paper charts. The follow-up required can be demanding for some patients; so, a dedicated national cardiac surgery coordinator should be overseeing the process and remain in close communication with the patient and all the relevant care providers. We recommend patients be routinely seen by a cardiologist at one, three, six and 12 months postoperatively and at least monthly by a nurse or trained, specialty practitioner in the district hospital NCD clinics [9]. At each visit, providers should perform a physical exam with full vital signs, assess patient's volume status, perform necessary lab examinations (INR for patients on warfarin, potassium and creatinine if patient is still on heart failure meds), assess for medication adherence or for signs of any complications, provide necessary counselling and assess for complications. After this early postop period, patients can continue to be followed by the local district NCD clinics within the PEN-Plus model with referral to cardiology as needed. The national cardiac surgical coordinator can continue to get updates on the patient's status through local NCD clinics and convey important information to both cardiologists and cardiac surgery teams.

25.2 Routine Management

25.2.1 Heart Failure

Heart failure after cardiac surgery can result from transient myocardial "stunning" due to prolonged cardiopulmonary bypass and ischemia times, coronary malperfusion, valvular pathology and changes in afterload or preload that can cause considerable fluid shifts. Furthermore, many patients undergoing surgery in LMICs will have some degree of heart failure preoperatively, which may be transiently worsened due to the surgical procedure itself. Typically, patients in these settings recover 3 to 6 months following surgery, with the greatest fluid shifts initially occurring immediately after surgery. Patients may initially require diuretics but weaning should be trialed if patients' symptoms and heart function on echocardiography improve. Generally, an individual with normal heart function should not require diuretics. Continued or worsening heart failure symptoms weeks after the surgery should trigger workup for new problem such as endocarditis, valve thrombosis or dehiscence, cardiac tamponade or a new arrhythmia. Please see Chap. 4 of *The PIH Guide to Chronic Care Integration for Endemic Non-Communicable Diseases* for more detailed information on the PEN-Plus model for the management of heart failure in rural LMICs.

25.2.2 Anticoagulation

While essential for patients with valve replacements and certain types of heart failure and arrhythmias, anticoagulation poses a significant challenge in LMICs, particularly in poor and rural communities [10–12]. We present here the PEN-Plus model for decentralized nurse-led anticoagulation management [8].

Health systems supporting a cardiac surgical program will need a steady supply of aspirin, warfarin and heparin. For patients with a mild to moderate risk of thrombosis—such as bioprosthetic valve replacement, mitral stenosis in sinus rhythm or peripartum cardiomyopathy—aspirin is an effective, safe, and inexpensive method for anticoagulation. For patients with extremely high risk of thrombosis—such as mechanical valve replacement, known history of thrombus or atrial fibrillation with heart failure—require greater degree of anticoagulation with warfarin. However, since warfarin requires many days to take effect and often has unpredictable therapeutic levels, many patients with very high risk of stroke—such as patients with mechanical valve replacements immediately after surgery—require a heparin "bridge", or additional fast acting anticoagulation, until warfarin is at therapeutic levels. Subcutaneous enoxaparin (Clexane), subcutaneous unfractionated heparin or intravenous heparin drips can be used. In our experience, some LMICs may not have the pumps required for safe IV heparin administration and the ability to frequently monitor partial thromboplastin time to ensure adequate anticoagulation, so subcutaneous is often used. See Table 25.1 for more information on specific indications and uses of anticoagulation.

Table 25.1 Anticoagulation Agents and Indications. (Table adapted with permission from: Bukhman G, Kidder A, editors. The Partners In Health Guide to Chronic Care Integration for Endemic Non-Communicable Diseases, Rwanda Edition. 2011.)

Indications	Warfarin or Aspirin?	Heparin bridge?	Goal INR	Duration of therapy
Heart failure and atrial fibrillation				
Peripartum cardiomyopathy	Aspirin	N/A	N/A	Lifelong
Mitral stenosis in sinus rhythm	Aspirin	N/A	N/A	Lifelong
Mitral stenosis with signs of prior stroke	Warfarin	No	2.0–2.5	Lifelong
Atrial fibrillation (without heart failure)	Aspirin	N/A	N/A	Lifelong
Atrial fibrillation (with heart failure)	Warfarin	No	2.0–2.5	Lifelong
Prosthetic Valves				
Bioprosthetic tricuspid Valve	Warfarin for the first 3 months, then aspirin	Yes	2.5–3.0	Lifelong
Other bioprosthetic valve (not tricuspid)	Aspirin	N/A	N/A	
Mechanical aortic valve	Warfarin	Yes	2.5–3.0	Lifelong
Mechanical mitral valve	Warfarin	Yes	3.0–3.5	Lifelong
Mechanical tricuspid valve	Warfarin	Yes	3.0–3.5	Lifelong

Warfarin is a vitamin K antagonist which achieves anticoagulation by inhibiting the synthesis of several coagulation factors (factors VII, IX, X and prothrombin). Warfarin can have unpredictable levels within the body given its metabolism varies greatly between individuals and has many interactions with common foods and medications [13]. As such, patients on warfarin must get their international normalized ratio (INR), regularly checked to measure the degree of anticoagulation. INR is a test that compares a patient's prothrombin to that of a "normal" individual. A normal INR is 1.0. While an increased INR suggests the blood is more anticoagulated, or more resistant to forming a clot. INR levels can change significantly for patients on warfarin depending on what medicines they are on or food they eat. Since Warfarin is a vitamin K inhibitor, food with high vitamin K levels will lower the INR and the efficacy of anticoagulation, putting patients at higher risk for thrombosis. Foods with high vitamin K content include leafy green foods (e.g. spinach, collard greens, dodo) and other vegetables (e.g. cabbage, Brussel sprouts and broccoli). However, a common misconception is that patients cannot eat vegetables. It is important to counsel patients that they can eat any foods as long as their diet is consistent without great variability from day to day. Furthermore, alcohol can unpredictably alter the INR of a patient who is on warfarin and patients should be counselled to limit their alcohol intake. See Table 25.2 for common drug interactions with warfarin.

Depending on the condition, there are different goal INR levels. There are many different factors for thrombus formation in patients with prosthetic valves, including (1) hemodynamic factors, such as low cardiac output states, the anatomic position of the prosthesis, and hyperviscosity, (2) surface factors, such as post-surgical endothelial damage, incomplete

Table 25.2 Common medications that alter warfarin effect and INR levels

Increase warfarin effect/INR	Decrease warfarin effect/INR
Acetaminophen	Anti-thyroid drugs
Allopurinol	Carbamazepine
Aspirin	Dicloxacillin
Cephalosporins	Griseofulvin
Cimetidine	Haloperidol
Ciprofloxacin	Oral contraceptives
Erythromycin	Phenobarbital
Fluconazole	Rifamipin
Metronidazole	Vitamin K
Macrolide antibiotics	
Omeprazole	
Sulfamethoxazole/Trimethoprim	
Thyroid hormone	

prosthesis endothelization, leaflet damage or deterioration, and (3) hemostatic factors, such as hypercoagulable states, suboptimal anticoagulation, and platelet reactivity [14]. Even between different types of mechanical valve replacements, mitral and tricuspid valve replacements have the highest risk of thrombosis given the lower velocity of blood flow through the valves, compared to the high velocity of blood through mechanical aortic valves. See Table 25.1 for the goal INR levels for each indication.

25.2.2.1 Initiating Warfarin

During the pre-surgical screening, providers must assess patients for any contraindications to warfarin or any conditions putting them at higher risk for blood clotting or bleeding. Warfarin is highly teratogenic; so, woman of childbearing age should have a negative pregnancy test at the time of initiation and be counselled on the importance of family planning. When warfarin is indicated lifelong, thorough counselling must be done to inform the patient that it will be unsafe for them to ever become pregnant without direct physician consultation and guidance towards transitioning to a more expensive, less available form of anticoagulation (e.g. enoxaparin), which requires meticulous compliance and careful follow-up. Respecting the ethical principles of patient autonomy and non-maleficence, providers should understand if patients decline cardiac surgery for this reason or request a bioprosthetic valve which can be managed with aspirin.

Starting dose for warfarin is typically 2.5 mg/day for adults or 0.1–0.2 mg/kg/day for children (max starting 2.5 mg/day). As previously described, patients with mechanical valve replacement are at very increased risk of thrombosis and require heparin bridge. For many LMICs, subcutaneous heparin is most feasible given it is inexpensive and doesn't require special IV pump. Typical dose for Enoxaparin (Clexane) is 1 mg/kg/dose twice per day and for subcutaneous Heparin 15,000 units/dose twice a day for adults or 250 units/kg/dose twice a day for children.

A patient with mechanical valve replacement that has an INR below 1.5 is at very high risk for thrombosis, and it is recommended to restart warfarin in the hospital with a heparin bridge until their INR rises above 2.0. Some patients with atrial fibrillation may start coumadin at home without a heparin bridge. Patients with liver disease can have dysfunctional coagulation pathway and may have an elevated INR without warfarin. These patients can still safely take warfarin but should be started at half the normal dose. See Protocol 25.1 for PEN-Plus suggestion on initiating warfarin therapy.

25.2.2.2 Anticoagulation Monitoring and Titration in Rural LMIC Settings

In addition to warfarin being fairly unpredictable, it can have life threatening consequences with subtherapeutic or supratherapeutic levels. If patient's INR level is too low, they can develop a thrombus on the valve, resulting in valve dysfunction, new heart failure symptoms, or thromboembolic events such as a stroke or pulmonary embolism. If a patient's INR level is too high though, they are at risk for bleeding episodes such as epistaxis, menometrorrhagia, cerebral hemorrhage or gastrointestinal bleeding. The therapeutic window is narrow for most patients and requires close monitoring and titration by experienced providers. In our experience, we train providers to worry more about thrombosis rather than bleeding in the setting of mild to moderately abnormal INR level, acknowledging that bleeds are common and can be life threatening at very high INR levels.

In the PEN-Plus model of decentralized NCD care, district hospital NCD clinics have the capacity to monitor and titrate warfarin levels, which is facilitated by nurses properly trained in the best practices for INR management. INR management has historically been viewed as difficult in rural and poor communities, partially because of the cost and expertise required of the laboratory equipment. However many point-of-care machines are portable, convenient and becoming more affordable for district hospital level NCD clinics. Patients who live far from even the district hospital could benefit from a portable personal INR testing machine to use at home with the assistance of a community health worker. Local health systems must ensure that they have procured a steady supply of testing strips and have a local means of repair or replacement should the point of care machines malfunction.

Typical regimen of warfarin is between 3 mg and 6 mg of each day, but responsiveness can vary greatly. The key to successful titration of warfarin is to make small and incremental adjustments, with frequent follow-up. Typically, warfarin is dispensed in 1 mg and 5 mg tablets and should be adjusted by 0.5–1 mg ($\sim$10–20%) at a time. After a dose adjustment, providers must wait at least 3 days before rechecking an INR and adjusting the dose. If an INR level increases from subtherapeutic to supratherapeutic, the appropriate warfarin dose may be between these two doses. INR levels naturally wax and wane slightly from day to day; so, if a patient's INR has been in therapeutic range for a considerable time, but now is only slightly off, providers should reassess in a week without making an immediate dose change. If the INR level is very high (for instance, above 5.0) or increased rapidly (for instance, from 2.0 to 4.0 in one week), prescribers should stop the warfarin for 2 days before resuming at a lower dose (20% below the last prescribed dose). Providers should never give fresh frozen plasma unless the patient is actively bleeding. See Protocol 25.2 for more information on titrating warfarin.

When a patient's INR is abnormal, especially if they previously had significant period of stability, providers should think of other causes of altered INR levels, including patient's adherence and diet, possible pharmacy or prescription errors, expiration data and quality of warfarin drug supply, acute illnesses, or any new medications or herbal therapies the patient may be taking.

Maintaining therapeutic levels in patients on warfarin can be incredibly challenging, despite a prescriber's best efforts. Health systems looking to build cardiac surgical programs need to think creatively about how to best support patients and prescribers. A national cardiac surgery coordinator will have a large role in communicating with the district NCD providers and assisting patient management as needed. Many health systems have advocated for an assigned community health worker to each patient on warfarin to directly observe therapy and provide education to the entire family.

A country planning to implement a cardiac surgery program must ensure that patients have

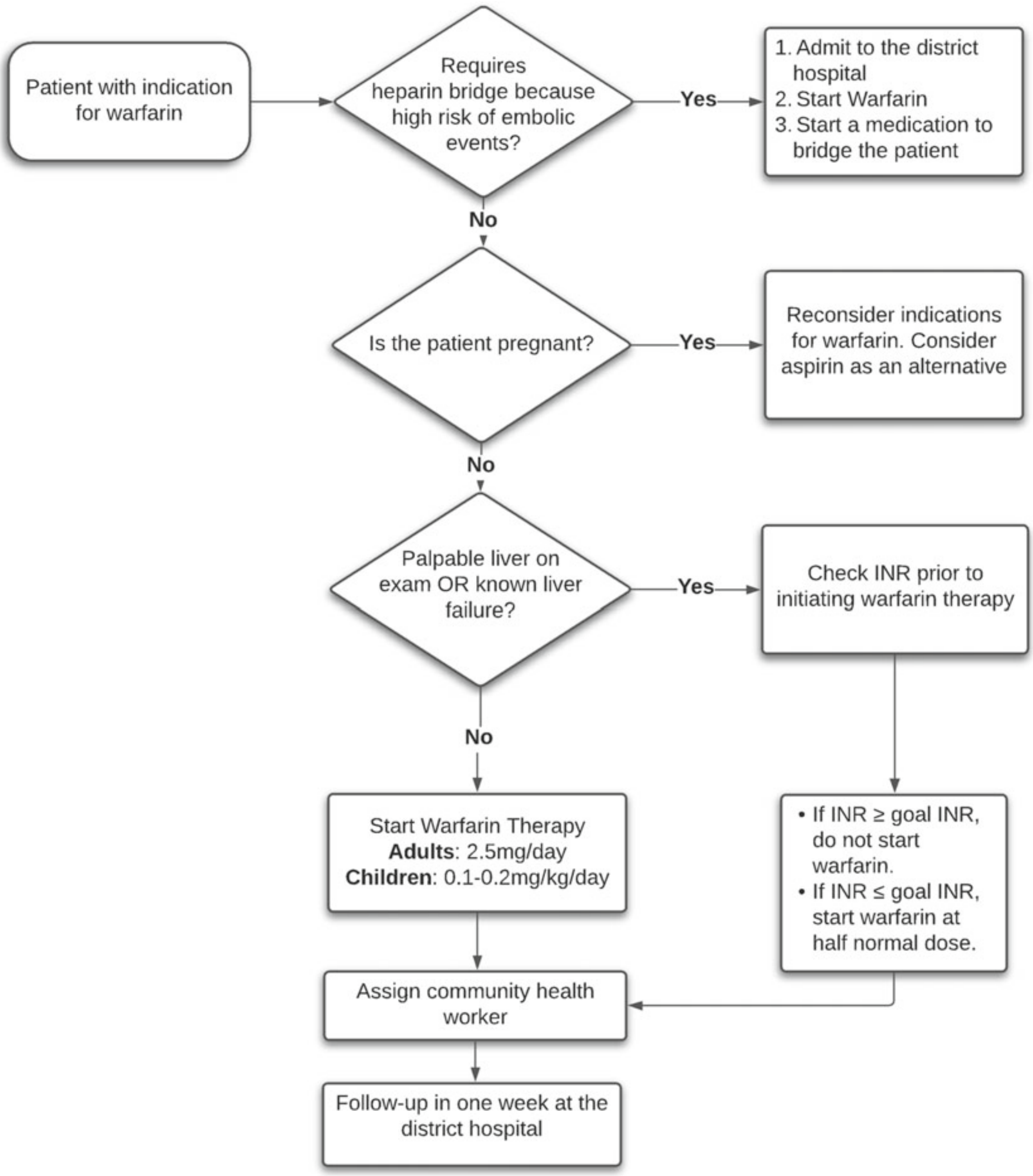

Fig. 25.1 Initiating warfarin therapy. (Figure adapted with permission from: Bukhman G, Kidder A, editors. The Partners In Health Guide to Chronic Care Integration for Endemic Non-Communicable Diseases, Rwanda Edition. 2011.)

consistently reliable access to quality warfarin without stockouts or disruption in INR testing. There is great variability in the exact composition and bioavailability of warfarin from different producers; so, health systems should attempt to continue to purchase warfarin from the same supplier. If changes become necessary due to inventory shortages or pricing, prescribers should be made aware, and INR levels should be checked more frequently. Furthermore, the national cardiac surgery coordinator should be in regular contact with NCD clinics supporting patients on warfarin to ensure a steady supply of unexpired INR strips remains available.

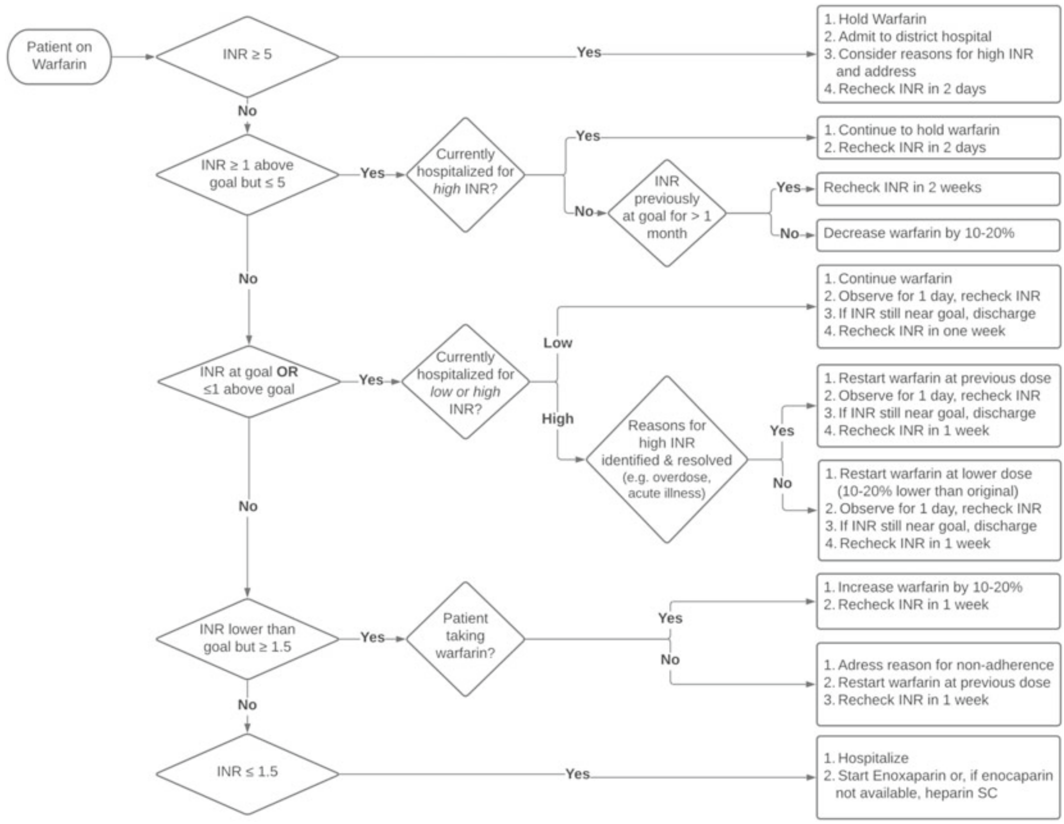

Fig. 25.2 Titrating Warfarin Therapy. (Figure adapted with permission from: Bukhman G, Kidder A, editors. The Partners In Health Guide to Chronic Care Integration for Endemic Non-Communicable Diseases, Rwanda Edition. 2011.)

25.2.3 Penicillin Prophylaxis

All patients with a history of acute rheumatic fever and rheumatic heart disease are at increased risk of developing acute rheumatic fever again. Furthermore, for patients with prosthetic valves, repeated episodes of acute rheumatic fever could be life-threatening. Therefore, all patients with prosthetic valves should be placed on lifelong penicillin secondary prophylaxis. Providers should use shared decision making with the patient to choose between either oral daily penicillin VK, oral erythromycin, or monthly injectable benzathine penicillin G. While monthly intramuscular dosing may be more convenient, there is increased pain with injections, which may lead to compliance issues.

25.2.4 Family Planning

Women with a history of cardiac surgery and heart failure are at risk for a complicated pregnancy with worsening heart failure given the expected fluid shifts of pregnancy. Furthermore, warfarin is a teratogenic medicine that has severe effects on a fetus. Women of childbearing age should be counselled before surgery on the need for lifelong contraception. With the woman's consent, it may further be beneficial to include the patient's family in this counselling, so all understand the dangers of potential pregnancies. Providers should offer both short and long-acting reversible contraception (LARCs) for women, or, if available, a vasectomy for their partner.

Of note, estrogen containing contraceptives can increase the risk of thrombosis in all women. There is no evidence that anticoagulation mitigates this risk; so, many guidelines have a history of thrombosis or mechanical valve replacement as a contraindication for combined oral contraceptives. In these cases, progesterone only contraceptives, particularly progesterone long-acting contraceptives like the levonorgestrel intrauterine device, have particular benefits for women with prosthetic valves. However, many experts agree that if progesterone-only contraceptives are not available or if the female patient prefers an estrogen containing contraceptive due to the unpredictable menstrual bleeding with progesterone-only contraceptives, estrogen-containing contraceptives are acceptable given that the relative risk of a complication from pregnancy is much higher than the thrombosis risk of estrogen containing contraceptives [15]. Of note, both estrogen and progesterone can affect the metabolism of warfarin and the INR levels. If a patient makes any changes with her contraception, an INR level should be checked shortly afterward.

25.3 Management of Ongoing Complications

25.3.1 Endocarditis and Fever in Patients with Prosthetic Heart Valves

Endocarditis of the prosthetic heart valve can be life threatening and may occur at any time after the surgery, although most common in the first 6 months. Infection can be seeded directly during surgery, typically presenting as an early infection, or by hematogenous spread from another source, typically a later infection. As such, patients should be instructed to take antibiotic prophylaxis before dental procedures, procedures with ongoing gastrointestinal, or genitourinary tract infections, or procedures on infected skin or musculoskeletal tissue [16]. Amoxicillin (2 grams for adults or 50 mg/kg for children) should be given 60 min prior to the procedure. Individuals with penicillin allergy may take Clindamycin (600 mg for adults or 20 mg/kg for children).

Endocarditis may present with infectious signs including fever, chills, body aches in addition to new signs of heart failure, new murmur, or loss of the mechanical click for patients with a mechanical valve. Classically, there are some systemic findings associated with endocarditis—such as Janeway lesions, Osler nodes, splinter hemorrhages—but these are very rare. Vegetations on the infected valve may embolize and cause lung or brain abscesses or cause a stroke or pulmonary embolism. Furthermore, the infection may interfere with the cardiac conductions system, causing heart block, or extend to the pericardium, causing a pericarditis.

Patients should have a temperature checked on each visit to the NCD clinic. Within the PEN-Plus model, if a patient has a temperature above >38C, both the district hospital physician and national cardiac surgical coordinator should be contacted. The district hospital physician should examine the patient, perform necessary laboratory examinations, including full blood count, inflammatory markers, and two sets of blood cultures (will often need to be sent to a national referral laboratory). Patients on warfarin should have an INR checked. Once two sets of blood cultures have been drawn, all patients should be started on empiric antibiotics. If there are signs of a new murmur, or any signs of sepsis or shock, including but not limited to, hypotension, tachycardia, labored breathing, the patient should be immediately resuscitated and transferred to the national tertiary referral hospital with the assistance of the national cardiac surgery coordinator. The need for fluid resuscitation and/or vasopressors should be assessed by the admitting physician, using a more conservative approach with fluid resuscitation for patients with decompensated heart failure with hypervolemia.

National cardiac surgery programs should analyze the local bacterial prevalence studies and antibiograms to create an empiric antibiotic regimen for the treatment of prosthetic valve endocarditis. A systemic review found that while there is a paucity of data in LMICs, Staphylococcus and Streptococcus organisms are the two most common causes of infective endocarditis, with Methicillin resistant Staphylococcus aureus (MRSA) being a particularly aggressive source of endocarditis [17]. As such, empiric treatment should include broad spectrum antibiotics covering both gram positive and gram negative bacteria, and all hospitals caring for patients with prosthetic valves should have a steady supply of MRSA-targeted antibiotics such as Vancomycin or Clindamycin. Commonly prescribed empiric regimens include an antibiotic with staphylococcus coverage, such as Ceftriaxone or Penicillin or Ampicillin or Vancomycin (if there is a high prevalence of MRSA), plus Gentamycin for synergistic effect and Rifampin for staphylococcus epidermidis coverage (required for prosthetic valve endocarditis). We refer providers to the in-depth infective endocarditis guidelines by the American Heart Association with recommendations for the specific pathogen identified [18]. Of note, some antibiotics may affect warfarin levels, and INR should be regularly monitored.

Management of endocarditis of a prosthetic valve is complicated because it requires IV antibiotics for 6 weeks. This poses a challenge as best infection control practices include changing peripheral IVs every 3–4 days. Midline catheters could be a solution if the hospital has the resources. Furthermore, some patients with an infective endocarditis of the prosthetic heart valve may develop valve destruction or degradation and require follow-up surgery. Therefore, there should be close communication between treating physician, national coordinator and cardiac surgical team.

Fever in patients with prosthetic valves is challenging as patients may still have other common causes of fever, including malaria, urinary tract infection, pneumonia or cellulitis. If there is clear evidence of another source of infection, directed therapy is acceptable. However, if diagnosis is unclear or if the patient is critically ill, the patient should still receive empiric broad spectrum antibiotics while awaiting the results of the blood culture. Furthermore, in certain settings where the prevalence of malaria is very high, a positive malaria test may be incidental and suspicion for endocarditis must remain very high.

Prevention of endocarditis is an important focus for a health system looking to build cardiac surgical capacity. Hospitals should practice high quality infection control measures to reduce secondary infections that can lead to endocarditis, including replacing peripheral intravenous lines every 3 days, encouraging ambulation to prevent bedsores, and urinary catheters should be removed as soon as possible to avoid urinary tract infections.

25.3.2 Sternal Wound Infection and Dehiscence

After cardiac surgery is completed, the sternum is re-approximated using sternotomy wires, which hold the bone together and provide stability for the chest. While post-operative sternal pain is normal, the sternum can become unstable and become infected if the wires dehisce or become loose. This is a surgical emergency. Clinicians can assess for sternal stability by placing the palm of the hand of the sternum and rocking it back and forth. A click may suggest instability and patients should be started on antibiotics and be seen by a surgeon immediately.

25.3.3 Pericardial and Pleural Effusions

Surgery on the heart requires the surgeon to open the pericardium and pleural sac, initiating an inflammatory process which can cause a pericardial effusion (fluid build-up in the sac surrounding the heart) with or without tamponade (when the fluid compressed the heart and interferes with the heart's function), or a pleural effusion (fluid build-up in the sac surrounding the lungs). These conditions can result in shortness of breath, heart failure, or cardiopulmonary collapse.

Pericardial effusion is normal following heart surgery and can present with a muffled heart sounds or signs of heart failure. Pericardial effusions are usually self-limiting within 3 to 6 months, but pericardial tamponade is life threatening. NCD providers and cardiologists should assess the degree of effusion on each post-operative visit with an echocardiogram and should contact the surgical team should the effusion grow or not resolve. If a patient present with signs of tamponade including hypotension, tachycardia or cold extremities, they should be emergently referred to a provider skilled to perform a pericardiocentesis. Tamponade should always be suspected in the setting of postoperative low cardiac output.

Pleural effusions may also present with shortness of breath and an exam notable for diminished breath sounds with increased dullness to percussion at the bases. Chest x-ray imaging will reveal a loss of a clear hemidiaphragm border. Most cases of pleural effusion following cardiac surgery are unilateral and on the left side. Most do not require a diagnostic thoracentesis but should be referred to a skilled physician for a therapeutic thoracentesis for patients with large, progressive or symptomatic pleural effusion.

25.3.4 Atrial Fibrillation

Atrial fibrillation occurs in 10–65% of patients following cardiac surgery [19]. The cause of this irregular conduction pattern is multifactorial, including atrial injury or stretching during surgery, the effect of being on cardiac bypass machine, and by pericarditis. While the highest risk for atrial fibrillation is on the second or third postoperative day, this increased risk may last up to several months and patients should be placed on beta blockers (typically atenolol) for the first 6 weeks after surgery can reduce the risk of this potentially fatal arrhythmia. After 6 weeks, the beta blocker can be gradually reduced but NCD district providers should have a low threshold to obtain an ECG should the patient present with palpitations, new signs of heart failure, irregular heart rate or tachycardia. If a patient is diagnosed with atrial fibrillation, they should be treated with beta blockers for rate control, with goal heart rate less than 80 beats per minute. If the atrial fibrillation continues, providers may use digoxin for rhythm control. All patients should be on warfarin, if not already started, to lower the risk of thromboembolic phenomenon.

25.3.5 Valve Thrombosis

As mentioned earlier, if a patient has a mechanical valve replacement and the INR drops below therapeutic range, they are at increased risk for thrombosis. Mechanical tricuspid valves hold the highest risk for thrombosis, followed by mitral and aortic valves. These patients are at high risk for embolic disorders including stroke and pulmonary embolism and should have access to appropriate interventions. Patients will present with a loss of the crisp closing sound of the mechanical valve. Patients should be counselled that if they lose the crisp mechanical sound, they should present for care immediately. The national cardiac surgery coordinator should facilitate an emergent transferred to the tertiary referral hospital.

If nurses within the district hospital NCD clinic have concerns for thrombus while waiting for transport, they should check an INR and if low, start a heparin bridge. At a tertiary hospital, treatment will depend on the resources of the hospital but can include surgery, thrombolytic therapy and anticoagulation. Emergency surgery is recommended for patients with New York Heart Association (NYHA) functional class II to IV status or a large thrombus [14].

25.3.6 Valve Dehiscence

Valve dehiscence occurs when the sutures attaching the replacement valve to the heart loosen or dehisce, causing blood to flow around the valve. Valve dehiscence can present with a new murmur and new signs of heart failure. Patients should be referred to the cardiologist for echocardiogram, with close communication with the national coordinator and the cardiac surgical team for potential need for reoperation.

25.3.7 Hemolytic Anemia

Hemolytic anemia may occur in patients with prosthetic heart valves, especially mechanical valves or valves that have dehisced, due to the shearing forces of blood as it passes the mechanical valve or around the paravalvular leak. Hemolytic anemia should be suspected in patients who develop anemia following valve replacement. These patients often present with fatigue and pallor, with or without signs of jaundice or cholelithiasis. If an anemia is discovered, after ruling out malaria, providers should treat patients with iron replacement therapy.

25.4 Other Considerations

25.4.1 Cardiac Rehabilitation

Cardiac rehabilitation is an essential part of postoperative management that can help patients recover their physical fitness, perform their activities of daily livings, and return to work. All patients that undergo cardiac surgery, especially those with previous physical limitations from heart failure, will have some degree of physical deconditioning as a result of the surgery. Cardiac rehabilitation consistent of a variety of services, including individual and group supervised exercise training, to regain physical strength. While cardiac rehabilitation significantly improves mortality and morbidity for patients with valvular surgery and has been shown to be cost effective, it is still not available in 60–80% of LMICs [20–24]. Even in LMICs that do have cardiac rehabilitation programs, studies reveal that lack of referral from physicians and patient financial considerations were barriers to patient participation. Some LMICs have used creative means to improve access to rehabilitation including hybrid in person and at home models using telehealth [24]. Other models have created comprehensive rehabilitation centers where patients have access to social workers and therapists for social and mental health support.

25.4.2 Nutritional Support

Providers must screen for and treat all cardiac surgical patients with malnutrition. Malnutrition is significantly associated with increased morbidity and mortality, both preoperatively and postoperatively [25]. Furthermore, given the interaction of many foods with warfarin, it is important that all patients have steady access to high quality food. While it has not been studies in the cardiac surgical patients, studies have shown that providing food and financial support to patients with HIV and tuberculosis improves overall outcomes and adherence to medication [26]. Thus, we recommend nutritional support pre- and post-operatively for cardiac surgery patients with malnutrition.

25.4.3 Socioeconomic Support

Rheumatic heart disease not only effects poor and rural families at higher rates, it also has worse outcomes for families with unfavorable social determinants of health [27]. Many of the sickest patients live in marginal housing with dirt floors, inadequate roofing, and poor access to clean water. Post-cardiac surgery patients are at particular risk of developing life-threatening infections in these conditions. We recommend that a social worker evaluate the patient's living situation and health systems develop systems to provide economic support to the poorest and most vulnerable patients. One example of such program is the Program on Social and Economic Rights (POSER) program through Partners in Health which supports patients with inadequate housing to the to have their house repaired or rebuilt and ensure access to clean water [28]. Another study revealed that providing financial reimbursement for transportation to clinic for patients with HIV, tuberculosis and leprosy, improved medication adherence and outcomes

[26]. While some may argue that these support structures are outside the scope of a national cardiac surgery program, we believe that it is required in order to achieve health equity and provide equitable access and ensure favorable outcomes to all.

25.4.4 Mental Health Support

Health systems should have systems in place to provide mental health support to patients with cardiac surgery. Studies in high income countries have shown that preoperative depression is linked with worsening mortality rates and that patients who have received valvular surgery are at increased risk for depression [29, 30]. Moreover, patients with depression were found to be more likely non-adherent to their anticoagulation therapy compared to patients without depression [31]. Mental health professionals should be integral members of the NCD team and will require innovative practices given the worldwide shortage of mental health professionals [32].

Acknowledgements The authors would like to thank the cardiac and heart failure patients, the Rwandan Ministry of Health and the Rwanda Biomedical Center for its commitment to health care as a fundamental human right. We also thank the leadership and staff of Inshuti Mu Buzima (Rwanda) and Partners In Health (Boston, MA) whose programmatic accompaniment of the public health sector in Rwanda led to this work. We also thank Drs. Corrado Concedda, Jim Rawn, Nathan Ruhamya, Gapira Ganza, Patricia Come and the four international humanitarian cardiac surgical teams (Open Heart International (Australia), Chain of Hope (Belgium), Team Heart, Inc (Boston, MA), Healing Hearts Northwest (Spokane, WA) —who all played an instrumental role in providing care, implementing training and the assisting with infrastructure development early in the course of Rwanda's national cardiac surgery program.

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26 Establishing and Expanding Cardiac Surgery Centers

Dominique Vervoort, Sashini Iddawela, and A. Thomas Pezzella

Abstract

Over 4000 cardiac surgery centers exist worldwide, yet with a skewed distribution: North America possesses one per 120,000 population, whereas sub-Saharan Africa and Southeast Asia have only one center per 33 million and 16 million population, respectively. Thus, there is a need to establish and expand centers in regions of need, especially in low- and middle-income countries (LMICs). In this chapter, we discuss the various needs from both a health system and infrastructure perspective to enable cardiac surgery centers to be established and scaled around the world. We illustrate past experiences through a focus on existing models to establish new centers in LMICs, and identify and propose opportunities for the development of new hybrid models moving forward in a sustainable, locally-driven, and context-appropriate manner.

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26.1 Introduction

Six billion of the current 7.8 billion people worldwide lack access to safe, timely, and affordable cardiac surgical care as a result of a lack of accessibility, capacity, quality, and/or affordability [1]. Among these, geographical barriers make up a substantial barrier in access to cardiac surgical care in low- and middle-income countries (LMICs) [2]. Worldwide, just over 4000 centers perform cardiac surgery, of which only a small proportion is present in LMICs [3]. Where North America is able to rely on one center per 120,000 population, sub-Saharan Africa and Southeast Asia have only one cardiac center per 33 million and 16 million population, respectively [1]. Moreover, existing centers are commonly faced with logistical barriers to increase surgical volume, including but not limited to costly surgical supply chains, stockouts, defunct donated equipment, competent health workers shortages, and high financial burdens for the local patient population. As a result, some well-established regional or in-countrey centers are faced with long waiting lists, small annual surgical volumes, and fiscally difficult decisions, balancing financial sustainability, patient outcomes, and the population's access to care. Here, we present and describe the health system and infrastructure needs of cardiac surgery centers with a focus on existing models to establish new centers in LMICs. Accordingly,

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_26

we identify and propose opportunities for the development of new hybrid models to sustainably build and scale cardiac centers across the globe in a context-specific manner.

26.2 Components of Cardiac Centers

Cardiac surgery centers are tertiary or quaternary care facilities that are able to perform open-heart surgery, either embedded within broader hospitals (public, private, charitable, or military) or functioning as standalone cardiac centers. Independently running cardiac surgery centers (i.e., those not supported by visiting teams) require extensive human and physical resources. In terms of workforce, no minimum targets exist; however, it has been proposed that a minimum of one formally trained cardiothoracic surgeon, one general surgeon, one formally trained cardiac anesthesiologist, two trained cardiologists (including at least one with formal cardiac intensive care training), a technician, a perfusionist, a biomedical engineer, and three cardiac nurses are required [4].

The physical infrastructure of cardiac centers is critically important given the vast resource utilization associated with cardiac surgeries. As a result, the upfront costs are considerable. In a cardiac operating room, standard operating room equipment and a cardiopulmonary bypass machine are needed at baseline. As programs become more established, extracorporeal membrane oxygenation is added. In case of hybrid suites, which are still uncommon but increasingly seen in state-of-the-art LMIC centers, catheterization and imaging modalities need to be established. Table 26.1 and Fig. 26.1 summarize the minimum equipment, drugs, devices, and disposables needed for cardiac surgical operating rooms. In addition to industry partnerships, novel programs in LMICs may consider used but recent equipment (e.g., less than 10 years old) from upper-middle-income countries such as India and China. However, caution should be used when using non-reusable or expired disposables, as well as with donations of equipment that may be either dysfunctional or not usable in the local context [5]. These countries are further producing novel instruments and materials at lower costs, which is critical as foreign anesthetic and cardiac drugs as well as prosthetic heart valves and rings are typically expensive. Hereby, local distributors are the interface between foreign and local companies and the government and private hospitals, and critical to negotiate lower costs.

In terms of diagnostics, imaging and laboratory services are at the cornerstone of preoperative planning and postoperative follow-up. Preoperatively, careful patient selection is necessary to best use scarce resources whilst adequately predicting risks of mortality and complications for cardiac surgical patients. Intraoperatively, careful monitoring is critical to timely detect complications. Postoperatively, valvular function, cardiac output, and postsurgical complications must be evaluated. Moreover, comprehensive intensive care units (ICU) are needed to best manage cardiac surgical patients in the early postoperative time and in case of hemodynamic instability or postoperative complications (Fig. 26.2). Unfortunately, the maldistribution of intensive care beds and trained personnel across the globe is a rate-limiting factor for many cardiac centers to increase volume [6]. Additionally, cardiology outpatient clinics are vital for longitudinal follow-up and anticoagulation monitoring. Lastly, local and national registries and databases should be encouraged, both to inform targeted public health programs and governmental buy-in, as well as to contribute to international registries.

Jointly, these components illustrate the systemwide impact cardiac centers may have due to their inherent interaction with all levels of a health system. These include community-level prevention and diagnosis by community health workers, preoperative imaging and risk assessment, intraoperative management, postoperative

Table 26.1 Minimum equipment needs for cardiac surgical operating kits

Setting	Items
Operating room	• Operating table and supports • Operating light • Head light • Cardiopulmonary bypass • Intra-aortic balloon pump • Instrument cabinet • Instrument table • Anesthesia trolley (machine, ventilator, monitor) • Laryngoscope • Nasogastric airways (assorted sizes) • Resuscitation bags (adult and child) • Pulse oximeter • Oxygen regulator • Defibrillator • Electrocardiography monitor • Surgical table pads • Basic surgical kit • Cardiac surgical instruments • Sternal saw • Cautery • Electric suction machine • Disposables and consumables – Sterile gloves – Cotton towels – Lap sponges – Vessel loops – Basic and cardiac surgical suture – Teflon pledgets – Intracoronary shunts of various sizes (1.5–2.5 mm) – Epicardial pacing wires, accompanying leads and pacemaker box – Sternal wires, accompanying needle holder and wire cutter – Rummel tourniquet and snares – Bone wax – Foley catheters
Pre-operative care	• X-ray unit • Computer tomography scan • Clinical laboratory /Blood bank • Electrocardiography monitor • Echocardiography
Post-operative care (ICU, ward, clinic)	• Intensive care unit beds • Electrocardiography monitor • Ventilator • Electric suction machine • Material trolleys • Infusion pump • Syringe pump • Mobile X-ray unit
Medicines	• Bedside anticoagulation and other basic drugs • Anesthesia
Other	• Stretcher • Autoclave • Blood bank • Refrigerator (OR, ICU, ward) • Devices (e.g., heart valves, rings, permanent pacemakers)

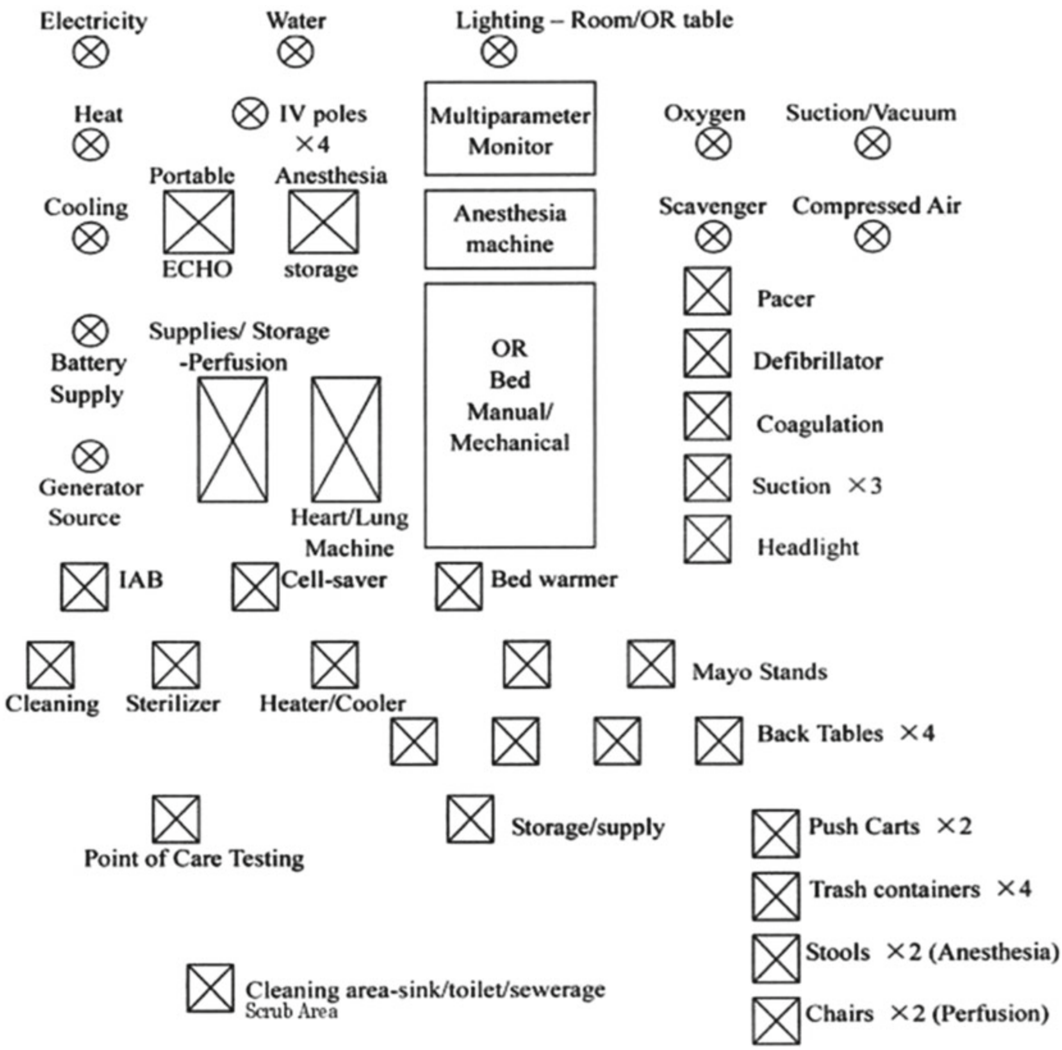

Fig. 26.1 The basic equipment needs for the cardiac operating room. Reproduced from Murala JSK, Karl TR and Pezzella AT (2019) Pediatric Cardiac Surgery in Low-and Middle-Income Countries: Present Status and Need for a Paradigm Shift. Front. Pediatr. 7:214. https://doi.org/10.3389/fped.2019.00214

ICU care, and long-term follow-up and provision of essential medicines.

26.3 Existing Models to Establish Center

Various models have been used to try and establish sustainable cardiac centers in LMICs. While some have been particularly successful, others have not, in part due to either a lack of long-term strategic planning or not being appropriate given the local context [7]. The currently recognized models broadly include the following:

1. *Ghana-Germany model*: In Ghana, Dr. Frimpong-Boateng established the National Cardiothoracic Centre after returning to his home country upon completing his training as a cardiac surgeon in Germany [8]. The model has been widely touted as one of the most successful models to leverage, due to the

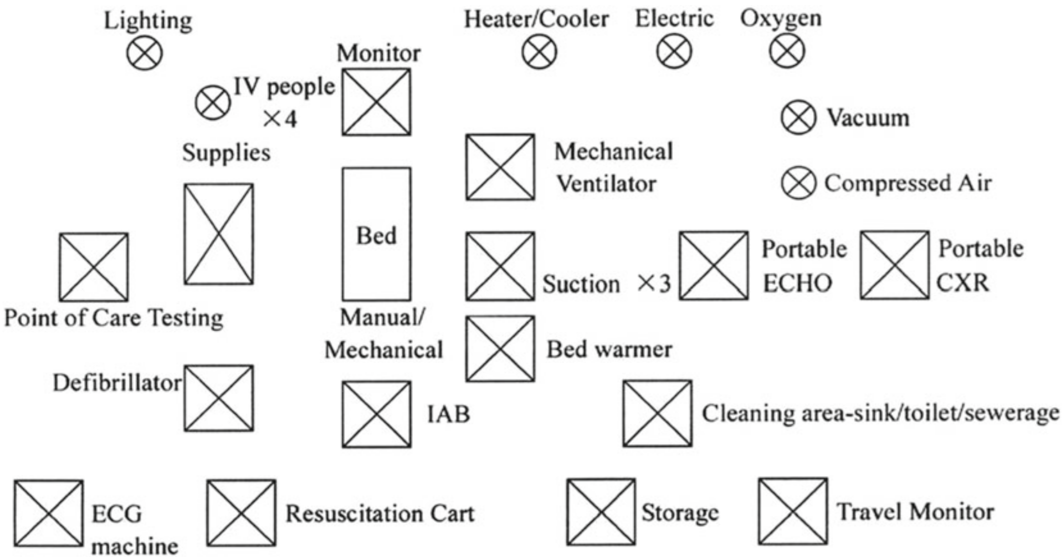

Fig. 26.2 The basic equipment needs for the cardiac intensive care unit. Reproduced from Murala JSK, Karl TR and Pezzella AT (2019) Pediatric Cardiac Surgery in Low-and Middle-Income Countries: Present Status and Need for a Paradigm Shift. Front. Pediatr. 7:214. https://doi.org/10.3389/fped.2019.00214

presence of local expertise (e.g., Dr. Frimpong-Boateng grew up and completed his medical school in Ghana) and the clinical expertise (e.g., training in a high-volume center abroad). In this model, a locally-schooled (i.e., medically-trained) clinician pursues cardiothoracic surgical specialty training abroad in a formalized fellowship manner, whilst maintaining local ties with both academic institutions and the government. Upon completing training and gaining the necessary expertise to function autonomously, guide cardiac teams, and train others, the surgeon returned to their country of medical school to establish a local cardiac center whilst maintaining an international connection with the center of training.

2. *Experienced Expatriate Consultant model*: This structure involves a senior expatriate surgeon being sponsored by a government to develop a local cardiac surgical program. Bringing the expertise of an experienced cardiac surgeon who has worked within an established program and can now locally embed themselves is useful; however, it could run into problems as the expatriate surgeon may not be familiar with local geography, traditions, and resource constraints. An adaptation to this model is the collaboration between entire centers, rather than an individual surgeon, such as that between the Deutsches Herzzentrum Berlin and the Sarajevo Heart Centre [8]. Such a model can reap the benefits of deepening institutional connections and facilitating exchange of information, whilst maintaining local ownership, ensuring context-specific programs, and facilitating heart team (i.e., including non-surgical health workers) training.
3. *Individuals and Teams Sent Abroad for Training*: Human resources are an integral part of establishing any form of service, and highly trained staff are imperative in cardiac surgery. As the largest volume of cardiac surgery today happens in high-income countries, sending staff for training in these regions used to be a prevailing norm. While this model enables the transfer of skills and wider exposure for the local team, it does not address significant barriers (such as resource constraints) that might make these techniques difficult to implement. For example, training

in state-of-the-art centers abroad may not translate into comparable practice in local centers, if resources are not available to a comparable extent. Further, the conditions encountered may not reflect those seen in the original country (e.g., LMICs have much higher rates of rheumatic heart disease or more progressive disease due to later presentations). An emerging trend is to send teams to upper-middle-income countries (e.g., India, China) which are rapidly expanding their cardiac surgical capacity, which would better reflect the disease burden in low- and lower-middle-income countries. It must be acknowledged that this model can incur significant costs, which may need to be subsidised, but is a step towards a more self-sufficient service.

4. *Mission Trip model*: As the first model for starting a cardiac surgical practice in an area which has little to no trained personnel, this may be considered the least sustainable. While it can be an important life-saving intervention for patients, it does very little to address the gaps in developing and providing a sustainable local program that will serve a population. This model is commonly also viewed unfavorably by local practitioners, who have expressed dissatisfaction at the effectiveness of skills transfer [9]. Possible adjustments include improving communication with local teams, centers, and other visiting teams, as well as setting defined training goals. It should be emphasized that this model is only a temporary solution to developing a permanent, self-sufficient cardiac surgical center, and should not substitute alternate models.
5. *Relocating Diaspora Surgeons model*: Brain drain is a significant hurdle for LMICs, which face critical shortages in human resources for health. This model, whereby diaspora surgeons are relocated to their country of origin following training, brings together experience and training with the unique knowledge of context and culture possessed by these staff. The framework can work in tandem with other models, such as training teams overseas and the Ghana/Germany model; however, it depends largely on the willingness of surgeons who train overseas to return after gaining experience. A middle-ground is for these surgeons to form diaspora-led surgical organizations, which have been noted to enact lasting improvements and establish self-sustaining services in other surgical fields [10].
6. *Supporting Centers to Independence*: lastly, various visiting teams have taken the approach of supporting existing local centers to become gradually more independent, higher-quality, higher-volume, and procedurally complex. For example, the collaboration between Project HOPE, Boston Children’s Hospital, Xin Hua Hospital, and Shanghai Children's Medical Center, which started in 1985, led to teams of volunteers to be sent from the United States to China each year until full local independence was feasible year-round [11]. Today, Shanghai Children's Medical Center is one of the highest-volume congenital heart surgery centers in the world, performing thousands of surgeries each year [11].

Naturally, the wider medical, financial, and political environment is a major determinant of the success of any of the programs. Importantly, a local champion and leader is necessary to ensure buy-in by the relevant stakeholders whilst maintaining a philosophy that pursues excellence despite resource constraints. Local ownership is critical to ensuring long-term sustainability and a gradual move towards independence (i.e., not relying on visiting teams to help operate) and increasing complexity of procedures. Holistic cardiac team training, rather than a mere focus on the cardiac surgeon, is needed to optimize outcomes and operative efficiency from the start [12].

26.4 Opportunities for New Models

Several opportunities may arise to establish cardiac programs, convening the lessons learned from previous models that have been successful.

These lessons most notably include the need for locally driven solutions and initiatives, sustainable funding considerations, and regional collaborations with other LMIC-based centers to draw from local experiences. While some LMIC centers are modelled after or inspired by high-income country centers, local variation in context, needs, and resources require local adaptation to best meet the needs of the patient population and healthcare providers. Moreover, the most successful models have witnessed the local champion, who is trained elsewhere in the country or abroad due to a lack of local training pathways, to leverage the connection with both sites through a bilateral collaboration and enabling shared learning.

Beyond these key drivers, public–private partnerships may be leveraged to accelerate and optimize the establishment of new programs, whilst providing an ability to expand existing programs. For example, Narayana Health in India is the largest cardiac center worldwide, performing approximately 8000 cardiac surgeries each year [1]. Through the development of economies of scale, a micro-health insurance scheme for the uninsured and poor patients, and "assembly line"-like operations management, Narayana has been able to scale its center in Bangalore and across India to achieve high-quality outcomes at the world's lowest procedural costs. Similarly, industry support can ensure a reduction in costs and the optimization of sourcing surgical supply chains to enable centers to maintain surgical volume year-round and gradually increase the volume and complexity of procedures.

Lastly, but importantly, the integration of cardiac surgical care expansion within National Surgical, Obstetric, and Anesthesia Plans (NSOAPs) is of critical importance [13]. Dozens of LMICs around the world are developing NSOAPs, long-term strategic plans to strengthen the surgical ecosystem, which are driven by Ministries of Health and supported by international organizations such as the World Health Organization and United Nations [14]. To date, however, cardiovascular care has been largely omitted in existing and budding plans. Thus, the establishment and expansion of centers must be rooted within broader health systems, recognizing the interplay between a cardiac center of cardiovascular division and other health sectors.

26.5 Conclusion

Low- and middle-income countries possess too few cardiac surgery centers, severely limiting access to quality cardiac surgical and interventional cardiology care when needed. Various models have been developed, tested, and proposed to set up sustainable programs, but few have succeeded. Lessons can be drawn from countries that were successful in establishing high-quality, low-cost cardiac programs and ought to be leveraged in other countries without sufficient centers as appropriate.

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27

Nuts and Bolts of Establishing a Contemporary Global Cardiac Surgery Program

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Abstract

The unmet burden of cardiac surgical disease worldwide is disproportionately shouldered by low & middle income countries. Strategies to address this disparity have relied predominantly on short term medical service trips from those in higher resource regions, but variability surrounding singular missions has historically jeopardized long-term effectiveness. We propose a framework for development of global cardiac surgical programs that endorses a methodical & structured approach in low resource countries, positioning programs and struggling centers to advance systematically toward sustainability and success through collaboration.

Keywords

Global cardiac surgery · Humanitarianism · Surgical volunteerism

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27.1 Introduction

The unmet burden of cardiac surgical disease worldwide is disproportionately shouldered by low & middle income countries. Strategies to address this disparity have relied predominantly on short term medical service trips from those in higher resource regions, but variability surrounding singular missions has historically jeopardized long-term effectiveness.

While the primary focus in delivering quality surgery is of obvious merit, the surprising neglect of host program-building & development remains pervasive. Without intentional establishment of equitable partnerships and reciprocal relationships, these initiatives have echoes of neo-colonialism that must be abandoned if sustainability is the collective target [1].

Although there are many successful models of global surgery, we've found from our experience that the following framework for low resource settings helps to position teams on a trajectory towards ongoing collaboration with specific targets to accomplish.

27.2 Identifying Need: Rules of Engagement

The concept of participating in humanitarian efforts resonates with many clinicians as fundamentally aligned with reasons they chose to

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_27

pursue the medical profession. But without structure & strategy, the best-intentioned individuals & teams can be led down the pathway of 'a solution looking for a problem.' This can manifest in doing the right thing for the wrong reason or going where not wanted or needed, two of the more commonly recognized 'sins of humanitarian medicine' [2].

When identifying a need, it's important that a group does not impose its own conclusion that assistance is required in a certain country, region or institution where it may not be solicited or even welcomed. Although global relationships can develop from clinician expatriate loyalties, a single patient/family/physician request for help, or personal experience in a certain region, individual connections without higher levels of support commonly are myopic in scope.

Rather, the most authentic collaborations develop when a Ministry of Health (MOH), regional healthcare administration, and/or engaged hospital leadership team request assistance as a host community. Bidirectional expectations can be established to outline realistic future goals that can be accomplished together, and in this scenario the likelihood of longitudinal collaboration is more favorable [3].

27.3 Site Assessment and Scout Visit

A clear summary of the needs, goals and objectives of the local team emerges from asking the host institution to first complete a comprehensive overview Pre-Mission Questionnaire (Fig. 27.1). This covers factors such as the regional health system, hospital infrastructure, training levels of key personnel, OR & ICU capacity, access to resources, current caseload, etc. The status of local security, epidemiological profile for communicable disease and the type of administrative & governmental support available for ongoing international collaboration is also of crucial importance [4]. This self-evaluation leads to positive energy among those locally involved and helps to identify specific areas in the healthcare process that need the most attention to move forward. Figure 27.1 demonstrates an example from an initial site questionnaire. The information this yields optimizes strategy, safety, and identification of essential equipment needs during the planning phase with the visiting team.

This first-pass questionnaire also provides the foundation for a subsequent on-site follow-up assessment by representatives of the visiting team. This scout visit is commonly represented by a surgeon, ICU nurse, and biomedical engineer who often spend 2 full days with the local team, visiting all relevant hospital facilities to verify and make amendments to information provided in the questionnaire. Infrastructure issues of importance include the power grid, frequency of daily outages, and back-up generator capacity & lag time for the operating room and the Intensive Care Unit. Oxygen plant logistics, functional triggers for ventilator alarms, and ability for multi-parametric monitoring are among other important issues for which competency should be confirmed. These examples are issues that can be detrimental or lethal if not understood & optimized prior to operating in a new program setting.

Other important areas to be checked include laboratory ability to run tests like ABGs & ACTs with a timeframe for delivery, if an X-ray can be obtained overnight, and proximity of blood bank with verification of reliable refrigeration. It's not uncommon for only whole blood to be available as opposed to platelets and component factors, and policies often require friends & family of a patient to donate their own blood in a corresponding amount to what is requested for the operation; upon completion, the corollary amount of products in the proper blood type will be released for that patient's operation. Other important issues that need to be elucidated before they're required include dialysis and permanent pacemaker availability after valve surgery.

In some locations, much of the required equipment and procedural guidelines may already be in place, but the Pre-mission

A. General information & Logistics

1. Can you please tell us what are the official names of the:

-President of the country …………………………………………………………………

-Prime Minister…………………………………………………………………………….

2. Please tell us the ***names, telephone numbers, fax numbers, E-mail & address*** of the following:

-! Minister of Health (MOH) ………………………………………………………………
……………………………………………………………………………………………….

-! The person AT THE MOH we should approach for communications during mission preparation?

-! His/her Address? ……………………………………………………………

-! Their Fax and e mail and telephone details:……………………………………
……………………………………………………………………………………………

-! The Director of the HOSPITAL's

-! Name: ……………………………………………………………………………………….

-! His/her e mail., fax and direct telephone line:

The HOSPITAL'S

Fax/telephone and postal address details:

……………………………………………………………………………………………

…………………………………………………………………………………………….

3. Has the MOH or Regional Minister approved our offer of assistance program for <u>your</u> hospital? Y / N

If NO, is this request already being submitted? Y / N

3a. Is this center a ***tertiary care*** facility for patients with cardiological problems? Y / N

4. If NO, is approval expected? Y / N

5. Will there be any restrictions as to what specialties can be developed in your hospital? Y / N

6. Could you tell us the name ***and contact details*** for the Rotary Club leaders for your area?

……………………………………………………………………………………

……………………………………………………………………………………

7. What is the population of the ***<u>region</u>*** that your hospital supports? ……………………

Fig. 27.1 Pre-mission questionnaire with permission from CardioStart International

Questionnaire helps identify those issues that can be resolved by equipment donation, and also determine how the educational program is best applied during the full team visit. This site visit is commonly conducted 6–12 months prior to the planned inaugural mission although MOH directives, economical issues and equipment procurement may sometimes force an extension

Space for further comments you may have….
8. What is the approximate population of the city? …………………………………………

9. What is the name and location of the most suitable Port of Entry for….

A] The VOLUNTEER Team: most convenient airport to use is………………………………….

B] For major donations by AIR freight …………………………………

C] For shipping containers by SEA freight …………………………………

10. Who funds the hospital – Government, Insurance-based Private group?
..........……………………………………...……

11. How many beds are available for general use in the hospital? …………………….

12. How many beds are or could be dedicated to cardiological and cardiac surgical services? ………………..

13. Is cardiac surgery already established at the hospital? Y N
If YES,
14. How long?...

15. The cardiac departments currently perform surgeries on (please circle)? Adults Children

16. Have you had visits from other visiting teams? Y N

17. If YES, when?

18. Please give names/addresses of those organizations involved. In the last FIVE years.
..........……………………………………..……………………………………

..........……………………………………..……………………………………

18. Do you have the equipment to do cardiological evaluation?

19. Do you have the equipment to do cardiac surgery treatment?
If YES,
20. How many cases are carried out each year?
……..

21. What percentage are :ADULT?……. PEDIATRIC? ……..

Fig. 27.1 (continued)

of this time interval. Examples of donations that are regularly sought include valves, sternal saw, vasoactive medications, oxygenators, cannulae, chest tubes and sutures. Some of these items can be hand-carried by the team, but when possible, inclusion in a shipping container directed to the host country may be helpful alongside other larger donations such as heart–lung & anesthesia machines, ventilators, and echo consoles, if required.

B. General hospital information & equipment status

Your Chief Biomedical Engineer's name, **email address** and phone number……………………………………………………………………………………….

1. Electrical supply issues -what is the voltage and current of the electricity supply to the hospital?

Voltage: 240V or 110v ....……..... Hertz: ……………………………..

-Does the ICU/OR areas have invertors/capacitors to protect against power loss? Y / N

2. If YES, what make/type are they?

……………………………….………………………………………….

-Are the ICU and Operating room areas on an independent supply? Y / N

-Are they protected circuits? Y / N

-Do you experience power surges? Y / N

3. If YES, how long do they last? …………………………………….

-Do you have power cuts? Y / N

4. If YES, how many times (e.g.in a week)? …………………………………….

-Does it effect the electronic equipment badly? Y / N

-Does the hospital have an emergency generator for the OR/ICU areas? Y / N

-Can clinical work continue if the main power source failed? Y / N

5. Does the hospital have portable (chest) X ray facilities readily available? Y / N

6. For measurement, what do you work in? (Circle which) feet/inches metric system

7. The team will need to communicate during the mission. Is it difficult to get cheap phones inside the country so that we can call each other? Y / N

8. Are networks available to US phones? Y / N

9. If we need to print and photocopy orders and protocols for your use in developing the program, will this be possible?

Please comment on any other important issues in regard to hospital general service supply.

………………...……...................……………….........………………

NOTE: *Please photograph specific plug outlets on the wall, and for your existing essential equipment, for our biomeds to decide which equipment they select.*

Fig. 27.1 (continued)

Significant time may be required for these items to be sourced & sent, with the shipping container obligating months at sea and additional clearance time at ports of entry. But this preparatory interval also allows the local team to address physical plant or biomedical engineering

C. Donations from CardioStart

1. Will you accept recently expired medical disposable donations (NOT drugs). Y / N

(In answering, please note:
A] that some of our donations come from USA, Canada, or UK. The expiration date for an identical product differs and many items are useful and safe to use, even after their expiration date.
B] that your answer must also consider Government Customs regulations – please check.

2. Will your hospital accept ***certified***, re-sterilized equipment through our US sterile service? Y / N

3. Would you accept clean (non-sterile) items e.g. dressings/bandages? Y / N

4. Do you have a secure store -room area with available space for a large donation? Y / N

5. Will your hospital provide for in-country release and delivery to your hospital of donations we send by shipping container? Y / N

These donations are checked, but CardioStart and its donors accept no responsibility for worthiness or safety of equipment given. We will expect donations to be distributed to the departments and not hoarded in locked cupboards for long periods of time.

D. Mission organization issues

Note: these may take six or more months so that we can prepare adequately.

1. When would YOU like *CardioStart* to visit for the two-week assistance? …………………………………

2. Are there any national public holidays, religious holidays, major sports events or periods which could make work in the hospital difficult or inconvenient during the time of a mission? Y / N

-If YES, give names and dates………..…………..........................…..……………………....

3. Are there any public holidays during the period you propose we visit? Y / N

4. What is the language ***most commonly*** used & preferred by your medical and nursing staff?
………...………………………………..

5. How many of the staff can communicate in English? (10%, 20% etc?) ....…………

6. In which language(s) are ward/ICU/OR written orders best given/understood? ….……..…
This information helps us to form an impression of how many ICU nurses and ward staff we should bring for the first mission.

7. Are you able to provide translators, if needed? Y / N

Please also tell us (or find out and tell us later) the name, address and telephone no. of the Head of the Foreign language department at the nearest university (who might wish to have their students practice English translation during the two week period). We will write to them.

………

Fig. 27.1 (continued)

E. CardioStart team members' health risks

1. Are there any current endemic or local communicable diseases we should be advised about before planning this mission? (e.g. Malaria, Yellow Fever, Sleeping Sickness) ….
………......

2. Are your patients who submit to surgery, screened for:

-HIV	Y / N
-Hepatitis B	Y / N
-Hepatitis C	Y / N

F. CardioStart accommodation, transport and food issues

Acknowledgment

- *Our volunteers pay for their own flights and will bring donations worth many thousands of dollars to support the local program. They also self-fund the evening meal they take each day from restaurants in the area, (unless you advise differently because of location or safety reasons. They need reasonably comfortable accommodation, breakfast and transport each day to/from the hospital provided by your hospital.*
- *Hotel facilities: We understand charges by some hotels can be considerable. We do not expect 4-5 star rating, but the hotel you recommend must be in a secure area, preferably, reasonably close to the hospital, have an available telephone at front desk, be manned 24 hours, and have a working internet. The manager must be able to confirm a willingness to pass on messages promptly to our volunteer leaders. Our volunteers will accept same sex room sharing with separate beds. Each room should have a good, working shower, clean facilities with bed linen, towels and soap assured each day.*
- *We will need availability of laundry service which individual volunteers will pay for.*
- *Breakfast should be available at no extra charge to the volunteers.*

Pre-Mission Questionnaire adapted with permission from CardioStart International

1. Is there reasonable accommodation close to the hospital for approx. 25 - 35 people available? (Approx. 14 rooms with room sharing) Y / N

2. Can your hospital/university pay for the cost? Y / N

If NO, could it offer a part-payment contribution with Rotary or local business sponsors? Y / N

3. Will your hospital arrange for daily transport for our volunteers to the hospital? Y / N

4. Can hospital transport support essential night/emergency visits to the ICU? Y / N

5. Is the area of accommodation reasonably safe from theft? Y / N

6. Tell us anything you can about the hotel facilities you recommend ***and its website address***?:-

……

……

7. Can you confirm if there are hot showers in each room available? Y / N

8. Can you confirm if breakfast is provided by the hotel? Y / N

Fig. 27.1 (continued)

issues identified during the site visit that require resolution prior to the safe initiation or development of cardiac surgery.

In planning the future mission date, consideration must be given to local holidays and/or religious multi-day homages which might interfere with patient/family/staff availability.

On completion of the scout team's visit, we recommend that a full report and inventory of what is available and what would be necessary

SECTION 2

AVAILABILITY OF SPECIALIST SERVICES

1. ANESTHESIA ISSUES

1. What is the name, tel/fax and ***E-mail*** of the Chief Anesthesiologist?

……………………………………………………………………………….……………………………

2. Could two anesthesiologists be available during ***CardioStart's*** visit? Y / N

3. Can your department deal with anesthesia in the following clinical areas?

- cardiac/thoracic Y / N
- pediatric Y / N
- neonatal Y / N

•! *Please provide some photographs of relevant equipment*

4. Your anesthetic machines:

- How many working machines do you have? ……………………………………
- What is the make & model type? ….…………………………………………….
- What kind of vaporizers do you have? …….……………………………………
- What modes can the ventilator component of the anesthetic machine offer?

………………………………………………………………………………………………………

- Are any of these, suitable for young pediatric patients (less than 25kg)? (please describe)

....……….…………………

We need to know that there are enough cables, and disposable transducers, etc., to make the clinical management happen.
Your monitoring capability in the Operating Room (OR).

5. What is the make and model of your current monitoring system in the OR?

………..…………..……………………………………………………

6. What gaseous anesthetic agents are available to you?
…………..……………………………………………………………………………..

7. What injectable anesthetic agents are available to you?

…………………………………………………………………………………………………….

Fig. 27.1 (continued)

8. Can your current devices in the OR measure the following at present?..... *Please photograph*
!

EKG	Y / N
TWO invasive pressures?	Y / N
TWO temperatures?	Y / N
Oxygen Saturation?	Y / N
End tidal CO2?	Y / N
Non-invasive blood pressure?	Y / N

9. Is there sufficient anesthetic equipment to run two OR's during the visit? Y / N

10. Do you have dedicated neonatal/pediatric equipment? Y / N

11. If YES, specifically, do you have……?

- ped/neonate facemasks for anesthesia
- ped/neonate ventilator/anesthetic circuits
- ped/neonate intubation equipment

12. Do you have any of the following items suitable for anesthesia?

(Please also circle the P, if you also have some pediatric sizes available for a particular item)

-small gauge arterial lines	P	Y / N
-central lines	P	Y / N
-nasogastric tubes	P	Y / N
-endobronchial suction catheters	P	Y / N
-endotracheal tubes - all sizes	P	Y / N
-tracheostomy tubes	P	Y / N
-intravenous tubing sets (with chambers)	P	Y / N
-overhead heater (for neonates)		Y / N

13. Are the OR and ICU monitors compatible (connections)? Y / N

14. Is intra-operative Echo available Y / N

15. Emergency (CODE) & drug cart specifically for resuscitation equipment and drugs in OR? Y / N

Fig. 27.1 (continued)

2. INTENSIVE CARE UNIT (ICU) – ISSUES *[Please photograph]*

Name, email and phone number of nurse in charge of ICU:

…………………………..……………………………………………………………………………….

1. Do you have a dedicated ICU area for heart surgery at present? Y / N

2. If you only have a general ICU, how many could be devoted to cardiac surgery use?

Adult……….. Pediatric .... Neonatal………

-If NO, do you have a ward which we *could* use for cardiac surgery? Y / N

3. Do you have any nurses who are already trained in ICU care to any level? Y / N

-If YES, how many?............................

4. Do you have nurses needing training by *CardioStart* nurses during our visit? Y / N
-If YES, how many could you make available ....…………………......………………..

5. What are the shift arrangements for your nurses - please state times:
-morning /afternoon/evening /night …………………..……………………..….…………..……

6. Please indicate what procedures and clinical activities your own nurses could cope with in your unit, if the visiting team is available.

o! **✓ (please tick each bullet sign that fits with your current nurse experience level)**

o! Can receive an intubated patient from the OR
o! Manage inotrope delivery pumps
o! Manage a ventilator
o! Manage an arterial line
o! Manage a central line
o! Manage invasive blood pressure
o! Manage a Swan-Ganz catheter
o! Perform vital observations every 15/30minutes
o! Suction a patient
o! Manage chest drains
o! Make appropriate decisions from vital signs and monitor information
o! Perform neuro-observations
o! Carry out patient physical assessments
o! Give pre-checked donor blood
o! Give certain injectable drugs, as ordered
o! Make appropriate decisions in support of managing a sudden cardiac/respiratory arrest
o! Take blood on own initiative or follow doctors order sheets

Fig. 27.1 (continued)

- Function in the ICU satisfactorily, without a doctor physically present in the room using preset protocols of practice.

7. What percentage of nurses available can carry out *most* of the functions above?.......................

8. General equipment: Does the ICU (or chosen area) have the following:

-telephone	Y / N
- second telephone with direct line from outside hospital into the ICU	Y / N
-defibrillator (with internal paddles available)	Y / N
-refrigerator for drugs, etc.	Y / N
Microwave (for heating iv fluids, formulae)	

9. Emergency (CODE) & drug cart specifically for resuscitation equipment and drugs in ICU? Y / N

10. Are nurses trained in basic life support (CPR) &/or ACLS? Y / N

Please take a couple of photographs of your monitoring capability in the Intensive Care area.

11. What is the make and model of your current monitoring system?

……………………………………………………………………………………………………….

12. How many beds in the ICU have monitors? ………………………..

- Can your current devices display/measure the following, at present?

EKG	Y / N
TWO invasive pressures?	Y / N
TWO temperatures?	Y / N
Oxygen Saturation?	Y / N
End tidal CO2?	Y / N
Non-invasive blood pressure?	Y / N

13. How many of these beds have monitors with the same capability? ……………

14. Do you have compatible electronic cables, transducers and tubing? (*Please photograph)* Y / N

15. Are these cable connections compatible with those in the OR? Y / N

16. Do you have a readily available supply of the following crystalloid infusion fluids?

Hartman's solution	Y / N
Normal Saline 0.9%	Y / N
Dextrose 5%	Y / N
Lactated Ringers	Y / N
Mini-infusion bags (100ml and/or 250ml) for drug infusions	Y / N

Fig. 27.1 (continued)

17. Does the ICU have non-sterile plastic gloves for general nurse use? Y / N

18. Do you have any fully working infusion pumps (*Please photograph)?* Y / N
If YES, please state the model and type: ……………………………………………

19. Do you have a supply of the necessary tubing for their use Y / N
…………………..…………………..…………….……

20. How do you routinely measure blood glucose in the ICU?………………………………………

3. ICU RESPIRATORY CARE ISSUES

1. How many working ventilators are available? ……………….………………….………

Please photograph
2. Which type are they?....……………...………

3. How many have working modes for pediatric ventilator management? …..…………………………

4. Which model/type are they? …..…………………………………………………………..………

5. Who manages the ventilators for patients – Doctor? Nurse? or Respiratory Therapist?
………..........................……………………………………………….…………………………….

6. How do you sterilize ventilator circuit equipment? ………………………...................……................……

7. Do you have ventilator circuits for pediatric/neonate application? Y / N

8. Do you have the appropriate connectors? Y / N

9. What is the size of the ventilator connectors you use for (State metric or inches):

- ventilators ………………………………………………

- oxygen supply ………………………………………….

- air delivery ……………………………………………..

10. In the ICU, how is Oxygen supplied: - piped? or by reusable cylinders? ……………………...…

11. Is Carbon Dioxide available? Y / N

12. Is Helium available? Y / N

13. Is air available in cylinders? Y / N

14. Is there vacuum at the wall? (wall suction) Y / N

15. Gas connectors to the cylinder – Please describe the type and size.

!

Fig. 27.1 (continued)

16. Do you have pressure tubing & regulators and flow meters for oxygen? Y / N

17. Do you have a Blood Gas machine with cartridges/disposables available?(*Please photograph)* Y / N
- If YES, what type is it? ....

-What measurements can it make? ……..…………………………………………………..

18. How long does it take, from the time you draw a blood sample to the clinical result being in your hands? =

(Time)…… Day time = …..….(minutes/hours); Night time = ………….(minutes/hours)

19. How many suction machines are available in the ICU? ....……

20. Do you have endo-bronchial suction catheters of varying sizes available (10.12,14G)? Y / N

21. Do you have humidified ventilator circuits? Y / N

22. Can you dispense standard (non-ventilated) bedside humidification? Y / N

---

4. WARD CARE ISSUES

1. Is there a 4-bed are for step-down post-operative patients which can be made available and monitored by local nurses?
If YES, please photograph Y / N
2. How many sphygmomanometers do you have available? …………………….……………………..

3. Do you have any EKG monitoring capability in this area? Y / N

4. Is there a defibrillator available in the ward area? Y / N

5. Emergency (CODE) & drug cart specifically for resuscitation equipment and drugs in ward? Y / N

5. BLOOD BANK & LABORATORY FACILITY ISSUES

1. Can blood count and electrolytes be easily measured at your hospital? Y / N

2. If you had a very sick patient, approximately how long would it take to receive the result for an urgent blood Potassium level after drawing blood? (Time)…… Day time = …..….(minutes/hours); Night time = ………….(minutes/hours)

3. Can you measure standard coagulation factor activity /clotting studies? Y / N

4. Is donor blood usually easily available in your hospital? Y / N

If YES, from where is most of it obtained from?

The patient (pre-operative venesection)	Y / N
Family relatives	Y / N
General population	Y / N
Military donation	Y / N

Fig. 27.1 (continued)

5. Which diseases are screened for when your hospital receives donated blood?

HIV	Y / N
Hepatitis	Y / N
Malaria	Y / N
Syphilis	Y / N
Chagas	Y / N
Sickle	Y / N

6. Do you have any of the following colloid ‘plasma expanders’ available?

Plasma	Y / N
Albumin	Y / N
Hetastarch	Y / N
Hemmacel	Y / N

-Other ………………………..…………………………………………………………..

7. Can your laboratory regularly supply at short notice:

Plasma (fresh frozen)	Y / N
Platelets	Y / N
Cryoprecipitate	Y / N

8. Does your hospital have the ability to perform histopathology? Y / N

9. Do you have any refrigeration units in the hospital or city that can cool to minus 20°C? Y / N
……………………………………………………………………………………………………

6. NUTRITION AVAILABILITY ISSUES

1. Is there an appointed supervisor for patient nutrition care? Y / N

If YES, what is the name of this person?….......................................……………………….........

2. Do you have:

-nutrition guidelines written down	Y / N
-fine bore naso-gastric feeding tubes	Y / N
-standard naso-gastric tubes	Y / N
-feeding pumps	Y / N
-formula feeding	Y / N

3. Can your pharmacy mix parental solutions (TPN)? Y / N

Fig. 27.1 (continued)

4. Approximately how many (10%, 20% etc…) of your local population have the following diseases:

-Diabetes Type 1……………….…………..

-Diabetes Type 11………………………….

-HIV-AIDS…………………………………

-Renal Failure………………………………

-Liver Failure………………………………

5. Are vitamins easily available? Y / N

6. Please describe the average staple diet in your local community:

……
……

7. CARDIOLOGY & CARDIAC SURGERY ISSUES

A. The Cardiology Department

1. How many doctors work in the cardiology department? ………………………….................................

2. Please give us the names, telephone and fax number or E-mail address of the chief Cardiologist and the names of the others who wish to be involved:
……………………………………………………………..……...……………

……………………………………………………………..……...……………

3. Do you have facilities to perform cardiac catheterization? Y / N

If NO, where can it be done? ………………………………………………………..……

……
If YES, what type of angiographic equipment do you have? State any limitations it has ……………

………………………………..…………………………………………………….…….…………….

4. What can you get done by catheter study at the present time (either on site or by referral in the city)?

-pressure /saturation? Y / N

-contrast injection Y / N

-angioplasty Y / N

-septal occlusion Y / N

-stent Y / N

Fig. 27.1 (continued)

-balloon valvuloplasty Y / N

5. Do you have a supply of catheters for invasive cardiological investigation? Y / N

6. If YES, is there any specific item you would like us to try and obtain?
…………………………………………… ……………………………………
………………………………………………………………………………………

7. Do you have a working echocardiography machine? Y / N

-If YES, which model? ………...………………………

8. Does it possess color-flow Doppler? Y / N

9. Is a trans-esophageal (TEE) probe available for use during the mission? Y / N

If YES, what is the size limitations (adult, juvenile, pediatric insertion capability?) _________________

10. Could TEE be available inside the OR for certain cardiac cases during the two week period? Y / N

11. Do you have a trained local echo-cardiographic expert available for the mission? Y / N

12. Do you have an intra-aortic counter-pulsation balloon device? Y / N

13. Do you have temporary pacing system equipment? Y / N

14. State any specific cardiology equipment shortcomings here ……………………………………………

……

15. Do you have permanent pacing system equipment? Y / N

16. Is a local company supplier available to give programming and technical support? Y / N

If YES, state name, contact information here ……………………………….………..

…………………………………………………………………………………………...…..……

…………………………………………………………………………………………...…..……

17. Is there a C-arm image intensifier available for use?
…………………………………………………………………………..….

B. Information about cardiological assessment and operation

1. Approximately how many patients are already on your waiting list?
Adult ....……………................ Pediatric …..........……………….

2. Are mechanical valves available in your country? Y / N

3. Is Coumadin/Warfarin available? Y / N

Fig. 27.1 (continued)

-If YES, can prothrombin times be monitored in any part of the city? Y / N

4. Is the INR screening test used? Y / N

5. Are any of your patients Jehovah's Witnesses? Y / N

6. Do your patients have any religious objections to certain procedures? Y / N

If YES, please describe ……….……………………………………………………………

7. Will your patients accept porcine valves? Y / N

………
………

C. General Cardiac Surgery Issues:

1. Is your hospital ***currently*** performing heart surgery? Y / N

-If YES, approximately how many bypass cases have been carried out during the previous year ?
……………………………………………………………………………………………………….............

2. Please state the name, telephone and fax number or E-mail address of the chief local Surgeon who is in charge of developing the cardiac surgical program and provide the names of all those who will available to work with our group....... …………………………………………..… ………………………………………
……………….……….………………………………………………………………………………………..

3. Do you have other visiting cardiac teams assisting you this year or next year? Y / N

If YES, please tell us the name of the organizations and when any visited previously
…………………………………………………..……………………..……….............................…..…………
…………………………………………………………………………………………………

4. Is your hospital the principal referral center for cardiac problems in the city? Y / N.

5. Are there other cardiac units in the city doing heart surgery? Y / N
-If YES, please name ***all*** other locations, including ALL private institutions
………………………..……………………………………………………………………………..…………
……………………………………………………………………

If YES, please give details of approximately how many cases/year they do…………………

………………………………………………………………………………………………….…………
………………………………………………………………………………………………….…………

D. Perfusion Issues

1. Is a local perfusionist available for cardiac surgery? Y / N

If YES, please provide full contact details:

………………………………………………………………………………………………………

Fig. 27.1 (continued)

2. Do you have a functioning heart lung machine available? Y / N

3. If NO, will your existing electrical supply in the OR room tolerate 30amp loading? Y / N

4. If YES, how many machines?.......................

- a] What make/models? *Please photograph* ....……………………………..…
- Age?............... ……………………………………...……………………………….……

b] If YES, do you have a second functioning machine? Y / N

5. Does the heart lung machine have a water cooler/heater? Y / N

If YES, what make is it?…………………………………………………………….….

6. What blender do you use to deliver gases?...

………………………………………………………………………………………………………

7. Is there an anesthetic vaporizer with the heart lung machine? Y / N

If YES, which anesthetic? (Circle appropriate) Sevoflurane? Isoflurane?

8. Which bubble sensor is used? (circle appropriate) *None available? Bubble? Level Sensor?*

9. Does the heart lung machine have a temperature probe capability? Y / N

10. How do you measure line pressures on the heart lung machine? ………………………………..

……………………………………………………………………………………………………

11. Do you have a saturation monitor? Y / N

If YES, what make is it?...…

If YES, do you have sufficient disposables? Y / N

12. Gas connectors to the cylinder – Please describe the type and size.

……………………………………………………………………………………………….

13. Do you have pressure tubing & regulators and flow meters for oxygen? Y / N

14. Is perfusion equipment (oxygenators and bypass circuit) available? Y / N

If YES, how many cases could you do with the current equipment? ………………………

Fig. 27.1 (continued)

15. Please confirm if you have or can obtain the following stock items:

(circle, and write P, if the size is only or include pediatric sizing, and also please mark approx. number)?

- Adult Oxygenator
- Pediatric Oxygenator
- Tubing kit
- Hemo-concentrator
- Cell saver disposables
- Connectors (1/2 x ½, ½ x 3/8, ½ x 3/8 x 3/8, 3/8 x 3/8, ¼ x 1/4, 3/8 x 3/8 x ¼)
- Arterial cannula
- Multi-stage venous cannula
- Single-stage venous cannula
- Spare tubing (1/2, 3/8, ¼)
- Retrograde cannula
- Coronary ostial cannula
- Perforated sump, sucker wands
- Root vent needle/tubing and cardioplegia

16. Do you have hand-cranks, tie bands and banding gun? Y / N

17. Do you have a machine for measuring ACT? Y / N

18. Do you have disposable tubes for 15 cases? Y / N

19. Are you able to obtain ice cubes (e.g. two buckets full)? Y / N

20. What oxygenator and perfusion disposables do you use (Make)………………………………...

21. Do you have oxygenators available for pediatric and neonatal perfusion? Y / N

22. What is the make and model of the ACT machine? …………..………………………………

23. Can you provide cardioplegia? Y / N

24. What blood/crystalloid mixture is currently used? …………………..…………………………………….. ..
....

25. Do you have dedicated giving sets for this purpose? Y / N

26. Do you have the following <u>readily</u> available to the OR? (Circle, please)

Protamine Heparin Electrolyte solutions for intravenous use

Fig. 27.1 (continued)

E. The Operating Room

1. What is the name of the principal Nurse who is in charge, (or) will be assigned to cardiac surgery in the OR?

……………………………………………………E mail address: ………………………..

2. Do you have a dedicated operating room for the performance of cardiac surgery? Y / N

3. If NO, could a room be available during *CardioStart's* visit? Y / N

4. Is there sufficient cardiac instrument equipment to run two OR's during the visit? Y / N

5. Do you have a full adult cardiac surgery set of instruments? Y / N

6. Do you have a full pediatric instrument set of instruments? Y / N

7. Do you have a full *thoracic* surgical set? (Adult/Pediatric: circle which you have) Y / N

8. *If NO, please list what you do have on a separate page, and what you need……….*

9. Could a partial set be pulled together from general surgical instruments you may have? Y / N

10. Can the operating table be made to tilt and roll? Y / N

11. Do you have a lockable area and cupboards close-by for essential items (sutures, valves, etc)? Y / N

12. Does your existing equipment include a powered sternal saw? Y / N

13. Is there a defibrillator available for the OR? Y / N

-If YES, does it have - internal defibrillator paddles? Y / N

- pediatric paddles? Y / N

14. How many suction machines are available in each OR? ……………………………........………....

15. How many autoclaves are available and in use?………………………………………….…………

16. Is ethylene oxide sterilization available to the hospital or in the city? Y / N

8. YOUR EDUCATIONAL NEEDS

1. Do you have regular educational periods for nurses and doctors each week. Y / N

2. On which day are these held? ……………………….

3. Do you have a room for teaching large numbers of healthcare professionals at once? Y / N

4. What lecture topics would you specifically like to have for your doctors and nurses during the two week period? (Please provide a list) ***(CardioStart*** teams will give special attention to these, and other topics).

Fig. 27.1 (continued)

.

Space below for any notes or information you wish to share with us……..

……

……

……

……

…………………………

Thank you!

Fig. 27.1 (continued)

for a safe mission to proceed is submitted for consideration and approval by the non-governmental organization responsible for the initiative.

27.4 Team Composition and Logistics

An assessment of educational needs during the site visit is made in collaboration with the local team, who usually declare specific areas of requested assistance. The mission must be responsive to local needs, and assembling a team whose skill and teaching goals match those of the host hospital is crucial. In surgery, the goal should not be to perform all aspects of the operation ourselves, but to empower our local colleagues via skill transfer and training in all key areas (Figs. 27.2 and 27.3). Thoughtful judgment in patient selection, pre-operative optimization, surgical technique, and postoperative care including recognition & management of complications is vital to ensure the success of the mission and to establish a foundation for future program development [5].

At least one volunteer from all key areas of cardiovascular care including cardiology, cardiac surgery, anesthesia, perfusion, and OR nursing are sought and invited. As in all centers of excellence, ICU nurses play a vital role. A common scenario is for 2 volunteer nurses to be paired with 2–4 local nurses per 8 or 12 h shift. In a 1 week mission we would ideally recruit 4–6 nurses to cover perioperative care & provide integral education. Working together with local colleagues, they share constant bedside assessment and hemodynamic interpretation &

Fig. 27.2 Language-appropriate education based on locally-identified knowledge gaps

Fig. 27.3 Empowering local clinicians by assuming the assistant role rather than primary operator when clinically appropriate

management skills, providing the bulk of real-time education and skill transfer for safe & efficient cardiac surgical patient care. This may involve using local translators (whom are often students within the profession).

Including a biomedical engineer in the visiting team is strongly recommended and very helpful in repairing, maintaining equipment, and assisting with infrastructure issues that will permit the local team to accomplish surgeries safely. They identify and resolve equipment compatibilities, mechanical failures, and maintenance upkeep concerns for vital support devices, commonly using a 'MacGyver' approach. Their work is inspiring to the local teams who are often exhausted from having to address multiple equipment-related issues.

Other helpful visiting team positions might include an intensivist, echo technician, respiratory or physical therapist. We also commonly utilize non-clinical volunteer in capacities such as database management, family liaison, outreach direction and general logistics coordination. Where opportunities exist, we try to include advance practice providers, visiting trainees and students in their traditional roles; by including them in the mission we can ideally engage future leaders in international healthcare support. It's important, however, that understanding of the primary goal in training the local team is acknowledged and prioritized. In this context, we've found that volunteers are readily willing to step outside of their usual scope to do what's necessary to serve the greater good of the mission.

Sometimes duplication of an assigned team member's role (i.e. two perfusionists instead of one) is helpful: a simple GI infection, unfamiliar food, altitude, or territorial issues can result in one or more essential team members falling ill during the mission, limiting its success. An ideal team is between 12–15 members. If larger, this may become a burden on the host, logistically and financially. We also try to be sensitive to the local team's sense of obligation in providing meals and other sundries. As guests, visiting teams should act graciously and be cognizant of effects their presence might have on host hospital operations and staff during the mission. Our presence, however well-intentioned, may create upheaval of the usual routine and pace of activity.

27.5 Before the First Surgery

Extensive communication between the local key contacts is required during the months prior to the mission: this includes patient screening, confirmed arrival and readiness of equipment donations, an updated inventory of consumables, locally available pharmaceuticals, and visiting team logistics that must be established well in advance of the team visit. Transportation from accommodation to hospital, particularly at odd hours for overnight ICU shifts, late operations etc. and concordant security concerns have to be resolved.

The first day in-country is commonly spent sorting and positioning supplies as well as convening a thorough patient selection meeting. These presentations should include preoperative history, examination, and pertinent studies for all candidates. Discussion should include all participating clinicians to air and resolve any potential concerns so that every phase of perioperative care is addressed. This also sets a tone that helps visiting and local teams to interact harmoniously, share subtleties of surgical judgment, and formulate the best clinical strategy for each patient throughout their hospital stay.

To prevent mis-steps and equipment shortcomings before any operation proceeds, we have introduced a comprehensive Dry Run Check List on the day before surgery begins that scrutinizes each feature of perioperative care and includes all key personnel (Fig. 27.4). A medical mannequin or one of the volunteers assume the role as 'the patient' assigned for surgery, and the team rehearses every step taken from hospital ward preoperatively to recovery in ICU, examining and ticking off every safety consideration (Fig. 27.5).

Examples include pre-op preparations, transfer to the OR table, overhead & personal headlight function, placement of perfusion lines and pump, positioning of adjunctive elements like electrocautery and suction lines, electrical outlets/suction capacity/inverter/capacitor/transformer evaluation, selection of surgical instruments, accessibility of all intra-operative supplies, monitoring visualization for anesthesia/surgeon/perfusionist, blood product storage location, ACT cartridge calibration, adapter compatibility for internal defibrillator paddles, temp pacemaker box function, how and where to obtain full oxygen cylinders/ambu bag/portable monitor for patient transport, pathway & patient transfer to ICU bed, monitor & IV pump changeover, ventilator set-up, warming device availability, ICU crash cart stock, re-intubation & sternotomy re-entry tray set-up, etc.

The list may seem excessive, but experience has taught us that despite vigilant attention to detail and preparation, issues uniformly emerge from the Dry Run Check List that require resolution before surgery proceeds.

"DRY RUN" WARD-OR-ICU-DISCHARGE CHECKLIST

PRE-OP AREA – CARDIOLOGY-SURGICAL ISSUES (CARDIOLOGIST OR ADMITTING SURGEON COMPLETES)	COMMENT/ACTION
A) General conduct and guidelines for CVT surgery *1. See protocol for cardiologists, anesthesiologists, perfusion and nurse* *2. We recommend all items are ticked as each issue is challenged and able to be confirmed as, "in place". Those not ticked should be re-evaluated by surgeon in charge to establish whether or not cases can proceed.* *3. Also recommended is that the "DRY-RUN" is repeated for a specific sub-section if an adverse event or peri-operative death occurs.* *4. The comment section can also be used to state how an issue is bring addressed or timeline, etc.* Tick ALL items already in progress or accomplished (adult AND pediatric)…. Do **NOT** tick items to be dealt with. For non-tickable items, (i.e. unavailable in the location being assisted) put a circle around the box **O** ☐ General consensus documents will be given to all team members involved.	
B] WARD AREA PREPARATION FOR PATIENTS: ☐ Admission process for cardiology patients has been clarified. ☐ Admission supplies available are: charts, forms, ID bands, patient gowns, blankets, pillows. ☐ Chlorhexidine , towels, for pre-surgical shower. ☐ Gurney or bed for transport *to* OR; ☐ Gurney or bed will fit in elevator if required). ☐ Oxygen transport cylinder for bed/gurney and nasal cannula or mask (for before and after case) is available. ☐ Consent Form is available (*surgeon must be the person to discuss & complete*) ☐ Review of clinical and investigative data (e.g. echo): arrangements made: For ______________________________(time/date/location in hospital) ☐ The local team's routine for reviewing Echo, etc., **is** in place as a regular arrangement prior to surgery. ☐ Routine for welcoming and managing relatives…how they are identified and spoken to: contact telephone info is confirmed to be in chart for each case undertaken. ☐ Routine for confirming medications being taking, and confirmation on whether or not Aspirin and Coumadin/Warfarin, etc., are being taken or, when stopped. ☐ Routine for blood draws and recording of results in chart. ☐ Routine for confirming pre-operative urinalysis that shows no signs of infection. ☐ Routine for pre-operative dental evaluation (***must*** for all valve patients).	

Fig. 27.4 Dry run checklist with permission from CardioStart International

27.6 After the First Mission

Quality metrics, data accountability & self-assessment are not commonly woven into the fabric of developing programs in low-resource settings; it's valuable to initiate these measures early from the inaugural operation to chart progress and benchmarks of the program and collaborative teamwork. Efforts to set this tone span from a structured Morbidity & Mortality discussion to a robust database of patient & operative information.

An example of one low-resource country that has been proactive about data collection and assessment is Nigeria. The Association of Cardiovascular and Thoracic Surgeons of Nigeria (ACTSON) recently endorsed participation in a national registry [6] to encourage assessment of progress and collective goal-setting. Examples of meaningful metrics that can be harvested include annual institutional activity (Fig. 27.6), overall distribution of

OPERATING ROOM – EQUIPMENT (NURSE OR OPERATING ROOM TECHNICIAN COMPLETES)	**COMMENT/ACTION**
C] OR General equipment assessment before beginning any operation: ☐ Adjacent OR utility room & sink for instrument wash is available. ☐ Outside sink with filtered water for surgical scrub. ☐ Soap & hand-sanitizer, wall mounted. ☐ Surgical masks and hats available. ☐ Dedicated (lockable) storage room ***close to OR*** for sutures, drapes and intra-operative disposables / equipment. ☐ Confirmed air, O2 source, vacuum from wall supply (or tank). CO2 source and tubing, if available, (to be directed into operative field). If using tank gas supply, regulators have been checked by biomed, and are ***confirmed*** to be accurate, working well and with good seals. ☐ Anesthetic gas scavenging line available ☐ Large trash holders & bags for ordinary and bloody disposables. ☐ "Sharps" box x 2 (anesthesia and circulating nurse area). ☐ Sponge receiver buckets. ☐ Work bench with electrical connection plug sockets in corner of OR ☐ Shelves or cupboards with doors in the OR for in-room supplies. ☐ A secure cupboard for medication storage is available and pharmacy has access to perform weekly review. ☐ High chair and work-table for circulating nurse. ☐ Duct tape, to prevent electrical multi sockets and extension cables from being trip points. ☐ Three surge protectors, and a multi-plug line extension: for anesthesia, perfusion & circulating nurse areas. ☐ Confirmation by Biomed that no overloading is likely from each supply source. ☐ O.R. (or immediately close by) telephone – checked to be working, ☐ Numbers listed for: blood bank, ICU, lab, pharmacy, ward, by telephone. ☐ Code cart and defibrillator in the room plugged in *and* checked weekly. ☐ Sterile internal paddles available in, at least two sizes (pediatric & adult). ☐ Electro-cautery unit, grounding pads, in room and checked. ☐ Electro-cautery procedure for each patient confirmed with OR Nurse team. ☐ Warming blanket and extra linen available or nearby warming source available. ☐ Arm boards, shoulder roll, support, lateral pelvic support, strapping, heel pads, two pillows and padding sheets in at least, two sizes, available. ☐ Documentation in drawer (OR log, suture list, instrument lists, pathology specimen forms; X-ray request form; blood bank forms). ☐ Spare wrist-bands (in case one has to be cut during line insertion).	

Fig. 27.4 (continued)

cardiac procedures (Fig. 27.7), or the transition in ratio of operations led by visiting teams to surgeries primarily led by local surgeons (Fig. 27.8).

Ideally in the near-term we will move as a specialty toward a centralized registry for global cardiac surgery that can inform data sharing and drive outcomes derived research in specific sectors such as low and middle income countries. For the current time, however, every collaborative mission can move us one step closer to that goal by promoting robust data capture within each global surgical program.

27.7 Conclusion and Key Points

We have found that this framework and mission strategizing works in the humanitarian sector; it endorses a methodical & structured approach in low resource countries that helps programs and

☐ Refrigerator access: cold irrigation/ ice slush; OR nurses know time required for THIS refrigerator; cold temperature measured to confirm no extremely low slush temperatures; ☐ Microwave or hot-water bath for fluid warming for OR scrub nurse to receive. ☐ Operating table, checked for Trendelenberg/tilt, locking, and stability. ☐ Instrument table, Mayo table, side-table. Access and walk-area defined. ☐ Steps for OR nurse and other personnel. ☐ Three stainless steel tables (Perfusion, Anesthesia, and circulating nurse). ☐ Functional surgical light and, if possible, a mobile standing light for emergencies. ☐ Available light source for surgical headlight (as per surgical preference). ☐ TWO (THREE preferred) separate mobile suction for end table, anesthesia and perfusion. ☐ Three emergency lights (hand-held flashlights) for perfusion, anesthesia and circulating nurse. ☐ UPS /power supply loading check by Biomed for THIS OR. ☐ Back-up O2 tank within close reach of the OR. ☐ Biomed has checked regulator valve. ☐ Mop for aspirate, spillage and blood removal products; ☐ Cleaning supplies for floor and for surgical instrument care. ☐ Wipes for non-sterile use on stainless steel surfaces. ☐ Glove selection (sterile and non-sterile) for usual sizes. ☐ Selection of drapes. If using cotton, the draping procedure MUST be pre-discussed and shown to surgical team; ☐ Confirm full instrument set available, including sternal saw *and* gigli saw. (If re-opening saw is not available, confirm a sector blade and Roberts or similar clamp is available). (See CardioStart adult and Pediatric set lists) ☐ **To discuss before 1st operation:** Planned entry of patient's gurney and OR table, for before and after operation management is confirmed, WITH position of ALL equipment in room, cables attached to power source, and preferences confirmed by all surgical team members. ☐ Available walk areas confirmed, respecting: Perfusion, Anesthesia, circulating nurse *and* including student observers. ☐ Access to power outlet sources, and avoidance of cable snaring is confirmed by surgical team and Perfusion staff. ☐ Position and restraints for thoracic cases, arm boards and pelvic support and confirmed to be satisfactory. ☐ Monitor(s) position (must achieve 180 degree view) that is easily visible to anesthesiologist, surgeon ***and*** perfusionist. ☐ Check table height (19" below surgeon or using step) and movement, tilt and Trendelenburg. ☐ Check position and movement options of OR lights so they don't obstruct monitor view or foul drip stands. ☐ Discuss & practice procedure in regard to choice of sliding sheet under patient for transfer from bed to OR table and transfer routine.	

Fig. 27.4 (continued)

struggling centers advance systematically, and positions the local team for success through collaboration.

A review of the fundamental key points from this framework include:

1. **Identifying a need** from engaged local clinicians with Ministry of Health and/or governmental endorsement, as well as local leadership support.
2. **Pre-mission questionnaire** completion by the local host team.
3. Follow-up **on-site scout assessment** by representatives of the visiting team.
4. **Constant communication between key contacts** of both teams for planning, preparation, strategy, and logistics.

OPERATING ROOM - ANESTHESIA (ANESTHESIOLOGIST OR OR TECH COMPLETES)	**COMMENT/ACTION**
D) ANESTHETIC ISSUES **Anesthetic and relevant machine checks** ☐ Functioning anesthetic machine has been checked. ☐ Anesthetic monitors confirmed to be working with two pressure functions. ☐ Cable connections are homologous or interchangeable with monitors in ICU ☐ O2-Saturation monitoring probe with long lead cable available. ☐ Temperature: central (nasopharyngeal, central, by urinary catheter, or rectal). ☐ End tidal CO2 and anesthetic agent monitoring working. ☐ EKG pads and cables available. ☐ Non-invasive cuff. ☐ Invasive arterial available in suitable sizes- (e.g 20 G Radial or 20 G Brachial or 18G/20g femoral arterial). ☐ Temporary pacemaker in room, and checked. Sterile leads available, and discussed with OR nurse for ease of attachment on the OR field. ☐ Four working IV infusion pumps fully charged are available (***always*** remaining on trickle charge). ☐ Anesthetic drug tray/cart *and* a work table (close to anesthesia area). ☐ Ventilator tube support clamp holder. ☐ Blunt non-sterile towel clips for anesthesiologist fiaxation of head drape. ☐ Sandbag to stabilize IV stand bases. ☐ Infusion pressure bags X2, for fast fluid delivery. ☐ Anesthetic patient chart, clipboard. ☐ One power outlet is available for anesthesia only, and permits multi-port power strip (confirm electrical load with Biomed). ☐ Anesthesia chair with sufficient room to stand at the head of table, for TWO anesthesia personnel and/or student observers. **Airway Tray** (must have essentials on shallow tray with small work table) ☐ Laryngoscope 2 handles with McIntosh / Miller Blades 3 and 4 (adults) ☐ Oral Airways - selection, phayngeal/laryngeal masks in various sizes; King airway, if available, and connectors to ventilator tubing. ☐ Stillette samples; K-Y Jelly sachet or tube. ☐ Intubing layringoscope glide, if available. ☐ Pediatric bronchoscope, if available. ☐ Ambu bag, adult and pediatric, connectors; nasal delivery cannulae, ☐ Cuffed Endotracheal Tubes: 6.5, 7,7.5, or 8 for women. Size 7.5, 8 or 8.5 for men; children's cuffed and uncuffed sizes available. ☐ Suction (dedicated to anesthesia) checked to be working with sufficient disposable tubing available to provide adequate line length for clearing airway.	

Fig. 27.4 (continued)

5. **Patient screening & selection meetings** with inclusion of, and input from all pertinent clinical team members.
6. **Comprehensive Dry Run Check List** completion with participation of all clinical stakeholders prior to any operation on a human patient.
7. **Ongoing data acquisition & assessment** to chart salient program benchmarks, inform data sharing & drive outcomes research.

We feel that this practice enables thoughtful development of a global cardiac surgical program poised to achieve sustainability (Figs. 27.9 and

- ☐ Suitable connectors and t-bars.
- ☐ Extra Yankauer sucker tips X 3.
- ☐ Endobronchial suction catheters X 5 in THREE sizes (if doing pediatric cases).
- ☐ Selection of tapes, ties, & blunt end scissors.
- ☐ Selection of syringes and 5ml Syringe for tube cuff inflation.
- ☐ McGill forceps.
- ☐ Code Cart defibrillator is plugged on for intubation emergencies. No cable interferes with travel close to patient in an emergency.
- ☐ Pharyngeal pack available in OR.

Gases

- ☐ Oxygen air, CO2 gas supply
- ☐ Oxygen cylinder for transport to ICU with ambu-bag checked by anesthesia before each case.
- ☐ Sevoflurane or Isoflurane in vaporiser with confirmation of filter cleaning.

Intravenous/arterial line access

- ☐ Stock of IV infusions, including Lactate Ringers or Normal Saline, colloid – Stock must be sufficient for two cases.
- ☐ Peripheral IV 16G or 18G or 20G,
- ☐ Central lines of choice, with selection including 3 or 4 port lumen if posible; must have sufficient stock duplicates for chosen type prior to each case.
- ☐ Stop-cocks, end taps, 7 inch extensión tubing, long extensión iv tubing; long extensión arterial (higher pressure) arterial line; 7inch connectors,
- ☐ Transparent dressing for line insertion (if not in kit), or at change out at end of case, if bloodied.
- ☐ Selection of size-o silk sutures with needle and one sterile scissor or surgical blade.
- ☐ Alcohol wipes.

Anesthetic drugs

The following are available:

- ☐ Midazolam 5-10mg
- ☐ Fentanyl 20cc (50 mcg/cc)
- ☐ Vecuronium 10
- ☐ Propofol 100mg – 200 mg IV bolus and infusion for bypass if no vaporizer on CPB circuit
- ☐ Phenylephrine 100mcg/ml 20 ml
- ☐ Ephedrine 3mg/ml 10ml
- ☐ Atropine 600mcg/ml 1ml
- ☐ Heparin 3 mg/kg IV
- ☐ Magnesium 5g
- ☐ Calcium Chloride 10mmol
- ☐ IV infusion 4 mg noradrenaline in 50cc NS, 0.01 – 1 mcg/kg/min
- ☐ Optional infusions:
- ☐ IV infusion 4 mg adrenaline in 50cc NS
- ☐ Dobutamine 500mg in 500cc NS; 2.5-5mcg/kg/min
- ☐ Dopamine, 2.5-5 mcg/kg/min

Fig. 27.4 (continued)

27.10). With regular repeat visits alongside structured curricula & training, progressive local independence can be put in place responsibly. With adequate planning, preparation, collaboration and commitment from both local & visiting teams there is enormous potential to establish a cardiovascular program that can ably serve its patients and community for the long term.

☐ Ephedrine 5-10 mg/cc ☐ Metoprolol 1mg/cc ☐ Nitroglycerin 50mg in 50cc IV NS infusion ☐ Milrinone 25-50 mcg/kg for load/bolus; infusion 0.25-0.75 mcg/kg/min ☐ Tranexamic acid or Amicar if available , follow protocol for dosing. ☐ Morphine 10mg iv ☐ Protamine 1mg for each mg Heparin given pre-CPB ☐ Pre-named labels for syringes or white small labels, pen; drawer tray (can use kitchen cutlery organizer). ☐ Lidocaine 1%, 2%, and 4% spray. **NOTES:**	

Fig. 27.4 (continued)

OPERATING ROOM – PERFUSION (PERFUSIONIST COMPLETES)	COMMENT/ACTION
E) PERFUSION ISSUES ☐ See PERFUSION CHECK LIST. ☐ Area set aside for perfusion storage (including heart-lung machine and heater-cooler) ☐ Blood Gas machine confirmed as working, and ***before each case***. ☐ Blood-gas syringes, heparin syringe caps, and knowledge of location of blood-gas machine. Rehearsal sample check on "Dry Run" and, day of surgery. ☐ Blood gas and other perfusion record chart ☐ Dedicated air/O2 gas supply & suction confirmed and operational. ☐ Drugs, as listed for perfusion ON PERFUSION CHECKLIST. ☐ H/L machine and Heater-Cooler with confirmed consistent, dedicated electrical supply loading and back up generator. ☐ Biomed check has been done of machine and loading. ☐ Hand-cranks x 2 by the machine ☐ Tie-bands for tubing connection; duct tape available to perfusionist. ☐ Perfusion packs & oxygenator supply confirmed. ☐ Connectors in various sizes. ☐ Supply cart (separate from anesthesia). ☐ Selection of syringes/needles, blood-gas syringes, alcohol wipes. ☐ Monitor positioning to be placed so it remains ***in full view*** for every case. ☐ Proximity to surgical field discussed and confirmed before cases begin. ☐ Position of lines and securement discussed and decided for draping routine. ☐ Low light source for perfusionist to be able to check oxygenator reservoir level. ☐ Low stools or boxes x 2 (essential). ☐ Disposable bags for items to be discarded. ☐ Bag or tray for items to be re-sterilized. **NOTES:**	

Fig. 27.4 (continued)

OPERATING ROOM – GENERAL (NURSE COMPLETES)	COMMENT/ACTION
F) OPERATION General Management ☐ Draping to exposure operative areas, protecting genitals, airway connections, exposing femoral vessels. ☐ (Femoral pulses are checked before induction; peripheral pulse is checked if femoral line has been inserted. ☐ Position of all equipment in the room to allow easy access: ☐ Anesthetic equipment ☐ Perfusion pump and heater-cooler and cart. ☐ Agreement on Circulating Nurse walk areas. ☐ Defibrillator position. ☐ Visible urimeter position for perfusion and anesthesiologist to observe. ☐ Agreement on draping, routing of perfusion and suction lines to sterile field. ☐ Organizing optimal position of lines, cautery, defibrillator paddles. ☐ Procedure to be followed for, "Time Out" ritual being carried out for EVERY case ***before*** the nurse hands the surgeon the scalpel. ☐ Selection of valves available, their type, size & expiration dates listed, and this stock list reviewed by OR nursing/technician team. ☐ Choice of chest drains and reservoirs, and suitable male-male connectors. ☐ Suture and Instrument trays are confirmed as adequate for case needs	***See separate lists***

Fig. 27.4 (continued)

OPERATING ROOM – TRANSFER (NURSE COMPLETES)	COMMENT/ACTION
G) END OF CASE ☐ Stock of pathology specimen receivers for laboratory and appropriate forms. ☐ Bio-hazard plastic bags. ☐ Items discussed about potential for re-sterilization. ☐ ICU bed prepared and ready. Patient siding routine agreed upon;(always moving patient only on anesthesiologist's instruction.) ☐ Free-standing drip stand (or bed-mounted) if possible. ☐ Transport monitor, fully charged (or ICU monitor). ☐ ICU monitor for chosen ICU bed, fully functioning. ☐ Oxygen cylinder, with ICU ambu bag ready for patient and by bed. ☐ Warm blanket (note: patient MUST be appropriately covered for transfer). ☐ Clean sliding sheet on bed – (ENSURE no lines snared on transfer to ICU bed!) ☐ Anesthesia drugs that are essential for transfer, are labeled and available on an anesthetic transfer tray. ☐ Discussion and agreement on process to verify immediate room decontamination, turnover time, and set-up for possible urgent return to OR. ☐ Scrub nurse field is to remain sterile until patient is connected to monitor and ventilator in ICU. ☐ "Bring-back to OR" sterile instruments and sternal retractor" are available for possible urgent return to OR (suggest these are left in ICU).	

Fig. 27.4 (continued)

ICU SET-UP AND MANAGEMENT (ICU NURSES COMPELTE)	COMMENT/ACTION
H) ICU set up – equipment & supplies for ICU. ☐ CardioStaret ICU protocols available if local ones already developed. ☐ Yankaeur and endo-bronchial suction (hanging and ready at head of bed). ☐ Access to head of bed: headboard, confirmed as removeable. ☐ Drip stands are secure, and syringe pumps securely mounted. ☐ Ventilator has been check by RT or anesthesiologist. ☐ ICU chart/documentation/pens in stock. ☐ Supplies for ABG and blood draws; ☐ Dressings, tapes in ICU stock. ☐ Code/Crash Cart is full and has been checked by pharmacist. ☐ Emergency lighting (portable) available. ☐ Overhead bed lighting is working. ☐ Portable suction unit in ICU x2 per patient is available. ☐ Ambu bag, connection & airway, hanging by bedside at all times. ☐ ICU has Code/Crash Cart identical with OR, with recorded log, seal and working defibrillator. ☐ Code Report Management sheets are in drawer; ☐ Emergency sterile "bring-back "tray (with blade, sutures kit & drapes, gowns, gloves, surgical hats,) is available. ☐ Sterile internal paddles are available in drawer with re-sternotomy equipment. ☐ Chairs for relatives during visiting hours. ☐ Surgeon, anesthesia, lab telephone contact- posted. ☐ OR staff are to be informed, (as a routine), when patient is considered stable so they can de-sterilize the OR field, then clean and prepare OR and instruments for autoclave. ☐ Blood gas analysis equipment is accessible to ICU staff.	
I) E RGENCY RETURN TO OR ☐ Inform OR staff/anesthesia on call. ☐ OR available, cleaned and prepped; OR key storage is agreed by all OR team. ☐ Sterile instrument tray set up/suitable disposables to hand. ☐ Oxygen cylinder is full on bed. ☐ Monitor cables ready for transfer. ☐ Transport monitor attached. ☐ Same IV drips sustained (especially, if on inotropes) and return to OR with patient. ☐ Suction of chest drains is ceased from airway suction management. ☐ Attach ambu-bag/connector. ☐ Same size ET-tube and suitable laryngoscope are at head of table. ☐ Available blood from ICU fridge to be obtained immediately.	

Fig. 27.4 (continued)

DEALING WITH EMERGENCY SCENARIOS. (ICU AND OR NURSES COMPLETE)	COMMENT/ACTION
J) EMERGENCY RE-STERNOTOMY IN ICU ☐ Protocol is available.	
K) Preparing for discharge ☐ Brochure and advisory statements about future care printed before first case ☐ Information sheet on how to manage wound, bathing and ambulation. ☐ Information sheet on how to manage medications including Coumadin/INR management. ☐ Nurse has been appointed for home advice/visit ☐ Patient/family has been given a copy of the surgeon's OR record.	
L) OTHER PROTOCOLS/Forms – to be available to team (or may use CardioStart recommended Forms). ☐ Full surgical instrument lists ☐ Re-Sternotomy procedure and tray ☐ Policy for management of Relatives ☐ Policy for management of Staff – inter-personal relations ☐ Policy on how to respond when a death occurs	

EXTRA NOTES

Name:

Signature:

CardioStart Surgeon Date: ___________

Fig. 27.4 (continued)

Fig. 27.5 A medical mannequin assumes the patient role in a Dry Run exercise to rehearse each step from preoperative ward to recovery in ICU; this allows confirmation of comprehensive safety checks & identification of issues requiring resolution before the first operation

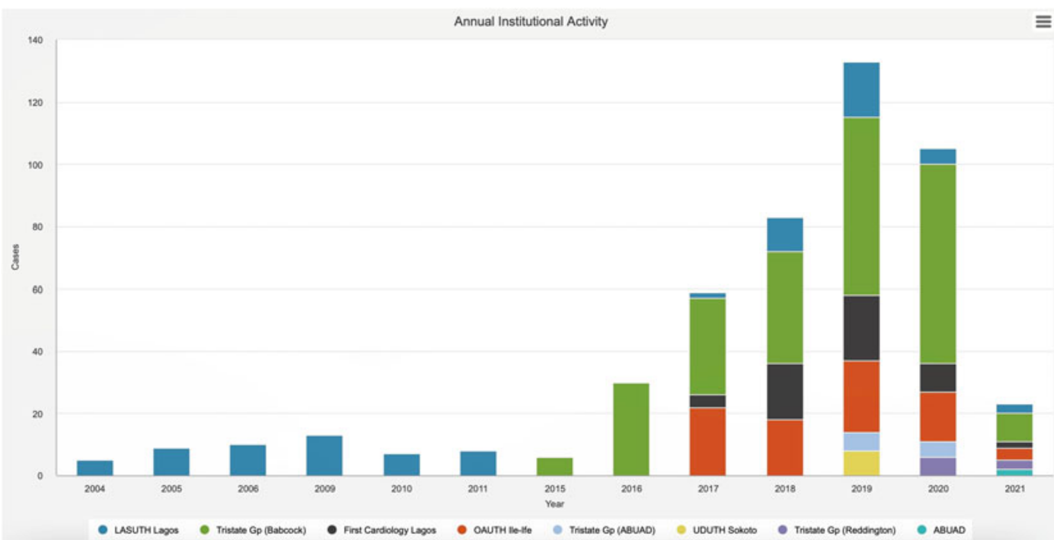

Fig. 27.6 Annual Institutional Cardiothoracic Activity in Nigeria from 2004 to 2021. Adapted with permission from www.nigeriaheartregistry.com

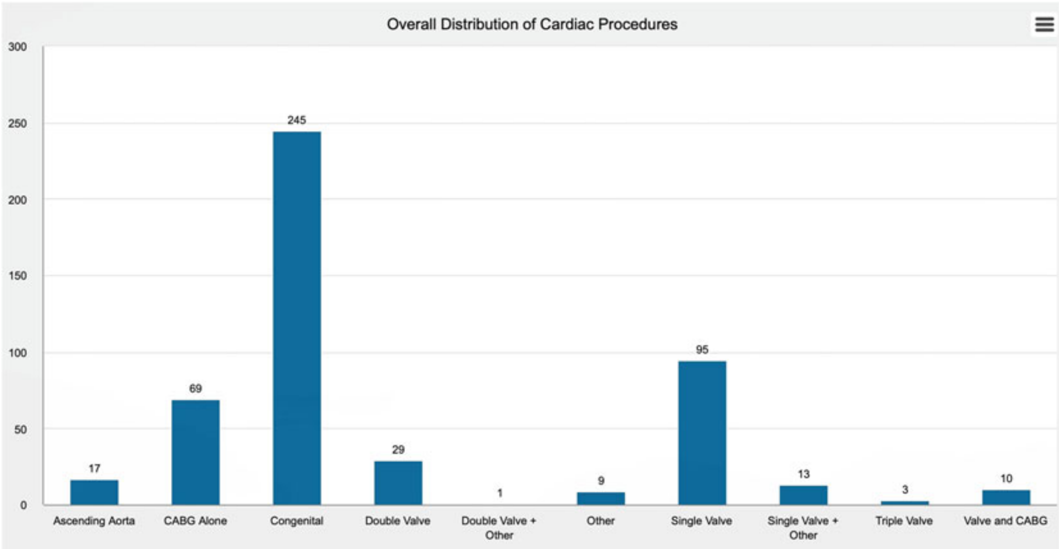

Fig. 27.7 Distribution of Cardiac Procedures in Nigeria from 2004 to 2021. Adapted with permission from the Nigeria Heart Registry

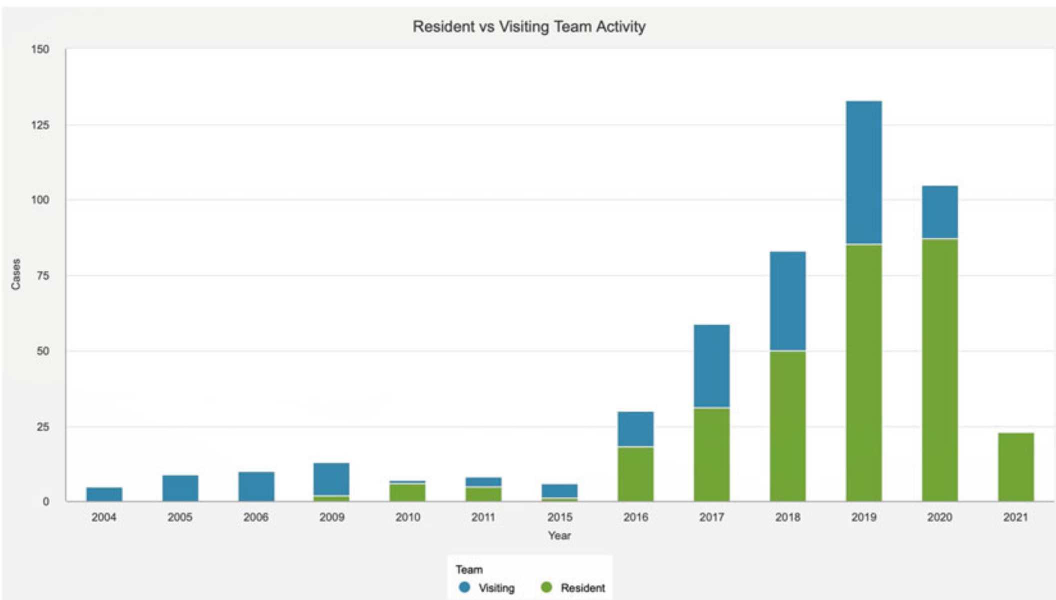

Fig. 27.8 Resident (local) team versus Visiting team Activity in Nigeria from 2004 to 2021. Adapted with permission from the Nigeria Heart Registry

Fig. 27.9 Postoperative inpatients during a cardiac surgical program-building mission in Ghana

Fig. 27.10 First postoperative clinic visit patients following a cardiac surgical program-building mission in Ghana

Acknowledgements CardioStart International for allowing inclusion & adaptation of proprietary documents.

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28 Cardiac Surgery Capacity Development in Emerging Countries

Salome Maswime, Christella Alphonsus, and Natercia Da Silva

Abstract

Cardiovascular disease is the leading cause of mortality worldwide and 80% of these deaths are from low-and-middle income countries. Every 3 out 10 people with cardiovascular disease will require surgical intervention, yet the vast majority of patients do not have access to cardiac and thoracic surgical services. Sub-Saharan Africa has only 22 cardiac surgical centres to serve 1.1 billion people with an average of 1.6 open heart operations per million population. In this chapter we discuss the burden of cardiothoracic disease in low-and-middle income countries, the unmet need for surgical care, and the work needed to improve surgical services.

Keywords

Global surgery · Cardiothoracic surgery · Global cardiothoracic surgery · Unmet need for cardiothoracic surgery · Access to cardiothoracic surgery · Surgical systems strengthening

28.1 Introduction

The unmet need for surgery globally, has led to` the rapidly developing emerging field of global surgery, which has emphasized that surgical services are the key elements of a properly functioning healthcare system and thus a prerequisite for accessibility of universal healthcare. African countries all face significant competing health challenges. Global cardiothoracic surgery can be defined as an area of research, practice, and advocacy that places priority on improving health outcomes and achieving health equity for all people worldwide who are affected by cardiothoracic surgical conditions or have the need for cardiac and thoracic surgical care [1]. Cardiovascular disease is the leading cause of death worldwide, with recorded 17.5 million deaths every year [2, 3]. Low-and-middle income countries contribute to 80% of these deaths [1]. The huge increase in the incidence of cardiovascular diseases in Africa has resulted in the increased need for management strategies of these conditions and the development of skills to

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_28

treat these conditions in tertiary level institutions. Cardiovascular disease has approximately a 30% chance of requiring a surgical intervention in low- and middle-income countries but approximately 90% of the population in low- and middle-income countries do not have access to cardiac surgery [1]. Few African countries have the resources to provide optimal cardiothoracic surgical services and care. As reported in 2014, a total of 22 cardiac surgical centres in sub-Saharan Africa were identified [1, 2]. In the reported centres, 57 surgeons performed 1.6 open heart operations per million population [1, 2]. In comparison, in the United States there is one cardiac surgical centre for every 120,000 population, whereas in Africa, there is only one centre for every 33 million inhabitants [1]. But in a continent still struggling to conquer infectious diseases and diseases of poverty, advocating and prioritizing cardiac surgery over other life threatening diseases is difficult. Cardiac surgery and advanced cardiac interventions are seldom prioritised and often integrated into regional services (Fig. 28.1).

28.2 The Global Burden of Cardiac Disease

Morbidity and mortality from structural conditions such as congenital heart disease (CHD) and acquired heart disease such as rheumatic heart disease (RHD) remain higher in African countries than in the rest of the world. RHD is rare in high-income countries, being almost seen as eradicated by the 1980s [4, 5]. RHD remains the most common form of acquired cardiac disease in children and young adults in Africa. It is the most preventable form of cardiac disease, though difficult to treat effectively without surgery. The burden of congenital heart disease is only part of the problem, with rheumatic heart disease (RHD) remaining the commonest cardiac problem, related to poor socioeconomic conditions [1, 4]. Congenital heart disease affects 1 in 125 live births per year, of which approximately 70% will require medical or surgical treatment in the first year of life [4]. In low-income countries more than 90% of people requiring treatment are not able access treatment or receive suboptimal care,

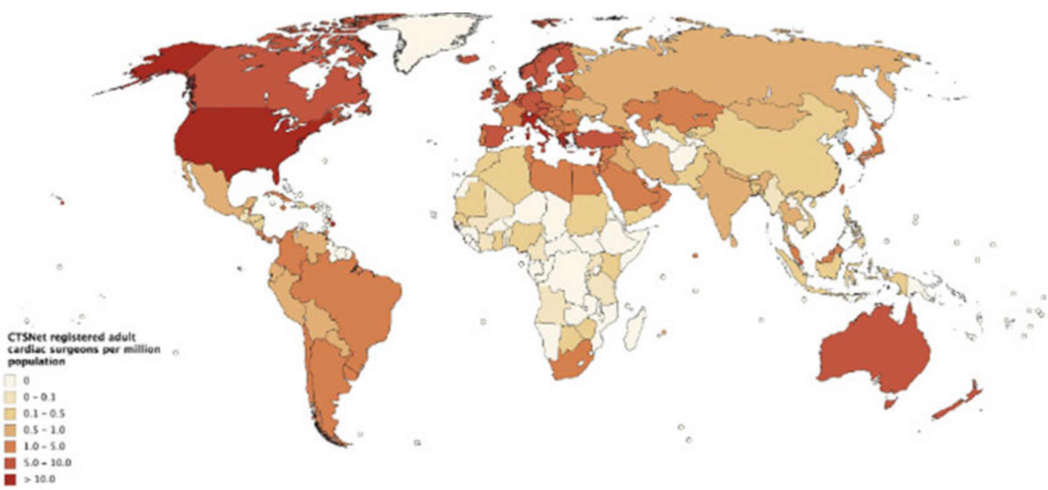

Fig. 28.1 *Adult cardiac surgeons per million population* registered with the CTSNet in August 2017 (Reprinted From: Vervoort D, Meuris B, Meyns B, Verbrughe P. Global cardiac surgery: Access to cardiac surgical care around the world. Journal of Thoracic and Cardiovascular Surgery Volume 159, Number 3, copyright 2021, with permission from Elsevier)

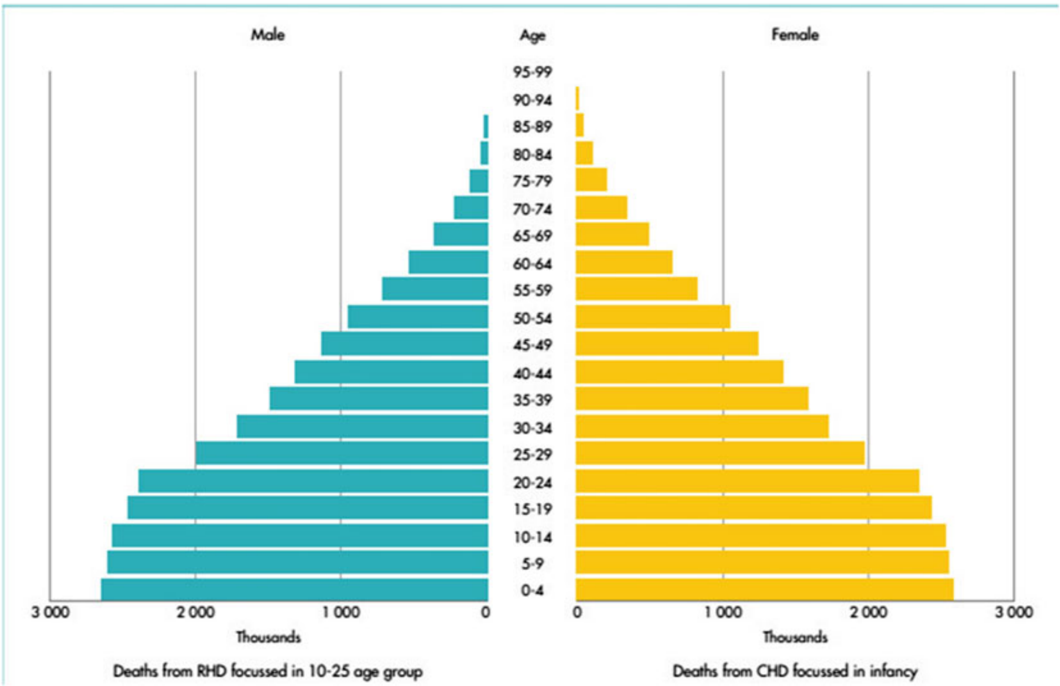

Fig. 28.2 South African age pyramid demonstrates population affected under 25 years old and age group most affected by both epidemics of acquired (RHD) and Congenital heart disease. (Hewitson J, Zilla P. Children's heart disease in sub-Saharan Africa: Challenging the burden of disease. Children's heart disease. SA Heart, Volume 7, Issue 1, Summer 2010, pp.18–29, with permission from South African Heart Journal)

with diagnosis in 80% being made once advanced or irreversible stages of heart failure have developed [1, 4]. If treated 85% of cases of congenital heart disease are expected to survive into adulthood but lack of treatment results in 1 out of 3 children dying within the first month of life [1, 4] (Fig. 28.2).

In low-income countries, only 11% of patients undergo operation for RHD, and it has thus been termed a disease of "social injustice" [1, 5]. A resolution to end RHD in Africa has been made by African leaders, with an explicit call to increase cardiac surgical capacity across the African continent [6]. In African institutions that may provide cardiothoracic surgical intervention, cases are frequently cancelled for reasons as minor as power outages, water and sanitation issues, no availability of blood products, no human resources and lack of consumables such as surgical materials and valve prostheses. In African countries with limited resources where surgery is concerned, the priority is given to congenital and rheumatic valvular cases resulting in most adults with other conditions, such as coronary artery disease and cardiomyopathy, never receiving treatment. Lack and delay in service delivery results in patients presenting with late diagnosis, which is extremely common in this context, with many patients presenting in the palliative stage, where surgical intervention is no longer feasible or safe. Without access to surgery, the costs of repeated hospitalisation for both acquired and congenital cardiac conditions are significant. It contributes to the intangible costs from premature disability and death.

28.3 Pulmonary Disease and the Unmet Need for Surgery

There is a clear imbalance between adequate facilities and surgical expertise, the lack of nursing staff and material resources. In South

Africa thoracic surgery is unique when compared to high-income countries, in having a large proportion of inflammatory pleural pulmonary disease in a younger population [7, 8]. Pleural pulmonary disease is often associated with chest trauma, empyema or communicable diseases such as Tuberculosis or non-communicable disease like lung cancer. If poorly managed or treatment delayed, thoracic disease affects patients' quality of life, employment and may contribute to unnecessary morbidity and premature mortality if not treated adequately. In South Africa, 90 thoracic operations are performed per million in academic cardiothoracic centres when compared to 400 per million in countries like United Kingdom and Germany [7–9]. Though having a higher burden of disease, treatment modalities are not met due to limited cardiothoracic surgical services, as a result of inadequate health care and lack of resources and trained surgeons. National health reform policies directing most funds to primary health care facilities, has had an unintended detrimental effect on tertiary specialist fields in academic institutions [7]. Understaffing and underfunding has led to patients being denied specialist care. Cardiothoracic surgery in South Africa is faced with the challenge of obtaining proficient surgical training of an international standard, with limited funding for surgical procedures and limited posts for training, struggling to survive the trial of a failing health care service in crises [7, 8].

28.4 Proposed Way Forward for Global Cardiothoracic Surgery in Low-and-Middle Income Countries

Lack of effective and sufficient human resources to provide optimal perioperative care remains the major limitation to meeting current surgical demands. There are very few centres that have the ability to provide adequate surgical services with an established comprehensive rehabilitation and palliative care program. The follow-up of local patients is generally acceptable but becomes more challenging for those patients who live in remote areas. Patients in rural areas need to consider spending money on transportation for follow-up appointments versus spending that money on food and other needs for their family. Due to these difficulties, studies have shown that the rate of loss to follow-up is more than 80% in patients living in the areas remote from the treatment facility [3, 10]. Majority live in remote areas, and accessibility to healthcare services is a major challenge. The vision for sustainable cardiac surgery in Africa needs a multidisciplinary team and framework for every country with an additional collaborative call for surgery such as made in "The Cape Town Declaration" [6]. A call made by societies and leaders with the aim to form a coalition of international individuals from cardiothoracic surgical societies, industry and government endorsing the priority of cardiothoracic care in low- and middle-income countries (LMIC). Advocating training of cardiothoracic surgeons and key specialities to be identified and endorsed within these centres [6].

28.5 Scaling Up Surgical Programmes

There are major resource bottlenecks that may hinder the scale-up of surgical programs. Training and fellowship programmes are being developed to contribute to various facilities through Africa and these sites participate in cardiovascular research. Research conducted by Forcillo et al., describe a conceptual 5 pillar framework depicting all areas that need to be addressed, to establish a functional cardiothoracic unit in a poor resource environment. The minimum requirements needed for each functional cardiothoracic unit is furthermore indicated in the Table 28.1, listing crucial requirements in establishing a functional cardiothoracic unit in resource limited setting. It is important to recognize that mere availability of cardiac surgeons does not necessarily translate to proficient access to cardiac surgery [10]. Adequate preoperative (e.g. imaging, laboratory services, cardiology, general medical care), intraoperative (e.g. blood banking, cardiopulmonary bypass equipment,

Table 28.1 Minimum surgical requirements defined to perform cardiothoracic surgery in low-and- middle income countries [2, 10]

Institution: • Dedicated cardiac and thoracic operating rooms • Catheterization Laboratory/hybrid theatre	*Surgeon*: • >100–125 cases/year • >2 surgeons/team • 1 Congenital surgeon • Trained Valvular repair and replacement procedures • Trained thoracic procedures • ICU trained
"HEART" team: • >2 Cardiologists – Trained in echocardiography & trained in cardiac catheterization • 1 Congenital cardiologist • Cardiac & thoracic anaethetist • Cardiothoracic intensivist	*Technician*: • 2 Perfusionists • 1 Cardiac technician • Respiratory physician
Nursing: • >6 Cardiac trained ICU nurses (1 nurse per patient) • 2 Cardiothoracic scrub nurses • Access to inotropes and vasopressors • >6 Ventilators • >6 ICU beds • Access to blood products (blood bank)	*Equipment*: • Cardiopulmonary bypass machine • Surgical equipment for valve repair and replacement techniques • 2 Transthoracic &1 transoesophageal echo probes
General: • Support from the department of health • INR clinic • 24 h laboratory facility • Collaboration and education	*Follow up*: • Follow up clinics • Referral and transportation system • Database

perfusionists, technicians), and postoperative services (e.g. intensive care unit, follow-up cardiology services) are essential [3, 10]. Central to the human resources crisis underlying cardiac surgical care, the need arises for high-volume and high-quality training facilities adapted to local needs (Fig. 28.3).

Prevention, Education and Screening: With the growing burden of CVD around the world, there is a noted increase in epidemiologic transition from communicable to non-communicable diseases in LMICs. Governments have increased the focus on preventing disease through inexpensive population-based policies. Late presentation and diagnosis of RHD are the norm and cardiac surgery itself cannot help all patients. Simplistic measures can be adapted such as timely antibiotic treatment for streptococcal sore throat (primary prophylaxis) and limiting the progression to RHD through recurrent attacks by ongoing antibiotic therapy (secondary prophylaxis) [4, 5, 10]. It may be unrealistic to expect to see advanced paediatric cardiac care in the near future in poor countries, but it is possible that prevention could be incorporated into the most basic health care systems. By thus establishing cardiovascular disease detection and awareness in the community, it may lead to better public advocators for improved health care services such as antenatal care, which in turn my contribute to the reduction of CHD. [3, 10]

Outreach Clinics: Governments should continue establishing outreach clinics for specialist physicians and surgeons. African countries all face significant competing health challenges. Regional hospital support and education of local physicians on cardiac surgery issues will be needed to strengthen early diagnosis and referral chains to prevent late presentation and avoidable mortality [3, 10]. The huge increase in the incidence of CVD in Africa has resulted in a call for management of these conditions and building capacity for referral and treatment at a tertiary level [10].

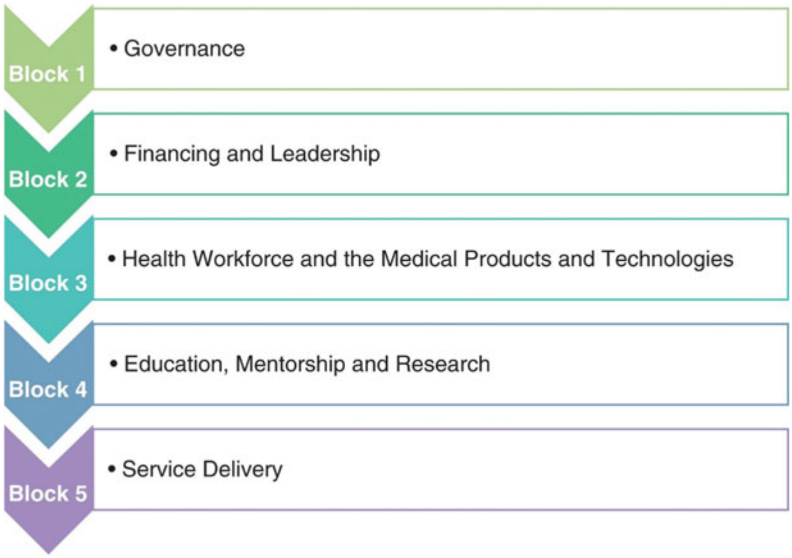

Fig. 28.3 Assessment of the current capacity to perform cardiothoracic surgery by the 5-block conceptual framework (Modified from the World Health Organization (WHO) Health Systems Framework) (Facillo J. Watkins D. Brooks A. et al. Making cardiac surgery feasible in African countries: Experience from Namibia, Uganda, and Zambia. The Journal of Thoracic and Cardiovascular Surgery. Volume 158, Issue 5, November 2019, pp. 1384–1393, copyright 2021, with permission from Elsevier)

Mentorship Programs, Collaboration, and Education: 'North–South'' hemisphere and "South-South'' hemisphere collaborations help to meet the training needs in cardiac surgery disciplines. These collaborations have been successful at recruiting physicians and surgeons alike. There are still limitations in the recruitment of other health professionals, such as Critical care intensivists, Perfusionists, and ICU nursing staff [10, 11]. Expanding collaboration teams to include these disciplines is crucial.

Transcatheter Valve Replacement, Minimally Invasive Procedures and New Technologies: Transcatheter valvular therapies could be used as a minimally invasive alternative to address valvular pathologies caused by RHD. In Cape Town for example, Strait Access Technologies has been designing a more affordable Transcatheter valve to treat aortic insufficiency [6, 10]. These procedures can be performed via a "minimalist'' technique which may improve ease of training for the surgeon and result in shortened hospital stays for the patient and the need for fewer resources from the health care system [10].

Establishing a Multidisciplinary Team: "Heart Centre": Formation of a heart centre which is privately managed with services purchased by government capital could be used in the public and private sectors. Cardiac surgery operates in a multidisciplinary environment where a team approach, working toward the same patient-centred goals offers the best chance of service excellence. It would be up to the state to determine its budget to increase access to cardiac care for patients completely dependent on the state for healthcare [10].

Collaboration of all these facets displayed in Fig. 28.4 are needed to achieve sustainability and improved outcomes with regards to access to cardiothoracic care.

28.6 Cardiothoracic Anaesthesia

The delivery of cardiothoracic services requires a multidisciplinary workforce which includes anaesthesiologists. The shortage of trained anaesthesia staff and subsequently specialists in

Fig. 28.4 Directions to achieve sustainability and to improve access to care (Facillo J. Watkins D. Brooks A. et al. Making cardiac surgery feasible in African countries: Experience from Namibia, Uganda, and Zambia. The Journal of Thoracic and Cardiovascular Surgery. Volume 158, Issue 5, November 2019, pp. 1384–1393, copyright 2021, with permission from Elsevier)

cardiothoracic anaesthesia is a global problem in LMIC. Training in cardiothoracic anaesthesia usually follows specialist training in anaesthesia. This is a wide field not only encompassing open heart surgery, but anaesthesia in cardiac catheterisation labs and anaesthesia for thoracic procedures. Continual upskilling is important and incorporation of transoesophageal echocardiography is seen as part of the gold-standard of intraoperative anaesthesia care. Safe perioperative care requires trained staff and also availability of drugs and monitoring equipment. These depend on stable supply chains systems, funding and procurement systems.

Training is often undertaken as a fellowship in cardiac anaesthesia. Many LMIC's do not have the resources to provide this training which can be undertaken in a host institution with a high-volume of cardiothoracic procedures most often in a high-income country. LMIC's usually lack the capacity and funding for fellowship training which normally occurs over a one to two year period. The minimum training required by the European Association of Cardiothoracic Anesthesiology (EACTA) in their fellowship program includes the following [1]:

- 150 cardiac cases with cardiopulmonary bypass per fellow per year; 30% or more of the cases should be non-coronary artery bypass grafts
- Training in the management of patients who have mechanical circulatory support
- Training in anesthesia for procedures undertaken in the interventional and catheterization laboratory
- Basic and advanced training in TEE
- Training in cardiac surgical critical care in the intensive care unit, for a minimum of 1 month

of basic training and 3 to 6 months of advanced modular training
- Training in extracorporeal perfusion technology of 1 week
- Training in thoracic anesthesia
- Training in supra-inguinal vascular anesthesia
- Training in interventional vascular (thoracic endovascular aneurysm repair, endovascular aneurysm repair) anesthesia and neuromonitoring

Capacity building in cardiothoracic surgery, requires investment in cardiothoracic-trained anaesthetists.

28.7 Continuity of Care

In areas with limited access to health facilities, patients are often lost to follow-up. Patients being lost to follow up is of great concern in rural communities and could be addressed by involving community health workers, medical telecommunication links and nurse practitioner led clinics [10]. African countries also face significant additional challenges, which include lack of equipment and physical bed space. These challenges result in far less surgery per week than should be the case per surgeon, despite ongoing growth in demand. Global awareness of these challenges may assist units to advocate for improvement in building infrastructure.

28.8 Fellowship Programs, Collaboration and Education

“North–South” and “South-South” hemisphere supportive African Fellowship programmes with either European or other African based countries are important collaborations and mechanisms for meeting training needs in cardiac surgery [3, 10]. Collaborations have been successful at recruiting physicians and surgeons, but less so in recruiting multidisciplinary teams including other specialists like intensivists, perfusionists and cardiac and ICU nurses. To address these gaps, a more comprehensive approach to cardiac surgery training will be required.

Online learning and medical telecommunication could complement hands-on learning. These methods increase knowledge and confidence with regards to skills such as echocardiography. These training programs reduce the need for additional human resources required for training staff. Education and support of regional hospitals, including local physicians, on cardiothoracic surgical issues would strengthen early diagnosis and referral chains to prevent late presentation and avoidable mortality [3, 10]. African countries should invest more in developing more training programmes to develop all the skills required to perform successful cardiothoracic surgery.

28.9 Research and Perioperative Databases

Establishing adequate surgical databases to guide clinical practice and replacing anecdotal decision making with clear treatment plans is essential. A Database allows for both clinical and healthcare system research [7, 9]. A national database would be an important asset in Cardiothoracic surgery to allow for standardization of care across all surgical units and means of obtaining a greater cohort of surgically treated cardiothoracic patients, to allow for improved research. Research is currently lacking in Cardiothoracic surgery in South Africa as a whole [9]. Databases can be setup in a user friendly manner, with easy access, record keeping and include parameters relevant to third world disease profile [7, 9]. Noting that the overall mean publication output per university in South Africa (SA) is as low as 0.6 cardiothoracic publications per year, emphasises is placed on the need for more randomized control trials [7, 9]. Moreover, tuberculosis and HIV are poorly represented in the SA cardiothoracic surgical literature in spite of their high incidence in our communities [8]. The SA thoracic surgical literature is almost entirely observational in design [9]. There are few RCTs investigating surgical topics, and no systematic reviews or meta-analyses [7]. The loss of surgeons with an interest in thoracic surgery from academic practice to emigration, retirement and private practice is significant. At the end of 2006 an estimated 30% of clinically active SA cardiothoracic surgeons were working abroad [7–9]

There is a clear opportunity for interventional research and new technologies. Transcatheter valvular therapies could be used as a minimally invasive alternative to address valvular pathologies caused by RHD [10]. Minimal invasive surgery is known to result in shortened hospital stays and the need for fewer resources. But these have not been utilised in many low- and middle-income settings.

Stakeholder interviews and facility surveys, have identified a lack of capacity to deliver cardiac surgery. Assessment tools have been described that can be used to identify gaps in care and develop and evaluate interventions and program improvements that sustainably increase access to surgical care. These tools also provide data for a more coherent health system response. Providing information on the amount of investment needed to facilitate the development of cardiac surgery units.

28.10 Prevention

Focus is shifting from cure to disease prevention. Governments are implementing inexpensive population-based policies [10]. The lack of human and material resources for treatment of existing surgical cases still remains an ethical imperative of treating patients who currently need care [2]. As mentioned secondary prevention, as seen with RHD, has been shown to be of substantial benefit in 3rd World countries, with prevention being feasibly provided for than cure [4, 5].

28.11 Access to Care

In many low- and middle-income countries patients patients have to make out-of-pocket payments. If open surgery is not performed in that country, costs are even higher, requiring surgery abroad [10]. Patients without health insurance have to find alternate sources of financing to meet surgical costs, including borrowing from friends and relatives and selling assets. Sustainable public finance of cardiac surgery services remains a major challenge, and in the short term, this will need to be addressed by increased aid through public–private partnerships [3, 10].

Access to tertiary care for patients living in the remote areas is often not sufficient to meet current demand. It is also unlikely to decentralize cardiac surgical procedures beyond the capital cities and therefore governments should support and invest in outreach clinics for specialist physicians and surgeons [10]. There are efforts to establish more outreach clinics that offer at least basic cardiothoracic surgical services.

In an attempt to bridge the gap in existing fragile health systems, humanitarian efforts have led non-governmental organizations (NGOs) to develop cardiac surgical programs in low- and middle-income countries [3, 10]. These programs range from overseas treatment to fly-in fly-out missions. These missions however often lack comprehensive quality control to evaluate the benefit or harm by recognizing that some fly-in fly-out organizations may not take into account the postoperative care of patients [10]. Leaving post-operative patients behind without the knowledge of the outcomes of follow-up care or availability of monitoring such as warfarin regimes and anticoagulation [3]. There is thus a need to work towards universal programs for local care teams and the establishment of sustainable preoperative and post-operative frameworks to enable good quality and holistic cardiac care [3, 10]. Flight services for patients who live in the remote areas exist but limitations to flight availability and cost are excessive. Treating more patients locally is an important aim because an operation in country compared to abroad is significantly cheaper [3]. With the centralization of cardiac care, the volume of cases could increase and training programs might improve.

Short-term mission trips to provide surgical care in settings where there are no specialists has worked well in many instances, but has not been without flaws. The lack of capacity building and training for the local surgeons and institutions leads to a lack of contribution to continuity of care. Visiting surgeons are seldom familiar with local needs and problems. Locals may develop a dependence on visiting teams with the visiting surgeons not being there long enough to address surgical complications [3, 10]. There would thus be a substantial benefit to move away from fly-in–fly-out cardiac surgery mission trips and build toward sustainable, local-led and bred cardiac centres but this can only be achieved by long-term, multidisciplinary planning and political support [3].

28.12 Simulation Laboratory

Simulation is described as a technique to replace or amplify real experiences with guided experiences that evoke or replicate substantial efforts in the real world in a fully interactive fashion. Simulation is growing in high-income settings, as it allows surgeons to improve their expertise without operating on humans. Whilst simulation has been found to be a very effective form of training, in high income countries, the cost has been found to be a barrier in LMIC's with financial constraints for service delivery. In settings where there is a shortage of essential surgical equipment, financial investment in equipment for simulation and human resources for training may not be justifiable.

28.13 Surgical Workforce, Diversity and Inclusion

Despite the high burden of cardiovascular and pulmonary disease, there is marked shortage of cardio-thoracic surgeons, especially in Africa and Asia. One cardiothoracic surgeon per population of 25 million in Asia, compared to 1 per 120,000 in Europe and North America. Africa has 1% of the world's cardiothoracic surgeons, compared to 42% in Europe, which does not match the disproportionately high burden of disease in Africa [1, 3]. Furthermore, there are wide disparities by race and gender of cardiothoracic surgeons, with only 15% of cardiothoracic surgeons according to the American College of Surgeons being female [12]. In 2018 the first black female cardiothoracic surgeon qualified in South Africa, despite South Africa having a long history of advances in cardio-thoracic surgery, including the first heart transplant in 1967 [12]. Greater efforts are required to improve diversity among cardiothoracic surgeons.

28.14 Conclusion

There is an increased priority to augment surgical services worldwide across all surgical disciplines. An exception has been taken with regards to global cardiothoracic surgery, where progress with regards to surgical services in LMIC still lag behind. When addressing global burden of disease, global cardiac surgery is the one subspecialty that is most often omitted, in an era where cardiovascular services are needed the most. There have been many advances in cardiothoracic surgery, even in low- and middle-income countries but there is still a misperception of cardiac surgery as an expensive commodity within the global health derogative and services provided and made available to the communities at large, are often inversely proportional to the world-wide leading cause of death in CVD. This is irrespective of the fact that there is a need of surgical care in 33% of CVD cases, as well as the clear cost-effectiveness on an individual level [3]. Cardiac and pulmonary diseases are leading causes of death globally, and people die mainly in communities where they cannot access care. Holistic cardiac surgical care includes the access to and timely outpatient disease detection, adequate referral mechanisms, state of the art imaging, laboratory services, and postoperative intensive care units and treatment modalities they provide [3]. Strengthening cardio-thoracic surgical health systems, requires a special emphasis of upskilling and training of locals, decentralising surgical services, comprehensive care, and ensuring that an inclusive pipeline of cardiothoracic surgical teams are established in Africa and other low-and middle income countries.

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29 Development of Sustainable Global Thoracic Surgery Programs in LMICs

Brittney M. Williams, Danielle N. O'Hara, Gift Mulima, and Gita N. Mody

Abstract

The development of a sustainable general thoracic surgery program in low- and middle-income countries (LMICs) requires closely coordinated multidisciplinary capacity building. Human and material resources for case finding and work up (radiology), intra-operative care (anesthesia), and postoperative management (critical care, pathology, oncology) are necessary to facilitate care of patients with general thoracic disorders. Here we review (1) the epidemiology of thoracic diseases treated with surgery, (2) barriers and solutions to capacity building, and (3) several examples of successful surgical programs that have served to not only provide general thoracic capacity but also strengthen the local health system overall.

Keywords

Thoracic surgery · Global surgery · Human resources for health · Chronic respiratory diseases · Lung cancer · Esophageal cancer

29.1 Burden of Thoracic Surgical Disease

Thoracic problems including respiratory infections, chronic obstructive pulmonary disease (COPD), and lung cancer are amongst the top drivers of the global burden of disease [1]. In LMICs, pleural space problems and lung masses are commonly sequalae of infection; however, non-communicable diseases including those caused by trauma, environmental exposures (smoking) and malignancy increasingly contribute.

29.1.1 Chronic Respiratory Disease

Chronic respiratory disease (CRD) including COPD, emphysema, and interstitial lung disease are a major driver of human suffering. Four million people die prematurely from CRD each year, making it the third leading cause of death worldwide [1]. Further, CRDs were responsible for over 110 million DALYs total (1470 per 100,000 individuals) in 2017—a 13.3% increase since 1990 [1].

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_29

Much of the development of CRD is attributable to preventable risk factors. Smoking and secondhand tobacco smoke exposure are two of the greatest and most widely targeted risk factors among policymakers. However, non-smoking related risk factors, such as indoor and ambient air pollution and occupational exposures have gained recognition as key contributors [3]. In fact, the leading risk factor for CRD in women worldwide is household air pollution due to indoor smoke created by biomass fuels used for cooking and heating [2].

The significant global burden of CRD was recognized as a key issue at the 53rd World Health Assembly in 2005. In response, the Global Alliance against Respiratory Disease (GARD) was created with a mission to improve global lung health and reduce the morbidity, disability, and premature mortality of CRD [5, 6]. In more than 30 countries, GARD activities led to the development and implementation of policies to guide prevention, diagnosis, and management of CRD, resulting in considerable improvements in partner countries. However, due to the paucity of reliable epidemiologic and clinical data from developing countries, gaps in CRD guidelines in LMICs remain, leaving nearly 2 billion people without national guidelines that address their respiratory disease [4, 6].

29.1.2 Pulmonary Infections

The burden of pulmonary infections falls disproportionately on LMICs given low socioeconomic status, poor access to public health programs (e.g. vaccination, nutrition, and building/water hygiene services), and a relatively higher incidence of HIV and other relevant comorbidities. Pathogens including bacterial, mycobacterial, fungal, and parasitic organisms can cause pulmonary complications such as bronchiectasis (chronic dilation of the airways), empyema (infection of the pleural space) and lung abscess, all of which may require surgical treatment.

Despite increased access to antibacterial therapies, the incidence of empyema worldwide appears to be increasing, perhaps due to resistance and/or community acquisition [7]. While intrapleural fibrinolytics are used in developed areas to facilitate or avoid surgical management [8], these agents may not be available in LMICs. Therefore, chest tube placement and/or pulmonary decortication are necessary surgical procedures to gain source control and promote lung re-expansion.

Tuberculosis and non-tuberculosis mycobacteria cause chronic lung infections and patients can develop serious sequalae including hemoptysis, inability to clear the organism (in multidrug resistant tuberculosis (MDR-TB) cases), and superinfected cavities such as mycetoma (aspergilloma a.k.a. "fungus ball") that may require pulmonary resection for management. Surgical outcomes for highly selected cases of MDR-TB resection at experienced centers are good with 8.5–22.6% morbidity, 9–13% recurrence, 0–5% operative mortality, and 0–12% overall mortality [9–11].

The most common indication for lung resection due to endemic parasites is Echinococcus, which seeds the lungs and liver and form large cysts (termed hydatid cysts). Cystectomy, or parenchymal sparing resections, are the mainstay of management for these after a course of antihelminth therapy to ensure no systemic response to cyst content spillage (Figs. 29.1 and 29.2) [12]

29.1.3 Malignancy

Cancer is the second leading cause of death worldwide and approximately 70% of cancer-related mortality occurs in LMICs [13]. Globally, lung cancer has both the highest incidence and mortality, responsible for an estimated 2.1 million new diagnoses and 1.8 million deaths in 2018 [14]. The principal risk factor for lung cancer is tobacco use, with approximately 71% of global lung cancer mortality attributable to smoking [15]. Although the age-standardized incidence rate of lung cancer is currently higher in developed countries, a relative increase in the incidence of lung cancer in several parts of Africa is anticipated due to the continued

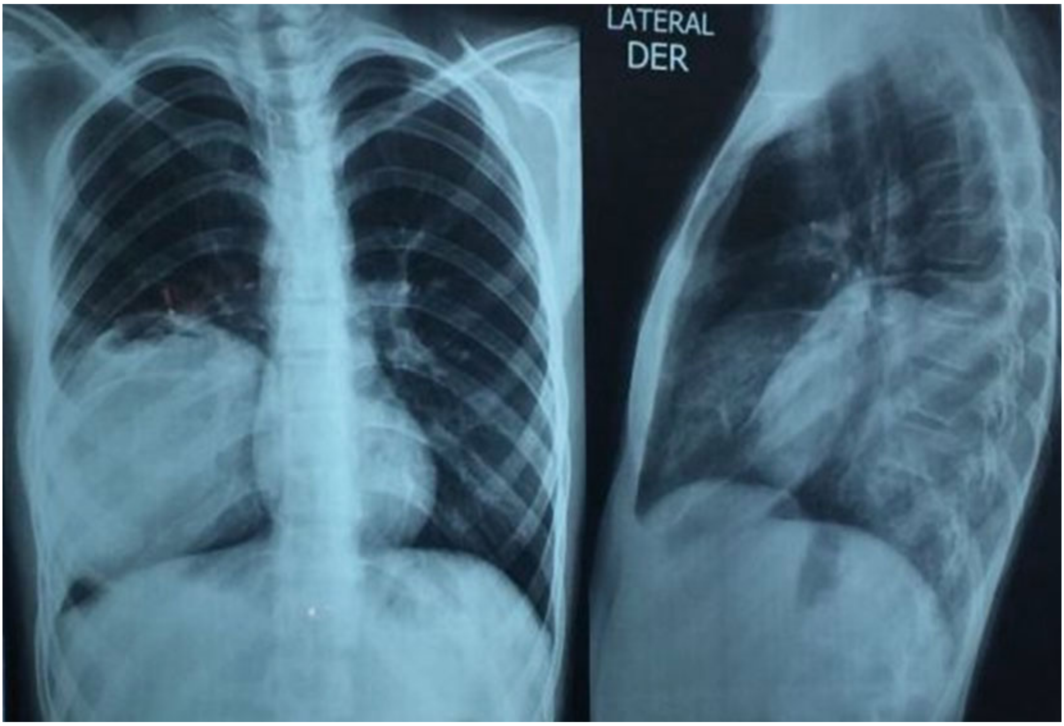


Fig. 29.1 Large right lower lobe hydatid cyst on chest x-ray

promotion of smoking, lack of tobacco cessation programs, and insufficient tobacco control policies [16, 17]. LMICs in Asia also illustrate this trend as the global burden of lung cancer continues to shift from high-income to developing countries [18].

Despite the growing incidence of lung cancer in LMICs, its management continues to prove challenging in this setting. While low-dose CT screening has been widely adopted in high-income countries, screening has not been implemented in many LMICs due to cost, lack of expertise, high false-positive rates related to endemic pulmonary infections, and the potential for over-diagnosis [19]. Without screening programs in place, patients in these settings do not present until symptoms arise; therefore, their disease is often locally advanced or metastatic at diagnosis. Surgical resection with curative intent is not an option for many patients diagnosed at this stage, thus, survival is poor in developing countries with a 5-year survival of approximately 9% compared to 19% in the U.S and 21% in Australia and Canada [20, 21]

Esophageal cancer is the sixth leading cause of cancer mortality worldwide, responsible for approximately 500,000 deaths each year [14]. Esophageal cancer disproportionately affects LMICs with over 80% of cases occurring in developing countries [22]. Certain regions have been found to host an exceptionally high burden of disease, with the highest incidence of esophageal cancer occurring in East Asia, East Africa, and Southern Africa [2]. Figure 29.3 shows the incidence rates of esophageal cancer for countries of varying economic index, demonstrating low-income countries carry a large burden of disease. East Africa, in particular, has emerged as a "hot spot" for esophageal cancer with mortality and incidence rates nearly seven times that of western and northern Africa [22–24]. Risk factors for esophageal cancer in this setting include tobacco smoking, alcohol use, open fire cooking, dietary nitrosamines,

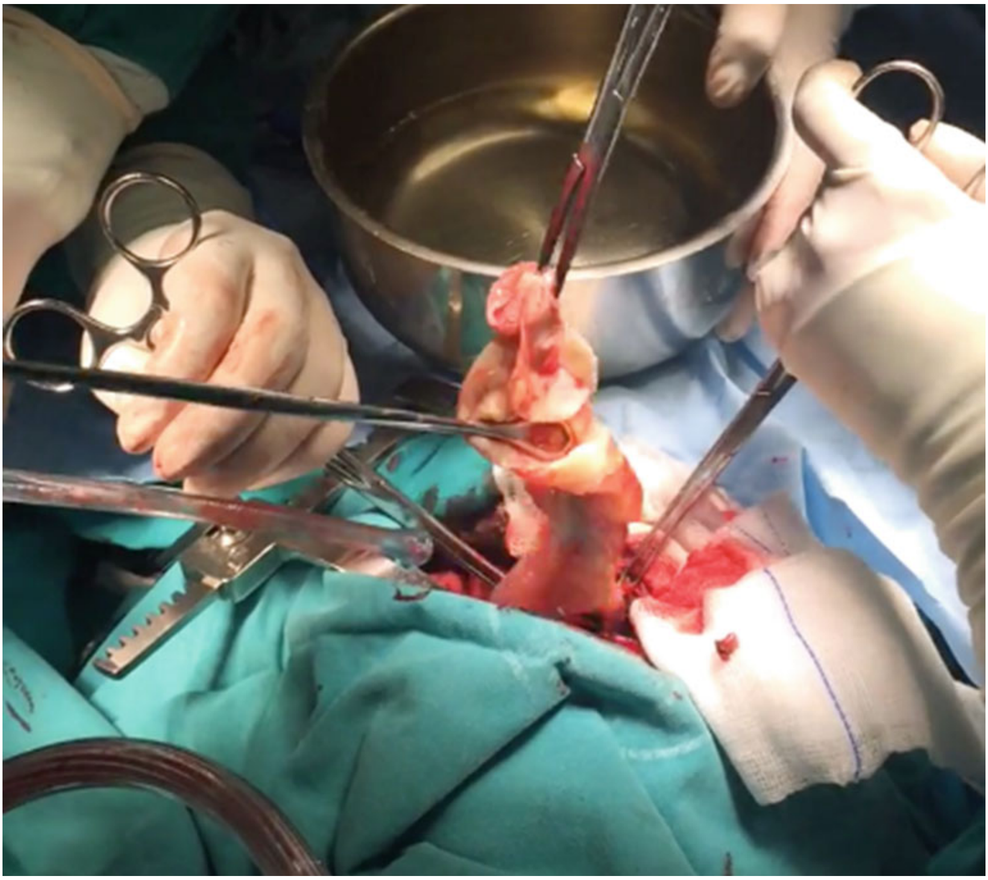


Fig. 29.2 Pulmonary hydatid cystectomy

consumption of piping hot tea, and low socioeconomic status [25, 26]

Due to the often advanced stage at diagnosis, the overall 5-year survival rate for esophageal cancer is only 15–20% [27]. The high morbidity and mortality associated with esophageal cancer are due to its asymptomatic presentation until progression to a locally advanced, obstructive mass or metastatic disease. While surgery is the primary component of curative therapy for locoregional disease, many patients in developing countries are precluded from surgery due to advanced disease at presentation [28]. Additionally, the availability of esophagectomy is scarce in many LMICs, therefore palliative therapies are more commonly utilized in this setting, including radiotherapy, esophageal stent placement, and gastrostomy tube placement [29].

29.1.4 Trauma

Trauma is a leading cause of death and disability worldwide, responsible for an estimated 4.8 million deaths each year [30]. LMICs bear a disproportionate burden of trauma-related mortality, with approximately 90% of trauma mortality occurring in developing countries [31]. These deaths are commonly associated with road traffic injuries as LMICs often have limited infrastructure for safe roads, insufficient safety equipment (e.g. helmets and seatbelts), inadequately enforced traffic laws, and limited access to prehospital care [32]. The thorax is injured in two-thirds of these trauma patients [33]. Up to 10% of all trauma admissions and 25–50% of trauma-related mortality can be attributed to thoracic injuries [34]. While mortality varies based on patient factors,

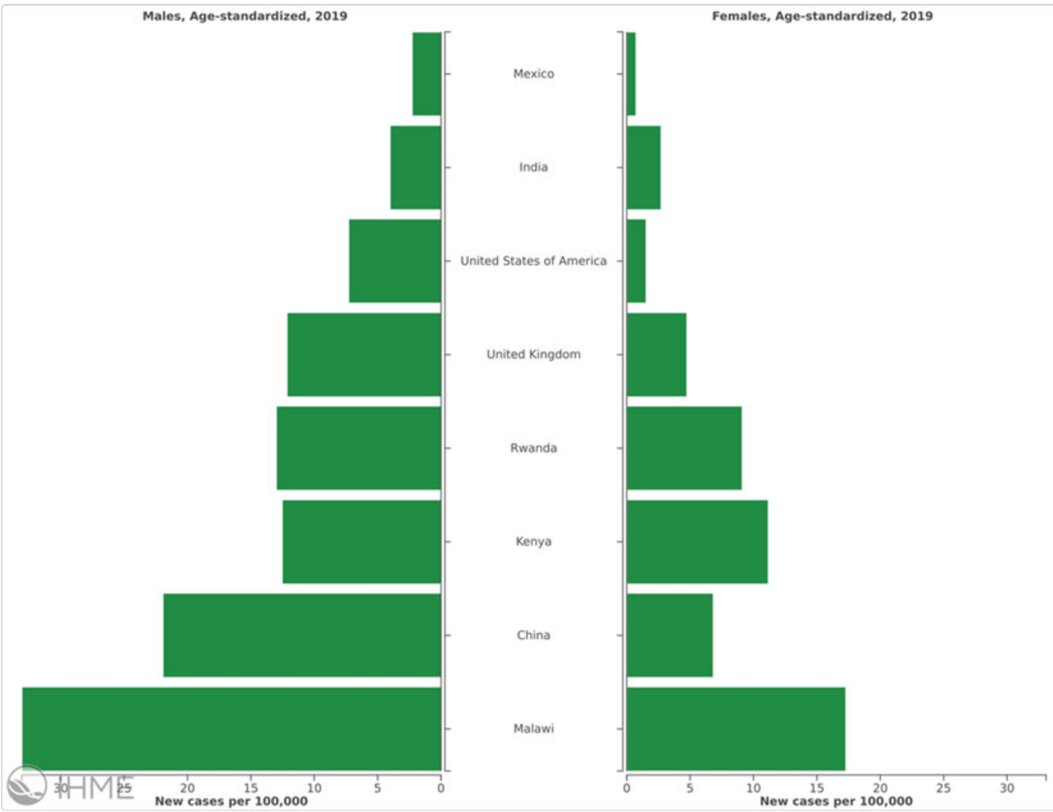


Fig. 29.3 Age-standardized incidence rate by gender of esophageal cancer for countries of varied economic index (*low-income: Malawi and Rwanda, lower-middle income: Kenya and India, upper-middle income: China and Mexico, high-income: United States and United Kingdom)*. Malawi has the highest age-standardized incidence rate of esophageal cancer worldwide [14]. Institute for Health Metrics and Evaluation (IHME). **GBD Compare Data Visualization**. Seattle, WA: IHME, University of Washington, 2020. Available from http://vizhub.healthdata.org/gbd-compare

mechanism, anatomic location of the injury, and available resources, mortality following thoracic trauma, including pre-hospital deaths, has been cited as high as 60% [35]. At Kamuzu Central Hospital, a tertiary care center in Malawi, chest injuries have the second highest mortality rate after head injuries (Fig. 29.4).

Blunt chest injuries are common in LMIC due to the high incidence of road traffic accidents (Fig. 29.5). The most frequent sequelae of blunt chest injuries are chest wall contusions, rib fractures, pneumothoraces, and hemothoraces, which can be managed with tube thoracostomy, pain control, and pulmonary toilet [36]. Penetrating chest injuries, which are more common in times of conflict, often require operative management to control bleeding. Moreover, patient with severe penetrating chest trauma, such as tracheobronchial injuries, often succumb in the field due to lack of pre-hospital care systems in these settings [37].

29.2 Current Barriers and Solutions

29.2.1 Imaging Techniques

Radiologic services provide several essential components of successful thoracic surgery program, including diagnostic capabilities, screening and surveillance of malignancy, and image-guided procedures. Despite the ubiquitous need

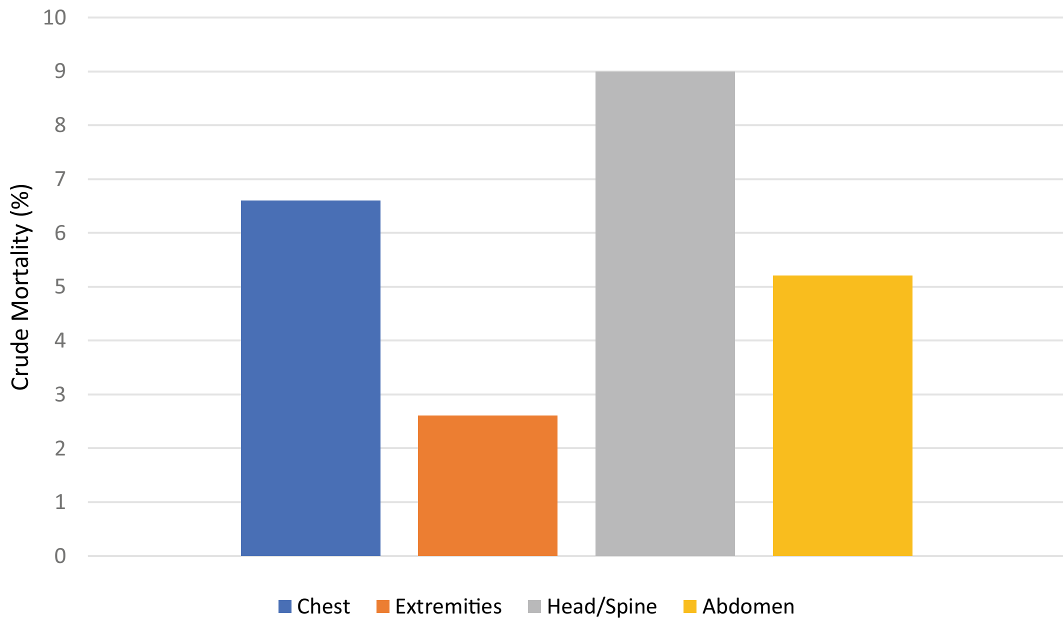
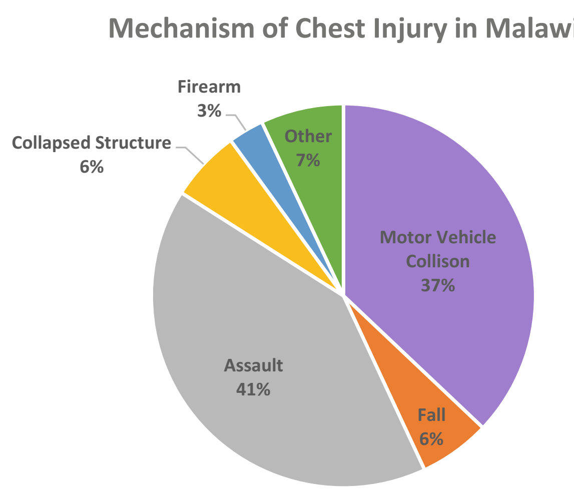


Fig. 29.4 Crude mortality by anatomic location of injury at Kamuzu Central Hospital, Lilongwe, Malawi

Fig. 29.5 Mechanism of injury of patients with primarily thoracic trauma in presenting to a tertiary care center in Malawi



for adequate medical imaging worldwide, an estimated two-thirds of the global population have limited access to these services [38]. Countries in Africa, Central America, South America, and Asia have between 0 and 5 computed tomography (CT) scanners per million population and less than 1 positron emission tomography (PET) scanner per million population [39]. Ultrasound (US) is significantly more accessible in resource-limited settings and the use of small portable US units have proven to be both effective and relatively low-cost [39, 40]. However, the deficiency in the number of sonographers and ultrasound-trained clinicians provides an additional challenge to its widespread implementation across LMICs.

Barriers to alleviating the disparity in radiologic resources include the cost, complexity, and training required to develop sustainable radiology services. Traditionally, areas of limited access have relied on humanitarian efforts to supply or augment radiologic resources. RAD-AID is an excellent example of a non-governmental organization (NGO) whose mission is to build radiology capacity in developing nations through economic strengthening, technological innovation, collaboration, and education [38]. Ultrasound training has become an increasing focus of numerous capacity-building efforts due to the feasibility and ease of use of US, particularly in trauma care with the widely used Focused Assessment with Sonography for Trauma (FAST) exam [41]. The educational model of Teaching the Teachers in which an LMIC physician obtains ultrasound training in a partnering country and returns to their home country to train further physicians, has been successful at increasing access to sonography [42]. However despite burgeoning educational efforts, several challenges to radiology capacity building, such as cost and infrastructure, persist.

29.2.2 Anesthesia Techniques

Anesthesiology and cardiothoracic surgery are uniquely interconnected, as techniques such as bronchoscopy and lung isolation are required for conduct of advanced general thoracic procedures such as lung resection. However, basic anesthetic care—with appropriate equipment and adequately trained personnel—represents a significant barrier to providing even straightforward general thoracic surgery such as pleural space interventions, such as decortication and pleurodesis, in LMICs. A 2016 study assessing the capacity of 614 facilities in 22 LMICs to safely administer anesthesia found that only 50% of facilities had consistent access to electricity, 61% had continuous oxygen supply in operating rooms, 43% had anesthesia machines available for use, and 56% had the self-reported capacity to perform general anesthesia [43].

Analysis through country-specific studies, including of surgical programs developed through international partnerships, have shown similar gaps. In Malawi, ventilators and end-tidal carbon dioxide monitoring were routinely absent in operating rooms [44]. In Rwanda, thoracic surgical training and mentorship have increased capacity for thoracic procedures; however, equipment such as bronchial blockers and double-lumen endotracheal tubes were not readily available for single-lung ventilation [45].

Furthermore, LMICs face a shortage of adequately trained anesthesia personnel. Whereas the United States has approximately 24 trained physician providers per 100,000 individuals [46], a 2010 study demonstrated that LMIC had 1 or less physician or non-physician anesthesia provider per 100,000 individuals [47]. Training is often short and continuing education is limited by a lack of access to anesthesia textbooks and web-based resources, and a shortage of proper training materials in teaching hospitals [47]. Potential strategies to strengthen the anesthesia workforce in LMICs include increasing the number of providers through expanded task shifting/sharing with non-specialist providers and expanding access to educational and competency-based resources through institutional partnerships and professional societies [48, 49]. Advocacy for investment in anesthesia infrastructure and equipment (e.g. the national Saving Lives through Safe Surgery (SaLTS) initiative by the Federal Ministry of Health in Ethiopia) is also necessary to improve anesthesia care delivery in LMICs [50].

29.2.3 Postoperative Care

Postoperative care of the thoracic surgical patient requires adequate pain control, pulmonary hygiene, and access to critical care. Due to the limited availability of thoracoscopic approaches in LMICs, the majority of thoracic surgery must be performed via an open thoracotomy. Adequate post-thoracotomy pain control is often challenging in resource-constrained settings. Only 6.7% of the global supply of medical opioids is accessible to patients in LMICs [51]. Other methods of pain control such as multimodal therapies are costly and regional anesthesia techniques require advanced training and additional resources [52].

Adequate pain management is essential for reduction of postoperative pulmonary complications, such as atelectasis and pneumonia.

Patients undergoing lung resection are often elderly with comorbid conditions that may increase the risk of postoperative cardiopulmonary complications. Even younger patients undergoing thoracic surgery for benign disease processes, such as pulmonary tuberculosis and bronchiectasis, have a high potential for morbidity and mortality [53]. Therefore, adequate access to intensive care units (ICUs) staffed with trained critical care clinicians and nurses and equipped with mechanical ventilators and both invasive and noninvasive hemodynamic monitoring is essential for post-operative management of critically ill thoracic surgical patients. Limited data exist on the current ICU capacity of developing countries; however, a 2015 systematic review found that most ICUs were only available in referral centers within major cities, the median ICU size was 8 beds, and 77% of reporting ICUs had access to a mechanical ventilator [54]. In Uganda, only 0.1 ICU bed is available per 100,000 Ugandans compared to 8.9 per 100,000 South Africans, and 20 per 100,000 Americans [55, 56]. However, expansion of critical care access poses a significant challenge in LMIC due to the considerable investment in resources, both human and financial, that are required to build critical care capacity.

29.2.4 Pathology

Accurate diagnosis, informed prognosis, and public health screening and surveillance programs rely on pathology and laboratory medicine (PALM) services, and limited access to PALM services is associated with poorer health outcomes [57]. For example, epidemiologic evidence suggests that a large portion of cancer-related deaths are preventable with early detection and treatment [58]. International partnerships and humanitarian efforts have been instrumental in increasing capacity for pathology services in LMICs.

Partners in Pathology, Pathology Overseas, and the African Field Epidemiology network, have made strides in expanding access to diagnostic, treatment, and surveillance programs for underserved patients in developing countries. Partners in Pathology, in collaboration with clinicians from Partners In Health, has obtained surgical biopsies and when pathologic diagnoses are made, provided chemotherapy or radiation treatment and long-term follow up to patients in Haiti and Rwanda [59]. Pathology Overseas coordinates volunteer physicians and technicians to aid and establish pathology laboratories, provide basic PALM services, and train local physicians in several low-resource countries [60]. The African Field Epidemiology Network (AFENET) has laid the fundamental groundwork to increase laboratory capacity development in Africa through several avenues, including training programs for scientists and managerial staff, equipment calibration, external quality assurance, and disease surveillance [61] While these programs have played a vital role in increasing the capacity to perform PALM services in LMICs, more work is to be done as gaps still exist. Expanding access to PALM in LMICs is vital to reduce the global burden of disease [62].

29.2.5 Workforce

Fundamentally, shortages in skilled workforce underlie surgical capacity building including specialty care such as thoracic surgery. Competing priorities often result in under-investment in the growth of workforce, which must be done in parallel with infrastructure and supply chain building. Critical shortages of these human resources compounded with unequal distribution of available healthcare workers in rural, underserved areas result in severely limited access to thoracic surgery in many LMIC populations. The WHO defines the threshold for a health workforce crisis as less than 22.8 skilled health professionals per 10,000 population [63]. However, in 2016 the density of medical doctors in LMIC remained as low as 0.1 per 10,000 population in Tanzania and Togo and 0.2 per 10,000 in Malawi compared to 50 per 10,000 in Austria, 40 per 10,000 in Sweden, and 26 per 10,000 in the U.S. [64]. Similarly, nursing personnel are critically low in many LMICs with only 0.7 per 10,000 population in Guatemala and 3 per 10,000 in Bangladesh compared to 125 per 10,000 in Australia [64]. Disparities in the surgical workforce are even more pronounced as only 12% of subspecialty surgeons work in Africa and Southeast Asia [65].

LMICs face several challenges related to level of socioeconomic development in the education, training, and retention of thoracic surgeons. Models to address these challenges include reliance on international volunteerism, twinning with partnering institutions or organizations, and creation of thoracic surgery training programs. While humanitarian efforts can be useful to address acute shortages, several criticisms of this model including postoperative care and sustainability are well-established. Creation of training programs has proven to be the most effective long-term solution to the workforce crisis in LMICs. However, of those that have developed thoracic surgery training programs, training methods vary greatly by region. One effective model has been the creation of a general surgery program that is then leveraged to create a thoracic surgery subspecialty training program. However, the success of any long-term solution to this workforce crisis will require significant investment from the local government, support of policy-makers, collaboration with international institutions, and both human and physical resources for the education and training of local thoracic surgeons.

29.3 Existing Models for Thoracic Surgery Program Building

The authors have been engaged in surgical capacity building programs in East Africa and other areas of the world. We provide an overview of our own efforts as well as those by other leaders in the field to inform future directions for thoracic surgery capacity building.

29.3.1 Malawi Surgical Initiative

Limitations in the healthcare workforce has been a significant challenge for surgical capacity building in the sub-Saharan Country of Malawi. Malawi has a government-based healthcare system comprised of 4 central hospitals and 23 district hospitals. Despite a population of approximately 19 million persons, as of 2006 the healthcare workforce in Malawi consisted of only 2 physicians and 59 nurses per 100,000 residents [66]; as of 2011, there were only 25 surgeons in public practice in Malawi [67]. The University of North Carolina at Chapel Hill (UNC) has maintained a strong clinical and research presence in Malawi since 1992 through a partnership between UNC Project-Malawi, led by the Division of Infectious Disease, and Kamuzu Central Hospital (KCH), a tertiary care center in the capital city of Lilongwe. While meaningful strides in the battle against HIV/AIDS were made during this time, the Ministry of Health also recognized the large unmet burden of surgical diseases, particularly traumatic injury, that contribute to significant morbidity and mortality in Malawi. Therefore, in 2006 the UNC Malawi Surgical Initiative (MSI) was created with the goal of improving surgical care through clinical service, surgical research, and increasing the Malawian surgical workforce.

In order to address this need, a Malawian general surgical residency was created in 2009 through a collaboration between the Malawi Ministry of Health, the University of Bergen with the Norwegian government, and MSI. The general surgery training program was established in accordance with accreditation guidelines developed by the College of Surgeons of East, Central and Southern Africa (COSECSA). The tripartite collaboration split duties between UNC, the University of Bergen, and the Ministry of Health for hiring and financial support of residents while the University of Bergen provided support for the physical infrastructure and surgical staff as well as resident trainees. The training program utilizes both visiting and local surgeons as well as senior surgery residents from UNC to support clinical, educational, and research activities. Challenges to sustaining this training program have included long-term financial stability and geographical barriers as the main campus of the only medical school in Malawi is located in Blantyre, several hundred kilometers away. Despite these challenges, KCH has graduated 2–3 resident annually since the first class completed the five-year surgical training program in 2015. This along with improved retention of graduates in Malawi and the region have served to bolster the surgical workforce in Malawi [68]. The program can serve as a model for other training programs in sub-Saharan Africa by demonstrating the synchronous goals of training local consultant surgeons, increasing access to surgical care, and growing surgical research. In the next wave of training, specialty surgical topics including neurosurgery and thoracic surgery will be taught as part of the curriculum during both virtual and in-person visits from UNC surgeons. The general thoracic surgery curriculum will include topics on trauma, pleural effusion management, and esophageal cancer diagnosis and treatment and will integrate simulation.

29.3.2 Tenwek Hospital—Bomet, Kenya

Tenwek is a 300-bed mission hospital in the Central Rift Valley that serves as a referral center to most of western Kenya. Tenwek was uniquely positioned to develop a cardiothoracic surgery center as esophageal cancer is endemic to the region and a leading cause of cancer among Kenyan adults. Recognizing this immense need, the Ministry of Health hired a surgeon specifically to develop a cardiothoracic surgery center. In 1997 thoracic surgeon Dr. Russell White joined the staff at Tenwek. Also a faculty member at Brown University in Providence, RI, Dr. White fostered a long-standing partnership between the two institutions. The program initially focused on esophageal and pulmonary pathologies and later expanding to address the increasing burden of advanced rheumatic heart disease.

In 2008, a five-year general surgery program was created at Tenwek under the Pan-African Academy of Christian Surgeons (PAACS) and COSECSA. Graduates are encouraged to work in an under-served area of Africa after program completion and for those sponsored by PAACS, are required to provide this service for each year of sponsorship. Following the success of the general surgery program, a three-year cardiothoracic surgery fellowship was established in 2018 to address the need for sustained thoracic surgical capacity in the region. As a result of these and other capacity building efforts, approximately 2500 major surgeries and 3000 minor surgeries are performed annually and Tenwek has become a leading center for the treatment of esophageal cancer in Kenya, performing more than 2000 endoscopies per year [69].

29.3.3 Human Resources for Health

Following the devastation of the 1994 Rwandan Genocide, the national supply of healthcare workers was severely curtailed. At the start of the millennium, the country had made strides in rebuilding its healthcare infrastructure and delivery system, resulting in a steep decline in premature mortality from maternal or infectious causes, as well as an increase in life expectancy [70]. However, gaps in healthcare personnel persisted. In 2013, Rwanda had 0.84 physicians, nurses, and midwives per 100,000 individuals, far below the WHO recommendation of 2.4 per 100,000 [71]. In addition, most physicians were trained as generalists and 90% of nurses had the lowest level of education available [71]. The Rwanda Ministry of Health responded by creating the Human Resources for Health (HRH) program, designed to “address both the proximal and distal drivers of the human resource shortage" by strengthening training programs and producing a specialized healthcare workforce [71].

In close partnership with the United States, the Rwandan Ministry of Health committed to facing the overwhelming financial, infrastructural, and personnel limitations of their medical training system [71]. A long-term academic consortium, HRH utilized the expertise of faculty from 14 US academic medical centers to increase the capacity and quality of provider education in Rwanda, as well as supply necessary equipment for specialized training facilities [71]. From 2012 to 2019, participating US institutions provided approximately 100 faculty to Rwanda per year [72]. Each faculty member was paired with a Rwandan physician in either an urban or rural facility. This one-on-one mentorship paradigm, colloquially termed "twinning," allowed for direct transfer of knowledge among partners and trainees, as well as mentorship and increased exposure to surgical subspecialties and increased academic capacity through research collaborations [65, 70, 71, 73] The program established a new medical residency, nursing specialty, health management, and oral healthcare training programs to meet country-specific healthcare needs [71]. To ensure nationwide sustainability of their workforce, the program provided financial incentives to new graduates to stay and work within the Rwanda community, especially in decentralized locations outside of city centers [65].

As a result of the HRH partnership, over 4500 health professionals graduated between 2012 and 2019 [73]. Further, surgical residencies increased their mean annual intake from four to 13 postgraduate students, and trained surgeons have since been distributed to hospitals in urban and rural locations [65]. To meet the need for subspecialized care, the program expanded surgical residency programs to include subspecialty training, recruited subspecialty experts for focused training and mentorship, and developed a surgical simulation center [45, 74]. Ultimately, HRH made significant progress towards a strong, sustainable workforce that is increasingly prepared to treat the surgical needs of the Rwandan population. In 2016, a general thoracic simulation course was implemented by Dr. Daniel and colleagues with improved confidence and knowledge of the local residents [74].

29.4 Future Directions

Since the declaration of surgery as the neglected stepchild of global health by Paul Farmer in 2008 [75], global surgery has gained widespread, international attention as an essential priority. The Lancet Commission on Global Surgery, launched in 2014, put forth key recommendations to improve access to safe and affordable surgical care, as well as a framework for establishing a national surgical plan in resource-poor settings [65]. Taken together, these steps have highlighted crucial gaps in the treatment of surgical disease worldwide, and they have defined key barriers to safe and accessible surgical care. By focusing on these barriers, several programs and partnerships have made great strides in increasing surgical capacity in LMICs.

Although improving equitable access to essential and even cardiac subspecialty surgical care has received burgeoning support from the global health community in recent years, a large unmet burden of thoracic surgical disease persists in LMICs. Increasing access to thoracic surgical care in low-resource settings will require substantial investment from local governments, hospital leadership, and global partners to improve the aforementioned infrastructural, equipment, and multidisciplinary workforce needs required for successful implementation of a thoracic surgery program.

Global partnerships are essential to successful implementation of a thoracic surgery program. While continued international volunteerism is necessary to address the acute shortage of the skilled workforce required, solutions that train local physicians and support staff will be necessary for long-term sustainability. "Twinning" with collaborating institutions has shown to be an effective model for training subspecialty surgeons and support staff. Additionally, establishment of fellowship training programs will provide long-term viability to newly implemented thoracic surgery programs. However, institutional support and access to the necessary anesthesia, pathology, and radiology human and physical resources will be critical to ensuring their ongoing success.

The initiatives outlined in this chapter describe early groundwork for improving access to safe and high-quality thoracic surgery in LMICs. They describe the potential impact of improved infrastructure, strong training and education programs, and surgical research collaborations in building a sustainable specialized workforce. Equally important to the success of these initiatives are the lessons learned during their implementation and maintenance. For example, the availability of surgical and anesthetic equipment should be considered in development of any sustainable thoracic surgery program, and low-cost thoracic surgical simulation programs can be further developed to extend the reach of subspecialty training [74].

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Part V

Leveraging Digital Health Technologies in Augmenting Cardiac Surgery Capacity

30 Digital Technology's Role in Addressing the Social Forces Impacting Cardiovascular Health

Fran Ayalasomayajula

Abstract

Overtime the masterful work of a surgeon comes undone, weathered by the absence of supportive care, a harmonious environment, and behavioral modifications. In this chapter, the reader is invited to consider those factors which contribute to the state of health for the post-operative cardiac patient as well as for the entirety of a population. There are indeed social factors which lead to and result in the premature fate of patients, the escalating cost of health care, and the disproportionate rate of readmissions plaguing healthcare centres. The goal of this chapter is trifold: 1. Expose and explore the underlying factors; 2. Redefine the opportunity for healthcare professionals to participate within the social constructs driving health and surgical outcomes outside of the clinical setting; and 3. Introduce digital behaviors as the sixth determinant of health outcomes. To accomplish these ambitions, research findings from a 2020 study on the Social Determinants of Health conducted by Reach, a global social impact organization, will be presented. In the study, medical specialists from around the globe participated in a focus group and a self-administered quantitative and qualitative survey to further understand the opportunities and barriers that exist for both cardiac patients and their care providers.

Keywords

Social Determinants of Health · SDH · SDOH · Community health · Cardiac care · Chronic disease management · Congestive health failure · Hypertension · Cardiovascular disease management · Digital health · Telehealth · Telecommunication · Social factors · Social impacts

30.1 Introduction

Around the world, healthcare providers are innovating ways to leverage new technologies to improve healthcare access, efficiency, and outcomes. Approximately one-third of clinicians today proactively recommend connected health solutions to patients and apply such technologies to improve surgical outcomes. Yet, widespread adoption of these programs must confront the realities of societal and personal challenges that inhibit patients from reaching a desired state of wellness. These same challenges also introduce healthcare complications including chronic and critically ill health conditions. This chapter examines the challenges of the social determinants of health (SDH), with particular emphasis

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_30

on global developments in cardiology and the determinants of post-surgical health outcomes.

30.2 Defining the Social Determinants of Health

The World Health Organization (WHO) defines SDH as “the non-medical factors that influence health outcomes [and] the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life” (2021).

Paradoxically, while a nation makes progress towards improving its economic stature, the health conditions and health status of its people may veer along a less positive trajectory. Course correcting the fate of a gross domestic product (GDP) without proper attention to social and environmental dynamics may result in an economic boom of a country at the cost of the health of its people. When one investigates conditions battled by those living in resource-constrained areas, infectious diseases are generally noted as the burdening issues. Through economic wherewithal such problems can be addressed with the installment of sanitation systems, sufficient nutrients, and other essentials. For example, malaria, cholera, and dysentery are all conditions which for the most part can be contained and are surmountable through investments in infrastructure, including clinical facilities.

However, it is important to caution against the known conditions that commonly plague more affluent nations. Chronic diseases are highly prevalent among affluent markets. For example, according to the American Heart Association, nearly 48% of adults in the United States suffer from cardiovascular disease (CVD) [2]. The conveniences of wealth and resource-plentiful environments are festering grounds for obesity, CVD, hypertension, and diabetes mellitus. The goal for all nations and the opportunity for emerging markets is to use the rise in their economic stature as an opportunity to prevent the impediments to health and wellbeing. Implementing practices, policies and regulations that help build and maintain new models of care and disease prevention for all individuals are key to promoting the health of a nation. This necessitates taking into account and directly addressing the environmental dynamics which lead to the state of poor health even in the wealthiest of nations.

Social determinants of health are not a condition but rather a complex interwoven set of attributes. Essentially a catch-all phrase, SDH represents multiple factors that impact and influence our lives and, in many respects, constitute the modifiable conditions that, if properly addressed, may result in a positive outcome on population health.

This is far from a preposterous statement. In 2015, the American Heart Association’s investigation of the conditions contributing to what they noted to be a decline in the cardiac health of Americans was attributed to SDH. The article stated that social factors directly impact the incidence, treatment, and outcomes of CVD [9]. The authors further postulated societal and environmental changes that impact diet and physical activities were offenders, along with acknowledgements that inequities inhibited many of the advances in prevention and treatment from benefiting everyone. In light of such phenomena, it is universally agreed that “the most significant opportunity for reducing death and disability from CVD lies with addressing social determinants [of health and] cardiovascular outcomes” [9].

Being clear on the meaning of SDH is important. Today, as SDH has become a popular term, there is a tendency among some to use the term as a synonym to describe minorities and people of lower socio-economic status. While certainly those living in impoverished or resource poor areas may be impacted by more identifiably detrimental conditions, the factors impacting their health are not mutually exclusive. The determinants of health reign true for all people and are driven by, not just where, but also how people live; the people, technology, and other resources that are available to support them; as well as by the systemic and institutionalized biases to which they are subjected in the course of seeking support and medical care. SDH do not break down to a simple construct such as a postcode and are not a fixed state.

30.3 Factors Influencing Health Outcomes

Let's explore the concept of SDH as a set of variables. As the broader healthcare community has begun to adopt the term SDH as part of its vernacular, the term is being referred to as if it were a constant. However SDH are fluid and in and of themselves are non-descriptive, neither positive nor negative, nor significant until clearly defined. Calling out the specifics of those factors which the profession has chosen to generically label as SDH is vital. Without a clear definition, we fail on two significant accounts.

Firstly, such generalities grievously simplify what in reality is a complex web of interconnected factors. Simplification results in the eroding of our ability to identify and address the underlying problems that contribute to poor patient outcomes. For example, heart failure is increasing in prevalence globally with several million cases that go undiagnosed. While it is known that many cardiovascular diseases end up in heart failure, the condition itself does not receive enough attention. Heart failure is not equal among all and approaches to address and managing the condition must be dynamic and responsive to individual needs and circumstances. This is indicative of multiple variants including (dis)ability, geography and lifestyle. It reflects a combination of multiple factors that may influence the health of individuals. Managing heart failure is complex enough and patients who experience the effects of SDH are faced with challenges beyond the cost of management and often are confronted with choosing basic needs of housing and food over access to care, leading to poor outcomes [4]. Generalities and assumptions are not well served by a cloak of ignorance and denial about these realities.

Secondly, the factors that may have a significant impact on the health and wellbeing of individuals today, are not all the same as those that impacted society years ago, and nor will they be the same as those in the future. The shifts are significant enough that it warrants a revisit of the original definition of social determinants of health. For example indicators such as access to personal computers and devices, e.g. mobile phones, were not factors considered in the early defining of SDH. These matters because a failure to acknowledge such shifting dynamics inhibits our ability to address problems in a manner that is pragmatic and environmentally, socially, and culturally appropriate in the context of population, sub-population, and individual needs. For instance the widening digital divide has a direct negative correlation on the health and wellbeing of communities, and a proportionally negative indication of an individual's health.

In the course of digesting and reflecting upon the concepts presented in this book, it is paramount to take into consideration the underlying foundation upon which these concepts are being introduced. In some respects SDH constitute the foundation. SHD are dynamic and shifting. There are upheavals and devastation in the forms of racial, ethnic, religious, political, social injustices, health inequities and economic turmoil. These factors directly impact the very livelihood, physical and mental wellbeing and stability of individuals. Such devastations are stressors that can lead to health-related problems, such as a cardiac related incident and can have prolonged detrimental effects that make for a stressful and difficult road to individual recovery.

How might we recognize such contributing factors and introduce a new way of promoting and preserving health and wellbeing? How can the course of surgical recovery for cardiac patients be a course of not only physical recovery, but an opportunity for significant sustainable life changes that redefine the personal definition of SDH for an individual?

When we talk about the influencers or indicators of health, it is crucial that we get specific. If we fail to talk about specifically what those factors are and how to address them, then we're not going to get individualized nor population level care right. We have already seen where gross assumptions and generalities have proven detrimental [3]. A recent statement from the American Heart Association notes that heart failure patients within the healthcare delivery system who are food insecure, have no access to transportation, medicines, education and healthcare have significantly poorer health outcomes [20].

To expand beyond the present-day moderate performance of surgery, we need to construct new frameworks that take into account the particulars and reflect the needs and demands of patients as well as surgeons.

The U.S. Department of Health and Human Services describes SDH as being made up of six key areas: health care, access and quality; education, access and quality; social community context; economic stability; environment and behavior and lifestyle (CDC 2020).

30.4 Healthcare Access and Quality

It is no secret that many people around the world have limited access to quality healthcare–from those living in remote areas to urban environments in developed nations. Timely use of health services can achieve the best health outcomes through access to a healthcare system, a clinic or a provider. This access to care has a profound impact on physical and mental health, including quality of life.

However, the barriers to care are many, from the high cost of care and inadequate healthcare coverage to limited availability of services and competent care providers. In the United States, where health insurance often defines access to care, one in 10 people live without healthcare coverage.

As a result, people without healthcare insurance find healthcare services, medications and other resources out of reach. Given a choice between putting food on the table and scheduling an appointment for an echocardiogram or a follow-up appointment after a cardiac event, individuals and families undoubtedly choose the former. Physical access to care is yet another factor. Often, social factors such as distance from the nearest hospital can determine the quality of care these individuals are able to access and receive.

These barriers result in delayed care, financial burden, unmet needs and preventable hospitalizations. While efforts are underway to increase insurance coverage and connect communities to healthcare, improving access beyond the healthcare environment plays a critical role in improving population health.

30.5 Social and Community

Social support and community connections significantly influence health and mental well-being. High levels of social support can reduce emotional stress and encourage healthier behaviors, as do perceptions of high social capital. A sense of belonging and community buffer against harmful effects of discrimination or othering.

A neighborhood with several incidents of violence can be a stressful environment for healthy outcomes. Social cohesion and capital create a protective support for populations that deal with everyday challenges out of their control such as income equality, limited economic mobility and access to resources.

It has been well documented that structural inequities, where people are separated into rich and poor areas which also impact the public education systems, is a determinant of health. The quality of a neighborhood not only defines the social context, but also shapes life and health trajectories. It results in preventable differences in health outcomes, including life expectancy. Racial and ethnic disparities add another layer of complexity.

Interventions to ensure that people get the social support they need, making connections with community members or loved ones, can offer a bridge toward improving health and fostering effective coping strategies. Without taking racial inequities, which are integral to the social framework, it can be challenging to predict and expect positive impacts.

30.6 Economic Stability

On the surface, economic stability might appear to have the largest obvious impact on health. People with steady jobs are likely to pay more attention to conditions like cardiovascular disease and take steps to manage the disease. Employment is inextricably linked to housing and food security. Solid economic growth provides opportunities to direct resources toward alleviating poverty and increasing economic mobility.

The World Health Organization rightly notes that "circumstances shaped by the distribution of money, power and resources at global, national and local levels" have a direct effect on the health of individuals [21]. Add to that a growing, global aging population means a reallocation of economic resources to pay for senior healthcare and fewer workers to stimulate economies. Declining health among the elderly correlates to disabilities and chronic conditions such as heart disease, calling for costly health interventions [22]. For governments that offer healthcare to residents, an aging population eats at budgets resulting in high healthcare expenditures.

Career counseling, opening up pathways for employment can aid economic stability. While dealing with an aging population could mean revamping healthcare systems to become effective, efficient and reliant on digital technologies and data, offering care at lower costs.

These measures require coordinated planning at the local, state and national levels with unified objectives.

30.7 Education Access and Quality

Higher levels of education often result in better understanding of health, an eagerness for disease management and a desire for wellness [15]. People with more education are more likely to follow treatment guidelines, learn about health risks and develop better skills and self-advocacy. A Reach faculty member and senior pharmacist prescribes that "SDH begins with education; education is a fundamental value asset for the language and literacy of health" (2020).

However, low-income households and individuals are unable to access a good education. Residents of poor neighborhoods experience inequities and data show they drop out of school or do not consider pursuing a college degree. This has an impact on economic stability, which in turn impacts access to care, creating the multifactorial combination referenced above.

In addition to increasing health literacy, providing access to telemedicine could augment education, access and quality of care. Healthcare consumers expect their care providers to keep up with the pace of advancements in technology enabled medical therapy and the advancing fields of telemedicine and remote patient monitoring. Particularly during the pandemic, both patients and providers are turning to remote care as the chosen path of care delivery and engagement.

Nonetheless, many patients, particularly older adults, are still more comfortable when they are in the same room with their clinician and this gap can be overcome by using visual education during a virtual visit to further engage and build patient confidence. Educating patients to actively participate in their health journey via telehealth has the opportunity to improve patient engagement. Digital health education also has the ability to modify patient behavior.

30.8 Environment

Neighborhoods influence the residents' quality of life. Going by the traditional SDH definition, conditions where people live, work and play, these communities can determine health outcomes. People who live in areas with high rates of violence could experience stress while locations where water and air are unsafe, could lead to infections and chronic illnesses.

Though underreported, climate change is steadily making an impact on health profiles, as extreme environmental changes bring floods, heatwaves, famines and new forms of infectious diseases. They could pose threats to the overall picture of health. These factors make an urgent case for individuals, institutions and providers to pay attention while managing and preventing diseases. Like other factors discussed here, not everyone is equally at risk. Location, which is often linked with economic resources, is an important consideration while examining environmental influences [13].

A phenomenon that often goes overlooked is the source of the pollution that infests so many urban cities. The majority of pollution, and in particular poor air quality that is inhaled by residents of urban areas, is not produced by those city residents. On the contrary, commuters entering the area for work and leisure are the culprits, dumping tons of exhaust on the neighborhoods of city residents. Air pollution causes respiratory as well as CVDs.

Yet another environmental attribute is food insecurity and scarcity in depressed and economically disadvantaged areas. These locations may have fewer healthy food options resulting in limited access to nutrition.

Designing interventions to the environment can lower these risks, from designing installing green spaces, encouraging the use of mass transportation, and healthy food delivery services to ensuring access to supermarkets that offer a variety of food options. Promoting digital health technologies which influence healthy behaviors to reduce negative outcomes is another way to ensure the detrimental aspects of SDH do not intensify.

30.9 Behaviour and Lifestyle

It is widely documented that lifestyle and behavioral risk factors can be a result of a combination of social and environmental elements. Accelerating urbanization and a growing middle class–especially in emerging markets–have led to people adopting a more sedentary lifestyle. These changes are increasing rates of obesity, diabetes, risk for heart attacks and stroke, among other chronic conditions. Diets in developing economies have shifted away from natural produce to increased consumption of processed foods and sugar. Eighty percent of chronic disease mortalities occur in developing nations [1].

Chronic conditions are expected to surge, especially with developing nations seeing the largest population growth. In the United States alone, it is estimated that more than half of the population suffers at least one chronic condition, while still others suffer more than one chronic disease. Many of these diseases could be prevented, delayed, or alleviated, through simple lifestyle and behavioral changes.

Against this backdrop, healthcare expenses increase exponentially, with each chronic condition requiring greater access to hospitals and physicians. This load is not expected to lessen anytime soon [8].

Initiatives to improve medication adherence, multiple disease management and treatment plans show promise. Testing new methods of reaching patient populations, such as digital technologies, while considering SDH, are becoming essential to alter behavior and lifestyle patterns toward healthier outcomes.

30.10 Digital Behaviour

Digital Technology has had such a profound impact across all aspect of life that in the opinion of the author, it is worthy of its own categoric standing among the other well-established health factors used to define SDH (See Fig. 30.1). The role of technology is so significant in its direct impact on the lives of individuals and populations, that one can arguably and justly recommended that Digital Behavior become a standardly measured and recognized SDH factor. Even in the devise of population health management solutions, or the case herein regarding post-surgical care, one must ask the questions: Does the patient have access to a data communication device? What is the level of digital health literacy? What is the best vehicle for monitoring and reporting? Is the patient a digital native? The answer to such types of questions may literally alter the care plan or intervention for a patient.

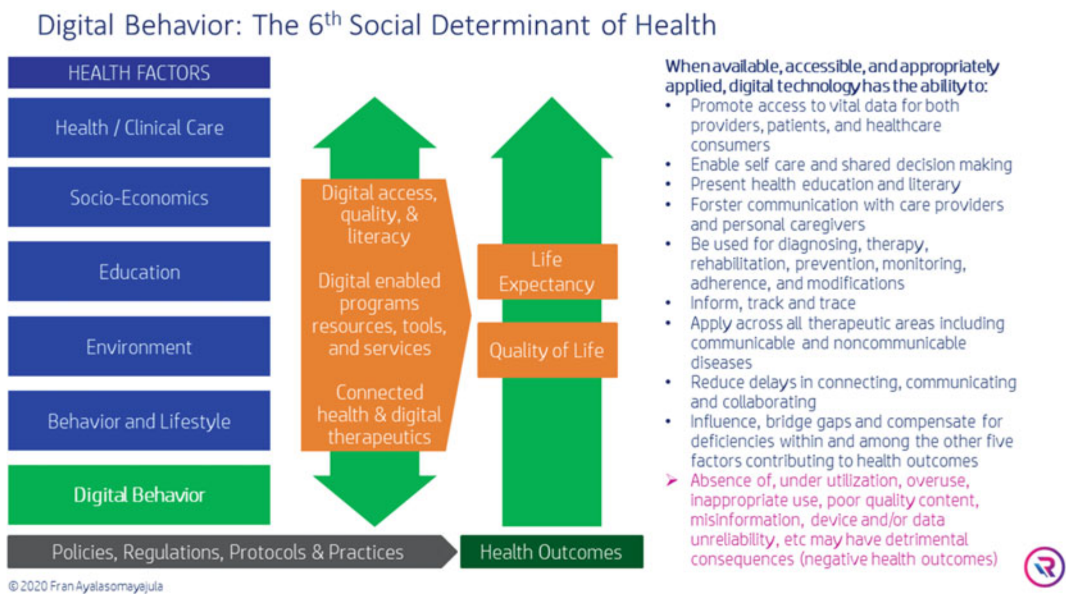

Fig. 30.1 The 6th SDH Factor: Digital Behaviors. *Source* Fran Ayalasomayajula. (2020). Digital Health Technology for the Advancement of Population Health. Reach

Having examined the key areas within SDH, it is clear that there are no simple interventions. However, at every level—nationally, regionally, locally, and individually, adoption of digital technologies and digital interventions, have been shown to be an indicator of advancement and present positive impact on patient health outcomes. Technology has the potential to allow patients to manage, and in some cases, prevent chronic and self-treatable conditions. From remote patient monitoring and blood pressure devices to virtual reality and telehealth, individuals are able to use smart tools to understand themselves and establish a stronger connection with their physicians.

Technology has the stage. Keeping tabs on patients with chronic conditions electronically, helping them adhere to recommended behavioral changes and treatment could help minimize costs of treating these patients. Establishing personalized treatments with artificial intelligence and machine learning algorithms can offer a deeper insight into individualized care.

The Covid-19 pandemic has led to a swell in the use of digital technologies at large. Social distancing and lockdowns forced individuals and systems to explore new ways to work, live and play. Digitized medical tools, from telehealth to remote patient monitoring, did not become hurdles. They became the pathways of choice. Online consultations, at-home drug delivery now leverage the power of smartphones. In developing nations, especially African and Asian nations, several millions of people have skipped the technological evolution process, going directly to today's options. The ubiquity of technology and its advancements, from medical apps to monitoring devices, has opened the door to multiple opportunities. It makes it easier to disseminate information, track diseases, provide health education, especially to populations that are traditionally underserved.

There is no denying that not everyone has access to technology. The highest at-risk populations often are those who lack a digital connection. About 72 percent of households in urban areas globally have access to the Internet at home, almost twice as much as in rural areas, 38 percent [10]. In spite of that, the convenience of these technologies and the mix of digital delivery options allow patients to interact with technology in ways that are beneficial to them. With the generation of health-related data, clinicians are able to focus on attending to patient's needs in a holistic fashion. We know from research that patients and clinicians are ready for technological solutions, and that those patients who do not have the tech tools to necessary to participate will fall prey to the digital divide. For this reason the author proposes that technology be categorically emphasized as a key factor to influencing health.

30.11 Provider Perspectives on SDH

For centuries public health professionals have recognized the importance of SDH; however their brethren, medical care providers, have traditionally not taken into account these elements. As globally care has shifted to a value-based approach to practicing medicine, public health principles and factors such as SDH have become instrumental in the delivery of sustainable positive outcomes for patients. For progress to continue to be made, medical professionals and administrators must understand and integrate programs and protocols that not only acknowledge, but also harness the impact of the factors contributing to health outcomes.

Figure 30.2 denotes that the roles and impact of digital health technology, using clinical care as the example. The notion that digitally enabled solutions have the ability to move care beyond the four walls of the clinical setting and to influence the other factors that influence health outcomes, is indicative of the possibility of digital health technologies and digital therapeutics to literally alter the prognosis for a patient.

In December 2020, Reach, a non-profit global social impact organization conducted interviews with ten (10) international key opinion leaders, healthcare professionals representing four (4) continents and seven (7) countries. Additional these same individuals completed a self-administered survey. Reach examined their perspectives on topics related to the social determinants of health. Healthcare providers from a variety of disciplines participated, including internal medicine physicians, lifestyle physicians, cardiologists, and cardiac surgeons.

The study was an examination of the social determinants of health and an understanding and attitudes towards related topics. The research reviewed the key characteristics of the social determinants and unveiled the perceived value of SDH to both providers and institutions. Uniquely the study called upon the practitioners to also take into consideration the role and impact of

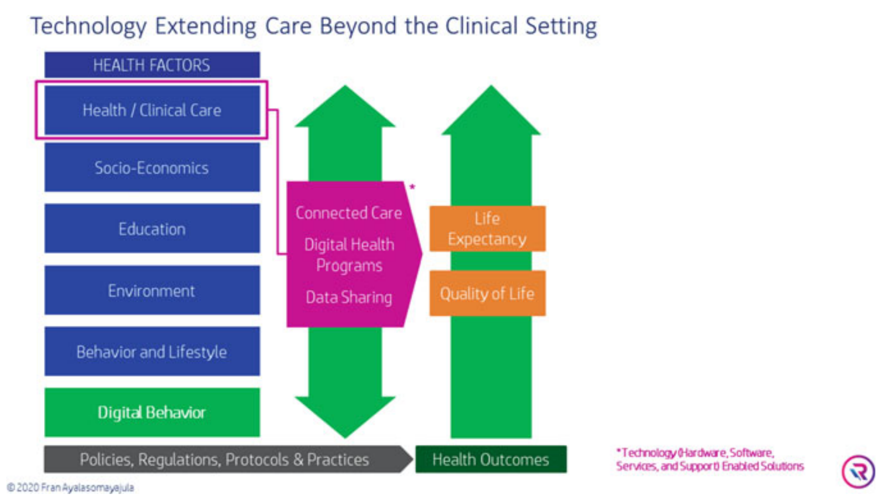

Fig. 30.2 Technology Extending Care Beyond the Clinical Setting. *Source* Fran Ayalasomayajula. (2020). Digital Health Technology for the Advancement of Population Health. Reach

technology in influencing social factors' bearing on the health of patients. The study further questioned the degree of healthcare's engagement addressing SDH at the provider and institutional level. The principal hypothesis was that while institutions acknowledge the social determinants of health, in general they do not consider themselves as having a role to play in counter balancing those factors, nor do they leverage technologies as an approach to addressing the challenges that social determinants may present. Whereas, providers believe that they have a significant opportunity to leverage technology and assume a greater role in influencing and counterbalancing social factors that influence patient outcomes.

For purposes of the study SDH was defined as the conditions in which people live, learn, work and play that affect a wide range of health risks. Six key areas of social determinants of health were explored. Reach aimed to define the impact of these key areas of SDH, using the unique vantage point of clinical care to land and expand digital technology and bring forth a position statement which reflects policies, regulations, and outcomes. The pros and cons of technology in this space, as well as the value within each of the social determinant areas were explored.

Study respondents were first asked to provide their own definition of SDH. Words which were spontaneously provided included job, work, education, income, social connectedness, and race. All of the suggested words are characteristic of the social determinants of health and may affect a range of health and quality of life outcomes and risks. Of all the words recited, job and work were the most common.

When asked to select the most important social determinant, economic stability was first, followed by health care and education (Fig. 30.3). The rationale for economic stability being most important was the idea that with financial security one has the ability to afford and access resources, which providers believe to be a priority for one's health. One provider's explanation was that "the lack of economic stability can negatively affect all other determinants" (Reach 2020). Failing lifestyle choices and the reality that healthy foods often cost more, supported their position that economic stability,

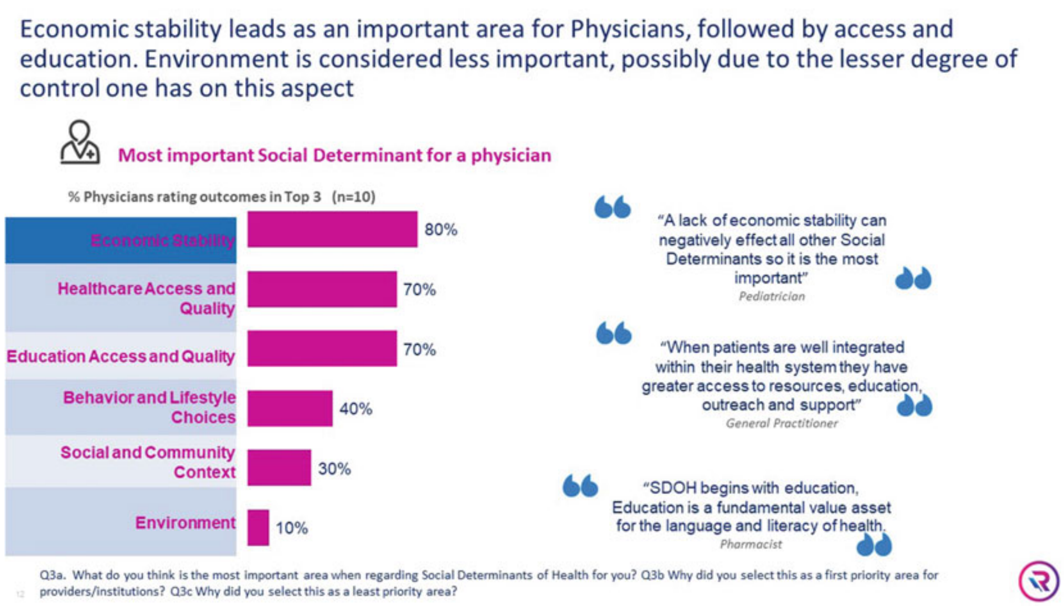

Fig. 30.3 Most important Social Determinant for a physician. *Source* Understanding the Key Components of the Social Determinants of Health. (2020). Reach. San Diego, CA

having financial stability is important. For others, general access to healthcare was deemed vital and they described, "not having access to healthcare, can decrease your quality of education" (Reach 2020).

Perhaps economic stability may be an important factor. However, data has shown that financial security alone does not equate to health and wellbeing for all. While the United States is the richest nation in the world, unlike its peer countries it has problems. Americans may smoke less and consume less alcohol when compared to other nations; yet, they have higher rates of obesity, drug abuse and are exposed to more inefficiencies in the healthcare system. So, it begs the question: Is wealthier always healthier?

The environment was deemed the least important social determinant. Respondents viewed the environment as being a factor that is the least within the control of the patient. The common remark was "it just depends on where you are born and how you grow up" (Reach 2020). This type of response brings into question what providers consider to be the "environment", indicating that perhaps the definition of environment in the context of the social determinants of health is not well understood by clinicians or that environmental exposure during childhood is considered by clinicians to be a determiner of future health conditions and cannot be reversed. However, the idea that the environment is fixed or that one remains or will remain in the same environment throughout their lifetime is questionable. In the context of the impact on cardiovascular health, changes in location or modifications in lifestyle and shifts in social factors can impact risk of cardiovascular disease (CVD) [12]. Environmental exposure on its own, i.e. pollution, can wield influence on the development and severity of CVD. When it comes to maternal health, prenatal homelessness is linked to higher levels of health care use [14]. However, simply connecting housing and maternal health is not the right answer. Sudden relocations could result in maternal deaths. Housing needs to be addressed in a broader societal context, taking into account all the factors that impact health, including racial inequalities.

An unsurprising finding in the study was that healthcare providers networks viewed having access to healthcare and quality healthcare as the most important social determinant for which both providers and institutions believed that they could help close the gap between the needs and solutions for SDH. As one respondent of the Reach study explained, "Healthcare access and quality is the determinant institutions have the most control over" (2020). Providers also indicated education as being of top importance (Fig. 30.4).

Providers in the study were further asked about the value of risk assessment scales, to which they responded there is a need and opportunity to incorporate more social determinant questions. "Behavior and lifestyle choices," as well as "healthcare access," were the main determinants respondents suggested be added to the health risk scale with questions related to diet and access to transportation to healthcare clinics and resources centers at the top of the list. The responses were consistent with findings from other studies in which providers assessed cardiac patient engagement.

As shown in Fig. 30.5, while in the Reach study healthcare access and quality as well as behavioral and lifestyle choices were top on the list, education access and quality, as well as economic stability weren't too far behind (2020). As they explain, healthcare must be accessible to all beyond hospital. One respondent describe it as the information that systems need to "begin to understand [about] their populations [in order to] develop appropriate solutions."

Considering opportunities to support patients in addressing risk factors, 70 percent of providers believe that technology leveraged by clinicians can improve SDH and are aware of technologies that are currently being used for these purposes (Reach 2020). In fact, all respondents stated that technology can bring value to SDH. Providers identified healthcare access and quality of care as having the greatest opportunities to benefit from technology, as shown in Fig. 30.6. Behaviour and lifestyle choices as well as access and quality of education were also deemed as gaining value from the application of technology. Surprisingly, physician respondents did not find as much value

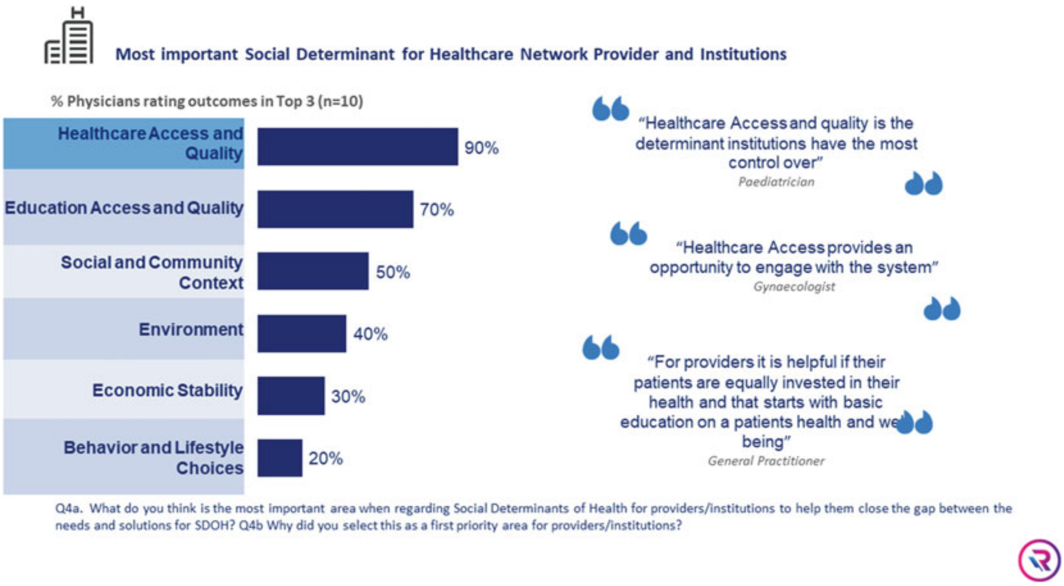

Fig. 30.4 Most Important Social Determinants for Healthcare Network Providers and Institutions. *Source* Understanding the Key Components of the Social Determinants of Health. (2020). Reach. San Diego, CA

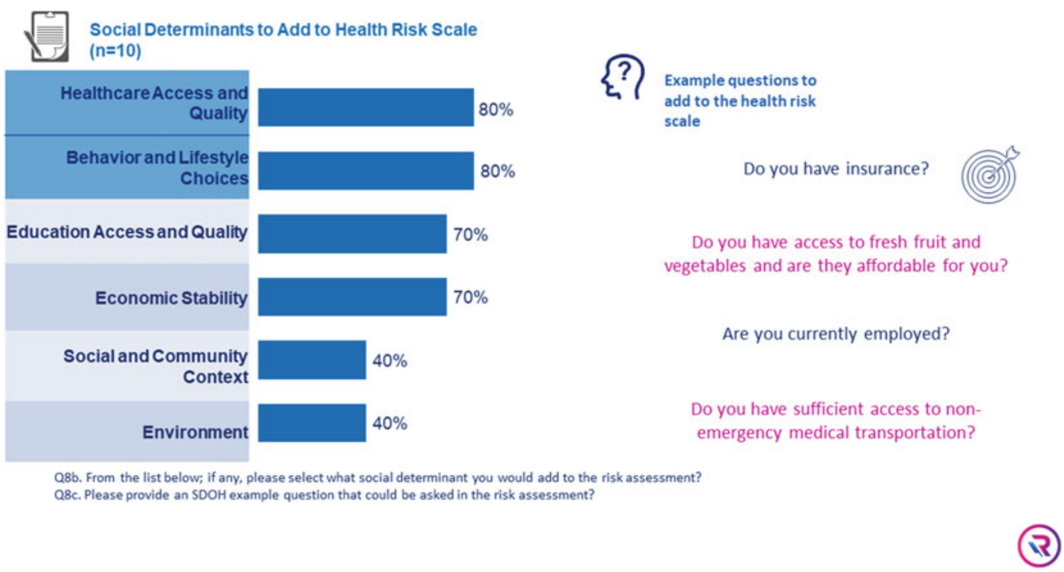

Fig. 30.5 Social Determinants to Add to Health Risk Scales. *Source* Understanding the Key Components of the Social Determinants of Health. (2020). Reach. San Diego, CA

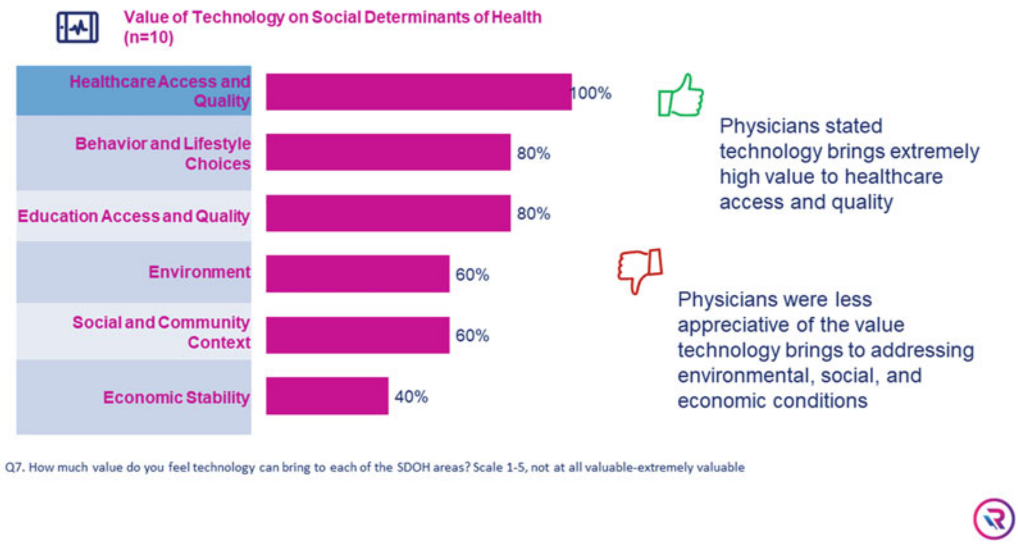

Fig. 30.6 Value of Technology in Addressing the Social Determinants of Health. *Source* Understanding the Key Components of the Social Determinants of Health. (2020). Reach. San Diego, CA

in the application of technology in addressing economic stability.

Thinking beyond risk assessments, providers believe technology may significantly reduce the barriers presented by SDH (Fig. 30.6). Although there are challenges which may arise when applying technology and storing data, the benefits outweigh the challenges. Technology can provide better access to healthcare and improve collaboration within health care teams. For example, technology facilitates all team members having the ability to be in the know of information, all the data may come together in that same institution. On the other hand, technology can also combine data from disparate systems that are not currently integrated. When brought together, a much more relevant understanding of the context of the patient's condition can be understood and therefore provide better care. However, one of the biggest pitfalls related to technology is the digital divide. For example some patients may not be able to afford the latest technology, and there may be some language and cultural limitations. For institutions, there may also be a high initial set-up cost. For many the main disadvantage of technology is the cost of implementing and sustaining, creating barriers to applying technology for the education and monitoring of the patient's health.

Even amidst the coronavirus pandemic, providers had mixed emotions regarding the use of digital tools. Most care providers felt COVID-19 accelerated the use and acceptance of technology in patient care [11]. Cardiology in particular was one area in which there was a surge in the use of digital platforms. Most believe that patients actually welcome the use of technology, whereas many providers voiced concerns regarding the long-term impact of the use of technology for patient support and their ability to convey empathy through such vehicles.

From the perspective of the respondents, there is a connection between all facets of SDH, for instance the ability to afford health care and resources such as education are interconnected. In this way, all categories of the SDH are important. Providers were also of the opinion that clinicians have a responsibility to accommodate for social determinants, particularly as such factors relate to health care access, where providers can utilize technologies such as telemedicine to increase access.

When specifically taking into account technology the majority of respondents were aware of technology that is currently being leveraged by providers that support SDH attributes. In fact respondents believe that technology may bring great value to all social determinants areas and that the healthcare system could gain from the use of more technology. Participants also believed questions around social determinants such as health care, access, behavior and lifestyle choices can be added to the RESCALE to assess at risk populations.

The opportunity for cardiology is similar to those of other specialities in healthcare. From Reach's findings, use of telemedicine for increasing access to education and post-surgical consults were deems to be useful applications. This aligns with findings other studies on telehealth and cardiovascular disease in which the researchers found that for the long-term risk reduction of CVD [18]. Self-monitoring of vitals combined with telehalth has proven to clinically significant improvements in blood pressure, hemoglobin A1c, and low-density lipoprotein cholesterol (LDL-C) [16]. This was attributed to such interactions between provider and patient reinforcing adherence to lifestyle and medication interventions and presenting opportunities to adjust medications based on vital data provided by patients [23].

Let's face it: Eighty percent of the factors affecting health outcomes happen outside of the clinical setting and 50 percent of those factors are economic and environmental. As for doctor visits? In 2018, South Korea had the highest rate of yearly visits to a doctor per capita at 17 yearly visits. Sweden was at the other end of the spectrum at 2.8 [17]. Globally we have the unique opportunity to help providers expand the reach and relevance of clinical care coverage through innovative technological interventions. Digital technology makes this possible.

30.12 Conclusions

Clinicians and healthcare systems underestimate, and perhaps underappreciated, their potential to have a huge impact on the lives of patients, even in other areas that categorically seem beyond the scope of the social determinants of which they represent. Consider the postoperative patient who is being discharged. The first 3 days post discharge are the most critical three days. However caution and consideration to factors that can lead to positive prognosis don't just transpire in those three days, but rather many days beyond. Everything thereafter needs to be taken into account to ensure that the patient remains healthy. Determining if the patient is indeed taking the proper preventative measures needed and is responding well to any drug therapy are critical to making sure the person doesn't end up back in the hospital. In that same vein, improving the living conditions of an individual pre-surgery may also result in better surgical outcomes.

For example a person challenged by food scarcity and behavior modification challenges, may do well with a diet that is prescribed and accommodated by the patient's healthcare provider. Why should the hospitality services of a hospital facility be limited to only offering food services for inpatient scenarios? Offering such services could be a huge opportunity for a provider network looking to diversify its portfolio by offering the services that they render to patients beyond the four walls of a hospital. Services being delivered today could be expanded and converted to a provision for patients preventively, pre-operatively, and post-operatively. This could help ensure that the individual is getting the right food re. Of course this doesn't have to be a service offered directly from the healthcare provider. It could be accomplished through collaboration with third party organizations. The key here is that by assuming the role of a "SDH buster" delivering food to individuals helps ensure that patients are getting the appropriate diet that they need. In time such services could potentially extend beyond the period that the patient is convalescing and be an added source of revenue for the facility, and digital technology may add in driving awareness, forecasting demand and supply, and both localizing and personalizing responses; so that needs are addressed when as well as where they are needed.

As noted in the summarizing figure above (Fig. 30.7), most healthcare professionals

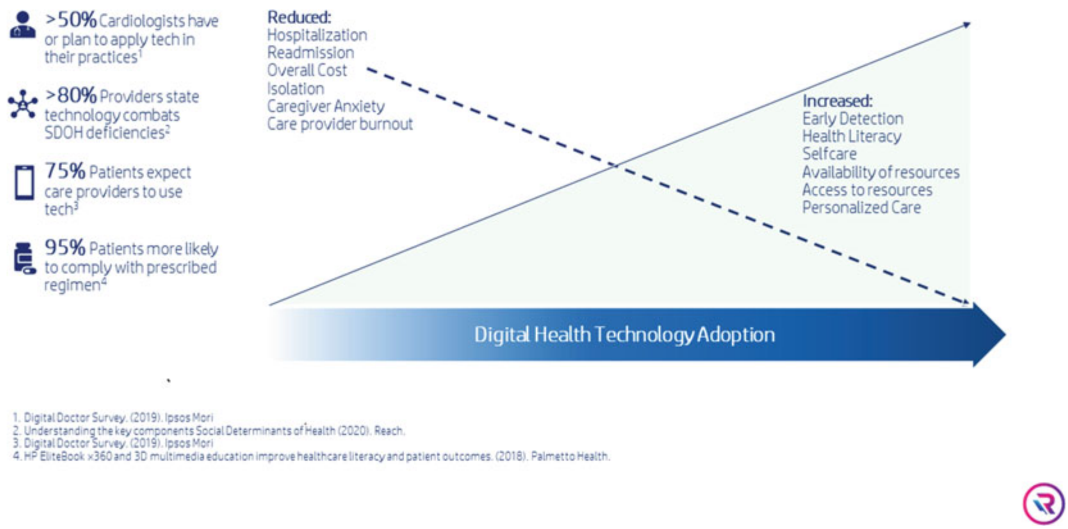

Fig. 30.7 Counter balancing SDOH deficiencies with the right set of tools & resources, digital health technology adoption yields

recognize the value that technology brings to the social determinants of health, and the vast majority are aware of technology being leveraged by healthcare consumers (Reach 2020). Education and lifestyle apps, as well as some remote patient monitoring apps are among the most common examples. To have the most impact on health care, access and quality begin with the end in mind to ensure comprehensive integration, cultural and social appropriateness, and sustainable long-term outcomes. Overtime, the value of digital health technology adoption delivers a positive effect on the well being of individuals as well the caregiver and the care provider ecosystem.

For those looking to embark on or refine existing digitally empowered programs, here are a few ways to increase digital adoption and provide for the diverse needs of populations:

- Start at the frontline: The COVID-19 pandemic has underscored the vital role that frontline workers play within hospital systems. Designing processes and systems to bring them on board is critical to the success of digital technologies. If frontline workers see value in technological interventions, it brings systems closer to seeing the impact of effective implementation. The key here is to be able to demonstrate the impact of being able to ease their ability to gather data; whether it is bringing ergonometric into their working lives, designing processes and systems and providing training and time to adopt new systems. Unless frontline workers, who are in direct touch with key situations on the ground, adopt digital technologies, it might be challenging to spread the awareness and adoption across systems and institutions.
- Prioritize integration: It should not be hard for a patient to access medical records or lab test results. By offering a single point of access to these records, users are more likely to choose a digital interface. The potential applications span the spectrum, from health screenings and baseline detections to post-treatment follow-up evaluations and adherence to treatment guidelines. Implementation of these systems could not only help reduce costs and inefficiencies but also improve overall healthcare value and patient outcomes.
- Pursue affordable innovations: Think big for the long term, but in the near term pursue shorter-term pragmatic goals that yield quick wins. This fosters stakeholder buy-in and the culture change needed to move forward.

Providing more value, better outcomes, convenience for less cost, complexity and time required by the clinician and the patient expands opportunities. It can be as simple as leveraging online communities to track healthcare trends, using trackers, monitors and devices to monitor health or retail clinics that provide affordable healthcare.

- Establish tangible long-term objectives: Perhaps the most vital focus is making sure that the clinicians and the administrators are able to deliver care within facilities and reach patients in meaningful ways. While remote patient monitoring has moved to the forefront and reimbursements make them possible, there is a ceiling that's being hit in terms of the scale. Healthcare IT is not designed to support the delivery of care outside the four walls, a clinical setting. For example, a heart attack patient being monitored at home after treatment with a kit which might include a blood pressure cuff, a weight scale, maybe a Bluetooth enabled pillbox to ensure medication adherence. To expand beyond small-scale programs to include larger populations that are subject to SDH make it challenging. An IT enterprise at a hospital is not prepared to tackle that problem. Establishing long-term objectives that encompass SDH and an understanding of underserved and vulnerable populations will require interventions from global providers. It does not mean it cannot be done. With a goal toward universal presence with appropriate technical support, future objectives need to take scale and broader reach into account.

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31 Emerging Opportunities for Sustainable Digital Health Enhanced Care Delivery Models for Improved Cardiovascular Surgery Outcomes

Valencia Joyner Koomson
and Chemuttaai Koech Lang'at

Abstract

Rapid expansion of internet access and mobile technologies in low-and middle-income countries has accelerated interest in digital health strategies to improve cardiac surgery outcomes in resource-constrained areas. Several pilot studies of wearable and portable health monitoring devices, virtual reality, and telehealth platforms have shown great promise as governments strategically invest in information and communication technology expansion and costs continue to decline for internet-assisted devices. However, future research directions on digital health systems and interventions must focus on overcoming key challenges in achieving interoperability with existing health care infrastructures, ensuring coverage across diverse socio-economic regions, and user-centric design approaches that incorporate the local cultural context to increase adoption and usability.

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Keywords

Digital health · Mobile health · mHealth · e-Health · Telehealth · Wearable devices · Low-resource settings · Developing countries · Low- and middle-income countries

31.1 Introduction

The global epidemic of cardiovascular disease has spurred innovation in mobile digital health tools and interventions for preventive care and disease management. For low- and middle-income countries (LMIC), the cardiovascular disease (CVD) burden is exacerbated by fragile and fragmented health care systems, high poverty rates, and a deficit of health care professionals. Over six billion people in LMICs do not have judicious access to safe or affordable cardiac care, and with insufficient healthcare providers and equipped health centers, there is disproportion in cardiac surgery output when compared to high-income countries.

Furthermore, LMICs are faced with the growing need to expand resource-constrained health systems beyond traditional services focused on communicable diseases, maternal and child health to now include noncommunicable diseases [7]. Managing acute illnesses, which is what most LMIC health systems are designed for, is very different than the complexities and needs of medical procedures and surgeries, or the chronic nature of non-communicable diseases.

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_31

Advancement in computing technologies and the expanding telecommunication solutions' reach, coupled with health innovation, predict an exciting future of healthcare experience for providers and patients alike. Integrating cardiac care into strengthened health systems and incorporation of tools, such as interactive voice response systems, short message service (SMS), text messaging, and smartphone applications, just to mention a few, have shown great promise in addressing gaps and barriers to optimum cardiovascular disease care throughout the world.

31.2 Digital Health Overview

Digital health is an extensive field spanning across the categories of mobile health (mHealth), health information technology (IT), wearable devices, telehealth and telemedicine, and personalized medicine. This area has grown over the last decade and continues to transform health care service delivery, breaking down barriers, addressing affordability and accessibility directly in creative ways that build up and strengthen the health system.

According to a recent report based on 2019 data, 75% of the 3.8 billion mobile internet users worldwide reside in low- and middle-income countries (LMIC) [5]. Due to aggressive network infrastructure expansion, the mobile broadband coverage gap has drastically narrowed yielding only 7% of the world's population living outside of coverage areas. Although text messaging and social networking are the most popular mobile activities in LMICs, there is a noticeable expansion of mobile services for education, bill payment, and healthcare management. The rural–urban and gender gaps in mobile internet usage have also dramatically decreased.

Across the continent of Africa, the formation of strategic partnerships between the information and communication technology (ICT) industry and Ministries of Health have spurred rapid advancement towards digital health solutions [11]. Furthermore, the adoption of digital, internet-assisted medical devices shows great promise for low resource settings, including could-enabled electrocardiogram systems for remote telecardiology diagnoses currently used in Malawi and Uganda [17]. A leading example of ICT expansion towards improving quality health care can be found in Rwanda [10]. The implementation of digital health solutions through partnerships between digital health service providers and the government has set the stage for Rwanda to become one of the first countries to offer universal digital health services.

The advancement of low-cost, multi-sensor wearable technology coupled with ubiquitous mobile devices has spurred development of telemedicine systems for remote patient monitoring in low resource settings. Real-time heart monitoring systems capable of tracking vital signs and wirelessly transmitting data to health care providers has shown great promise for timely diagnosis and treatment of patients in remote areas and elderly populations [6, 8]. For post-operative management of cardiac surgery patients, wearable fitness trackers have the potential to facilitate faster recovery and improve functional ability. Fitness trackers are typically worn on the wrist or embedded in a mobile application to track daily physical activity, including distanced walked, step counts, and type of movement. Several trials have shown that wearable activity trackers used within a remote or home-based patient monitoring program can improve patient outcomes compared to a center-based cardiac rehabilitation program [14].

31.3 Models of Digital Health Care Delivery

31.3.1 Avatars for Preceptorship and Mentorship

Preceptorship is a proven approach to capacity building in various settings. Surgeons across the world are utilizing advanced wearable and wireless technology to implement virtual reality systems to collaborate, teach and expand preceptorship. In 2014, Professor Shafi Ahmed, a surgeon at Barts Health NHS Trust, used Google

Glass to teach 13,000 surgical students from 115 countries, bringing them all into his operating theater virtually [16].

In 2017, three surgeons from Mumbai and London, including Professor Ahmed, appeared 'live' as avatars in a single operating room to carry out a colorectal cancer procedure [3]. Wearing Microsoft Hololens headsets to virtually interact, as if in the same room, they drew on three-dimensional holograms of a patient's tumor and evaluated best course. This demonstration shows the great promise of virtual reality in bringing together specialists from multiple locations to increase patient safety and improve outcomes. Furthermore, this unique mode of merging technology and healthcare can potentially provide greater access to specialist care and improve global health equity for LMICs.

A tele-proctoring study in Mozambique carried out over six months evaluated remotely proctored surgically procedures between a local surgeon and a US-based reconstructive surgeon [9]. Using video and audio wearable technology as demonstrated in the Video Graphic 1 and Fig. 31.1 images below, Google Glass and XpertEye tele-proctoring software, twelve procedures were livestreamed in real time. Despite limited connectivity and latency challenges, all procedures had successful outcomes with surgeon acceptance on the innovative approach. With an effective education and mentorship model, along with technology have been demonstrated capacity building and strengthening of specialty surgery in resource-limited settings, there is scale opportunity for LMICs.

31.3.2 Portable Ultrasound and Hand-Held Electrocardiogram Imaging

Point-of-care ultrasound and electrocardiogram tools are attractive for LMIC settings as they are compact in size, can be battery-powered, requiring minimal infrastructure and training. With their introduction over a decade ago, physical visits to imaging center or cardiac clinic are no longer a hindrance in the capture of critical biodata for screening or diagnosis.

An interesting case is in the utility of more appropriate monitoring during pregnancy, labor and delivery with a specific focus on the opportunities for fetal cardiac monitoring and assessment. Limited access to complex medical devices for fetal cardiac monitoring in LMICs is well known. However, recent assessments of telemonitoring combined with portable ultrasound have been demonstrated to be more efficacious than the standard of care and yield cost-effective gestational outcomes [1, 15].

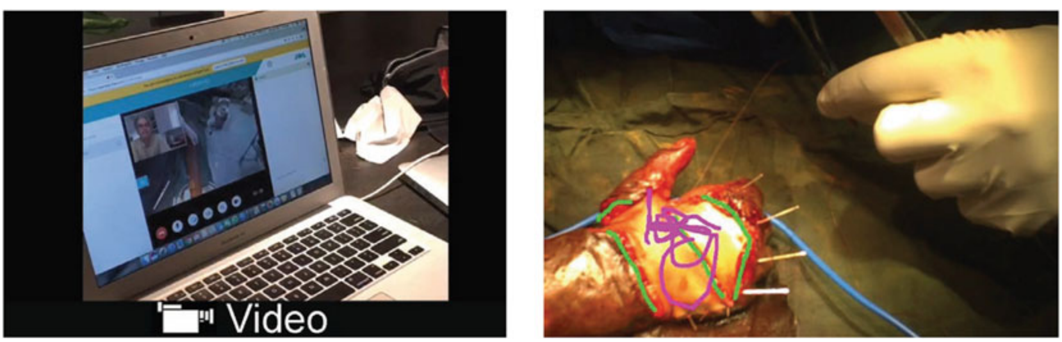

Fig. 31.1 Remote "tele-station" [9]

31.3.3 Robotic Cardiac Surgery

After the world's inaugural cardiac surgery in 1998 was performed via robotics, robotic surgery departments began to emerge in health care centers across middle and high income countries.

In 2002, Intuitive Surgical's da Vinci console received United States FDA approval for use with cardiac surgeries [4]. In Latin America, Brazil carried out its first robotic cardiac surgery in 2010. Colombia did not have the capacity nor infrastructure for technology assisted procedures at the time and it wasn't until seven years later that robotic cardiac surgery began in the capital city of Bogotá. Figure 31.2 below shows the robotic arm set-up for the early cardiac surgery procedures performed using a da Vinci Xi console [2].

Colombia, which had been carrying out minimally invasive and video-assisted cardiac procedures since the 1990s, followed suit and in 2012, performed its first robotic thoracic surgery. Robotic-assisted surgery is still not as widely practiced even in high-income countries, and in low-and middle income settings, the challenges of limited resources and infrastructure needs have precluded fast adoption.

31.3.4 Chronic Disease Management via Telehealth/Telemedicine

Various advancements in telehealth and telemedicine have been piloted and implemented across LMIC with solution targeted at appointment bookings, community health worker screening, provider tele-consultation, e-prescriptions, even insurance e-claims [7]. These solutions have been quick in adaptation, but scale has not always been as fast with barriers of interoperability and connectivity still persisting.

Medtronic LABS' Empower Health model of care brings together diagnostics and innovative software technology to create a unique end-to-end model of care for the most common risk-factors of cardiovascular disease, including hypertension, diabetes, obesity [12]. The model

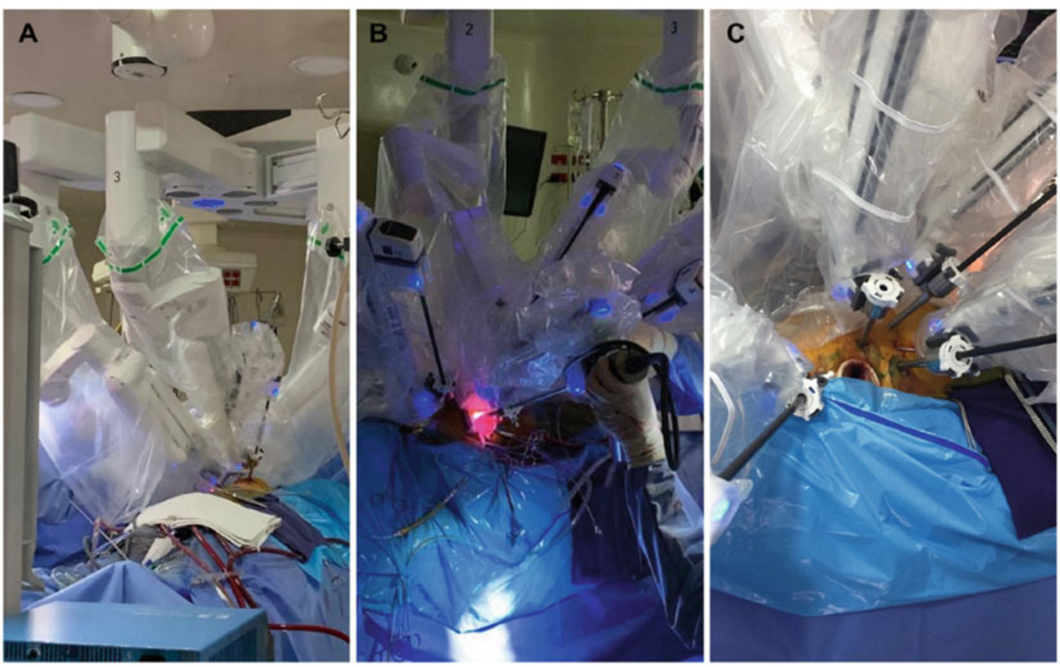

Fig. 31.2 Robotic cardiac surgery arm docking and placement [2]. https://www.scielo.br/scielo.php?pid=S0102-76382020000600990&script=sci_arttext

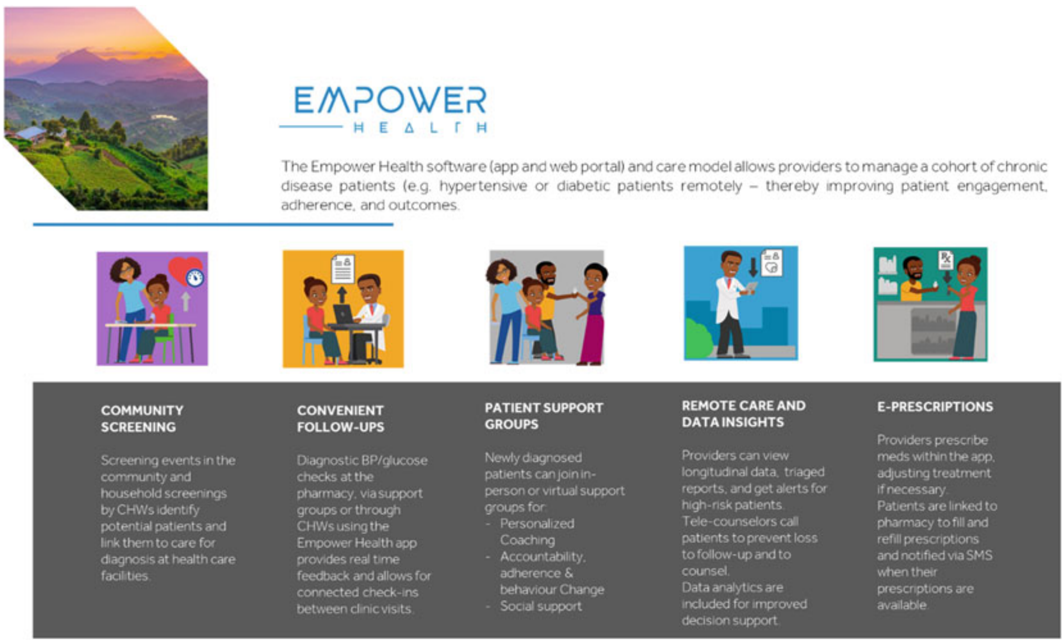

Fig. 31.3 Empower Health model of care (reprinted from Medtronic LABS internal documentation)

includes screening, linkage to care for diagnosis as well as longitudinal clinical management and adherence support. This model, refer to Fig. 31.3 below, was co-created with clinicians, nurses, patients and pharmacists in Ghana and Kenya.

Empower Health consists of a mobile device, diagnostics (e.g., an automated blood pressure machine and a glucometer), and a software application—combined in a platform to allow for remote management, improve disease awareness, reduce the burden of disease, and improve the efficiency of managing hypertension and diabetes for both patients and clinicians. This is a model that incorporates point-of-care diagnostics and is expandable across many other chronic conditions.

This model was piloted in 2016 in Kumasi, Ghana. After 6 months of recommended weekly BP monitoring, systolic blood pressure decreased significantly ($p < 0.01$) in both the overall cohort (-4.7 ± 18.7 mmHg) and in the uncontrolled subgroup (-15.2 ± 17.6 mmHg). As a result, the proportion of the population with uncontrolled hypertension decreased from 39 to 27% ($p = 0.01$).

Post-pilot, the real-world implementation of Empower Health has continued to demonstrate clinically significant outcomes [13]. The model continues to be scaled through strategic partnerships to integrate and complement both private and public health systems to expand impact across the African continent and beyond.

The Empower Health technology platform combines various functionality laid out in Fig. 31.3 for comprehensive care provision. There are multiple other chronic disease applications where this model will prove useful and the clinical expansion pipeline includes conditions such as heart failure and other cardiovascular conditions, mental health, chronic respiratory diseases, tuberculosis and even some cancers. The ability to integrate in diagnostics, external sensors, and wearables are especially appealing for the last mile reach.

31.4 Conclusions and Discussion

Digital health interventions targeted to improve cardiovascular outcomes are critical to design, deploy and sustain, especially in resource constrained settings. The exponential growth in wireless and portable/wearable device technology, reduction in cost for internet-assisted services and devices, and steady expansion in access, has created a path forward for sustainable digital health technologies in LMICs. Forward-looking investment in information and communication technology infrastructure and policies are a first step towards implementation of digital health solutions in LMICS. However, there are critical barriers to consider. Digital health solutions and interventions require co-design with stakeholders to incorporate the local cultural context, and facilitate interoperability with workflows and existing infrastructure. Digital technology development must be patient-centric and provider-centric to promote adoption and adherence. The local context in terms of mobile device access, internet connectivity, and scalability must be at the forefront. Population-level studies with rigorous assessment are needed to drive evidence-based solutions.

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32 The Role of Technology and Innovation

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Abstract

Technology holds a significant role in the past, present, and future of cardiac surgical care capacity in low-to-middle income countries (LMICs): a role that holds positive value overall in opportunity and outcome, despite recurrent and emerging practical and ethical challenges to different stakeholder groups. Aided by case studies, this chapter discusses the value of both creating technologies to benefit cardiac surgical care directly, and creating environments for technological innovation. This is addressed by examining the value of technology for, and within, human and physical resource development. Human resource development, consisting of cognitive, technical, and reflective components, is developed through two complementary approaches: increasing the minimum quality standard achieved by healthcare professionals, and increasing the maximum quality standard achievable. Both of these strategies are hugely helped by the implementation of technology to facilitate new training methods, relationships, and career opportunities. The discussion of physical resource development is guided by the journey of development and implementation taken by individual technologies, identifying key forms of support required to combat potential issues and increase the chance of success. Technology requires significant resource investment by a varied portfolio of stakeholder groups to deliver on its current achievable, and future potential promise to contribute significantly towards cardiac surgical capacity development in LMICs.

Keywords

Technology · Innovation · Stakeholders · Environments · Quality · Improvement · Human resource · Physical resource · Development · Implementation · Training · E-learning · Online resources · Video · Mobile application · Simulation · Robotics · Collaboration · Communication · Research tools · Software · FOSS · Blockchain · Virtual reality · Augmented reality · Artificial intelligence · Machine learning · Programming · Database · Statistics · Human-centred design · Infrastructure ·

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_32

Health technology assessment · Accreditation · Procurement · User-uptake

32.1 Introduction

Developing the capacity for providing cardiac surgical care in LMICs, like any component of healthcare provision, must include elements of adaptability and innovation. In recent years the role of technology to support, maintain and even transform healthcare provision has grown significantly. It is vital therefore to include this journey of technology—its past, present, and future—and how it applies to capacity development in cardiac surgical care specifically.

This chapter begins by discussing the benefits and challenges to the development and implementation of technology, in particular in low-to-middle income countries (LMICs), and relating to a resource-intensive speciality such as cardiac surgery. The practical and ethical considerations are relevant and should encourage reflection that remains for the successive components of the chapter. The role of technology is broadly split into two themes, corresponding with central elements of surgical capacity: (1) human resource development, and (2) physical resource development. These themes are both interdependent and necessary for the future of healthcare provision.

When defining the role of technology in cardiac surgical capacity development it is worth highlighting the separation between (a) creating technologies, and (b) creating environments for technology development and implementation, or 'innovation'. This tension between building capacity through single technologies, versus developing environments that foster innovation, runs throughout this discussion. The development of multiple components of this complex system of tools and environments must be concurrent, accurate, and evolving.

32.1.1 The Value of Technology and Innovation

Broadly, technology can allow for the improvement of existing healthcare service provision, either through the development of an existing or new function; and innovation catalyses the continual creation, evolution, and implementation of valuable technology. Technology can even reframe a problem or service entirely: it may open up whole new avenues of interaction between patient and healthcare worker, or capture previously unknown or lost sources of data. Technology can help specific healthcare environments as it develops, and 'leap-frog' multiple intermediate steps or components within a complex problem when extrapolated to different environments. Well-built and well-supported tools, born from well-structured environments, have much to offer to increase cardiac surgical capacity in LMICs.

The identification of and approach to problems of healthcare service provision attract human and physical resources: the problems may inspire, and offer unique opportunities to individuals, organisations, and communities. Individual healthcare workers may be empowered to broaden their experience and build their skills whilst working on a local problem; organisations and communities may be supported and benefitted by the positive social and economic influences of this work, and wider groups may have the capacity to benefit from the successes and failures in outcomes. Technological tools and approaches can scale beyond the initial community they were built to serve (Case Study 1).

Case Study 1: Using social media to disseminate data about COVID-19

Social media is often seen as a platform for social interaction only, but the pandemic has highlighted how simple tools on social media can be effective for disseminating data and promoting discussion. Functions such as the hashtag (#) on *Twitter* are useful for labelling responses so that a particular discussion topic can be easily searched for. Moreover, the prevalence of social media and the increase in smartphone usage in LMIC populations has brought social media to the forefront of valuable, equitable, and low-cost digital technologies.

In 2015, *The Annals of Thoracic Surgery* and *The Journal of Thoracic and Cardiovascular Surgery* established a collaborative known as *The Thoracic Surgery Social Media Network* (TSSMN) [1]. The main goal of this collaboration was to use the reach of social media to disseminate and discuss key publications within the sphere of thoracic surgery. The collaborative frequently held tweetchat on *Twitter* to discuss particular studies or manuscripts.

However, during the COVID-19 pandemic, both journals pivoted on this established network and capitalized on digital technology to foster discussion at an international scale on the topic of COVID-19, its impact, and best practices. Topics were crowdsourced on their social media platforms. During the tweetchat itself, key topics were discussed such as: (1) triaging thoracic surgical patients during COVID-19; (2) surgical education during COVID-19; and (3) limited resource availability (e.g. PPE) during COVID-19. Anyone from anywhere in the world who had access to the internet and an account on Twitter could respond to these discussions. A total of 273 participants were recorded across North America and Asia [2].

From Twitter. Used with the permission of the author.

The Coronavirus-19 (Covid-19) pandemic, similar to any significant challenges in circumstances or resource constraint, has done much to highlight both the existing challenges facing healthcare and the opportunities for technology to contribute to solutions. Consequently, the role of technology in healthcare provision has grown significantly across the world: for example, it can help to minimise issues of geographical and financial accessibility through telehealth, and encourage collaborative problem-solving by the sharing of experience and evidence online.

Surgical care in LMICs, and cardiac surgical care specifically, presents significant challenges for accessibility. These challenges discussed elsewhere in this book, include the difficulties of building, scaling, and sustaining capacity for a rapidly evolving and resource-intensive healthcare speciality. However, resource constraint and continuous development are often described as drivers of innovation: individuals, organisations, and systems are forced to adapt to find accessible solutions to meet important needs. In this process, innovation decreases the costs and increases the accessibility of the available solutions. This reframes cardiac surgical capacity development in LMICs as a compelling space for technology and innovation.

32.1.2 The Considerations and Challenges of Technology and Innovation

Alongside the potential value of technology and innovation, some considerations and challenges arise. First and foremost, there are commonly raised questions about acceptable levels of disruptive change, and continually considering its balance of cost and benefit.

The introduction of any technology requires changes to existing practices, perhaps for both service providers and users, and these may be significantly disruptive to hinder or even halt implementation. Services providers may not be willing to change their practice due to varied concerns: about deliverable care quality, especially during a transition period; about lacking the skill-set needed to employ the new technology; or even an inflexibility in practice or innate resistance to change. Patients may have equally important concerns: again on the subject of deliverable care quality; or even challenging elements of psychological or cultural resistance. Frequently these barriers to technological acceptability are interlinked, and require patient and intelligent design to overcome; these are features that a strong innovative environment of human and physical resources can provide (Case Study 2).

Case Study 2: Surgeon and patient barriers to adopting robotic surgery

In 2011, a group of researchers conducted semi-structured interviews with surgeons to identify some facilitators and barriers to the uptake of robotic-assisted surgery [3]. One of these barriers was the learning curve that comes with the adoption of such technology. Surgeons did not want to spend time learning how to operate with a robot if they could already effectively operate without one. Moreover, some felt that there were more risks to robotic surgery due to a lack of tactile feedback. Another barrier cited was the time and resources required to set up the equipment before surgery.

A similar study to evaluate the public perception of robotic surgery found that many patients were worried about technological malfunction during surgery putting them at risk [4]. Others expressed concern about the cost associated with developing and implementing the technology, the cost associated with the training required for surgeons, and the additional time that would be required during surgeries if robots were used. A sizeable number of patients had a misconception that robotic surgery referred to the robot autonomously performing surgery without a surgeon's control.

These research studies show that the implementation of technology is a multi-faceted endeavour and requires rigorous auditing and data collection from different stakeholders. Simply proving that innovation is effective in achieving a target is often not sufficient in guaranteeing buy-in from stakeholders and large-scale implementation.

Commonly, technologies require significant upfront capital investment to develop and implement, even if they promise (and may deliver) longer-term cost-saving. This is particularly true for the high-resource speciality of cardiac surgery. It is also a reality that any healthcare provider has limited financial resources, and that this is distributed by calculations of cost-benefit or cost-efficacy. In any rapidly developing field, or concerning new technology, there is likely a limited evidence base to demonstrate this value. This can make new technologies a risky investment for healthcare providers, who are looking to balance immediate clinical value with longevity. Therefore technologies benefit from a broadly supportive environment with well-developed mechanisms for evidence synthesis, evaluation, and accreditation.

The increased risk may be balanced by a strong drive for innovation, secondary to various forms of resource constraint or insufficiency of existing services. This is perhaps strongest in the least well-developed parts of healthcare provision, of which cardiac surgical care is one. This drive must be kept in perspective alongside the other considerations and should be maintained through continuous, thorough, and proximate evaluation of where the most important problem areas and most promising solutions lie. Maintaining the appropriate balance of service delivery and innovation is a huge challenge, especially in the case of weaker and more easily exploited governance, regulatory, and procurement environments.

LMICs represent a group with significant heterogeneity in every regard, and so transferability of any evidence base about technology is challenging. This extends from different healthcare policy and provision environments to broader socio-economic and cultural considerations. Questions of transferability must account

Table 1 Considerations of stakeholderStakeholders groups

Stakeholder groups	Questions to consider
Healthcare providers *(public and private; as buyers and users of technologies)*	What is the aim of the group? What is its nature and scale? How does this relate to technology? What is the contribution of the group to its aim? How does this relate to technology? What is the influence of the group on other stakeholders? What incentives or pressures does the group have? What toolkit or capabilities does the group have?
Government *(local, regional, national; as buyers and users of technologies)*	
Independent regulatory agencies *(as accreditors and regulators of technologies)*	
International multilateral organisations *(e.g. WHO; as buyers, users, regulators and providers of technologies)*	
Civil society / Non-governmental organisations *(as buyers, users and providers of technologies)*	
Education providers and training bodies *(as buyers, users, regulators and providers of technologies)*	
Private sector companies *(as providers of technologies)*	
Service users and communities *(as buyers, users and providers of technologies)*	

for these different circumstances alongside the stakeholder groups involved, and how these may play a role in the creation and implementation of any technology (Table 32.1).

32.2 Human Resources

Human resource development is one of the central components of capacity development, and it is a key channel for the role of technology.

The components of human resources can be broadly split into three components: cognitive, technical, and reflective (Table 32.2). Although these three components frequently overlap with and even potentiate each other, it is useful to consider how different technologies impact them. We will use these components through this section to help us understand the impact of healthcare technologies on developing human resource capacity.

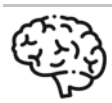
Human resource capacity can be summarised as a spectrum of ability to provide quality healthcare (Fig. 32.1). On one end of the spectrum is the minimum standard of quality that a healthcare system provides, and on the other is the maximum standard. The spectrum, therefore, represents the range of healthcare qualities available within this system. To improve the human resource capacity of cardiac surgical care, therefore, there are two options: (1) improving the minimum standard; and (2) improving the maximum standard.

The first option, improving the minimum standard, involves increasing the number of practitioners who meet the minimum standard—safe healthcare practitioners—or raising the acceptable minimum standard for all. This option looks to provide an immediate solution to the recurrent issue of shortages of healthcare workers, particularly in such a resource-intensive speciality as cardiac surgery.

The second option, which lies at the other end of the spectrum of quality, involves increasing the number of practitioners who meet the maximum standard—the most desirable healthcare practitioners—or raising the maximum achievable standard for all. This option looks to further the capability of cardiac surgical provision as a whole, looking towards the future of the speciality.

Not only do these two options represent the most common targets for healthcare technology, but they are also linked: an increase in the maximum quality may provide a clear justification for ensuring an adequate minimum; equally

Table 32.2 Components of Human Resource

Component	Definition	Delivery	Examples
	Information, knowledge or content possessed by an individual	Includes the use of textbooks or other sources of raw information	Knowledge about medical content, or the function of healthcare system, including governance and infrastructure E.g. Knowledge about the indications and contraindications for cardiac catheterisation
	Procedural or activity-based skills or abilities possessed by an individual	Includes mentorship and guided teaching by a senior	The ability to perform medical procedures, and contribute to the functioning and improvement of a health care system E.g. The ability to perform cardiac catheterisation
	Non-cognitive, non-technical ability possessed by an individual	Includes self-reflection and reflection on the behaviours of other stakeholders	Using mechanism of reflection with others to develop high quality patient-centred care E.g. Discussing the outcome of a cardiac catheterisation procedure with the patient

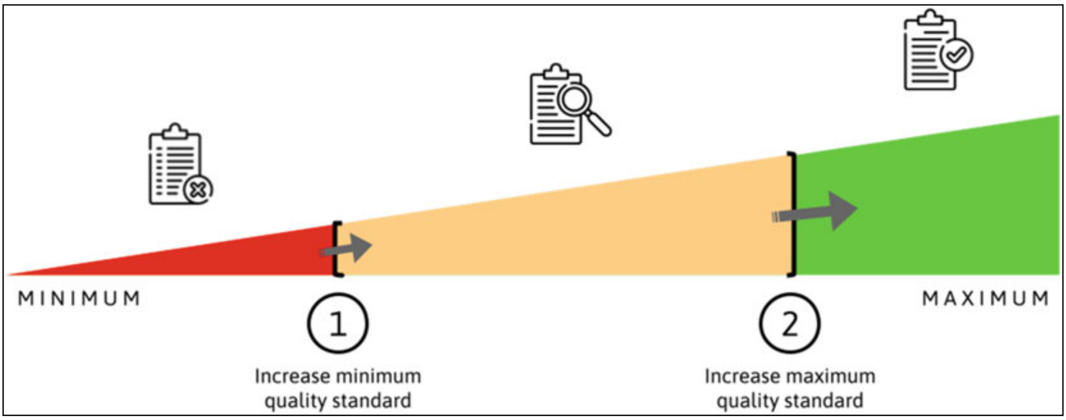


Fig. 32.1 Spectrum of quality standard *Approach (1): Raising the minimum quality standard achieved by healthcare; Approach (2): Raising the maximum quality standard achievable*

raising the minimum quality may provide a drive towards leveling-up the maximum.

Technologies that push the boundaries of the possible are perhaps the most compelling in their appeal to aspiration and imagination, however, this should not be to the detriment of 'less innovative' technologies that have a greater impact on providing safe cardiac surgical care to all who need it. These approaches raise further ethical and resource-allocation considerations. For example: What size of disparity should be tolerated between the minimum and maximum standards of healthcare quality? How should limited financial resources be allocated, and how should regulatory frameworks be designed, concerning this disparity? To what extent should this disparity be permitted to generate inequity in access to high-quality cardiac surgical care? Although the full discussion of these issues is beyond the scope of this chapter, these are important to consider.

32.2.1 Improving the Minimum Quality Standard

Previous approaches to improving minimum quality standards using technology have frequently supported methods of human resource development that are unidirectional from HICs to LMICs, ethically challenging, and even disempowering for LMIC capacity development.

Within these frameworks, LMIC healthcare workers may feel obliged to meet externally-set training criteria, and even complete training external to their healthcare system in HICs, to meet a perceived minimum quality standard. Individuals and groups in HICs may encourage this framework by simply transferring their training unadapted, and so under-developed, into the healthcare service of LMICs.

If the training standards, and even the training itself, aren't located within or adapted to the LMIC healthcare systems in question, the technologies developed for training purposes may not fulfill their required role. This can create a negative cycle: trainees use the 'best available' training technologies, which are externally developed; this minimises the need for developing those that are LMIC-specific; consequently, few such technologies are developed to parallel those from HICs.

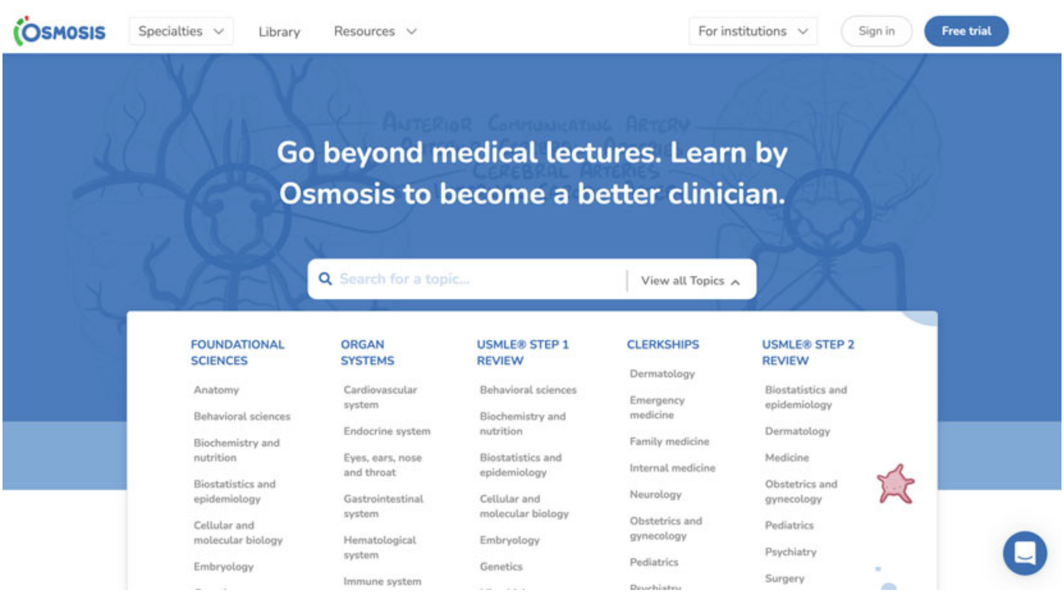
However, current approaches which seek to equalise and evolve the training relationships between HICs and LMICs, and to develop the local training capacity of LMICs, present valuable and evolving opportunities for the use of technology for human resource capacity development.

32.2.2 New Training Methods

Various means of developing the cognitive component of human resource capacity have arisen using the internet, and the accessibility of these means continues to grow insofar as issues of connectivity—such as cost and geographical coverage—are minimised.

Online resources, in the form of websites, e-books, mobile applications, and videos, present a wealth of information that is often free or low-cost to access (Case Study 3). Websites (e.g. *Osmosis*) and digital textbooks or e-books often contain sufficient information to meet the minimum quality standard, and to equip practitioners to help with more common presentations and procedures. Equally video sites (e.g. *MEDtube* and *YouTube*) have libraries with thousands of videos relating to cardiac surgery; this includes videos explaining key content, discussing case presentations, and even showcasing surgical procedures. Mobile applications, although less accessible by requiring a smartphone, also present valuable information in an engaging format, particularly for emergencies (e.g. *Congenital Hearts* for visualisation of congenital heart defects, *Cardiac Surgery Board Review* for cases and practice examination questions, *RICS* and *EuroSCORE II* for patient risk evaluation, *iResus* for resuscitation pathways, *BNF* for pharmacology). There is, in addition, a growing quantity and quality of training resources available online to facilitate building new technologies within innovative environments; for example quality improvement (QI), health informatics, human-centred design methods, and computer science (e.g. *Coursera*, *edX*). This content is increasingly accessible and can be applied to physical resource development, as discussed later in this chapter.

> **Case Study 3: Online Resources**
> **Websites**
>
> Many websites cater to delivering medical education material to healthcare students, including those that both deliver content and offer assessments. One popular platform is *Osmosis* [5]. It has a subscription-based model for students to access their content, with an option of accessing free material. The user interface is easy to use, with a broad library of content searchable by specialty, occupation, or topic.



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Videos

YouTube is the largest and most popular video streaming site in the world [6]. It is free of cost to view and requires only a stable internet connection. There are hundreds of medical education channels that produce and publish high-quality content that is even recommended by some medical schools. These channels teach a large variety of topics at different depths, and hence are usable by all healthcare professionals at all levels of training. *YouTube* function also allows for alteration of video quality, allowing streaming of videos in areas with poor internet connection. Organisations like *Lecturio* and *Osmosis* have *YouTube* channels that frequently post high-quality video lectures on different topics, delivered by renowned experts.

Mobile applications

With the advent of smartphones, and smartphone usage extending to many rural and remote parts of the world, mobile applications have begun to play a huge role in education. One example of a smartphone application being used in education and clinical practice is the *British National Formulary* (BNF) mobile app [7]. It is a searchable database of all pharmacological treatments approved in the United Kingdom. Each drug is listed with its dosage, uses, contraindications, and adverse effects and is widely used by the healthcare workforce in the National Health Service. This app allows important pharmacological information to be easily accessed by healthcare workers, reducing the burden on training healthcare professionals as well as reducing room for human errors.

Online courses

Other technological resources are aimed at building capacity by delivering educational content in a more structured and accredited way. *Coursera* is one amongst many websites that offer online courses, some of them for free [8]. These courses are designed and led by leading experts in their fields from institutions around the world. Delivery online allows flexibility for students as to how, when, and where they wish to take the course. Moreover, free online courses are an equitable way for healthcare systems in low resource settings to build capacity. This trend of online courses is widely referred to as Massive Open Online Course (MOOC).

The evidence base

Apprehension towards using these online resources may stem from concerns about whether the quality of content is adequate to train healthcare workers to the required standard. Research has found that students often use online resources as an adjunct to traditional methods of learning, not as a replacement [9]. While students' experience of the quality of these online resources may vary, objective testing revealed that they match traditional methods for knowledge and skills provided. Institutional support is required therefore to provide students with a curated library of high-quality online resources, adaptable to feedback measured and the outcomes achieved.

Technologies to develop the cognitive component of human resource development are increasingly paired with those to develop the technical side too, to provide an efficient and effective training package. Simulation technologies are available in both a physical (e.g. surgical and resuscitation simulators) and a virtual form (e.g. mobile applications) and are consistently improving in their quality, scope, and cost (see *Future developments*).

Cardiac surgery, as a highly specialised form of surgery, currently has less content available than many other medical and surgical specialties, and this content is largely for surgeons. However, the development of online resources is frequently significantly more accessible than other forms of resources such as traditional textbooks. Developing and distributing the content is associated with low or even no costs, and there are far fewer barriers to collaborative development and rapid distribution of content using other forms of technology. Consequently, it is likely that this issue of low content volume will rapidly change as these technologies continue to increase their use and capability. All of these technologies can be combined to enhance the ability of majority-online—or entirely online—teaching of cardiac surgical care delivery; this makes the aspiration achievable of teaching specific skills to increase capacity.

Resource co-development and distribution are empowered by collaboration and communication technologies that are designed to be accessible, and in some cases are already widely used. Email lists, alongside messaging platforms such as WhatsApp, allow the easy connection of individuals, the creation of groups, and the dispersion of knowledge and resources. *WhatsApp* has been used by local research teams to both encourage and understand the implementation of the WHO Surgical Safety Checklist; used because of its existing widespread integration into local clinical teams.

Case Study 4: Using *WhatsApp* to establish communication networks between hospitals and increase uptake of the WHO Surgical Safety Checklist

A study was conducted by *Mercy Ships*, The Benin Ministry of Health, and King's College London University to develop and evaluate an implementation framework within LMICs for the WHO Surgical Safety Checklist (SSC) [10]. The methodology involved a 3-day training and 4-month follow-up. At the end of the 3-day training period, a *WhatsApp* group was created, made up of researchers and those who attended the training, for peer-to-peer support. The intention of this group was to establish a network of hospitals and healthcare professionals who could share best practices on how to implement the SSC effectively and to directly ask researchers or other practitioners about any issues they were facing. While the group itself was not an item of study, the innovative use of *WhatsApp* to establish communication channels for the exchange of information highlights how simple technology can be utilised to establish and facilitate the exchange of information between clinical environments across broad geographies.

These collaborative processes for both providing and developing healthcare services will in tandem improve the reflective component of human resources. The interconnectivity and relationship building that is core to these processes frequently necessitates high levels of reflection, to identify shared experiences and translatable insights. This can catalyse leadership development and enhance problem-solving capacity. Allied with the value of these collaborative tools, eLearning platforms are increasingly used for leadership and management competency development directly.

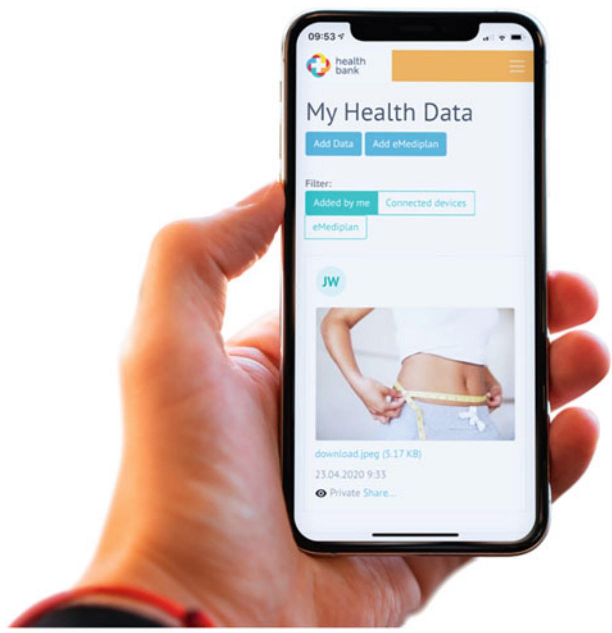
32.2.3 New Relationships

The value of technology for partnership building is abundantly clear in its ability to foster greater connections amongst educational and clinical organisations on any geographical scale. The rise of online collaboration and communication tools, as highlighted above, builds the cumulative cognitive, procedural, and reflective capacities of the organisations involved. New forms and outputs of partnership are being developed that rely on technology to exist and prosper. This online community building can occur through forums and professional groups; collaborative databases and research tools (e.g. *REDCap*); free and open-source software (FOSS) development; and international online conferences, hackathons, and themed events. The new and evolving technology of blockchain, with its key attributes of transparency, authenticity, and decentralisation, can be used for the improvement of academic and research practices. By aiding the accreditation of research methods and standards, such as transparent data review, and promoting improved large-scale databases for research, blockchain can facilitate open science initiatives and tools.

Case Study 5: Blockchain technology to create data management and exchange platforms that can impact research capacity

A Swiss digital health start-up known as *Healthbank* has built a data storage and transfer platform that provides patients with transparency and full access to manage their medical information [11]. This is in contrast to other healthcare platforms which rely on physicians or hospitals to store and manage patient data, resulting in a lack of transparency and control given to patients.

Healthbank gives users the ability to make their data available for medical research in return for financial compensation. Using blockchain technology, *Healthbank* has established a unique data management and data exchange platform that can facilitate research efficiently, with greater autonomy for patients. This technology has the potential to reduce the logistical burden of research, allowing LMICs to build their research capacity.



Used with the permission of Healthbank Cooperative.

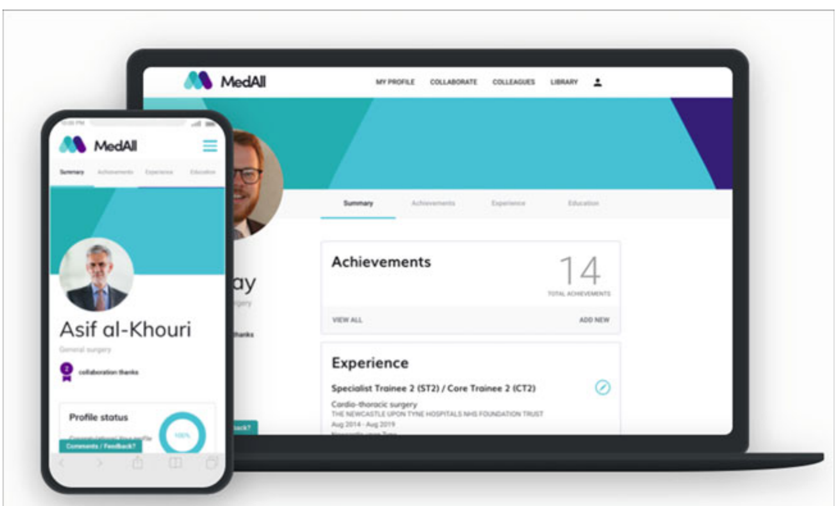
This growing possibility of events, research, and communities also carry the promise of healthier relationships between educational and clinical settings in LMICs and HICs. Sharing a diversity of perspectives enhances training and improves capacity for innovation development, as it places a clear value on a broader range of skill-sets and experiences. In addition, it offers a more symbiotic alternative to historic power imbalances that are promising for future healthcare service development.

32.2.4 New Career Opportunities

Building value in local skill-sets and experiences can be assisted by formally recognising that value, through the form of accreditation or other career development opportunities. Online platforms can be used to build restricted communities of accredited or accomplished healthcare workers; this can include the application process, elements of continuing professional development (CPD), and maintaining updated communication with members of the community (Case Study 6). These platforms can be enhanced by the new application of other technologies such as blockchain, which can be used to improve the verification of attributes of individuals and organisations.

Case Study 6: Professional development and career-building with *MedAll*

MedAll is a website and mobile application that allows users to build their portfolios online and upload all their certificates and achievements onto the platform [12]. The platform also has social features, allowing users to connect with other healthcare professionals. The transparent virtual portfolio allows people to connect based on their expertise and interests. *MedAll* also has pages where organisations that are running events can create automated feedback and certificate functions for its attendees. The certificates are then directly uploaded to the attendee's portfolio. While *MedAll* is not a restricted community, its function and layout provide insight into how effective professional virtual communities can be built.



Used with the permission of MedAll.

These communities for career development opportunities can even develop as centres of human resource excellence, producing their own training resources or research for example. The College of Surgeons of East, Central, and Southern Africa (COSECSA) is one such example of this (Case Study 7). In nascent fields like global cardiac surgery, these communities can evolve in their identity to fulfill important roles for the speciality, such as producing governance processes or training pathways.

In addition, these online communities can themselves be dedicated to the creation and implementation of technologies to assist in cardiac surgery capacity development. Early adopters of these technologies are well-placed to enhance the use of those currently available, and to influence the next phase of tools, owing to their relevant experiences and skill-sets from working with technologies previously.

Case Study 7: College of Surgeons of East, Central and Southern Africa (COSECSA) neurosurgical fellowship

COSECSA began offering neurosurgical fellowships in 2006 [13]. This is a 4-year program where trainees rotate through the hospitals within the COSECSA region. Along with this, they have to maintain an online log of their cases, complete several online courses and satisfy other criteria such as authoring and publishing an academic article. At the end of the 4 years, trainees will be expected to sit an oral and written examination before they are awarded the fellowship.

The emphasis on utilising technology to build future surgeons is evident not only in certain fellowships that COSECSA runs but also in the college's strategic plan for the upcoming years. COSECSA has emphasised creating a multi-platform and mobile-accessible college. This includes creating robust information management systems to track and analyse trainee experience, and monitor and evaluate trainee standards; for example, a universal and accurate electronic logbook for COSECSA's neurosurgical fellowship. It also includes the delivery of online content, such as workshops for research writing. These strategies will inevitably require the development and implementation of technology to help the education of future surgeons.

32.2.5 Future Developments

The evolving field of technology-enhanced human resource development carries considerable promise for the future, albeit with the usual caveats: the accessibility of technology and its requirements financially (e.g. individual and provider costs), culturally (e.g. language, literacy), and in infrastructure (e.g. internet connection, power). Numerous applications of emerging technologies are thriving in HICs which are, and will continue to be, concurrently developed in or transferred to LMICs.

The combined use of video-telephone software programs and online platforms are increasingly used for teaching; *Proximie* is a platform that allows surgeons to collaborate on the preparation and practice of procedures remotely. Virtual reality (VR) and augmented reality (AR) are used for anatomy teaching and intra-operative assistance (e.g. *Microsoft Hololens*).

Case Study 8: Surgical procedure collaboration with *Proximie*

Proximie is an online platform that allows surgeons to 'virtually scrub in' and collaborate on the preparation and performance of surgical procedures remotely, using live video and augmented reality technology [14].

For example, in Gaza in 2016 *Proximie's* platform was used to guide a local operating surgeon with difficult hand surgery, by virtually connecting an experienced hand surgeon from the Conflict Medicine Program at the American University of Beirut to assist. In Gaza, a bird's-eye view camera was set up to provide sight of the surgical field. This was streamed onto a tablet with the *Proximie* AR overlay onto a tablet, so that the operating surgeon in Gaza could see the surgery, along with the visual instructions provided by the assisting surgeon. Audio communication was concurrently established to allow for discussion during the surgery [15].

The *Proximie* platform has subsequently been used in various circumstances around the world to deliver surgical care expertise and has demonstrated significant value during the Coronavirus-19 pandemic. The platform has been shown to be non-inferior to onsite-guided procedures for robotic urological procedures and presents a significant opportunity for expertise-sharing within cardiac surgery [16].

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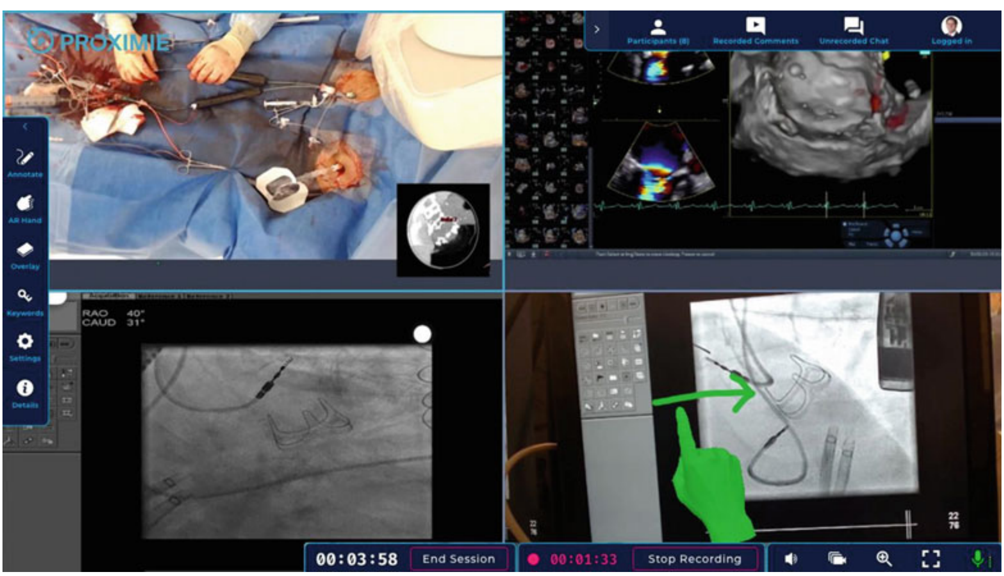
Artificial intelligence (AI) and machine learning (ML) are applied to a growing portfolio of use cases within healthcare capacity development and offer significant promise in the field of human resource development alone. For individuals, AI and ML can be used to analyse, personalise and enhance surgical training, and improve surgical performance; for trainee and practitioner populations as a whole, they can be used to minimise risks and maximise quality within healthcare. These may in turn be combined and enhanced with surgical simulation and robotics to create an efficient closed-loop of skills development and deployment (e.g. *Digital Surgery* as part of *Medtronic*).

Case Study 9: Creating a closed-loop of skills development and deployment with *Digital Surgery*

Touch Surgery^{TM} products are an examples of digital technology that can be used both



to train surgeons, and improve surgical practice [17].

The *Touch Surgery™* mobile application allows trainee surgeons to virtually practice operations using their step-by-step, interactive training resources. In addition, it allows teachers and supervisors to track the content covered by their trainees. This adjunct to traditional learning and teaching media has been shown to improve technical skill ability greater than a textbook: this was demonstrated in a randomised control trial for surgical residents in the University of Rwanda, measuring their preparation for a tendon repair procedure using either textbooks or the *Touch Surgery* app [18]. The value of these tools for curricular learning has also been validated through the accreditation of the tool from the Royal College of Surgeons of England, allowing trainees to receive recognition of continuing professional development by completing modules on the app.

In tandem with the *Touch Surgery™* app, *Touch Surgery™ Enterprise* is a platform available to operating rooms that allows for the recording and analysis of surgical procedures. This smart computer records, anonymises, and analyses surgical procedures; this tool can help surgeons uncover new insights and improve surgical performance [19]. Significant potential lies in the application of this technology to more surgical specialities, including cardiac surgery, and future integration with robotic surgical simulation and practice.

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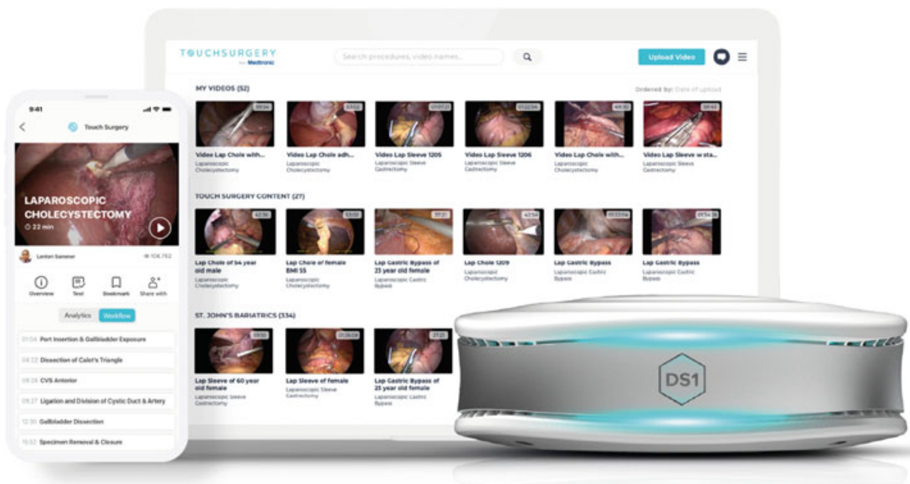

32.2.6 Improving the Maximum Quality Standard

The imbalance within relationships between LMICs and HICs concerning healthcare provision has hindered the ability of LMICs to raise the maximum quality standard of care. Building strong local capacity for technology development and implementation has been disregarded or deprioritised in favour of meeting minimum quality standards; a decision which is understandable given the existing challenges of providing universal health coverage (UHC). In place of this, the successes and failures of technology and innovation have frequently been directly transferred from LMICs to HICs, a system that creates further issues. Furthermore, there are concerns about the ethics and acceptability of developing and implementing technologies in countries with less well-developed regulatory environments; or in countries where a lack of existing services creates a strong incentive to accept an option regardless of its negative attributes. Despite this, the growing global healthcare need provides a strong imperative to face and surmount these challenges that are frequently met by technology.

Consequently, developing and implementing technology to raise maximum quality standards within LMICs is a challenging and rapidly growing field. The approaches echo those used to improve the minimum quality standards, as many of these challenge many existing elements of healthcare delivery.

New training methods that include continuous data collection and analysis will begin to close the loop on cardiac surgical training and practice, identifying issues and targets for the improvement of care provision. New relationships, aided by collaboration and remote working technologies, can generate new insights through research. Paired with the academic study of innovation implementation, including implementation science, social science, and complexity science, these insights can increasingly lead to changes in healthcare provision and policy. New career opportunities may allow for the diversification of cardiac surgery as a training pathway and as a speciality, as has occurred in other surgical fields.

In the future, these developments ought to lead to an increasingly broad and well-distributed research and innovation capacity, that is not limited to a small number of higher-income environments. As barriers to effective cross-border and multi-disciplinary collaboration dissipate, individuals and organisations will increasingly build their portfolio of skills and experience to the benefit of cardiac surgical care globally.

Key recommendations

- Strategies for improving the human resource capacity through technology should consider their influence on the cognitive, technical, and reflective components.
- Technology can be powerful for both improving the minimum and maximum quality standards, and the strategies for these are interconnected.
- Technology can be used to improve human resource capacity for delivering cardiac surgical care now; however, it can also be used for creating innovative environments to deliver the cardiac surgical care of tomorrow.
- There is a growing body of technologies that create enormous potential for the provision of cardiac surgical care now and in the future through a combination of new training methods, new relationships, and new career opportunities.
- Significant potential lies in technology for the improvement of human resource capacity for future cardiac surgical care; a well-developed specialised evidence base is needed to deliver on this.

32.3 Physical Resources

Cardiac surgery is often considered a resource-intensive capacity, with significant physical resource demands. In tandem with its ability to assist with human resource demands, technology may also provide solutions here. The focus of this section is to explore the two-part journey of technologies as physical resources for improving cardiac surgical care: (1) their development, and (2) their implementation. Examples of physical resources that contribute to improving cardiac surgical care, and to building an environment of innovation, are discussed within the context of technological development and implementation. Consequently, this is not an exhaustive list of all technologies available for cardiac surgical care; rather an attempt to capture the key considerations behind technological development for the speciality now and in the future.

32.3.1 Technology Development

As discussed earlier in the chapter, resource constraint is both a central challenge to cardiac surgical capacity development and a major positive influence on technology and innovation development. Other contributing factors include building an environment with a strong innovation capacity and allowing for the transfer and adaptation of evidence and technologies from other environments where possible. 'Leap-frogging' is a term used to describe where a solution developed for a problem is transferred from its developing environment to a fresh context; a context in which no valuable solution may yet exist. The transfer of this more 'well-formed' solution may confer benefit, as it reduces the need for the receiving environment to bear the various costs of technology development. It may even facilitate the development of new opportunities by pivoting or learning from the initial one (Table 32.3). This strategy has seen both success and failure within the context of global surgery.

32.3.2 Clues of Successful DevelopmentClues of Successful Development

When considering these opportunities arising from knowledge and technology transfer between environments, and their examples, there are key clues for delivering successful development of

Table 32.3 Opportunities from technology transfer

	Explanation	Example
Piggy-backing	Technologies that develop off the back of the original, presenting a new opportunity that is only possible with the existing technology as a foundation	Using machine learning and deep neural networks to automatically analyse ECG patterns. This technology requires existing ECG technology [20].
Idea replicates	Replication of the idea behind the technology, using cheaper or less feature-heavy technology, making it more viable in instances of resource-limitation	Sree Chitra Tirunal Medical Centre in Kerala India developed their own tilting disc heart valve, fully compliant with ISO standards and affordable to patients of the low Income group in their hospital, as importing valves was too expensive for the hospital budget. This is an example of innovating toward a solution in a cheaper way as compared to its competitors [21].
Repurposing	The repurposing of ideas or, technologies to new problems that they weren't originally designed for	In India, Tongaonkar and colleagues developed a new mesh for inguinal hernia, as the usual mesh cost $108 per patient. Using mosquito nets they demonstrated highly positive outcomes with almost no additional risks, and a fraction of the cost [22].
Reverse innovation	A technology developed or adapted for LMICs delivers value back to HICs where the opportunity was originally Identified	In 1984, Dt Oswaldo Borraez was assisting in a laparotomy but an abdominal infection prevented the surgical team from fully closing. Dr Borraez suggested using a 3-litre polyethylene urine bag to temporarily close. The bag was sterile and reduced infection rales, allowed effective monitoring of the wound due to its transparency, and was extremely cost effective compared to normal temporary wound closure techniques: this is now widely practised [22].

technologies: clues about where the development happens, who is involved, and how it happens.

Successful technological development occurs within the environment where the technology will be used, close to the problem. Those experiencing the problem as it stands may become future users of the technology, and they will have a unique perspective about the problem at hand. These may be healthcare practitioners of various kinds, from Community Healthcare Workers (CHWs) to cardiac surgeons, or even patients and members of the community. Engaging the broad groups of future users as key stakeholders is crucial to designing a technology that both addresses the problem at hand, and addresses the challenges associated with technology discussed at the beginning of the chapter, including sustainable user engagement (see Table 32.1). These same stakeholders may lead the development of the technology, responding to the problem if they consider a solution valuable, necessary, or even urgent.

Technological development that involves local stakeholders, close to the problem, is a strong starting point for successful development. Initiating and sustaining this development, sufficiently to demonstrate its success, or the value of a technology, requires consistent, thorough, and high-quality evidence synthesis. The evidence must answer core questions about both the safety and utility of the technology, within the development environment and more broadly if possible to maximise its potential impact.

32.3.3 Helpful Resources and Support

These clues can guide the evolution of innovative environments supportive of technological development: what resources and forms of support are valuable, and how can these be best accessed, improved, and exchanged? Again it is useful to consider the *where, who*, and *how* of technological development.

32.3.4 Where Does Development Occur?

If technological development best occurs in partnership with the communities and locations proximate to the issue, the ability to connect with these groups is very important. Technology can be used to simultaneously collect high-quality data in real-time to identify problems or unmet needs, and the different perspectives of those facing these problems or with these unmet needs —including patient groups and clinicians. Technology offers easier scalability than more manual methods of data collection, leading to more achievable distributed research capacity, including to traditionally remote and hard-to-reach groups, and so greater diversity of experience and expertise. Even once the development process starts, this ability to collect real-time data extends to gathering feedback about the developing solution. This method of 'lean' or adaptive design minimises resource waste, including important non-physical types such as psychological capital with the future user population. Furthermore, reducing waste extends the impact of the available resources.

32.3.5 *Who Is Involved in Development?*

The design process should involve a variety of stakeholders, who should all be well-equipped to contribute. In the human resource section, we discussed the use of technology for learning, or for delivering cardiac surgical care, and for meta-learning, or for how to develop technology to improve care. These valuable skill-sets include technological development skills—such as software programming for website or mobile application design, database management and statistics—and business development skills—such as human-centred design, marketing, operations, and finance.

Individuals and groups, empowered with these skills and their experiences, can connect through communities and events that seek to encourage co-creation: forums, panel discussions, and hackathons (design sprints focused around solving a particular problem). These opportunities can be considered part of an idea exchange infrastructure, whose reach and potential impact are significantly increased by technology (Case Study 10). They can exist online, dispersed across broad geography with reduced barriers to access. This allows for teams of co-developers to form, allowing for crowd-sourcing of data and efforts, and work enhanced by collaborative technologies.

Case Study 10: Developing novel ways to foster innovative multidisciplinary environments

Hackathons are events designed to foster lateral thinking, multidisciplinary working, and contribution to an environment of innovation. These are events where groups of attendees are given a specific problem statement and are challenged to build a solution to the problem, working in a 'sprint' under time constraints. This format started within the broader technology industry but has expanded into various sectors, including healthcare, as a way to approach collaborative problem-solving. This includes 'surgathons': hackathons focussed on identifying solutions to problems within surgical care and anaesthetic delivery. Between 2018 and 2019, the branch of the International Student Surgical Network (*Incision*) in Rwanda ran 3 surgathons. Local and international faculty were invited to provide mentorship and talks to contribute to fostering an innovative environment.

Researchers have identified 3 key pillars in the surgathon model: global surgery, innovation, and ethics [23] Such a model has been credited with creating strong innovative ecosystems with exposure to multidisciplinary working. However, researchers noted that the solutions themselves should not be a metric for the performance of the surgathon. The value of the surgathon lies in the experiential learning and exposure to collaboration. Organising such events should be a continuous process, whereby the broader ecosystem that is built will over time encourages innovation amongst its members.

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32.3.6 How Does Development Occur?

Even with a problem identified, and a well-equipped, multi-stakeholder group working on it, there remain challenges in initiating and sustaining technological development itself. A base level of resources is required to develop working prototypes of technology, even at an early stage (Table 32.4).

Technological: Technological resources are vital for providing a platform on which the technology can be built, tested, and iterated during its development. This includes devices (e.g. computers, smartphones, mobile phones) and underlying key infrastructure (e.g. internet servers and reliable connectivity); the cost and utility of these are continually improving. Other technological resources that overlap with human resources, such as software programming expertise, are widely available through free-and-open source software (FOSS) and online marketplaces for hiring software programmers. Both decrease the costs of creating and iterating during the development process. It should also be noted that, as shown in the Human Resource section of the chapter, new technologies need not be expensive or sensational: the repurposing of existing tools at low cost may create significant benefits. This pairs the potentially lower technological resource demands with the increasing supply of capability.

Financial: Financial resources are, of course, vital for technological development. Although the funding landscape differs significantly between LMICs, it is essential that the right forms of funding are available to those creating new technologies: this includes the right quantity, origin, and destination of the funding. The

Table 32.4 Types of resources and support needed to develop technology

Type	Definition	Examples
	Providing a technological foundation on which to develop the new technology	Devices (e.g. computers, smartphones, mobile phones) Infrastructure (e.g. internet servers and reliable connectivity) Skills (e.g. software programming expertise) E.g. Digital Surgery [17]
	Sources of funding for different stages of development	Feasibility, seed and scale-up funding E.g. Innovative funding instruments [23]
	Institutional validation and support to facilitate successful development	Incubator and accelerator programmes, departmental collaborations E.g. Surgathons [22]
	Support and opportunities for experimentation during development	Research partnerships, clinical champions E.g. Tilting disc valve [25]
	Guidance to support the transition from development to implementation	Open-access events and educational resources E.g. Building HTA capacity in Ghana [26]

scale of funding available should be a spectrum from smaller ‘feasibility’ quantities, to test the early hypothesis of a solution, to ‘start-up’ or ‘seed’ funding, for building a fuller and perhaps market-ready product or service, to ‘scale-up funding, for improving the product or service or increasing its impact in implementation. These funds may originate from grant funders, such as national governments or NGOs offering awards or competitions, or from investors, such as private companies looking for a financial return. The funding could be in newer, innovative forms; this includes those that allow for early experimentation or greater economies of scale (Case Study 11). The destination of funding offered may be limited by specific missions or targets from the funders, created to set a strategic direction. This exercise of targeted funding towards particular problems recruits technologies in development with an immediate value.

Case Study 11: Innovative financing for technology

Innovative financing is an umbrella term used to describe methods of raising and procuring funds that don’t conform to the usual categories of public funding, private funding, and external funding. Researchers identified and described 4 innovative financing instruments through case studies: voluntary solidarity levy, voluntary contribution, performance-based instruments, and bonds, and securities [24]. They described 5 sequential stages to financing surgical systems: mobilize, pool, channel, allocate, implement. By deploying innovative financing instruments at these different stages of financial allocation, one can improve the limits for sustainable spending.

These financing tools can be used in developing, implementing, and disseminating healthcare technologies. The role of financing may also directly impact how effectively that technology is developed and implemented. Researchers have found that the diffusion rate of drug-eluting stent technology within hospitals that had reimbursement-based financing models is higher than those that operated on global budgets [25]. Therefore, when thinking about using financing to develop technology, it is important to consider how these funds are mobilized, pooled, channeled, and allocated.

Institutional: Securing funding through awards or competition also confers a degree of validation onto the developing technology, particularly if it originates from reputable institutions. Institutions of any stakeholder group, frequently educational organisations and NGOs, can also provide knowledge transfer and academic support for tool development and accreditation, and connections to potential buyers that bridge to implementation of the technology. This may be in the form of idea ‘incubator’ or business ‘accelerator’ programs, which can be delivered effectively online. Institutions looking to support capacity building for cardiac surgical care can do this indirectly, by committing resources to support the next generation of valuable technologies as they develop: an ‘investment’ in multiple forms.

Experimental: Developing technologies need to pilot their offering and synthesise evidence that answers initial concerns about safety and value. To achieve this, they need physical spaces and opportunities to pilot or test. This includes patient groups or clinical settings with which to repeatedly test how the technology functions with its future users, and evaluate whether it presents a solution to the original problem identified. Furthermore, it includes opportunities for peer review and multi-disciplinary working, with experts by experience and experts by study (Case Study 12). Again, institutions looking to drive capacity building need to commit to providing these opportunities for experimentation sustainably, and in tandem: for example, robust partnerships between educational organisations and healthcare providers.

Case Study 12: A multi-disciplinary approach to experimenting with frugal innovation

In the southern Indian state of Kerala in the 1980s, a group from the Sree Chitra Tirunal Medical Center decided to build their own tilting disc valve, to reduce the cost of procuring and importing valves [26]. However, as there were limited resources available, the group partnered with multiple organisations including the Indian Space Research Organisation, the South Indian Textile Research Association, and the National Aerospace Laboratory to develop and test their model of disc valves. Many of these partnerships were based on professional connections, goodwill, and a shared vision. Building and maintaining research partnerships with institutions from other fields and disciplines is vital, as medical technology is a multidisciplinary endeavour.

Regulatory: Once the development process begins to produce a viable technology, it is crucial that the right regulatory guidance is in place to support the transition to implementation. This is discussed further in the *Implementation* section.

32.3.7 Technology Implementation

A strong environment for technology development must be accompanied by similarly strong support for implementation, to deliver on promised positive impact for cardiac surgical care. At the same time, direct implementation of technology without an accompanying LMIC-based development phase will face significant challenges: the technology will not be able to adjust to the environment, causing issues with initiating and sustaining proper use of the tool (Table 32.5). These problems offer clues to how successful implementation can be facilitated, firstly at the accreditation and procurement stage, and secondly at the user uptake stage (Table 32.6).

Table 32.5 Potential issues with direct implementation

Accreditation and procurement	
Poor transferability of use case	Reduced cost-efficacy or cost-effectiveness decreases the willingness to pay from buyers; particularly without sufficient support with accreditation
Increased risk of harm	Different system architecture or procedures increase the risk of technology misuse or resulting harm; particularly without sufficient support with accreditation
Reduced opportunity to demonstrate utility	Technology is not easily discoverable, and / or not given the opportunity to demonstrate value
Lack of opportunity to apply the technology	Different system architecture or procedures prevent the need for the technology
User uptake	
Lack of necessary adjacent components	The technology cannot function well independent of other necessary but missing technologies or structures
Lack of user acceptability	Users not engaging well due to differences in practice
Lack of necessary users	Requirement from the technology for a sufficient quantity of skilled operators and/or maintenance

Table 32.6 Examples of technologies developed and implemented for cardiac surgical care

Stage	Example	More information
Community and diagnosis	Patient cardiac risk factor monitoring	Wearable sensors detect a patient's heart rate and send it directly to smartphones via mobile apps. While such technology has been developed, they are yet to be implemented effectively in an LMIC due to their cost, the level of knowledge required to operate them, and the cost required to maintain them [28].
	Clinician cardiac risk factor monitoring	*Himore Cardiopad* is a device that allows physicians to check patient ECG remotely through mobile networks. This cardiopad is slowly coming into practice, owing to its easy-to-use touchscreen interface, and robust structure that allows it to withstand humid conditions and shock from dropping, all of which are key characteristics in an LMIC setting [29].
Pre-operative	Communicating pre-operative requirements to patients	Patients can use the *Listeo* smartphone app to get information about pre-operative requirements and preparation. *Listeo* allows anaesthetists to upload personalised pre-operative requirements, and patients can access these securely through the app. This technology is still in its preliminary phase, undergoing randomized control trials. It will still undergo national studies and HTA assessment before it is widely adopted [30]
	Telemedicine	As parts of Switzerland are situated far from cardiac surgery centres, a group of researchers evaluated the use of telemedicine to diagnose and determine the correct surgical approach for patients requiring coronary angiography. Their results showed more than 90% of cases reaching the right diagnosis and surgical approach [31] Telemedicine has been widely adopted, especially during the Coronavirus-19 pandemic. However, there are limitations to telemedicine such as the literacy rates of patients, availability of telecommunication technology, or internet capabilities [32].
Intra-operative	Pulse oximetry	*Lifebox* is a leading NGO that supports safer surgery around the world. They deliver thousands of pulse oximeters to LMICs, and provide training and workshops to healthcare workers. The availability of pulse oximetry technology has allowed many surgical teams, including cardiac surgery to complete the WHO Surgical Safety Checklist and administer anaesthesia in a safe way to patients [33] 

(continued)

Table 32.6 (continued)

Stage	Example	More information
		© *Siriti/Lifebox* *Used with the permission of Lifebox.*
	Portable cardiac catheterisation	In 2013, researchers described a system of catheterization for LMICs that does not require the use of a catheterization lab. Using a C-arm X-ray system, portable ultrasound machine, guidewires, and catheters, the team demonstrated safe catheterization in 28 out of 30 patients, including paediatric patients. After this initial feasibility study, the next phase of implementation should demonstrate value compared to available gold-standard treatment [34].
Post-operative and follow-up	Community-based follow up with Community Health Workers (CHWs)	A study from 2018 examined the difference between delivering refresher training for CHWs, either via in-person workshops or via a low-cost tablet. They found that both media yielded equivalent scores on outcome measures around knowledge of the subject (in this case, pneumonia). However, the study noted concerns of technological literacy—one CHW said they did not feel comfortable voicing that they did not know how to use a tablet—and practicality—this included battery life and video buffering [35].
	Telemedicine	*Airmed-cardio* is a digital platform aimed at community-based follow-up for patients with chronic heart diseases. Patients were given portable recording equipment and a connected phone with the app. Cardiac data, including ECG, were collected and automatically transferred to the hospital database, where physicians could access it securely and use it to guide treatment [36].

32.3.8 Accreditation and Procurement

The specific accreditation and procurement processes for healthcare technologies in LMICs are variable and rapidly changing, and so beyond the scope of this chapter. The key to success for any technology in these domains however is a strong demonstration of safety and value. To identify safe technologies, perhaps the most important exercise, the potential harms, and adverse effects need to be identified and quantified. This is particularly important to maintain during periods of nascency or momentum in the field of health technology, true of both cardiac surgical care and many LMICs. To achieve this there is a need for resilient regulatory environments, coupled with a recognised accreditation if standards are reached. Blockchain is a technology that can be used for creating a transparent and legitimate record of this accreditation process.

Identifying technologies of value is ultimately a question of resource allocation, and health technology assessment (HTA) is a policy tool designed to help with this. HTA provides information regarding finite resource allocation for the achievement of UHC, through the form of evolving research, adaptive guidelines, and other forms of support. Institutionalised HTA should be central to the goal of using well-developed and well-implemented technology to improve cardiac surgical capacity. However, HTA capacity is lacking in many LMICs due to a lack of awareness and implementation on the part of policymakers and researchers.

Building HTA capacity demands the commitment of stakeholder resources, most notably from government actors, through HTA policy statements and road-maps, accessible funding, and well-supported case studies throughout the interim stages of development. HTA should aim to harness existing academic expertise and new collaboration between related disciplines, and take steps to reward resulting stakeholder engagement, scientific integrity, and accessible outputs from this work. This could include strong HTA partnerships between ministries of health and academic or educational institutions; the creation of transparent, high-quality databases to support evidence synthesis; and open-access educational tools for supporting calculations of value (e.g. cost-effectiveness and cost-utility). Much of this HTA capacity development mirrors the work required for facilitating technology development and implementation, and the two are likely symbiotic. HTA can also support the creation of accredited marketplaces for buyers to find—and indeed developers to share—technologies, as HTA can ensure a minimum level of safety and value (e.g. the NHS App Library). This would help both developers to find the market for their technologies and continue to improve them, and buyers to maximise the benefit to their patients (Case Study 12).

Case Study 13: Building Health Technology Assessment capacity in Ghana

In 2003, Ghana implemented its National Health Insurance scheme to achieve universal health coverage (UHC) [27]. To maintain sustainability, the Ghanian Ministry of Health (MoH) had to explore the development of Health Technology Assessment (HTA) tools. Developing HTA requires a strong cohort of available local expertise, as well as a large base of literature relevant to the area of healthcare where HTA is employed. With the help of the International Decision Support Initiative (iDSI), the MoH undertook: (1) an evaluation of the technical capacity required to undertake HTA; and (2) an HTA to examine the cost-effectiveness of treatments for hypertension.

The technical working group, assisted by experts from the UK, consisted of stakeholders from the MoH, the National Health Insurance Authority (NHIA), academics, clinicians, and NGO representatives. The multi-disciplinary collaboration within this group provided a strong bridge between academia and policy-making.

Many issues about the development of HTA for hypertension were identified during this work; for example, the key gaps in the academic literature relating to hypertension management. Tackling these kinds of issues requires the capacity development of public health researchers who can undertake, lead, synthesise and disseminate national studies on treatments. Short courses could also be conducted for policy-makers on how to interpret HTA results. Another key issue highlighted was the need for open communication between government and academia to allow for the appropriate setting of research priorities. The government of Ghana is looking to develop, institutionalise and integrate HTA into its national healthcare system, to inform national policy on care provision.

32.3.9 User Uptake

After accreditation and procurement, for users to begin using the technology, it needs to be 'found'. Ensuring that there is transparency and accessibility of the available technologies for healthcare practitioners and patients is key here, particularly in fields such as cardiac surgery whose service provision is developing too.

Once the technologies have been found, next they need to be used. There is a clear and immediate reliance on broader technological accessibility. These considerations are often involving wider health and infrastructure policy areas, and so beyond the scope of this chapter. Given the growing reliance on technology more broadly, the implementation should capitalise on the behaviours already established where possible to maximise the chances of sustainable uptake.

Beyond this, it is often challenging to identify why some technologies are used and some aren't. Growing academic fields, such as implementation science, are valuable when integrated into both the design and implementation processes. As discussed elsewhere in the chapter, this is aided by the education of developers in human-centred design processes (often via technology), and aided by proximity to the diverse community experiencing the problem that the technology solves (again facilitated by technology). Contributions to the growing body of implementation-related research should continue to include both the 'successes' and 'failures' of implementation, as they present a valuable resource to be learned from more widely, perhaps through sharing via online communities.

In some instances, there are clear limitations to a technology hindering successful implementation, including practical problems (e.g. issues with comprehension, or where training is required) and a lack of autonomy or trust in the users (e.g. CHWs for cardiac risk factor screening). This can be mitigated with human resource development in the form of eLearning modules or helpful online communities, as discussed earlier in the chapter. Additionally, the use of the technology needs to be sustained: this is where the supportive environment for technology and innovation is crucial. The technology and its users both need to be able to pivot, and integrate into the existing processes and systems for providing cardiac care.

Supplying the plethora of resources and support for technology development and implementation, justly and equitably, remains a significant challenge for all stakeholders, who themselves are significantly limited in capability. With limited resources to allocate, these stakeholders have to make decisions to identify which developing and implementable technologies are worthy of their support. The huge proliferation in technological solutions for healthcare demonstrates the momentum behind the growing sector, and how valued it is to the future of healthcare. These stakeholder decisions hold significance for the direction cardiac care takes as a sector and as a service, raising questions about health policy beyond the scope of this chapter.

As highlighted previously, the heterogeneity in the quality of existing support environments between LMICs creates an imbalance in what is achievable. Addressing this imbalance, and levelling up all environments for supporting technological development and implementation is a central challenge for delivering accessible and equitable cardiac surgical care supported by technology. This levelling up, and the introduction of new technologies to support cardiac care should not be to the detriment of existing healthcare provision, the perceived value of non-technological contributions, and broader vital missions, such as UHC.

Key recommendations

- Enhancing the contribution of technology to developing cardiac surgical capacity should involve significant support for, and using physical resources. This should focus on developing and implementing technologies that can provide direct improvements to cardiac surgical care, in addition to building valuable underlying environments for future innovation.
- The value of support can be understood by understanding the journey of technologies from an identified problem to a sustainably implemented solution, in two phases: development and implementation.
- Facilitating technology development successfully should include: connecting the developers with a range of stakeholders proximate to the problem who can provide unique insight, data, and access; foundational technological support; financial assistance; institutional validation; opportunities to experiment; and regulatory guidance.
- Technology implementation is most effective in tandem with development,

both to ensure that the value of technologies is maximised, and potential issues of direct implementation are minimised.

- The sustainable implementation relies on well-designed support structures and processes, and well-equipped individuals, throughout accreditation, procurement, and user uptake; health technology assessment (HTA) capacity should play a significant role.
- Examples of technologies developed and implemented for cardiac surgical care can be seen in Table 32.6.

32.4 Summary

Technology is growing to become an important factor in the delivery of healthcare services worldwide, across different areas of medicine and different environments. This change, seen by many as a pivotal transformation in improving healthcare for all, is building at a rapid pace; cardiac surgical care in LMICs is not, and should not be, an exception to this.

Technology offers a valuable role in building cardiac surgical capacity across the intertwined domains of human and physical resource development [37]. This is deliverable by improving care provision today, and by building innovative environments for the benefit of tomorrow's technology. Technology is increasingly powerful for improving the achievable standard of human resources through various innovative approaches and applications. Equally, technology can act as a powerful physical resource, and so the journey of precise development and sustainable implementation is deserving of significant resource investment. Despite the significant challenges to all stakeholders, across practicalities and ethics, policy, and practice, the future is compelling for the role of technology in cardiac surgery capacity development.

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37. See attached Summary Infographic.

33 Augmented, Virtual and Robotic Capabilities in Cardiovascular Program Capacity Building

Atul Gupta, Robert Metzke, Olesya Struk, and Aleksandra Popovic

Abstract

The role of technology in ecosystem partnerships is to augment local skills and capacity in health services delivery, and to better connect information and health professionals in a way that enables them to take on new roles to help each other. Technology over the past three decades has resulted in dramatic acceleration in the progression from open surgery to minimally invasive, image-guided therapy (IGT). Today, imaging technologies like X-ray and ultrasound allow real-time, in-body visualization of instruments and anatomy without the need for surgical incisions. These advancements coupled with the ongoing miniaturization of endovascular and percutaneous devices have allowed interventional physicians to perform procedures often without general anesthesia and via incisions no larger than a few millimeters. This results in patient recoveries measured in hours to days, rather than weeks as seen with traditional open surgical repairs. Reduced costs, faster recoveries and shortened hospitalization stays are powerful enablers towards capacity building, empowering hospitals to treat more patients per day. Still, new and different skills will be required for doctors, nurses and technologists to perform and support image-guided interventions and minimally invasive surgery and to operate the sophisticated imaging systems, medical devices, and implants that are the backbone of these procedures. This chapter will describe how technologies like extended reality and robotics can be enablers of capacity building in LMIC, if enabled by a strong ecosystem partnership.

Keywords

Extended reality · Robotics · Mixed reality · Augmented reality · Wearables · Image-guided therapy · Telehealth · Ecosystem · Philips · Education

33.1 Capacity Building as a Part of Overall Health System Strengthening

Capacity building is a critical component in the overall strength of a health system. Several trends have illustrated the urgent need for further acceleration in building system capacity including a perfect storm of an aging population, a growing population, and a sizable increase in chronic cardiovascular disease. Global pandemics over the past two decades, such as SARS and COVID-19, have further emphasized that hospitals and governments need to re-think the approach for capacity building.

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_33

Technology is a great enabler, and augmented, virtual and remote technologies along with robotics and AI will open new possibilities for medical education, infrastructure expansion and overall organization of the health services delivery. Done properly, this will also enable the quadruple aim of improved outcomes, improved patient and medical staff experience, and care delivery at lower cost for a community.

The role of technology in ecosystem partnerships is two-fold: (1) augmenting local skills and capacity in health services delivery, and (2) revolutionizing collaborations by connecting information and health professionals in a way that enables them to take on new roles to help each other.

Technology over the past three decades has resulted in dramatic acceleration in the progression from open surgery to minimally invasive, image-guided therapy (IGT). No longer does a physician need to surgically open the patient in order to physically see and touch the part of the body where repair is required. Today, imaging technologies like X-ray and ultrasound allow real-time, in-body visualization of instruments and anatomy without the need for surgical incisions. These advancements coupled with the ongoing miniaturization of endovascular and percutaneous devices such as balloons, catheters, and stents—have allowed interventional physicians such as cardiologists and surgeons to perform procedures as diverse as cardiac valve replacement, cardiac ablation for arrythmia, aortic aneurysm treatment, coronary artery angioplasty, stroke thrombectomy, and more—often without general anesthesia and via incisions no larger than a few millimeters in diameter. This results in patient recoveries measured in hours to days, rather than weeks as seen with traditional open surgical repairs.

Faster recoveries, shorter procedure times, improved outcomes, and reduced costs have resulted in widespread clinical acceptance of minimally invasive image-guided procedures. Furthermore, reduced recovery and hospitalization stay is a powerful enabler towards capacity building, empowering hospitals to treat more patients per day [1].

Still, new and different skills will be required for doctors, nurses and technologists to perform and support image-guided interventions and minimally invasive surgery and to operate the sophisticated imaging systems, medical devices, and implants that are the backbone of these procedures. This learning curve can pose challenges to fully utilize such technology.

Different technical infrastructure will also be required both within a hospital, but also between hospitals and outpatient clinics, to enable the communication and real-time data transfer needed for cardiovascular care and interventions. Furthermore, patient engagement, guidance and education are a critical part of this process. And ultimately, patients need to be supported by the health system to be aware they need a specific treatment, to be directed to the respective location to receive the surgery, and to be supported by a public health coverage to avoid financial hardship.

The above illustrates the complex interdependence and collaboration required between stakeholders, beyond just the health care providers. Integration across the health care continuum is paramount for capacity building. This means the local ecosystem must integrate elements across the complete cardiovascular patient journey pathway: from healthy living and disease prevention, to early diagnosis, to treatment, and then to recovery.

Another mechanism for capacity building relies on remotely connecting experts to local medical practitioners for medical training and also to deliver real-time support during a procedure (Fig. 33.1). Technology can play an important role here as well, especially when it is aimed to enhance skills of the providers. For example, Extended Reality can provide rich environments for safe and cost-effective education and learning of new procedures, it can provide an environment for intuitive digestion and interaction with information, and it can aid during the procedures through providing flexibility in workflow by virtualizing physical objects. Wearable technology can increase ability to connect to patients and improve data collection and follow up. Robotic technology has a promise

Fig. 33.1 Mixed Reality combined with telepresence can enable remote education and real-time support during the procedure

to improve skills of the surgeons and interventionalist and perform repetitive and risky tasks.

33.2 Examples of emerging technologies

33.2.1 Extended Reality

Extended Reality is a term referring to all applications combing virtual and physical environments. Virtual Reality (VR) refers to entirely computational environments where users can see, interact with, and otherwise experience virtual worlds. Although the first concepts of these environments have been demonstrated in the 1960s and the term has been in wide use since the 1980s, recent breakthroughs in miniaturization of electronics and optics and increase of computational power led to a 20-fold adoption of VR headsets in the last five years, both in consumer and professional use. In the context of this book chapter, we will refer to VR for the environments that are combing previously generated medical information (e.g., images, devices, animation, simulations), excluding environments that combine previously generated models with real-time, live data. Augmented Reality (AR) refers to environments where real-time world information is combined with previously generated virtual content. For example, Dynamic Coronary Roadmap is combining coronary 3D anatomy with live fluoroscopy images [2] or ClarifEye system combining the view of the surgical field generated by four high resolution cameras, with the internal 3D view of the patient to construct a 3D augmented-reality view of the patient's external and internal anatomy [3]. The SenitiAR [4] solution combines visualization of 3D electrophysiology mapping and device information with real-world interventional suite environment allowing the operator to control and manipulate models while preserving the view of their physical surroundings. Mixed Reality (MR) refers to environments where virtual, physical world are not only superimposed as in AR but are interacting with each other and with the user. For example, Philips' environment for interventional procedures allows an operator to control both virtual objects (holograms) and physical objects (imaging system and devices) using mixed reality user interfaces (Fig. 33.2), such as eye gaze and gestures [5].

Fig. 33.2 Mixed reality will integrate photorealistic anatomic holography to improve perception of anatomy, and will allow for more intuitive controls of the medical equipment by using voice, gaze and gesture

Extended Reality can be delivered to the operator through screens, user consoles, or wearable devices. Although Extended Reality is usually associated with wearable technology in the consumer world, a broader definition is more suitable for healthcare since many use cases can are translatable and applicable to different delivery methods. For example, an environment for surgery planning or training can be delivered through a traditional or a stereoscopic screen and standard user interfaces (touchscreen, mouse, keyboard), but it can also be delivered through a wearable VR headset (e.g., Oculus Quest or HTC Vive). Although wearable VR headsets provide the user with richer visualization, more realistic spatial perception, and more natural user interaction, traditional delivery can provide flexibility in location and time of use and allow sharing of with users without access to a wearable device. Augmented Reality can be delivered through superimposing information on the screen (e.g., ClarifEye, HoloSurgical), through a stereoscopic console-based system (e.g., da Vinci robot console), or through a wearable headset (e.g., SentiAR). Mixed Reality is typically delivered through a wearable headset (e.g., Microsoft Hololens or Magic Leap ML1) allowing both intuitive visualization of 3D objects and immersive control in the physical and virtual space.

33.2.1.1 Extended Reality in Education and Training

Extended Reality has a potential to transform the way education and training is delivered to medical students, physicians, patient, and caregivers [6]. For medical students, Extended Reality environments can provide affordable access to rich 3D anatomical information allowing interaction with the human body, practice procedures, share information with teachers and peers. Compared to physical simulators and cadavers, Extended Reality environments tend to be significantly more affordable, allow flexible content for different types of trainees, and can be customized for specific learning objectives. In addition, recent study demonstrated a significant improvement of ability to understand relative 3D position of anatomical structures in a VR group compared to a paper-based learning [7]. Some universities are routinely applying Extended

Reality in their curriculum, for example, HoloAnatomy software developed by Case Western Reserve University uses Mixed Reality (with Microsoft Hololens 2) to combine natural classroom environment with virtual 3D anatomical objects in a collaborative fashion [8].

In the future, a digital twin of the patient [9], representing anatomy, physiological processes, and disease states with dynamic capabilities to realistically adopt to therapy, in combination with Extended Reality, can provide environment to safely learn all aspects of patient care. For physicians, Extended Reality provides a safe and affordable environment to practice new procedures and use new tools and devices. OssoVR is developed as a virtual environment for practicing orthopedic surgical procedures, with recent expansion into structural heart procedures. An example of hybrid approach is Mentice VIST combining physical simulators of interventional procedures and virtual representations of images and devices delivered through traditional screens or wearable AR, depending on the user's preference and training objectives. Liebig et al. [10] demonstrate feasibility of hybrid physical and VR simulator to improve the learning curve of endovascular procedures (mechanical thrombectomy) using patient CT data.

Extended Reality can enhance patient and caregiver experience and alleviate anxiety before and during cardiac procedures by providing a new way to learn about the procedure and interact with physicians. For example, Project Brave Heart at Stanford Lucile Packard Children's Hospital aims to reduce anxiety in pediatric cardiology patients through a VR experience that includes education about the procedure and practicing techniques for relaxation during the procedure [11]. Patients and their families were given VR headsets and software to take home and use the headset at their convenience. A recent study by Hooglugt et al. [12] demonstrated significant reduction of pre-procedural anxiety using psychological evaluation in adult patient undergoing cardiac procedures (PFO and ASD closure) using VR experience to understand the procedure compared to a control group receiving a standard pre-procedural education. Furthermore, they demonstrated a significantly shorter anesthesia time in the VR group, indicating that lower anxiety can reduce procedure time.

33.2.1.2 Extended Reality for Surgical and Interventional Procedures

Extended Reality has a potential to provide intuitive viewing and interaction with 3D patient data and allow hands free, immersive control of the data and the environment. As a consequence, the use of Extended Reality technology in cardiac care has first emerged in the space of planning and performing interventional and surgical procedures.

The Extended Reality technology has a potential to improve experience and accuracy of viewing and interpreting 3D images through holograms for pre-procedural viewing and planning. Brun et al. [13] validated the use of Mixed Reality for visualization of CTA images in congenital heart patients demonstrating that 3D experience contributed to better understanding of complex heart anatomy. Dutcher et al. [14] conducted a prospective study of use of EchoPixel VR technology for CT image visualization, manipulation, and measurements in patient undergoing left atrial appendage occlusion procedure. The VR-based pre-procedural planning was associated with a reduction of procedure time and led to a greater accuracy of WATCHMAN device selection compared to a control group undergoing only the 3D-TEE imaging.

During minimally invasive procedures, the interventional team uses rich sources of information, such as 2D and 3D images, planning data, device information, physiological data, and demographic patient data. Augmented and Mixed Reality can improve staff experience while viewing and interacting with the data compared to traditional screens and input devices while preserving visual contact with the physical world and each other [1]. For example, SentiAR [4] application for electrophysiology procedures provides interventional staff with a set of tools to visualize 3D data from commercially available electrophysiology mapping systems as 3D holograms that are manipulated with hands-free Mixed Reality interface, such as gesture and eye-gaze. The staff can share holograms in a collaborative environment, either by taking their unique view of the model or by assuming the same viewing direction to discuss the anatomy for planning or educational purposes. Philips' Augmented Reality concept, built for Hololens 2 [5], integrates data sources and presents it in an Extended Reality environment tailored to the needs of the user, allowing flexible placement of screens (floating or attached to physical world), viewing and interaction with 3D holograms, and hands-free system control using gestures and eye-gaze. The virtual screens are not subject to space limitations and issues that can arise in use of traditional screens (glare, obstruction, dirt). Mixed reality controls, that combine virtual and physical world allow workflow and are not restricting positioning of the care team to specific locations in the interventional suite. The content and interactions can be shared within the interventional team, with a future option for telepresence and remote proctoring.

33.2.1.3 Robotics in Cardiovascular Care

Robotic technology has been in use in different surgical disciplines including cardiovascular surgery and radiotherapy since the early 1990s. In recent years, new application fields for robotics emerged, particularly in diagnostics, rehabilitation, and hospital services. In general terms, a robot is a machine designed to perform tasks automatically. In medicine, the controller/responder architecture [15] is the most commonly used implementation of the robotic technology with the operator in a closed-loop control of the tasks performed by the robot. Da Vinci robot is an example of this architecture, with surgeon, using a console with immersive 3D viewing and physical input interfaces, controlling robotic arms (responders) simultaneously.

Another common interaction architecture of robotic technology in medicine is collaborative control, where the operator and the robot collaborate to perform tasks. MAKO robot for joint replacement surgery guides the surgeon to perform the cuts precisely based on the pre-procedural plan, while still being in control of the surgical instruments. During the last decade, autonomous robotics, where robots are performing tasks without a direct human supervision have found a wide adoption, especially in manufacturing and self-driving cars, in medicine, autonomous robot architectures are in their infancy. Autonomous robots have been demonstrated in low-risk scenarios, such as UV disinfection robots (e.g., Ubtech ADIBOT) or mobile robots for materials and clinical supplies in hospitals (e.g., Aethon TUG).

The da Vinci Surgical System is, as of 2021, the only robotic surgical system approved by the United States Food and Drug Administration (FDA) for cardiac surgery. Since the first procedure performed in 1996, robotic-assisted mitral valve surgery remains the most commonly performed procedure using robotic technology [16]. This approach provides surgeon with advanced 3D visualization and enhanced dexterity by robotically mimicking hand-like movement in minimally invasive surgery. Limitations include cost, complexity, and access to specialty tools in combination with the robot [17]. In interventional cardiology, the robotic technology is used to precisely control interventional devices, e.g., catheters, guidewires, balloons, and catheters [16]. Past and current interventional robots are designed in controller/responder architecture, with interventionalist operating the robot from a console with joystick-like interfaces. Examples include Genesis and Sensei robots for ablation therapy for atrial fibrillation, Corpath GRX and Robocath for percutaneous coronary interventions. The robotic assistance allows interventionalist to perform the procedure from a safe distance reducing radiation dose to operators. In addition, robotic control improves stability of the catheter [18].

Diagnostic uses of robotic technology in healthcare and cardiovascular care is an emerging field. Adams et al. [19] describe a prospective study of eight patients undergoing adult abdominal sonography using MELODY robotic system, demonstrating no significant difference in measurements of liver, spleen, and proximal aorta between robotic and control groups. Sengupta et al. [20] show feasibility of a long-distance, robotic echocadiolography exam.

As a result of COVID-19 pandemic, the use of robotics in healthcare has accelerated [21] providing more efficient and safe mode of interaction with people and spaces, especially in domains of disinfection and logistics. For example, robots equipped with ultraviolet surface disinfection have demonstrated effective reduction of viable load of SARS-CoV-2 [22]. At the Medstar Washington Hospital, mobile delivery robots are used to deliver linens and medicines [23].

33.3 Acceleration of Technology Adoption for Capacity Building During Pandemic

The COVID-19 crisis has had the unintended effect of acting as a major accelerator of digital health technology to build capacity and to maintain or even enhance care delivery. Around the world, we saw the value of collaboration as overburdened hospitals struggled for ways to transfer patients with cardiovascular conditions to where they could still get the specialized therapy they need.

In the US, certain procedures were moved to outpatient settings such as office-based labs and ambulatory surgery centers (Fig. 33.3). These facilities, which have been growing in number for over a decade, have helped to offload hospitals while offering an alternative for patients who would otherwise suffer from a delay in care. It can bring care closer to the patient, and the rapid technologic developments in minimally invasive cardiovascular interventions are destined to further enable procedural care in remote out-of-hospital settings. This shift to outpatient settings is actually not a new development. Over the past years, the US Centers for Medicare & Medicaid Services (CMS) have set the stage for it through reimbursement policies that promote the performance of certain procedures in outpatient settings. In 2020 CMS announced sweeping regulatory changes under the Hospital Without Walls program, making it easier for US hospitals to transfer patients to outpatient settings or to set up their own ambulatory surgery centers [24]. This illustrates the need for close cooperation between payors, governments, hospitals and industry.

Bringing care closer to the patient is also being enabled through virtual digital tools. Project ATLAS (Accessing Telehealth through Local Area Stations) is part of the US Veterans Administration (VA) telehealth initiative [25], which sets out to better serve the nearly 9 million Veterans who receive care through VA including 4.7 million who live in remote, rural locations. This partnership between the VA and Philips uses telemedicine and wearables to enhance underserved veterans' access to health care. It brings together remote patient monitoring solutions including WiFi-enabled electronic scales, blood pressure cuffs, thermometers and pulse oximeters—all linked to a secure, high-speed internet connection. ATLAS sites aim to make health-care delivery safer and more efficient by offering convenient locations to receive care closer to home, thereby reducing obstacles such as long travel times and poor internet connectivity at home. Geographic and digital divides are not unique to the US, and these types of digital tools can be used in underserved regions around the globe.

With telehealth moving from novelty to necessity and being embraced by patients and physicians alike, it appears we won't go back to how we did things before. Like many other disciplines in healthcare, interventional physicians have transitioned to virtual ways of staying in touch with patients and with each other. In fact, the US VA saw over 1,000% increase in video visits from March to June of 2020 and an exponential increase in demand for telehealth appointments [26].

As more devices are connected, wearable and implantable devices will be able to generate robust and large quantities of data streams. This is transforming the concept of "telehealth" or remote patient management. Clearly this can improve access to care.

Fig. 33.3 Office based labs have helped expand access to care by bringing select minimally invasive procedures out of the hospital, and closer to patients. During the pandemic these helped offload hospitals, preserving valuable resources for the critically ill

Connected devices and wearables are driving transformations in care delivery across multiple specialty areas. However, where we used to be able to collect only disparate or episodic data points (weight, blood pressure, heart rate, oxygen saturation, sleep, and EKG data) across different systems, a platform integrating the comprehensive combination of todays and also tomorrow's connected devices, coupled with the global ubiquity of smart phones, and supported by cloud-based computing will be transformative towards turning health data into actionable therapy.

Healthcare workers also are relying on virtualization for education and peer-to-peer collaboration. For example, technology accelerated by COVID19 lockdowns allowed Philips to digitally stream in clinical application specialists into the interventional suites and operating rooms to provide interventional cardiology physicians real-time support during PCI procedures. Advances in virtualization enabled physicians to test-drive and learn how to use Philips interventional systems from continents away, using mobile robots with cameras and cloud-based simulators (Fig. 33.4). Wearing a head-mounted display, physicians will be able to share what they are seeing in real-time and consult their peers for advice as they are operating on a patient. These tools will help bridge physical distances with virtual solutions.

33.4 Technology Coupled with Ecosystem Partnerships

Technology in combination with ecosystem partnerships is an emerging approach for capacity building in cardiovascular programs. An ecosystem for capacity strengthening is a community with organizations and actors, in combination with technology elements, which operates as a large alternative organization. It has a need for coordination, modularity, collaboration and flexibility. In cardiovascular program to strengthen capacity such components should include, infrastructure environments, care delivery models, medicine, supplies and technology, education and training systems and community engagement. Ecosystem operation requires an

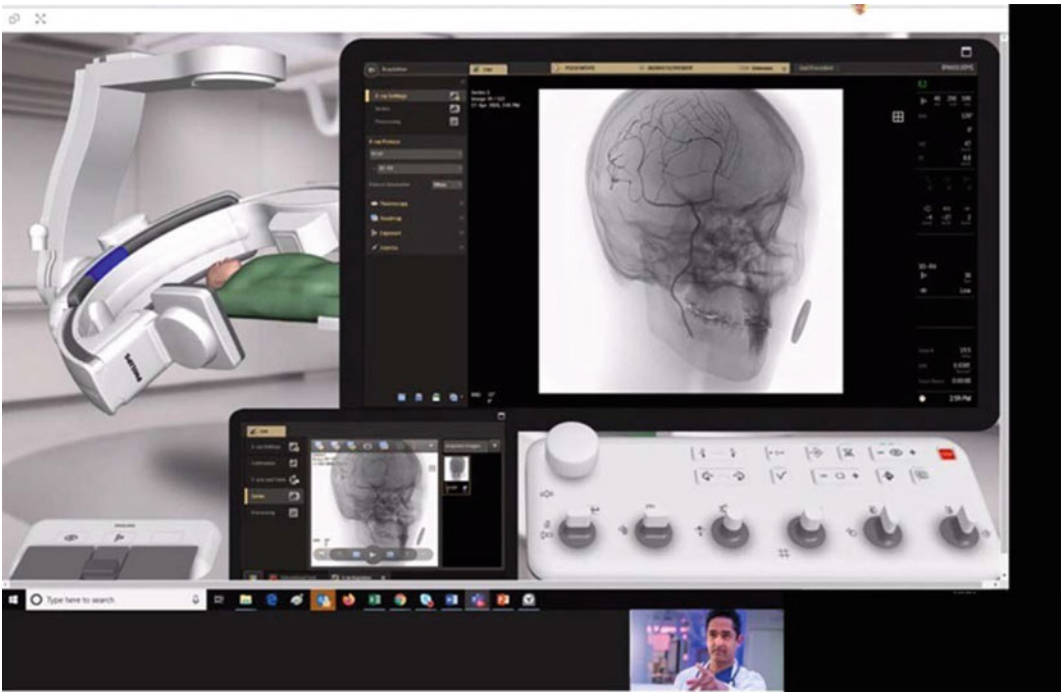

Fig. 33.4 Advances in virtualization enabled physicians to test-drive and learn how to use Philips interventional systems from continents away, using cloud-based simulators

innovative and open mindset, on the contrary to a linear and centralized organization traditionally implied by a program. Final integrated solution is more complex than any individual participant could provide. Ecosystems should mobilize and incentivize its participants. Ecosystem members have a platform to connect with each other and to collaborate on. Together with governance principles, such platform is a key enabler to deliver on an ultimate ecosystem goal. Ecosystems can operate on different levels, and their goals can vary on strategy vs. implementation ratio: international level that often provides strategic guidance and tools, technology level that is mostly implementation focused, and national or regional program level that can be both.

On an international level, with the growing role of digital and connected technology, ecosystems of public and private players are helpful or capacity building strategies. For example, health tech company Philips, NGO PharmAccess and impact consulting Dalberg has founded an ecosystem collaboration platform Digital Connected Care Coalition (DCCC). The DCCC is growing multi-stakeholder collaborative—including private companies, investors, social entrepreneurs, academia and non-governmental organizations—that works in the health space in LMIC. It focuses on promoting synergistic actions across sectors, learning for scale to accelerate the digital transformation of healthcare to achieve universal health coverage. It operates in a neutral, inclusive, collaborative, open and transparent way, and forms tailored action groups around key challenges to achieve the milestones set out for 2020, 2025 and beyond. The members' benefits are shared investments and risks, network, and access to knowledge and learnings.

A main challenge in leveraging technology for capacity building is implementation. While most low- and middle-income countries have national health agenda and in most cases also digital health strategy, the competences, skills, resources, financing and governance needed to achieve this are often limited. Challenges for the successful implementation include scalability, replicability, lack of scientific evidence to prove impact and deliver results, information fragmentation, interoperability, workforce, limited regulation and unsustainable funding. Such ecosystem brings common vision, knowledge and marketplace for collaborations, and is united around the common goal to achieve UHC2030, working with one common framework e-health of ITU/WHO and is connecting via the DCCC collaboration platform. By defining a country and a health space of focus like cardiovascular health space in India, the international ecosystem can fuel a local ecosystem creation by pulling international stakeholders and contributors and leveraging global resources.

A project or program ecosystem for capacity building is project ECHO that has a mission is to democratize implementation of best practices for healthcare to underserved people all over the world [27]. It started as a free, educational model and mentored community providers across New Mexico in how to treat the condition. The project ECHO grew into an international, scalable telehealth platform to educate health practitioners by peers and experts and to help them with patient cases remotely. For example, in India, the project has over 35 active hubs in 11 states, in each one in collaboration with a local ecosystem, and with a clinical focus aligned with the local community and government needs.

A networked technology ecosystem is an organization around a scalable technology platform or solution. One of its archetypes in an enhanced (digitized) solution ecosystem that creates a (digital) network of complementary around an existing core product to enhance its functionalities and create connectedness.

For example, a portable ultrasound Lumify by Philips connects to a Reacts collaborative platform (Fig. 33.5). Leveraging innovative technologies, such as Augmented Reality, for remote virtual guidance, supervision and training, this platform provides unique interactive tools designed to meet the multi-faceted collaborative needs of healthcare professionals and patients. The Reacts platform has already been deployed in more than 80 countries, across various disciplines in both clinical and educational settings. It allows healthcare professionals to interact remotely and dynamically in a wide range of applications, from teleconsultations, secure messaging, remote wound care and tele-ultrasound, to interactive telesurgical assistance

Fig. 33.5 Midwives at rural health clinics in Kenya can now conduct basic ultrasound exams on pregnant women and share data remotely for global virtual collaboration, using Philips Lumify powered by Reacts

and remote procedure supervision. Lumify with Reacts can provide valuable diagnostic insight for front-line care providers to manage COVID-19-related lung and cardiac complications. Moreover, by enabling remote communication, Reacts reduces the need for physical interaction and can therefore help minimize the risk of virus transmission for medical teams. During the COVID-19 pandemic, Philips has also successfully piloted Reacts to provide case support during image-guided therapy procedures, remotely assisting clinicians as they diagnose and treat patients with coronary artery disease and other cardiovascular diseases.

With the help of technology, capacity building can be performed rapidly, if enabled by a strong ecosystem partnership. Key success factors of such partnerships are a government's endorsement, community involvement, accessible and appropriate technology applications, as well as a strong collaboration platform and governance.

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34 Establishing National Telehealth Service in a Lower Middle-Income Country—the Ghana Model

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Abstract

Telehealth can contribute to achieving Universal Health Coverage by improving access to quality, cost-effective, health services wherever they may be. Telehealth offers the opportunity to provide comprehensive, accessible, available and affordable curative, preventive and wellness promotion services to populations irrespective of their location within a country. When adequately leveraged, telemedicine can provide the platform for driving the development of innovative programs to improve primary health care in Ghana and other Lower- and middle-income countries (LMIC). The Ghana Telemedicine Program (GTP), which is one of the successful telemedicine projects in Ghana, is currently deployed in six (6) regions in Ghana with a potential reach of six (6) million citizens, started as a pilot implemention by the Millennium Villages Project (MVP) in the Amansie West District of the Ashanti Region in 2011. The GTP uses Information and Communications Technology (ICT) to connect community health workers to medical specialists via 24-h teleconsultation centers. Doctors, nurses and midwives in the teleconsultation centers coach community health workers and advise on the treatment of their patients for a specified range of service. The GTP strengthened healthcare capacity and empowered community health workers; it also helped improved quality of care, avoiding unnecessary referrals by 31% and reducing transport times and costs for patients. While the current design of the Ghana Telemedicine Project is aimed at improving access for rural and last mile dwellers, it has inadvertently cut out many middle-class and urban dwellers who also need access to various telemedicine services; such as counselling on infant feeding or breast-feeding counseling, medication adherence guidance, triaging and consumer health information among others. An expanded equitable telehealth reaching all segments of the society presents a good opportunity to contribute to Ghana meeting the WHO Primary Health Care (PHC) elements that include (i) meeting people's needs through comprehensive and integrated health services and (ii) empowering individuals, families and communities to optimize their health as key advocates, as co-developers of health services and self-carers

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_34

and caregivers. The current Ghana Telemedicine Project is being upgraded to a full telehealth service to include (i) community health worker (CHN) telementoring service are (ii) Direct Telehealth Service accessible to the population (iii) Referral Management (iv) Training (eLearning Delivery platform). The modalities for delivering these telehealth services will include Synchronous, Asynchronous and Remote Monitoring and with patrons will be able to access telehealth services using voice, text (messaging such as WhatsApp), images and video technologies built on both mobile telephony and internet technologies. As part of the implementation open source technologies such as asterisk call center suite will be deployed. A telemedicine suit of applications that includes electronic medical records system, machine learning and artificial intelligence tools and an integration solution will be also be deployed to provide the technology platform to support the Ghana Telehealth Service.

Keywords

Telemedicine · Telehealth · Ghana · Community health nurses · Telementoring · Direct telehealth service · Data science · Synchronous and asynchronous platforms · Remote monitoring

34.1 Definition

Telehealth is the "delivery of health care services, where patients (mediated by CHN or direct) and providers are separated by distance [1, 2]. The provision of the service is either (i) direct, involving the patient and the healthcare worker [3] or could be (ii) between the patient and healthcare specialist through the mediation of another health professional [4]. Telehealth uses ICT for the exchange of information for the diagnosis and treatment of diseases and injuries, research and evaluation, and for the continuing education of health professionals.

There are number of categories when it comes to the Telemedicine applications [5, 6]:

1. The first asynchronous store-and-forward in which clinical information for non-emergencies are stored and sent to a specialist for diagnosis and prescriptions at convenient times. This involves the use of various technology solutions and typical specialties they are used include diagnostics, referral management, seeking secondary opinions among others [7].
2. The second is the synchronous interactive encounter, usually a consultation involving a patient interacting with a specialist health worker either directly or through the mediation of another health worker, who has limited capacity to provide care. Services are provided in real-time using telephony (usually mobile) and the internet involving the use of text/messaging, voice, video and other multimedia [8].
3. The third is remote monitoring, which helps the medical specialist monitor the condition of a patient using various devices remotely. These devices include various wearables used especially in cardiology [9].

Though used interchangeably telehealth and telemedicine are not the same, telehealth is a superset of telemedicine [10]. While the focus of telemedicine is on the curative and involve the provision of remote clinical services such as consultation, diagnosis, treatment and transfer of medical data [11], telehealth involves preventive, promotive in addition to the curative and usually include non-clinical services such as training and administrative procedures [12] such supportive supervision, monitoring and mentoring.

Telehealth can contribute to achieving Universal Health Coverage by improving access to quality, cost-effective, health services wherever they may be [13]. Telehealth offers the opportunity to provide comprehensive, accessible, available and affordable curative, preventive and wellness promotion services. There have been a number of telemedicine implementations in Ghana; these include the Vodafone Healthline, Ghana Telemedicine project and other small telemedicine initiatives with varying degrees of success.

34.2 Case Study One

34.2.1 Ghana Telemedicine Project (GTP)

The Ghana telemedicine program started as a pilot project implemented by the millennium villages project (MVP) in the Amansie West District of the Ashanti Region in 2011, covering 30 communities of about 35,000 people. The Novartis Foundation worked with local and international partners on the pilot model. The GTP uses information and communications technology (ICT) to connect community health workers to medical specialists via 24-h teleconsultation centers. Doctors, nurses and midwives in the teleconsultation centers coach community health workers and advise on the treatment of their patients, helping them manage emergency cases that are beyond their capacity and avoiding unnecessary referrals using protocols that are converted into structured step by step guides. The telemedicine program strengthened healthcare capacity and empowered community health workers; it also helped improved quality of care, avoiding unnecessary referrals and reducing transport times and costs for patients [14].

The successful implementation and scale up of the Ghana Telemedicine project have demonstrated that 31% of referrals can be prevented via the deployment of teleconsultation services alone. Also, through the GTP CHN mentoring became relatively easy to perform. Based on the pilot's success, the Ghana Health Service selected it for implementation across the Ghana in 2016. The Novartis Foundation worked with the Ghana Health Service and Ministry of Health on a roadmap for scale-up, then set up and staffed six teleconsultation centers across the country to support the objective of reaching national telemedicine coverage.

Components of the Ghana Telemedicine Project (GTP)

The Ghana telemedicine [15] project has a number of components working in tandem to deliver the teleconsultation service. These components include:

- **Hardware infrastructure** forms an essential component of the Ghana Telemedicine Project. It involve the acquisition of a mixture of open market and special proprietary hardware equipment that includes: IP Phones, VoIP GSM devices, computers, networking equipment, power backups, mobile phones and hands-free gadgets.
- **Software solutions** are also another critical component of the Ghana Telemedicine Project. This includes the IP PBX system built on top of the Asterisk open source project. The Ghana telemedicine platform also had a client SMS based app called childcount [16] + that made use of SMS communication and could run on a feature phone (not smartphones). What was missing was a teleconsultation records system; so teleconsultations clinical data were captured using paper-based systems.
- **Connectivity** involved the use of mobile internet provided by the telecom companies in Ghana.
- **Clinical protocols and guidelines were** developed and extensively used to provide step by step guidance for all calls to ensure the provision of consistent diagnostics and treatment services to CHNs who call the teleconsultation centers for assistance. These guidelines were however limited to common conditions and were also paper based (Fig. 34.1).

34.2.1.1 Workflow of GTP

Range of Services Available Under the GTP

Under the Ghana Telemedicine Project (GTP), the range of services was limited to counseling and mentoring on how to manage a limited set of conditions for which protocols were developed. These protocols were restricted to only CHN mediated voice calls with no opportunity for patients to seek care directly. The list of conditions, for which step by step protocols and guidelines have been developed are:

1. Antepartum Hemorrhage
2. Post-partum Hemorrhage
3. Pregnancy induced hypertension

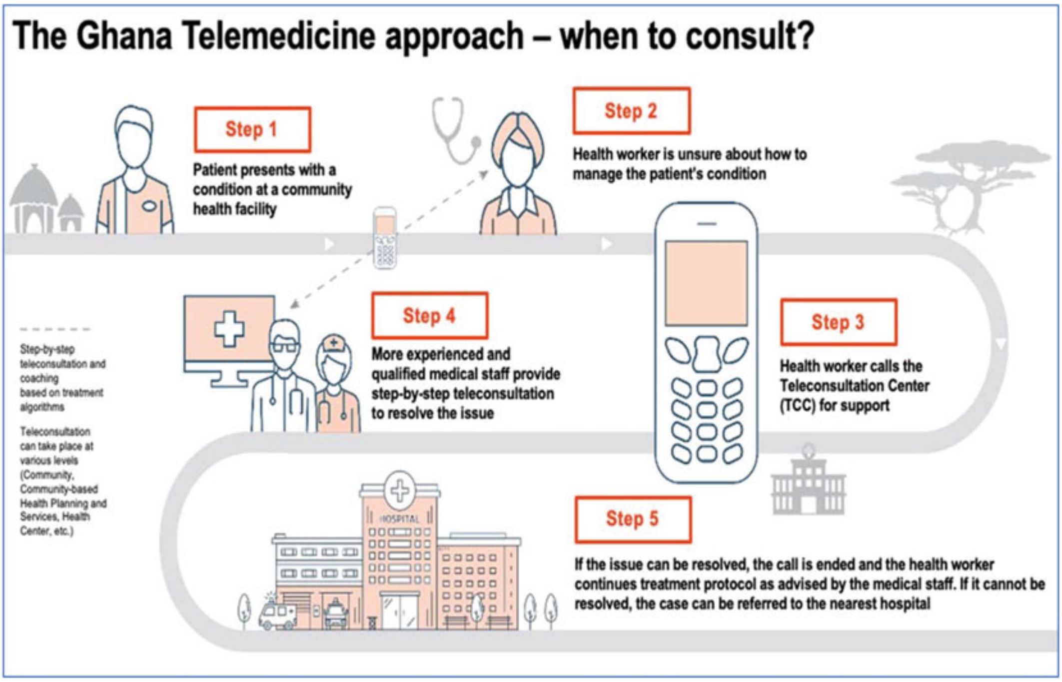

Fig. 34.1 Workflow for Ghana Telemedicine. *Source* Interactive Ghana Telemedicine Toolkit with kind permission from Novartis Foundation

4. Diarrhea diseases
5. Cough management
6. Fever management
7. Public health reporting

34.2.1.2 Opportunities for Increased Access

There is evidence from the data that the Ghana Telemedicine project has chalked some successes leading to the scale up of the TCC services to six (6) regions and potentially reaching a population of 6 million, with, even the limited range of services. Extending the national scale-up to all regions have the potential to further increase the reach and make telemedicine services available to all Ghanaians. This also has the potential to provide some essential services to large sections of Ghanaians, especially now that health facilities have had to reconfigure their operations in response to the global COVID-19 pandemic.

An expanded telehealth program presents a good opportunity to contribute to meeting at least two of the elements of the PHC identified by the WHO [17], i.e. meeting people's needs through comprehensive and integrated health services and empowering individuals, families and communities to optimize their health as key advocates, as codevelopers of health services and self-carers and caregivers.

While the current design of the Ghana Telemedicine Project is aimed at improving access for rural and last mile dwellers, the truth the of the matter is they are not the only citizens with access challenges. There are many middle-class and urban dwellers who, at many times, need access to various telehealth services e.g. counsel on infant feeding or breast-feeding counseling, medication adherence guidance, triaging and health information among others; who can equally benefit from telehealth services. Unfortunately, the current design of the Ghana Telemedicine Project prevents such persons from accessing critical services thereby creating equity issues regarding access to telemedicine services.

Again, the current technology design of the GTP is minimal, using voice communication with no automation or chatbots to offer unattended automated access to context relevant health information and counseling services. The guidelines and protocols developed for the GTP are all paper based and thus require the intervention of CHN for a teleconsultation encounter to be completed. Meanwhile, telemedicine offers the opportunity to integrate safe computer mediated telehealth counseling, consumer health information and AI mediated service delivery capable of being delivered to a large population with little or no requirement for additional staffing.

It is on the basis of the opportunities presented above that the program for the scale up of the current implementation with the setup of a National Telemedicine Center that is capable of providing telehealth services across all regions is being implemented. The high smartphone and internet penetration [18] in Ghana currently and the technology savviness among the populations have created the right environment for the upgrade of the current Teleconsultation Centers (TCC) into an upgraded Ghana Telehealth Service.

> While Ghanaians in rural areas with limited infrastructure and connectivity face greater challenges to access healthcare, the truth is that they are not the only Ghanaians who are in need of telehealth services, and who can benefit from upgrading TCC into a full Telehealth Service.

34.2.2 GHS Telehealth Program

The Ghana Health Service Telehealth Program will continue the scale up of the teleconsultation center to provide telehealth services to all regions in Ghana. After that, the TCC shall be strengthened to gradually provide an upgraded telehealth services to the people of Ghana. The telehealth service will target primary health care in both rural and urban areas. The focus of the telehealth project is two-fold

1. System Strengthening
2. Service Delivery

34.2.2.1 System Strengthening Using Ghana Telehealth Services

The telehealth service is being designed to support the Ghana Health Service current strategy of setting up a network of practice where model health centers will be established and linked with surrounding facilities within subdistricts. Under the network of practice model, staff at the spokes shall seek mentoring support from peers and also from the hub. Specialist and scare resources for service delivery shall be shared using a telehealth platform. Some of these services shall include teleradiology, telecardiology and related matters. Telehealth technology solution for the model health center hubs and the spokes.

34.2.2.2 Service Delivery Using Ghana Telehealth Services

The services will be accessed by citizens either

1. Community health nurse (CHN) mediation (Provider-to-Provider telehealth) or
2. Directly using telephone and Internet connection (Patient-to-Provider telehealth).

The aim for strengthening and upgrading the GHS telemedicine project into a full telehealth service is to increase the reach of telehealth services to a larger segment of Ghanaians beyond those who access the service via CHNs, and making available to them services which they hitherto had difficulty accessing either because of remote location, lack of provision or overcrowded health facilities.

The objective of the upgrade of the TCC into a full Telehealth Services are:

1. Improve the operations of the CHN mediated teleconsultation service to include:
   a. Mentoring of CHN in service delivery
   b. Expand and support the delivery of essential health services using concepts such task shifting, integrated supportive supervision and others.

2. Extend telehealth service directly to the Ghanaians using Internet and mobile telephony.

34.2.2.3 Components and Range of Telehealth Services

The telehealth program shall have four arms

1. Community Health Worker Mediated Teleconsultation arm
2. Direct Telehealth Service arm
3. Referral Management arm
4. Training (eLearning delivery platform) arm (Fig. 34.2)

34.2.3 Key Projects Under Ghana Telehealth Program

There a number of interventions that will need to be undertaken to upgrade and continue the scaleup of the Ghana Telemedicine project into a full-scale **Telehealth Service**. These include both ICT and non-ICT (clinical and administrative) interventions that is expected to make telehealth service ubiquitous and available all over Ghana. The interventions include

1. Scaling of Teleconsultation Services across all regions
2. Upgrade of the current teleconsultation Service Telehealth Service through the
   1. Implementation of Technologies for Telehealth Service Delivery
   2. Integration/Interface with Health information exchange to share data with facility EMRs and community based mHealth systems
   3. Development of comprehensive telehealth protocols, care guidelines and procedures development project
   4. Implementation of a digital decision support system to support telehealth care

3. Framework for Telehealth operations research and development with M&E

34.2.3.1 Modalities for Telehealth Service Delivery

The upgrade of the TCC into Telehealth Service will be done gradually and incrementally and

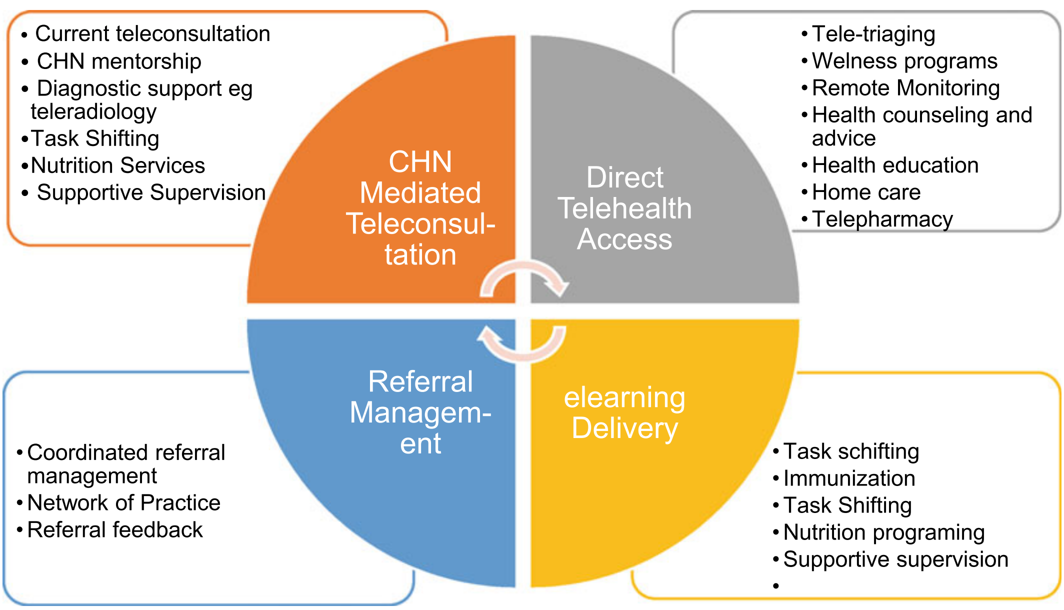

Fig. 34.2 Components of the upgraded Ghana telehealth service

will involve a move from the telephony-based (voice and SMS) methods of accessing telehealth services to include the use of Internet (Fig. 34.3).

Under the new telehealth services clients will access healthcare using text, voice, images and videos under both low and high bandwidth connectivity environments.

The modalities for delivering telehealth services will be through the use of synchronous and asynchronous communications and will also involve the use of remote monitoring technologies [19] (Fig. 34.4).

34.2.3.2 Upgrade Implementation

The upgrade implementation will go through the following iterative stages

1. Pilot of direct Telehealth service
    1. Design telehealth service using design thinking and service design principles and metrics.
    2. Implement technology solution using available technologies such mHealth and other digital health technologies.
    3. Implement initial phase as a pilot using implementation science methodologies to learn lessons for rollout to the remaining TCCs.
2. Evaluation
3. Scale up by integrating new Telehealth with Teleconsultation centers (Fig. 34.5)

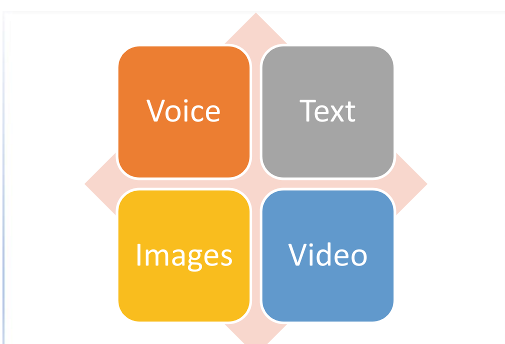

Fig. 34.3 Telehealth access methods

34.2.3.3 Implementation of Telehealth Service Delivery Technology Upgrade

Telehealth services run on a robust technology backbone and to ensure effectiveness and results, a suite of technologies rather than a single software app should be used to implement the technology backbone for any telehealth service. In Ghana, this suite will include open source software applications and also proprietary software systems. This software suite runs on a backbone that has both special and general hardware equipment as part of the technology suite. Two general groups of systems will be used, i.e. the main telehealth technology platform with APIs that enable relevant client apps to connect leveraging the various modalities for exchanging patient data during a telehealth encounter. Also included in the stack is voice communication using mobile telephony.

Telehealth Control System (Integration)

The telehealth control system is usually an integration of multiple special applications running on special hardware setup purposely for delivering telehealth services. The implementation will be to provide the integration platform for all these disparate specialized software platforms to work together for the sole purpose of supporting the delivery of telehealth services. The components of the telehealth control suite will include:

- Patient care systems
- Call Center application called Asterix, an open source call center app already integrated with the hardware currently being used in the six (6) TCCs
- Image and video archiving and communication system
- Video streaming system
- AI and machine learning engines to support clinical decision making

The technology implementation focuses on integration of software and hardware components to deliver a solution suite. APIs for exchange of data will also be developed to ensure there is interoperability with hospital EMR systems and

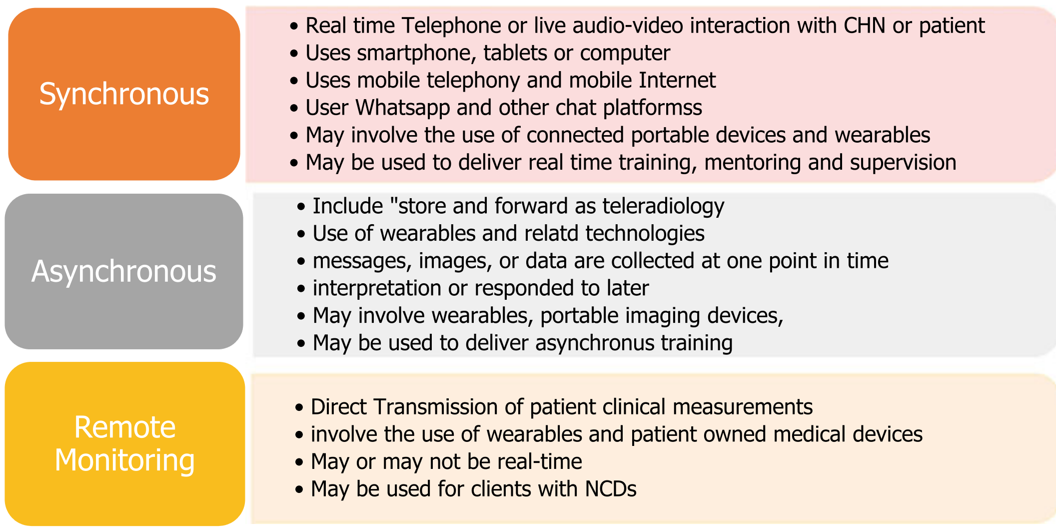

Fig. 34.4 Ghana Telehealth service delivery models

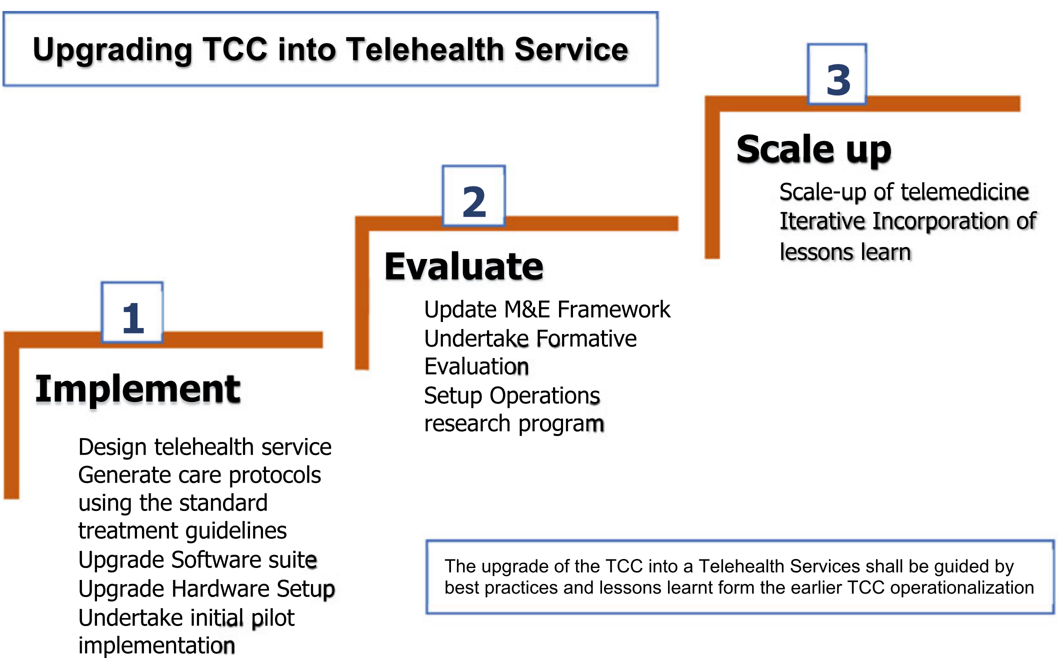

Fig. 34.5 Stages for upgrading Teleconsultation to Telehealth service

reporting platforms like the DHIMS2. This API will provide clients applications such as eTracker and other mHealth applications to interface during a telehealth encounter.

Telehealth Client Systems

While regular telephony will suffice for a client (CHN and citizen) to access telehealth services, a client and a CHN mHealth solution capable of running on android and iOS devices as well as web browser client will be implemented for use by clients. The telehealth control system API will be designed to enable apps developed by development partners and private sector partners to connect to the telehealth control system. These apps can connect using any of the modalities for assessing telehealth services.

Toll Free number and Short Code Dialing

To enable congestion free connection to the TCC, a short code shall be acquired from the national communication authority (NCA) and these shall be linked to toll free numbers to be acquired from Telecom companies in Ghana who will be encouraged to provide the toll-free numbers for only on-net calls, and this will be offered as part of their corporate social responsibility. In exchange they may be offered advertisement space on the telehealth platform.

34.2.3.4 Clinical Decision Support System for Telehealth

In Telehealth Care service delivery, guidelines are critical for the provision of a consistent quality telehealth services; usually provided through the modalities and communication channels. To this end the Ghana standard treatment guidelines will be modified and translated into computer executable format to serve as a guide for telehealth service delivery.

34.2.4 Reimbursement

Telehealth services like regular health service delivery comes at a cost. Many telehealth initiatives and pilots in Ghana have mainly been funded by donors and other short-term funding arrangements. While these mechanisms are essential to help countries setup infrastructure, policies, procedures and the necessary structures required for the take-off telehealth services, these funding arrangements eventually dry up. Continuous investment for telehealth infrastructure setup is needed in:

1. Developing technology innovations to support telehealth
2. Innovations in service design and delivery
3. Robust implementation research to continually generate evidence for policies on reimbursement and other related matters

For significant country level scaleup to occur, and for uptake of telehealth services to experience increased uptake it is essential that telemedicine service delivery is reimbursed using existing mechanisms for reimbursement for traditional health service delivery. While this will ensure sustainability, it will provide the needed substrate for continuous improvement and the continued innovation. It also support the incorporation of advanced technology and service design innovations into the telehealth service delivery ecosystem.

34.2.4.1 Health Insurance

Ghana health financing mechanisms have gone through an evolution since independence. After years of piloting mutual health insurance schemes in some districts [20] Ghana introduce the national health insurance scheme to replace out of pocket payments with the passage of the NHIS law in 2003. Since then, continuous innovation and improvement and implementation issues lead to the promulgation of a new National Health Insurance law in 2012. With this law the traditional health service delivery in Ghana is funded on four models, i.e. National Health Insurance Scheme, out of pocket payments, Private Health Insurance, Corporate funding and others.

The National Health Insurance Scheme in Ghana, funded by tax, membership contribution and social security [21] is the main health financing mechanism in Ghana. While a lot success has been chalked, significant number of challenges still exist. These challenges include but not limited to.

Cost containment challenges: Ever increasing claims payments raising scheme sustainability issues.

Inequity issues: The NHIS coverage in Ghana currently is less 50%. While the package of services is wide and includes over 90% of conditions reported in public health institutions, some patients are made to co-pay for the services they receive [22]. Unfortunately, the architecture of the private health insurance organizations which are supposed to cater for the additional services is such that, preference is given to only formal sector worker. This means many persons within the informal sector do not get the opportunity to enroll in the private health insurance to fund the component of service delivery client has to copay. The implications are that, many informal sector workers and even some formal sector workers whose organizations have no arrangement for private health insurance have no access to health insurance beyond NHIS. The reluctance of these private health insurance organizations to open membership because of the fear escalating claims reimbursement is the main cause.

These health insurance organizations are designing innovative methods for cost containment aimed curtailing the rising cost of claims reimbursement. Fortunately, in Europe, Telemedicine have been demonstrated to reduce health cost and found to be a cost-effective way of delivering health service [23]. With the absence of local evidence health insurance organizations in Ghana have been reluctant to reimburse for telemedicine services.

34.2.4.2 Micro Insurance in Healthcare

Increasingly however, a fifth and emerging mode of health financing in Ghana and other LMIC is micro-insurance in health care financing.

"*Health micro-insurance—referred by different names such as community-based health insurance, micro-health insurance, mutual health insurance, community-based health financing, community health insurance* etc. *-is a form of micro-insurance in which resources are pooled to mitigate health risks and cover health care services in full or in part. Health micro-insurance schemes are more complex in nature compared to life insurance schemes, as they provide services towards specific risks or illnesses and involve the role a health care provider, whether independent of or in partnership with the scheme. The scheme can be provided by government, a private insurance company, an NGO or a CBO"* [24].

Despite the above definition of Health micro insurance, telecom company involvement in financial inclusion in Ghana and other LMIC countries has led to corporations like MTN and AirtelTigo getting involved in areas such micro health insurance.

MTN, leading telecom company in Ghana as part of its financial services strategy has introduced a micro-insurance in health that is being run by a subsidiary called Ayo. This microinsurance being run aYo has a 2-part benefit plan that include:

- **MyLife Benefit** is payable if either policyholder or registered family member passes away and has one of benefit package of six thousand Ghana Cedis (GHS 6000) lump sum payment
- **MyHospital Benefit** is payable to the policyholder if he/she spends at least 1 night at the hospital due to illness or accident. This package covers in patient stay at One Hundred Cedis per night of hospital stay.

The premiums for these packages are deducted during recharging of phone credits for regular calls.

34.2.5 The Way Forward in Telehealth Reimbursement

While out of pocket payment for telehealth services remains the most ready mode of funding mechanism to cater for reimbursement of telehealth services, we have limited evidence on the willingness-to- pay (WTP) for telehealth services studies and assessments in Ghana. Further studies are required for this to be ascertained.

34.2.5.1 NHIS Reimbursement of Telehealth Services

Involvement of the National Health Insurance Scheme in the reimbursement of telehealth service will require both legislative and policy changes to the existing practice. The National Health Insurance Scheme has within the 17 years of implementation has undergone a complete replacement of the law and has further undergone an amendment, with the amendment being undertaken as recent as the 2021. Considering these recent changes, the necessary legislative and policy changes required to add telehealth services to the NHIS benefit package may face some challenges that can delay implementation. At best telehealth may be included after a lot of evidence have been generated and advocacy for inclusion strengthened.

34.2.5.2 Private Health Insurance Reimbursement of Telehealth Services

Private Health Insurance programs have been supplementing the national health insurance scheme in providing funding for enhanced medical services. The private health insurance providers have some forms of capitation and in the arrangement for reimbursement traditional health services. There is a lot of reluctance to reimburse for telehealth by private health insurance providers. Further evidence needs to be generated to convince these providers the need to reimburse for telehealth.

34.2.5.3 Telehealth Reimbursement with Micro Health Insurance

The micro health insurance presents the most viable and readily implementable opportunity for reimbursing telehealth services in Ghana. The mechanisms and techniques for mobilizing the premium payments and also the sheer ability to mobilize large enrolment of citizens in both formal and informal sector; together with the absence of legislative and policy bottlenecks makes the microinsurance model of health financing the best mode for reimbursement of telehealth services.

34.2.5.4 Reimbursing Telehealth with Payment for Services and Grant Support

In the early years, telehealth services will likely benefit extensively with a mix of pay-for-services to maintain the continued operation and service delivery and the donor funds for investment in technological innovation and telehealth service program design. With micro insurance, legislative and policy hurdles are a minimal and there is also the aggressive effort in new product development.

34.2.6 Evaluation of Telehealth in Ghana

Telehealth and telemedicine services are expensive and disruptive and that could put additional pressure on already constrained resources for health service delivery in Ghana. The need to have a comprehensive evaluation framework is therefore critical care. Telemedicine and telehealth are still in their nascent stages, with best practices and approaches for implementation largely unknown. The need to combine these evaluation frameworks with a robust implementation research regime is important to ensure that impact can be measured and new field-tested procedures and protocols for replication and continuous improvement can be put in place.

The factors influencing the successful implementation of telehealth services are varied and multifaceted and have multiple dimensions. Telehealth services in Ghana therefore will need its assessments to be continuous right from the planning stage to the implementation and the assessment of performance [11]. The evaluation regime for the Ghana telehealth project will demonstrate both telemedicine benefits and making improvements in health service delivery.

The evaluation framework for the Ghana Telehealth Program will focus on

4. Performance
5. User satisfaction
6. Quality of services offered
7. Cost—benefit analyses
8. Barriers and promoters of adoption
9. Uptake of Telehealth Services
10. Access to telehealth services (service availability)
11. Economic evaluation of telehealth services

The evaluation of telehealth services benefits will be looked at three different levels i.e. short term, medium term and long term (Table 34.1).

According the results of a study by WHO-PAHO on telemedicine community of practice, variables to be measured in telemedicine evaluations should include:

- Project feasibility
- Acceptance by professionals.
- Sensitization of authorities and decision-makers
- The technical capabilities of users
- Its cost, benefits, efficiency, and effectiveness
- Accessibility, acceptability both by the patient and by health workers
- Attainment of the proposed, desired, and expected objectives and achievements.

Many experts' groups in various LMIC [25, 26] have used various approaches and gone ahead to develop models for the assessment of telemedicine. This include a five-dimensional assessment that include performance measurement (time, quality and cost), outcome measures such as safety, efficacy and effectiveness, summary measures that looks at cost comparisons, operational considerations focusing on access, acceptability and quality; other issues looking at confidentiality, legal and responsibilities.

A much-expanded evaluation model is the six major component evaluation frameworks, an integrated model that Nepal et al. [27] have proposed. This model has 6 key dimensions of health domains (e.g. Cancer, mental health, diabetes, cardiovascular diseases, respiratory diseases), health services (Consultation, diagnosis, monitoring, triage, mentoring, training/education, treatment), technologies (Store and forward, real-time video, hybrid (real-time + store-forward), fully integrated EHR, real-time video with visual aids, advanced telehealth with sensors), communication infrastructure (NBN fiber, NBN wireless, NBN satellite, wireless 3G/4G, dial up, cable, DSL, ISDN), environmental settings (Location, medical professionals, devices, interactions) and socioeconomic analyses (cost, benefits, barriers, clinical outcomes).

The evaluation of the Ghana telehealth program shall adopt an expansive evaluation model that involves an amalgamation of these tested models. Design will therefore incorporate these models of assessment and extra efforts will be put into ensuring data flows continuously.

Table 34.1 Example benefits (non-exhaustive) indicators for evaluating telehealth services (source: WHO, PAHO)

Short term evaluation indicators	Medium term evaluation indicators	Long term evaluation
• Increase in number of specialties per offering unit (to measure acceptance among physicians and hospital administrators) • Increase in teleconsultations held (to measure the progress in the health system) • Patient savings (to measure the financial impact on patients) • Time from when a teleconsultation is requested until it is held (to measure telemedicine's advantage over regular referrals and the time it saves in patient care) • Satisfaction (both patients and health workers) • Wait time between the scheduled time and the teleconsultation • Number of teleconsultations in a given period	• Relationship between teleconsultations held and the relative drop in regular consultations • Hospitals taking part in telemedicine out of the national total • Number of differed teleconsultations • Number of hours not used or free • Number of technical problems per unit • Time taken to resolve technical problems per unit	• Number or percentage of patients being monitored by telemedicine • Improvement in monthly consultations over previous years • Average savings over previous year."

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Part VI

Cardiology and Cardiothoracic Surgery—A Global Perspective

35 The Story of Rheumatic Heart Disease in Rwanda: Capacity Building for Comprehensive Cardiovascular Care

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Abstract

Originating from group A streptococcus pyogenes infection (commonly strep pharyngitis or strep throat), rheumatic heart disease (RHD) is the leading acquired heart disease among children, adolescents, and young adults worldwide. If left untreated or not properly managed with the appropriate antibiotic regimen, the disease can develop into an inflammatory condition, affecting critical organs, including the heart and its valves. With fulminant heart failure as part of its pathophysiology, advanced cases often require tertiary levels of care and, frequently, surgery. Unfortunately, many of these cases are seen in resource-limited settings that lack the necessary human and capital resources, making surgical intervention prohibitive. Although its history has presented unique challenges to the development of healthcare infrastructures, partnerships with humanitarian medical organizations and a global commitment to decentralized non-communicable disease (NCD) strategy, has enabled Rwanda to provide enhanced cardiovascular care, including surgery, to members of its most vulnerable population to address the burden of RHD in the country. To sustainably combat the burden of RHD, strategic investments in human resource capacity-building through comprehensive training of all involved is required. This can be done by leveraging existing partnerships and balancing local health priorities to

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_35

combat this disease while considering management and mitigation of other pressing communicable and non-communicable disease burdens. To eradicate RHD, further efforts must focus on increasing public health awareness about the danger of the illness and promoting early detection and treatment of the primary infection using antibiotics. The purpose of this chapter is to chronicle Rwanda's extraordinary achievement of advancing from a resource-destitute country with a historical context of unconscionable genocide toward an evolving ecosystem of health advances and sustainable cardiovascular care.

Keywords

Global health · Rheumatic heart disease · Rwanda health · Cardiovascular disease · Non-communicable diseases

35.1 RHD as a Disease of Poverty

The incidence of RHD in any nation is resultant of multifactorial health challenges, which are often informed by the social and economic frameworks at hand. The course of the disease within a particular region, especially one of extreme poverty, demonstrates a snowballing of health challenges that can cripple the youth and future of a nation. In many high-resource countries, comprehensive health policy interventions have largely eradicated RHD. However, in Sub-Saharan Africa, the disease is the most common form of acquired cardiovascular abnormality observed in children and adolescents [1]. In this region, RHD is estimated to affect 5.4 in 1000 individuals [2]. Researchers in Rwanda estimate the prevalence of RHD to be about 7 in every 1000 school-aged children [3]. Children incapacitated by advanced-stage disease are unable to perform usual activities of daily living, thereby, limiting their ability to receive an education or sustain employment. This cascading effect ultimately hinders the development and economic advancement of families, communities, and the county at large. Without advanced cardiac surgery, reliable follow-up medical care, secondary prophylactic treatments and decentralized access to available treatment, there arises a low likelihood of these children regaining their ability to thrive and live into adulthood [2].

35.2 Scope of the Disease

Worldwide, non-communicable diseases (NCDs) have surpassed communicable diseases as the leading causes of death. This shift has been described by Omran and others as a remnant of shifts through stages of the epidemiological transition [4, 5]. In higher-income countries, generally understood to be at more advanced stages of this transition, the burden of NCDs is undeniably high, contributing to 90% of all deaths and serving as the leading causes of mortality and morbidity in this area [6]. These same shifts are being seen around the world. The poorest 1 billion people in the world are most concentrated in Sub-Saharan Africa and Southeast Asia [7]. In Sub-Saharan Africa, the burden of communicable, maternal, neonatal, and nutritional diseases (CMNNDs) has been declining since the early 2000s, although it remains significantly high. Nevertheless, NCDs are the second leading cause of mortality, accounting for 35% of all deaths [6]. This creates a "double burden" of disease, requiring nations, such as Rwanda, to institute novel strategies for the prevention and management of NCDs while continuing to address CMNNDs.

Cardiovascular diseases (CVDs) are a major contributor to this rising cause of chronic disease-related mortality. CVD accounts for about 13% of all deaths in Sub-Saharan Africa and 37% of all NCD deaths [6]. Over the past three decades, mortality from CVD has increased by over 50% [6]. Interestingly, the presentation of CVD differs in resource-limited settings than in higher-income nations. Of the accrued burden of CVD and congenital heart diseases, 34% are seen in those under 30 years old in the world's poorest nations while this age demographic only accounts for 3% of the same diseases in higher income countries [7]. One predictive factor of this disparity is the occurrence of specific CVDs that are endemic to the region, such as RHD, which tends to affect younger individuals.

RHD develops because of untreated group A streptococcal (GAS) infection that results in pharyngitis [8]. This condition is commonly known as strep throat and is easily treated with penicillin. However, when undetected, untreated, or undertreated, GAS can result in rheumatic fever, an autoimmune response to the bacteria, leading to systemic inflammation [8]. When this inflammation affects the valves of the heart, acute carditis, and valvular damage results, causing chronic rheumatic heart disease and eventually leading to heart failure [8]. The multistage development of this disease provides many opportunities for prophylaxis and treatment. However, in areas with limited healthcare access, all these checkpoints can be easily missed, and young individuals present with extreme and advanced cases of RHD. The link between this disease and resource limitation is further evidenced in its more common presentation in rural areas than urban centers [7]. Additionally, the specific burden of the disease on children and young adults makes this disease a unique contributor to disability and premature death [2]. It is essential that in efforts to combat the rising burden of CVD around the world specific strategy to protect the young and at-risk is made an investment priority [9].

The successful prevention and management of CVDs and RHD specifically require strong and well-coordinated health systems. Rwanda represents a uniquely positioned context to explore how a broken health system has been able to amass the resources to address the challenges of RHD. Further, the specific setting of Rwanda creates a compelling challenge to the prevention and treatment of critical cases of RHD. In July of 1994, following the Genocide against the Tutsi, the Rwandan government was faced with the challenge of rebuilding the health system that had been torn apart by years of civil war and violent ethnic tension [10].

35.3 The Genocide Against the Tutsi and the Rwandan Health System

The 1994 Genocide against the Tutsi had detrimental effects on Rwanda's health system. It is estimated that roughly 1 million, out of the then population of 7 million, people were killed and another 2 million fled the country during and in the aftermath of the genocide. In addition to the loss of human resources, many health facilities, government infrastructures, and needed supplies were destroyed. At the end of the genocide, the remnant of the health system inherited the physically, mentally, and emotionally wounded population amid a long period of economic ruin.

The Rwandan government has instituted unity and reconciliation to rebuilding the country crippled by war and genocide. As a part of this reconstruction, Rwanda committed significant investment in healthcare. In 2011, Rwanda and South Africa were the only African countries to meet the Abuja Declaration calling for at least 15% of government spending to be focused on healthcare. Rwanda was also among the few countries to meet many of the Millennium Development Goal targets, despite its fragile state. The government instituted a universal healthcare model by initiating community-based health insurance premiums based on socioeconomic categories and the ability of people to pay, created a workforce by recruiting and training community health workers, integrated and utilized new technology, and strengthened global partnerships to improve health access and delivery and build local capacity.

In a nation so recently devastated by the immense loss, investments in the future generation are more than essential. Rwanda is an East African regional model of achieving exemplary communicable disease outcomes and addressing the NCDs that ravage the country [11]. In November of 2006, the Rwandan Government decentralized care for NCDs and made the eradication of RHD a national priority [12]. This process started the work of developing new and sustainable efforts to effectively track, prevent and treat severe cases of this destructive disease [12]. RHD presents a specific challenge to Rwandan health and a need for targeted strategies to decrease the burden of this disease among the nation's youth. One effective strategy explored is the decentralization approach called PEN-Plus. PEN-Plus is an integrated strategy that builds on the World Health Organization's Package of Essential Noncommunicable Disease Interventions (WHO PEN) in order to increase the quality of services for severe chronic NCDs at primary referral facilities (e.g. district hospitals). Full details of this model and how its integration has been applied to addressing RHD in Rwanda is explored elsewhere in this volume (Figure I: Alizadeh et al.).

35.4 Strategic Direction for Eradicating RHD in Rwanda

When looking at the treatment of severe cases of RHD, one is often struck by its occurrence in the first place. Multiple checkpoints of prevention and treatment are passed by the time rheumatic fever with inflammation extends to the heart. Eradication of this condition in certain parts of the world has primarily come about through systematic detection and treatment of the initial streptococcal infection with antibiotics [8]. Both cost and differences in health-seeking behavior prove to be major challenges to the implementation of this method of primary prevention in resource-limited areas. Estimates find that the throat swab culture for GAS and subsequent antibiotic treatment would amount to about USD 50 per child [8]. Additionally, with limited access to primary care, it is less likely for patients to seek care for sore throats [8]. Many patients who develop rheumatic fever do not report having recent cases of sore throats [8]. With the initial case of the pharyngeal infection going undetected, the ability to provide primary prophylaxis is limited.

Beyond primary prevention, a sequence of 3 or 4 weekly injections of benzathine penicillin can be provided to those with previous episodes of rheumatic fever or RHD as a form of secondary prophylaxis [8]. However, while this prophylactic treatment may reduce the recurrence of rheumatic fever, there is no evidence that it slows the development of chronic RHD or reduces the mortality from RHD [8]. Primary prevention and, perhaps secondary prophylaxis for cases of rheumatic fever can be implemented but will take national scale programming. Currently, the Awareness Surveillance Advocacy Program, operating under the Pan African Society of Cardiology, is working to raise awareness about RHD and implement pilot programs that will pave the way for this national program [8]. The Rwandan Ministry of Health has declared it a goal to expand diagnosis, screening, and prevention at teaching and district hospitals [12]. Continued commitment, time, and collaboration will be needed for the adoption of primary prevention as an effective strategy against RHD in Rwanda.

With estimates of about 7 in 1000 school-aged children in Rwanda suffering from RHD, treatment access is an ethical imperative [3]. The late detection of many of these cases in Rwandan youth has created a critical need for reliable cardiac surgery to perform the essential valvular replacements needed to allow survival [2]. With only four native cardiologists in Rwanda and the recent training of the first native cardiac surgeon, the country is severely limited in its capacity to care for these patients with a country-wide population of 12 million. The complexity of providing adequate surgical care involves more than just having the necessary personnel, it requires resources such as specialized equipment, blood products, and sterile operating theaters. Access to such resources are considered luxuries in lower-income and resource-limited countries and as a result, Rwanda has looked outside of its borders to augment its limited cardiology and surgical capacity [12].

In 2006, collaborative efforts were established between the Rwandan Ministry of Health, Rwanda Health Foundation, and four international humanitarian organizations [12]. Teams from Belgium, Australia, and the United States began traveling in, providing cardiac interventions and mainly conducting congenital disease repairs and RHD valvular surgeries [12].

Although these programs demonstrate the feasibility of modern cardiac surgery in Rwanda, they have their shortcomings [12]. The vision for the future of these international partnerships is "the establishment of a domestic self-sustaining, comprehensive cardiovascular program, with the capacity to independently provide cardiac surgery and perioperative care," [12]. To facilitate the building of a domestic program, international organizations have committed to sustained skills transfer initiatives and funding the training of certain local physicians [12]. Training of nursing and ancillary staff has taken place during the previous visits of the surgical teams [12]. Additionally, Rwanda's Ministry of Health has committed to building sustainability by supporting local clinicians, nurses, and ancillary support staff to gain specialized training abroad [12] (Figure II).

35.5 Recommendations

After an evaluation of the proposed strategies and current efforts to treat and eventually eradicate rheumatic heart disease, the recommended strategic focus is on the continued development of sustainable, local cardiovascular expertise. Additionally, efforts to improve education on RHD and expand primary care service to allow for improved detection of primary infection must also be made. With the framework of partnership already established, further investment in training opportunities presented by international humanitarian organizations, such as Team Heart Inc and Chain of Hope Belgium, will be effective. Ultimately, the goals of these partnerships are for continued mentorship, knowledge transfer, and the eventual creation of a Rwandan cardiac center [13].

Rwanda has pioneered great feats in line with this core strategy already. In 2011, the Human Resource for Health program worked to develop a long-term strategy to increase the number of healthcare professionals in the country and decrease dependence on foreign aid, with a focus on the augmentation of training quality and expanse [9]. In the pursuit of Rwanda's self-sustainment, steps to improve the effectiveness of global aid delivery and build up fundamental health care infrastructure are required. Infrastructure to support the budding human capital is being built through novel programs at the School of Public Health in Rwanda. New master's programs in the country are training individuals to be leaders in both hospital and healthcare administration and global health delivery [9]. The innovative strategy by the Human Resource for Health program looks to address the near and distal factors that have led to the current physician shortage by expanding training access and increasing incentives to work in rural areas and the public sector [9]. Additionally, while foreign funding and teaching have been used to jumpstart this program, the intention is to have the training be fully funded by the Rwandan Ministry of Health budget and conducted by local teachers and clinicians [9]. Through the expansion and continuation of this commitment to investing in the training of local experts in CVD and cardiac surgery, a sustainable solution to the paucity of RHD treatment availability can be developed.

35.6 Challenges

Before RHD treatment, primary detection is of critical importance. Yet, low levels of health-seeking behaviors in Rwanda is a significant barrier to be overcome for the successful curbing of RHD. The Theory of Planned Behavior models human behavioral achievement as a result of the combined factors of motivation and ability [14]. With a low motivation to seek out care for a seemingly benign sore throat and difficulty in the ability to access such care, the extant trends relating to the low detectability of the original streptococcal infection will continue. Through education on GAS and its various sequelae, social and subjective norms can be altered. Education and increased access to primary health care facilities will also allow for altered perceptions of power and behavioral control allowing for community-wide modifications to health-seeking behavior. Through a Health Belief Model lens, changes to the perceived severity of the early signs of GAS infection and rheumatic fever along with the perceived barriers to healthcare need to be made [15]. Altogether, systematic efforts will be needed to overcome the challenge of health-seeking behavior and allow for earlier primary detection and prophylaxis treatment.

Additional challenges arise in the effort to increase sustainable, local surgical capacity. Major deficits exist in the financial and human capital needed to actualize the goal of establishing a comprehensive cardiovascular program. To address these challenges, the continued investment will be needed from the Ministry of Health and international humanitarian partner organizations. Through iterative growth and effective fundraising strategies, sustainable sources of funding can be secured. At the heart of these efforts, there is a need for comprehensive education into the importance of specialization in cardiovascular care and the available avenues for interested parties to participate in this work. Rwanda has various other important health needs, such as addressing CMNNDs, also meriting systematic governmental investment. This work must be posited as compatible with these more novel advances in essential specialized care. This approach is already being taken as the Ministry of Health has systematically taken on NCD treatment and prevention projects while maintaining infectious- disease control [9]. Specific efforts to expand partnership, secure funding and combat a lack of information are needed to combat the challenges presented by needed interventions to expand available treatment services for advanced RHD in Rwanda.

The additional challenge that presents after conducting cardiac surgery is the follow-up of patients. Unlike high-income countries, where many patients have a primary care provider to organize perioperative and post-cardiac surgery care, most resource-limited settings lack this safety net. When post-surgical patients are discharged to the community, they rely on local community health centers and remote district hospitals. These facilities are often staffed by nurses who serve as the primary care providers for all patients. An effective approach would employ the strategy of training the nursing personnel and general practitioners in providing advanced, cardiac-specific care, including echocardiography evaluation and interpretation, anticoagulation management, and appropriate emergency triage.

35.7 Innovation and Technology: Telemedicine as a Way Forward to Improve Cardiovascular Health in Resource-Constrained Settings

The burden of the severe, end-stage presentations of RHD is substantial and is crippling the future of a post-genocide and post-civil war nation. Some of the steepest declines in premature mortality in low-income countries over the past decade have been in Rwanda [9]. This is just one example of the incredible capacity for health and workforce development that Rwanda has demonstrated in the aftermath of genocide just two and a half decades prior. Rwanda has overcome massive challenges in its recent history and by investing in sustainability and human resources, they can also overcome RHD, allowing young Rwandans to live lives full of possibility and unhindered by cardiac disease.

On the road to establishing sustainable human resources and capacity expansion, innovation and technology will play a growing role. Ultimately, consistent opportunity for advanced training and continued education in the area of cardiovascular disease and other critical medical areas will be necessary. That said, limited access to advanced cardiovascular education and sustainable options for in-country training present significant barriers to capacity development in many countries like Rwanda. The COVID-19 pandemic has further presented greater challenges, limiting international travel and in-person classroom education and teaching. However, the combination of innovation with high-speed internet and other modes of modern technology have paved the way forward in many areas of education around the world (Figure III). Herein lies an opportunity for countries like Rwanda to maintain educational initiatives despite geopolitical instability, economic injury and global pandemics.

During the peak of the pandemic, telemedicine was used as a substitute to in-person visits to maintain medical care and access. Similarly, virtual education peaked during the pandemic as well. Lessons learned from the increase in digital health utilization and virtual education in regard to effective modalities and techniques can be applied to the provision of global cardiovascular and surgical education. There has been success in global infectious disease virtual learning utilizing digital platforms which have shown cost savings and comparable knowledge acquisition to in-person learning [16]. For global cardiovascular education, an example of a successfully implemented virtual education program is the International Cardiology Curriculum Accessible by Remote Distance Learning (ICARDs-Haiti), which was implemented in Haiti in 2019. The ICARD-Haiti curriculum was established as an entirely virtual, learning platform, which enabled live-streaming, image sharing, and meaningful interaction. It also maintained educational opportunities for physicians-in-training in Haiti during the COVID-19 pandemic and provided uniquely tailored educational content to medical practice in Haiti. Now that a proof of concept has been established in Haiti, the goal moving forward would be to utilize a similar virtual platform to expand educational opportunities in Rwanda. Here in lies the real opportunity to provide care to patients while educating local personnel beyond just mid-level providers and house offices. Using telemedicine infrastructure, patients may receive care all while local staff collaborate with nurse educators from around the world for instruction and preceptorship. There has already been the establishment of initiatives for in-country nurse training. It is only a matter of time that the capability will expand to virtual platforms, which will possess the unique potential to enhance the reach and provision of cardiovascular care in the country.

35.8 Team Heart and Rwanda's Race to Establish Cardiac Surgery to Address the Surgical Burden of RHD; It Is Not Just About Surgery

Since Team Heart first visited Rwanda in 2006, the progression to establish a sustainably functioning program in cardiac surgery has remained at the forefront of efforts by leaders in healthcare, as well as international partners, to address the needs of a growing population marginalized by heart disease. Team Heart was first introduced to Rwanda through Boston-based Partners in Health. The invitation to bring a team to perform cardiac surgery was issued by the Minister of Health and the then CEO of King Faisal Hospital. The initial goal was to address the burden of young adolescents suffering from end stage rheumatic heart disease through life-saving cardiac surgery. There has also been a focus since the initiation of Team Heart on increasing the skills and numbers of local staff, and, from the earliest stages, the desire for King Faisal to be recognized as a regional center.

This NGO partner approach was promoted by developing programs in near-by countries such as Uganda, Kenya, Tanzania, Mozambique and Cameroon with visiting partners of expat teams in the absence of local specialists. Since 2007, Team Heart has visited King Faisal Hospital, in Kigali, Rwanda at the invitation of the Government of the Republic of Rwanda through more than 8 turnovers in CEO's, (average 1.75 years served) and 6 Ministers of Health (average 2.3-year term served) which has provided some challenges over the 14 years of experience. The efforts to create a Rwanda-based Center of Excellence and regional referral center in cardiac surgery have the potential to impact the local economy, as well as positively impacting foreign investment for the country.

Through each of the changes in leadership, there has been a period of adjustment of government priorities, strategies, and vision. It has been critical to work closely with leadership to ensure the alignment of strategy and vision. Through each change in leadership, King Faisal Hospital and the Rwanda Biomedical Center (RBC), the care-delivery arm of the Ministry of Health, have remained committed to identifying gaps in skills and in areas of needed focus for the overburdened human resources to progress to operate independently. Although a country-wide human resources guide indicates gaps in the public sector expertise, there has been a more moderated plan developed for King Faisal Hospital, where all cardiac surgery has been performed to date.

Through consistent partnership with international cardiac surgical NGO programs, such as Belgium Chain of Hope and critical Rwandan stakeholders, the urge to move the cardiac specialty care agenda forward has had a strong foundation with the University of Rwanda Schools of Medicine and Nursing and the Rwanda Heart Foundation. Bringing all stakeholders to the table has faced challenges with many partners covering a global expanse. When all stakeholders have been able to work together, it has been possible to identify the existing expertise and program strengths and gaps, to assist in highlighting what is critically needed for a sustainable program. For example, the Belgium team has identified and supported training in cardiology and anesthesiology, while Team Heart has focused on support for cardiac surgical training out of country. Agreements between the teams to use the same theater packs and perfusion circuits increase patient safety and enhance the efficiency of the local team. Communication between the teams remains committed with shared resources and common goals for the support and benefit of the overall program.

Through a more comprehensive effort, other areas have been identified as equally important in training of critical hospital staff for the surgical, nursing, and critical care teams. Improving diagnostic capability at the health system point of entry is needed for all cardiac care; cardiomyopathy, hypertension, ischemic heart disease, congenital and rheumatic. Participating in echo-skill training for NCD nurse-led clinics has been a project where Team Heart has played a critical role since 2014, with TH sonographers partnered with the NCD Division at the RBC for skill transfer and nurses for improved education. Further identifying gaps in care of post-operative patients for INR management has led to the creation of a Nurse Specialization Fellowship program in collaboration with the University of Rwanda, School of Nursing. This intensive one-year certificate program is offered to nurses practicing in point-of-care cardiac care, peri-operative, ICU, or NCD clinic settings who currently have a baccalaureate or master's degree. In year one, the applications for each spot counted more than six applications for each position indicating both the enthusiasm and the need for such a program. In an informal written survey to Rwandan cardiologists to gauge their opinions and potential participation, the cardiologists overwhelming supported the Specialized Nurse concept and offered their assistance for mentorship in the clinical setting.

Programs in awareness and prevention for RHD with screening in civic meetings and gatherings have been developed through partnerships with local faith-based and other non-governmental health care organizations. Using a Team Heart-developed coloring book, which is provided free to children who are screened for RHD, it is possible to reach a family of 6 to share information regarding the link between untreated strep throat and rheumatic heart disease. In 2011, an echo-screening program in Gasabo district identified 6.7/1000 of school-age children with moderate changes of RHD. Since then, the Government of the Republic of Rwanda has worked hard to improve the living conditions, nutrition and access to primary health care. These measures help to address the root causes for strep throat, which can progress to rheumatic fever and the resulting sequelae of RHD. Preliminary numbers in a contemporary nurse screening program demonstrates some reduction in evidence of RHD in a pediatric population. This is gratifying and would be expected and well-received as poverty-reduction initiatives reach across the country.

In 2012, the Minister of Health required expat teams to become registered in Rwanda with the INGO board, which included a licensing and monitoring process. Team Heart is the only expatriate cardiac surgical team which fulfilled this obligation. Two of the existing 4 cardiac surgical teams withdrew at that time, citing program funding challenges.

At the time, the Human Resources for Health (HRH) Program was being initiated and planned to bring experienced cardiac and thoracic surgeons to help address the gap and progress more rapidly to a homegrown team of experts and to establish local training. The support in the area of non-cardiac thoracic surgery faced challenges in available human resources. As a result, the country did appreciate an increase in non-cardiac thoracic surgery with excellent skill transfer to general surgeons, particularly in the public sector. Between 2006 and 2020, King Faisal hospital retained the services of a visiting consultant from Uganda to visit periodically for clinical evaluation, teaching and surgical care to address a gap until the newly trained and Board-Certified Rwandan cardio-thoracic surgeon returned from South Africa in May of 2019.

In addition, the country has requested expertise from global specialists in surgery who support the direction and vision of establishing a cardiac center. However, despite the consistent message, funding for critical elements of a heart surgery program-operating theater space, capital equipment and a reliable supply of disposables for perfusion and theater- has continued to lag in support.

In 2018, the Cape Town Declaration was published and detailed the proceedings of a meeting in Cape Town, SA in December 2017, focused on the lack of access to cardiac surgery in the developing world. It issued a clarion call to the cardiac surgery, cardiology, government, and medical device communities regarding the need to improve access to cardiac surgery in areas such as Rwanda. These are areas where cardiac surgery has the potential to help people suffering from end-stage RHD if certain gaps in the supply chain, human resources and leadership can be addressed. In 2019 a call for applicants for programs was issued, and Rwanda applied under the leadership of Dr. Maurice Musoni. Following a site visit in February 2020, Rwanda was selected as one of two initial pilot sites for endorsement [17]. Due to Covid, there has been a delay in implementation, however the program will provide monitoring and evaluation, surgical mentorship, as well as some support for consumables (oxygenators, valves, etc.) during the pilot phase, in a concerted effort to increase access to cardiac surgery for the people of Rwanda.

It is clear, to this point, consistent cardiac surgery performed in Rwanda is dependent on the entire team to be trained well and supported in a systematic approach that does not yet exist. It is also dependent on a highly reliable supply chain for medications and disposables, underwritten by a robust government investment. Also, of critical, and, indeed, existential, importance for sustainability is the availability of reimbursement for patient care for cardiac surgery supported by the government. In 2016, a white paper was commissioned by Team Heart from Brandeis University health care economist, Diana Bowser, PhD, MPH, of the Heller School International Health Care Policy Program. Dr. Bowser examined the feasibility of a cardiac surgical program and indicated that Rwanda, by virtue of a track record of success by visiting expatriate teams, as well as training of key local personnel, was poised to make this move toward sustainable cardiac surgery. The caveat remained, however- the government would need to remain supportive with a dedicated funding stream to support the development of a Rwandan cardiac surgery program until it became self-sustaining [13]. To support the initiative, the government has funded a cardiac catheterization laboratory and hired expat interventional cardiologists in order to expand services. They have also recently opened a new diagnostic and outpatient facility to accommodate the increased number of expected patient visits in its role as a regional site for cardiac care.

There is no doubt there is a critical need in-country for cardiac specialized surgical services for both vulnerable and middle-income people suffering from heart disease. There is likewise no doubt that a regional cardiac center for the more than 30 million people in Rwanda and surrounding countries would benefit greatly from having a high quality cardiac surgical program. To realize this dream, in all its complexity, and with all its challenges, there are few, if any, shortcuts. Indeed, all the critical steps described herein must be addressed and combine successfully in order that sustainable cardiac surgery in Rwanda, ultimately staffed by Rwandans, can become a reality.

35.9 Conclusion

RHD is the most common cause of acquired heart disease in children and young adults worldwide [1]. It is also often referred to as a disease of the poor [1]. Rwanda is presented with a challenge to radically expand and strengthen the local health system, to reduce a major cause of premature death [1]. Through concerted efforts to expand detection, train local cardiology and surgical talent, and increase awareness of this disease amongst health care providers, eradication is possible. But it will take targeted investment in primary care and hospital settings, the expansion of international partnerships, and continued leadership from within the Rwandan Ministry of Health and relevant in-country policymakers.

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36 Telecardiology in Ghana: Perspectives from Korle Bu Teaching Hospital and Cardiovascular Diagnotics Clinic

John Kpodonu, Wisdom K. Atiwoto, and Jacques Kpodonu

Abstract

Telecardiography started in Ghana in 1977 at the Korle Bu Teaching Hospital with the introduction of a portable stand-alone M mode echocardiograph fitted with transducers for phono-mechanocardiography. The rest of the development took place at the Cardiovascular Diagnostics Clinic (John Kpodonu) with the introduction of a combined 24-h ABP/Holter in 2004, to be followed by 24–72 h Holter and 24-h ABP monitors in 2012. ECG wearables were introduced at the Cardiovascular Diagnostic Clinic in 2018 and to date has been well received by patients. Point of Care Ultrasound (POCUS) was introduced in 2020 using a tablet ultrasound device which has considerable potential for teaching, training of paramedical staff for task shifting, leveraging distance echocardiography by virtue of its Bluetooth and internet connectivity. Future research would focus on novel wearable EKG technology embedded in clothing. Wearable embedded clothings can be worn and removed at will to enable patients to have their bath or shower; the battery can be changed without interfering with the recording process and is therefore very suitable for long duration recording and for remote monitoring. Empowerment of nurses and other paramedical staff is emphasized as being an important component of a successful sustainable telecardiology program within a national telehealth infrastructure meant to provide affordable and quality healthcare to the citizenry no matter where they live.

Keywords

Holter · ABP · Telecardiology · Teleechocardiography · Point of care ultrasound · Wearables · Remote monitoring

ABP = ambulatory blood pressure

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36.1 Introduction

Norman Jeffrey Holter [1] invented "Holter monitoring" in 1962 [2] but it was only in 2001 that the smallest solid state digital Holter recorder, "Aria Impresario" with full fidelity and multiday capacity, data reduction, display, and

J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_36

report generation system was completed and introduced to the market [2].

Telecardiology uses digital technology to enable cardiologists to examine patients and sometimes treat patients at a remote location. The examination can use a digital stethoscope, camera, ECG and even an echocardiograph. A trained nurse or other trained health personnel in a remote location can position the stethoscope on a patient and the cardiologist in his clinic in another location is able to hear the patient's heart and lung sounds; in similar manner the cardiologist can examine the patient's breathing pattern, jugular vein pulsations, leg or other swellings, review his ECG, echocardiogram and other images. The cardiologist acts within the framework of a Telehealth infrastructure and can therefore make recommendations and treatment after the examination so that telepharmacy program can ensure delivery of prescribed medications.

36.2 History of Telecardiology in Ghana

In 1977, as Head and founder of the Noninvasive Cardiac Laboratory of the Department of Medicine of the Korle Bu Teaching Hospital, University of Ghana Medical School, Accra, (John Kpodonu) introduced portable stand-alone M mode Aloka ultrasound machine fitted with ECG and transducers for phono-apexcardiogram or phonomechanogram. Bedridden patients then had their echocardiogram and phono- apexcardiograms performed on the wards. Unlike 2D guided M mode of today, special skills were required to identify the various valves. Mitral stenosis was diagnosed by decreased diastolic closing slope of the valve leaflets, the loss of mirror movement of valve leaflets, the reduction of the area between the anterior and posterior valve leaflets, valve thickening etc. Aortic regurgitation showed coarse vibrations of the anterior mitral valve leaflet in diastole while aortic stenosis was diagnosed by valve thickening, by the reduction of aortic valve excursion during systole etc. That was the beginning of tele-echocardiogram or point of care ultrasound (POCUS) in Ghana. It was also the beginning of point of care phono-mechanocardiogram which combined ECG, phonocardiogram and apexcardiogram or carotidogram.

But it was in 2004 that the CARDIOVASCULAR DIAGNOSTICS CLINIC (John Kpodonu) introduced a 24-h Combined Holter/ Ambulatory Blood Pressure machine (Combo/ Holter/ABP) Micro SIW (AM5600) marketed by Advanced Biosensor. In 2012 the clinic acquired stand-alone 24–72 h Holter monitors and stand-alone ABP monitors. ECG Wearables were first introduced in 2018 with Kardia (AliveCor), Micor and later WIWE. Tele-echocardiography with embedded artificial intelligence diagnostics was recently introduced in 2020 at the clinic and is in its initial pilot stages.

36.3 Technology

1. ***Combined/ECG-Ambulatory Blood Pressure (Combo ECG/ABP) machine*** (Advanced Medical Micro Recorder AM5600)

This device combined 24 h Holter and ambulatory blood pressure (ABP) monitoring functions. While the Holter recorded double channel ECG signals continuously, the ABP component recorded blood pressure (BP) readings, pulse rate and pulse pressure at programmed intervals. Graphs from the two devices were simultaneously displayed as a polygraph. Apart from the diagnostic value of each device, their combination is very useful in observing correlations between blood pressure variations, pulse, arrhythmias, silent myocardial ischemia and ST changes in acute coronary syndromes.

2. ***AB-180R and DL800***

The AB-180R is a stand-alone 3-channel 24–48 h Holter recorder marketed by ADVANCED BIOSENSOR; which was updated to the DL800 a 24–72 h 3-channel recorder manufactured by Braemer Mfg. These devices continue to provide invaluable service as a non-invasive electrophysiology laboratory. The devices combined with software offered arrhythmia detection, ST analysis, heart rate variability, and pace maker detection among other functions. Changes in ECG wave morphology and pattern created the opportunity of determining the pathophysiology of arrhythmias. Holter monitoring thus provides some degree of telecardiology that was rendered more suitable for full telecardiology by developing longer duration devices which did not require in-person return to the cardiologist and by removing the inconvenience of patients' inability to have their bath or shower. A lot of progress has been made in this domain by adding telegraphic transfer of data or by disposable patches but emphasis today is on wearable devices.

3. ***ABP (24 h) monitoring***: A newer device the (AcuuWinPro) Oscar2) (Suntec Medical) is a stand-alone device which replaced the combined Holter/ABP recorder AM5600 and has more advanced technology including a reporting methodology similar to Holter. It provides information concerning maximum, minimum, systolic and diastolic BP, mean BP, pulse pressure, mean arterial pressure, averages asleep and awake, BP loads awake, asleep, average for the whole day as well as the corresponding histograms. Results can be displayed either as bar graphs (BP Trends versus Time) which are easily understood by patients or as "areas under the curve" used to compute BP loads which serve as therapeutic guidance (Fig. 36.1). The area under the curve display is very useful because it takes into account other comorbidities like diabetes mellitus and hypercholesterolemia; this information about comorbidities is essential to determine thresholds for each patient. An adjustment of thresholds automatically displays the corresponding area under the curve and the corresponding BP load and therefore helps in adjusting individual patient's medication dosage. It also improves compliance because patients get motivation when they see their area under the curve during review ABPs.

36.4 Wearable Devices

Wearables have been used in cardiology for a long time and many new devices have emerged during the past decade. Many of them have been widely adopted by ordinary consumers, patients and physicians alike. In 2018, we briefly tested Kardia (AliveCor) and Micor which are both internet based and all worked as event recorders and can record an unlimited number of ECGs. Owing to its relatively low cost and its convenience, WIWE became more popular.

1. ***Kardia (AliveCor)***: It was tried for a very short time, and like Micor, it is web based and works with an app and telephone. ECG is recorded by placing one finger from each hand on an electrode or sensor. The tracings are very clear and can be observed in real time.
2. ***Micor***: It is a bracelet (Fig. 36.2a) and also works with an app on smart phones. The ECG is recorded by positioning one finger on the sensor for 30 s; an ECG signal is displayed on the device during recording and the ECG tracing is automatically transferred into the app on the mobile phone for immediate transmission to the cardiologist by email. The resulting ECG tracing is very clear and easily legible (Fig. 36.2b).
3. ***WIWE***: It is a credit card size flat smart pocket ECG machine with oxygen saturation measure function (Fig. 36.3). It can be used on demand with results ready in one minute. Like Kardia, recording is done by placing one finger of each hand on each electrode of the device and the tracing is ready within one minute with a report in the format shown in Fig. 36.4a. As a phone accessory, the recorded ECG tracing is transferred to a phone using Bluetooth and the report can be sent immediately to the cardiologist whose address is programmed on the patient's phone. It delivers a one minute clear ECG (25 mm/sec, 10 mm/mV) tracings at a time (Fig. 36.4a). The ECG is analyzed by an algorithm and can be reviewed and confirmed by the cardiologist. It displays among other

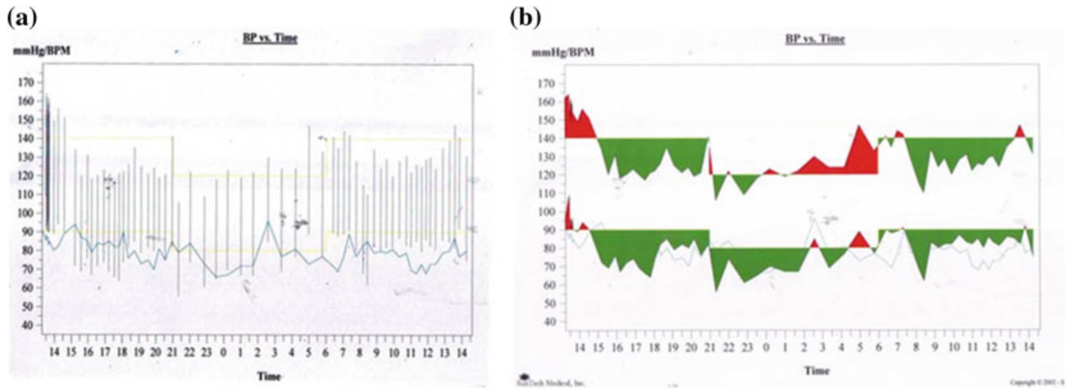

Fig. 36.1 **a** BP display as bar graph, **b** BP display as area under the curve

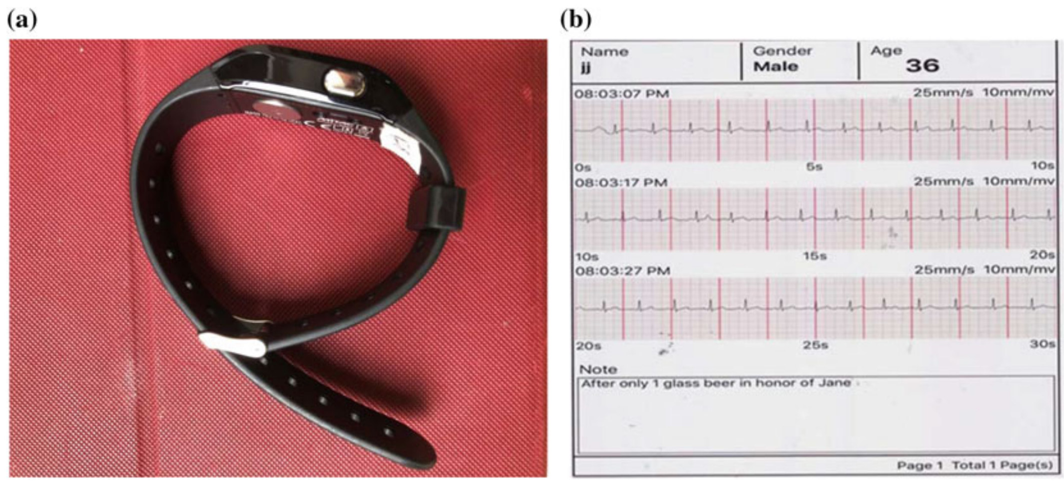

Fig. 36.2 **a** Micor. **b** Micor ECG. Note space for Doctor's report

things, PQ intervals, QRS duration, QTc interval analysis for ventricular repolarization heterogeneity, Poincare plot for heart rate variability and oxygen saturation. It also shows an average majority cycle with wave borders and tabulates patient results side by side with normal values for comparison. The overall report is summarized in 3 colored circles, each coded green yellow or red to alert the patient whether or not to send the report to the cardiologist immediately. The report is displayed as in (Fig. 36.4a–c). It is normal as in-dicated by three green circles at the top of Fig. 36.4b. Figure 36.5 shows severe abnormal ventricular heterogeneity in a patient with hypertrophic cardiomyopathy; this is indicated by a red circle at the top in Fig. 36.5a.

The device is very much patronized by patients from Accra and other regions in the country. The main indications are arrhythmia monitoring and detection, mainly patients with palpitations, pace maker surveillance, patients with stroke and other patients with disability who find it difficult to come to the clinic for review ECGs. About 70% of patients who complain of palpitations do not have any arrhythmia and have great relief when their recordings are explained to them. It can be very useful in the diagnosis of

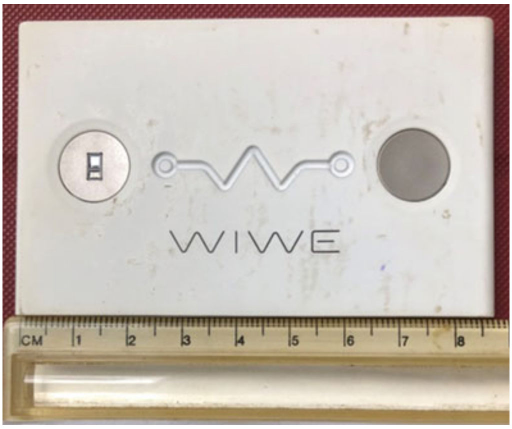

Fig. 36.3 WIWE

acute coronary syndromes especially in STEMI. The commonest findings are supraventricular ectopic beats, ventricular ectopic beats and paroxysmal atrial fibrillation. Two pace maker patients with paraplegia and stroke respectively have been followed up for many years at home.

36.5 Teleechocardiography with Kosmos Echonous

In 2012, we submitted a teleechocardiography proposal to the Ministry of Health (MOH) titled ***Distance echocardiogram with web based assessment for referrals at distance.*** It was a pilot study designed to train 10 non cardiologists in each of the administrative regions of Ghana, to acquire customized echocardiographic views using a tablet, transmit results to the very few qualified cardiologists in the regional hospitals. The philosophy was to later replicate this to lower level healthcare professionals (e.g. nurses, health assistants etc.…) so that the latter could carry out echocardiogram recordings in health centers or district hospitals, send results to doctors in different places, thus rendering quality health care affordable and accessible to all, including the poor no matter where they reside. Many studies [3–5] have confirmed that (POCUS) is feasible and can render immense service to the health care system. A recent study [5] using nurses to record echocardiograms in heart failure patients, confirmed that this approach is not only feasible but also reliable and also demonstrated that by using expert support by telemedicine, more patients with heart failure can gain the benefit of diagnostic ultrasound. It is our hope that the vision can now be realized with a novel device.

36.6 Artificial Intelligence Enabled Hand Held Tablet Echochardiography (KOSMOS ECHONOUS)

KOSMOS ECHONOUS (Figs. 36.6 and 36.7, 36.8, 36.9, 36.10 and 36.11).

Introduction: If Holter monitoring and wearables in particular are playing an undeniable positive role in modern cardiology, echocardiography has been another very important milestone in the field and has become, with ECG, an indispensable diagnostic tool in daily cardiovascular medical practice. That is why this new technology can be said to bring cardiology to a new height because of its functionality, not only as a teleechocardiograph but also as a mobile non- invasive cardiac laboratory for (POCUS).

AI enhanced handheld POCU for distance echocardiography: It is an artificial intelligence (AI) enabled handheld ultrasound device for the Heart, the lungs and abdomen, enhanced by autoguidance, autolabeling and autograding properties of echocardiograms. The spectral Doppler function recently added (Fig. 36.12), now allows flow velocities to be measured. This device is ideal for telecardiology in particular and telemedicine in general since it can also be used for abdomen and lungs.

It also carries out automated calculations of important physiological measures of function such as the ejection fraction, chamber stroke volumes, cardiac output and heart rate (Fig. 36.8). It will offer comprehensive and secure ultrasound functionality and data management augmented with artificial intelligence.

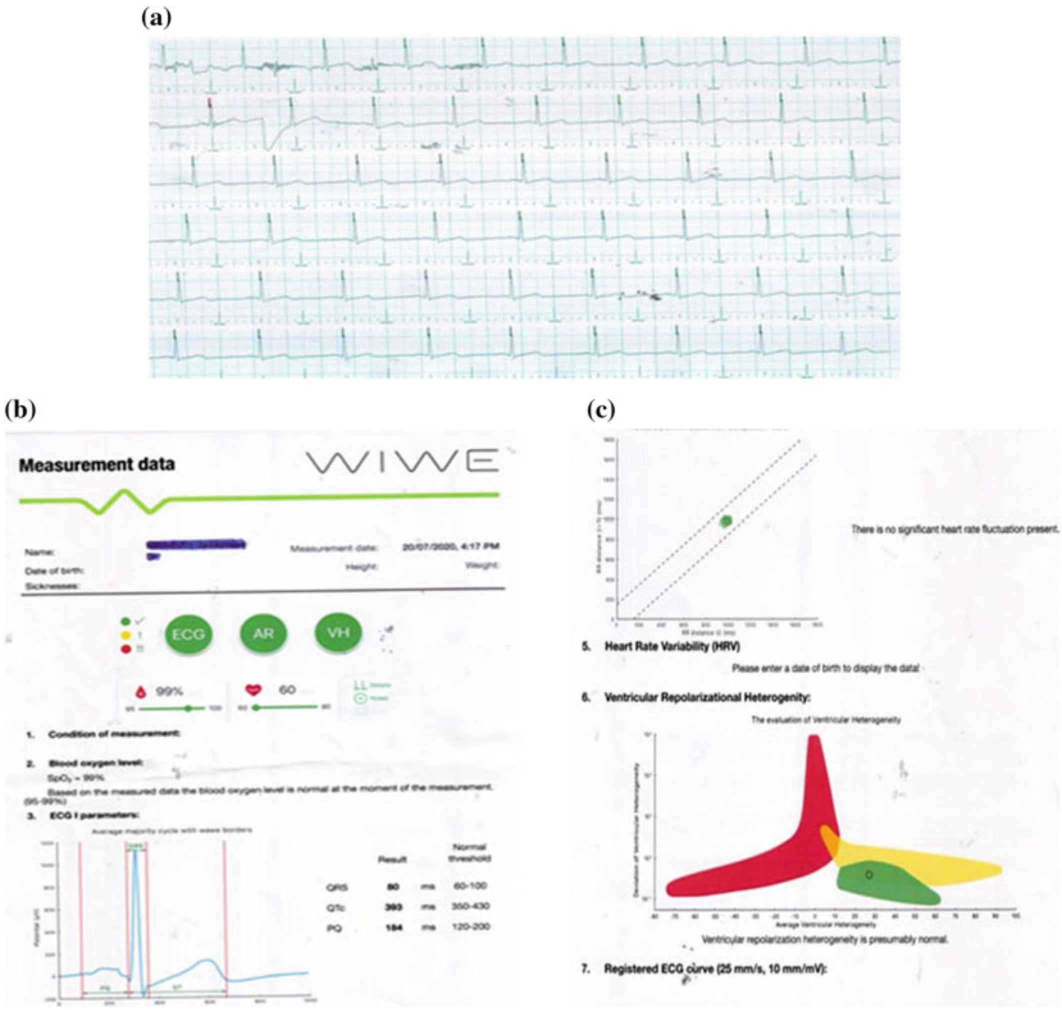

Fig. 36.4 **a** 1 min ECG tracing of a patient with WIWE. **b** Normal report summary, **c** graphic presentation with Poincare plot in upper left quadrant

The cloud-based platform will also allow users to wirelessly upgrade new functions and capabilities of the system as they become available, as happened a month ago when spectral Doppler functionality was added.

For training: The in-built ECG and digital stethoscope functionality together with the auto-properties listed above make it an excellent device for teaching not only cardiology to medical students and residents but also for training paramedical staff to carry out echocardiograms in remote areas to send to cardiologists for interpretation and further action.

Phonocardiograph for point of care auscultation: The digital stethoscope together with the ECG and 2D echocardiograms make this device a portable phonocardiograph for teaching heart sounds and murmurs (Fig. 36.7a–c). Indeed there is a stethoscope (Fig. 36.7c) which can be connected to hear the heart sound while the sound can also be seen simultaneously on the screen as a phonocardiogram (Fig. 36.7a, b). The 2D

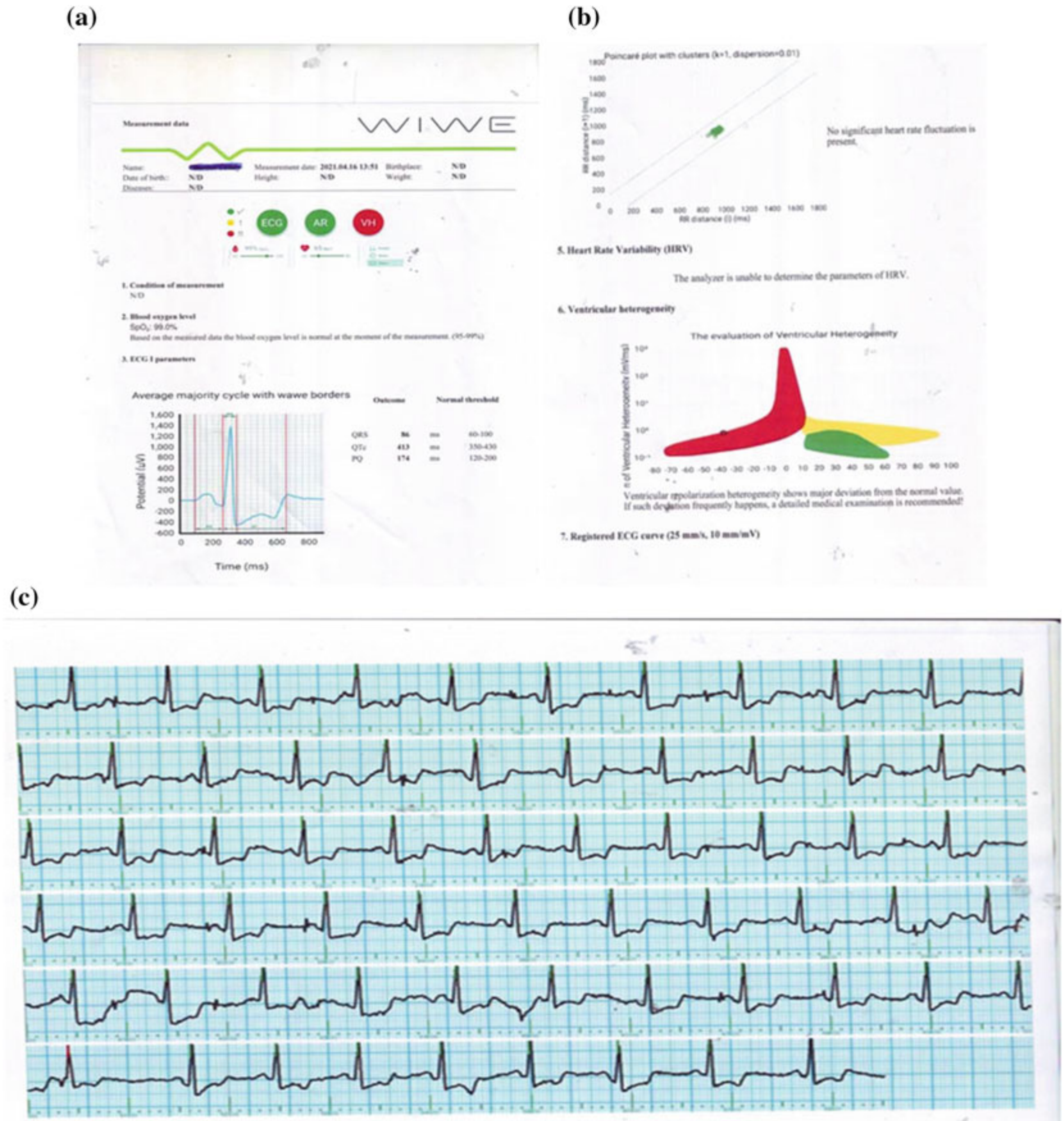

Fig. 36.5 **a** ECG showing abnormal ventricular heterogeneity (red circle) and abnormal T wave on ECG. **b** above: Poincare plot showing normal heart rate variability; below: graphic representation of ventricular heterogeneity. **c** ECG showing grossly abnormal T waves; QTc is normal but ventricular heterogeneity determined is grossly abnormal

image is displayed on top in each case, allowing to see the corresponding cardiac valve position during the cardiac cycle as well as the corresponding wall motion status (Fig. 36.7a, b).

Teaching of medical students and residents: Real-time auto-labeling of the structures being scanned facilitates the teaching of cardiac anatomy and pathophysiology while real-time auto-grading of the quality of image obtained on a scale from 1 to 5 and autoguidance properties in the form of probe instructions, help training and rapid and optimum image acquisition. This will greatly improve learning of ultrasound without an instructor and also learning cardiac anatomy.

The combination of pulsed wave (PW) and continuous wave (CW) Doppler, ECG and digital

Fig. 36.6 Echonous tablet (Bridge) with probe (Torso)

auscultation makes this device suitable for teaching the cardiac cycle and heart sounds and murmurs and also for understanding and interpretation of murmurs.

Echo images taken with the Echonous Kosmos device are very clear and comes with many editing tools for measurement and annotation after recordings (Fig. 36.9, Fig. 36.10). Comparative echo images of the same patient taken with a standard lap top cardiac echo machine

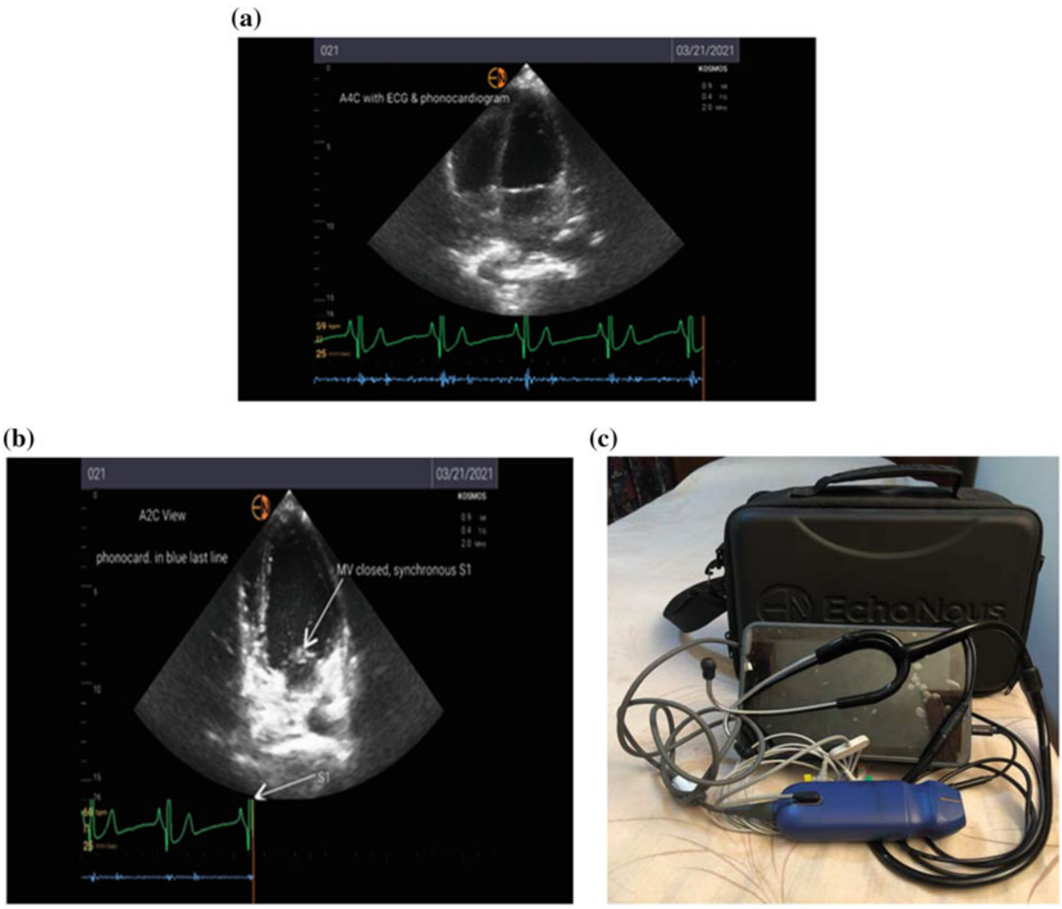

Fig. 36.7 **a** A4C view with ECG in green and phonocardiogram In blue; note synchrony of S1 with QRS S2 with end of S2. **b** A2C view with mitral valve closed and ECG and phonocardiogram; note synchrony of S1 with R wave of ECG and mitral valve closure. **c** KOSMOS with ECG cable, stethoscope, carrying case

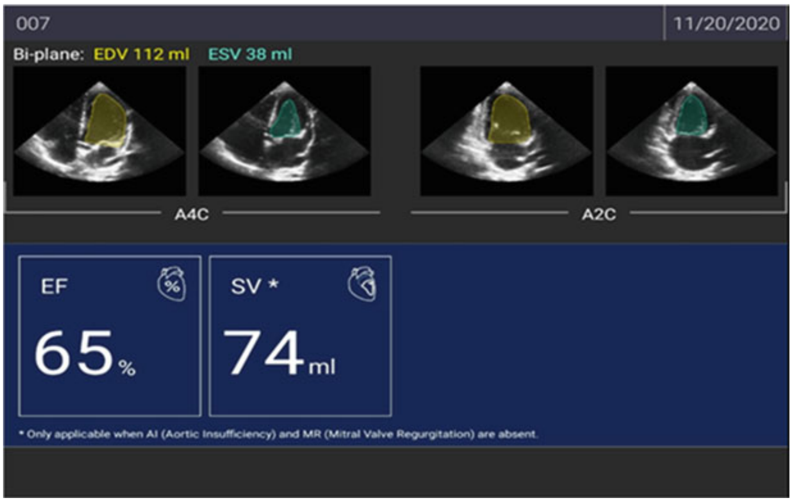

Fig. 36.8 AI calculation of EF: the 1st 2 pictures are A4C views in diastole and systole; the 3rd and 4th are A2C views in diastole and systole; the space below displays EF and SV; if ECG is connec-ted the blank space displays CO and heart rate respectively. Abbreviations: AI = artificial intelligence; EF = ejection fraction; A2C = apical2chamber; A4C = apical4- chamber; CO = cardiac output; CI = cardiac index; SV = stroke volume

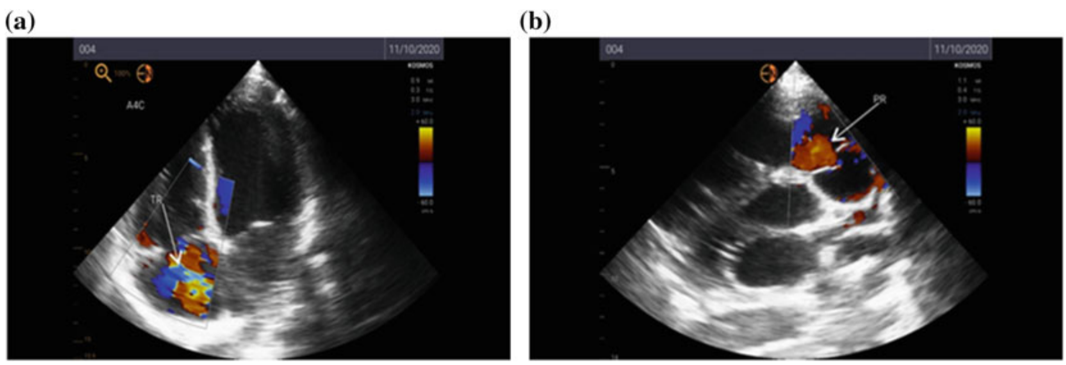

Fig. 36.9 **a** A4C view with color Doppler showing severe tricuspid regurgitation in an SS sickle cell patient. **b** modified PSAX view aortic level with color Doppler showing moderately severe pulmonary regurgitation in the same patient

Sonosite and with Kosmos show that images quality are on par are shown in Fig. 36.11.

Pulsed wave (PW) and continuous wave (CW) functions recently added make this device a complete echocardiograph capable of measuring both low and high velocities and can diagnose any heart condition like any other echocardio-graph (Fig. 36.12). Work is in progress to com-plete it with tissue Doppler functionality.

With network connectivity Kosmos Echo-nous can be used anywhere

The presence of wireless connectivity and the ability store and upload images in remote loca-tion with blue tooth and internet connectivityakes it very useful and a transformative tool for mobile echocardiography in remote locations.

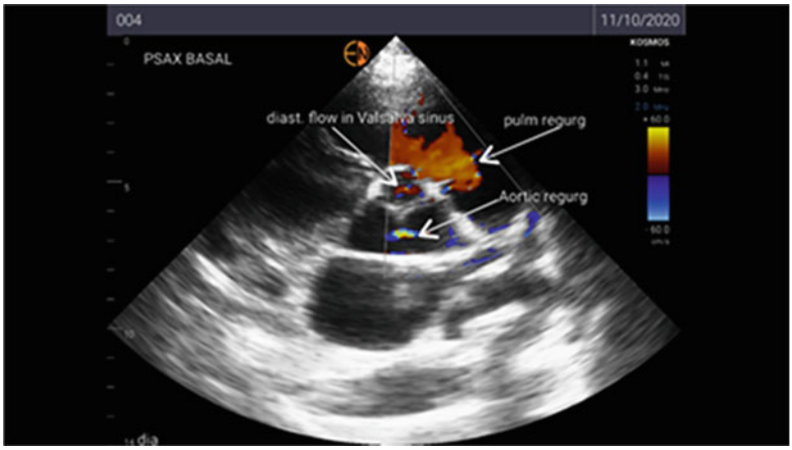

Fig. 36.10 PSAX view Aortic level of same patient as in Fig. 36.9 showing Aortic regurgitation, a more severe pulmonary regurgitation; it also shows editing tools. Abbreviations: PSAX = parasternal short axis

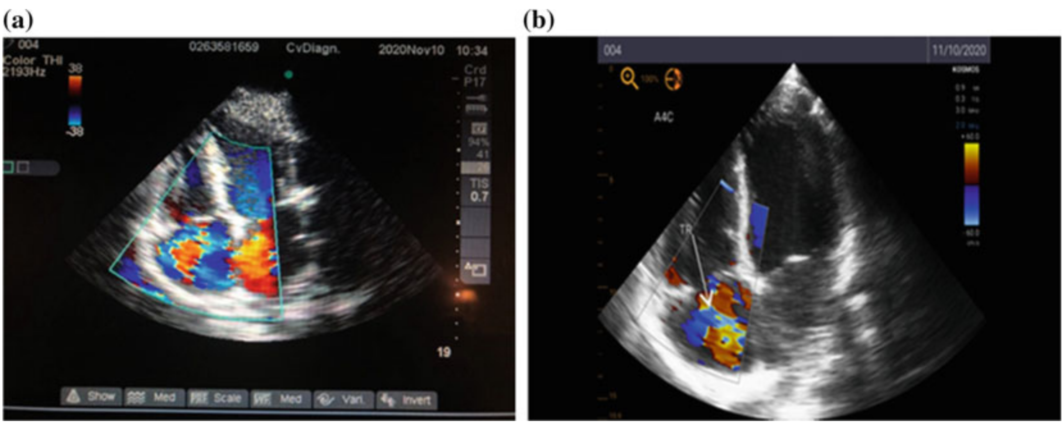

Fig. 36.11 **a** patient scanned with Sonosite. **b** Same patient with Kosmos Echonous

36.7 Future Perspectives

Looking back over the years we see a continual upgrade of the devices from a portable echocardiograph/phonomechanocardiograph in 1977, to the 24 h Combo Holter/ABP, to the 24 h ABP (Oscar2), to the 24–72 h ABHolter, to novel wearables (Kardia, Micor and WIWE), to the beginning of tele-echocardiography and hopefully to Cardioskin https://www.cardioskin.com/en/auth/login recently released on the market for long term ECG monitoring. We also note the acceptability of these tools and the enthusiasm they carry. But their paucity in the country, their cost and the lack of public awareness do not allow majority of patients to benefit from them. There is a large disparity between the number of cardiologists and cardiovascular disease burden and this has been made worse in recent times by the Covid-19 pandemic.

Training and Empowering the auxiliary health care staff like nurses and heath assistants or other paramedical staff for task sharing has been shown to be highly beneficial for the health care systems [3–5]. Institutions which have been successful in this process (5, 7, 8) have made various recommendations. Training for task shifting in telecardiology should be structured and should have specific workflows and goals for interoduction technology like wearables and POCUS in tele-cardiology. Telecardiologym-training programs should be integrated into national health care system, taking into

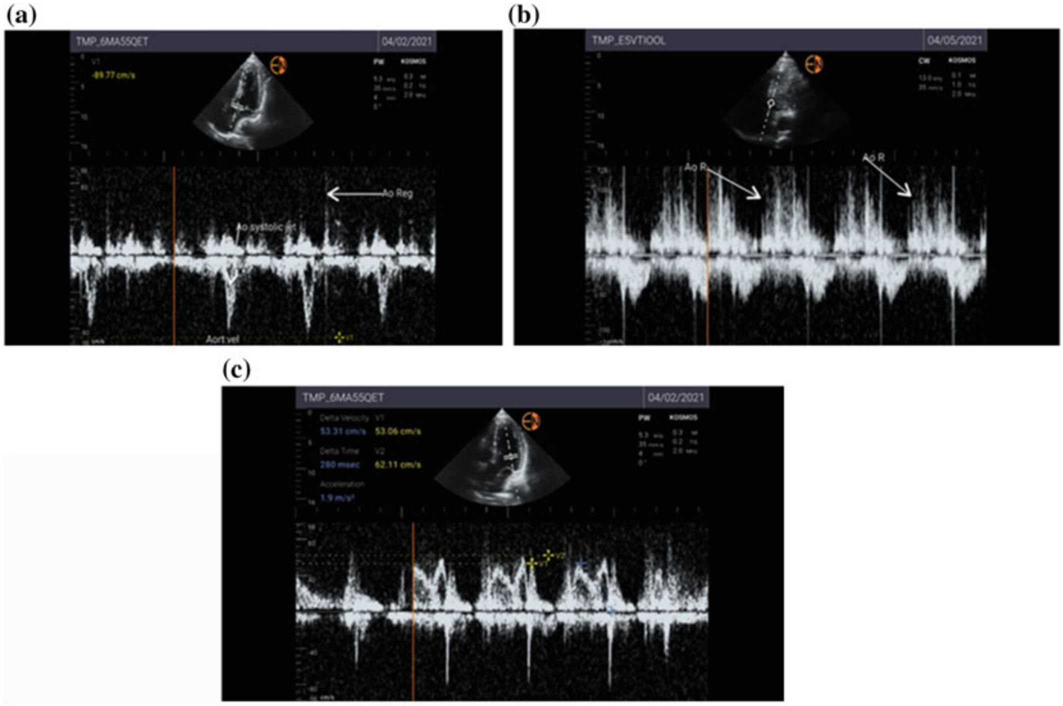

Fig. 36.12 **a** PW showing aortic regurgitation. **b** CW showing aortic regurgitation. **c** PW mitral valve with very mild left ventricular diastolic dysfunction

consideration national realities and should be adaptable to geographical and other local factors. There is need to allow for innovation to suit various cultures. The Covid-19 pandemic has heightened the utility of telemedicine in general and telecardiology [6, 7] in particular by increasing the potential of wearables; new wearables now incorporate body temperature, heart rate, oximetry, blood sugar etc.… to allow for remote disease monitoring of patients. Empowerment of nurses and paramedical staff leads to immense cost reduction and improvement in health care for the population as a whole, with particular reference to the poor and those living in remote areas. Patients in remote areas do not need to travel to capital cities or tertiary hospitals in the regional capitals to have an ECG or an echocardiogram for emergency or outpatient visit. POCUS [3–5] from a remote area will save time, improve diagnosis by virtue of the fact that the image can be saved,uploaded on a server or a cloud platform and available for a remote read by cardiologists anywhere.

In a recent report, Nascimento et al. [4] used POCUS in a study in Brazil and discovered that there was a considerable burden of significant heart disease with an especially high prevalence among sickle cell patients; they observed that POCUS may improve early diagnosis and referral, presumably serving as a prioritization tool to deliver cardiovascular care to low-re-sourced areas through task shifting. They highlighted the importance of the systematic evaluation of asymptomatic patients in underserved areas, where the burden of heart disease may be higher.

In another study Peters et al. [3] on their part cited reports that many medical schools and postgraduate training programs have or are in the process of developing curriculums to teach POCUS. In the same paper they cited reports suggesting that POCUS can be applied in remote settings without routine access to formal ultrasonography to determine which patients may benefit from a complete echocardiogram. POCUS will significantly decrease the need to transport Covid-19 patients (6,7) around in the hospital for other tests such as MRI etc.…thus reducing considerably the risk of contaminating other patients, thus improving outcome and saving lives.

Government involvement with training, publicity and research programs

The benefits of POCUS are overwhelming and have been amplified by the Covd-19 pandemic. Government should create a suitable environment by improving the communication system on the whole territory and building the appropriate and uniform cloud platform for the whole territory so that other health sectors like fetal tele-echocardiology [8] can be integrated for tele-referrals and teleconsultation. It should encourage and facilitate cardiology-specific research [9] and training programs and also find solutions for the challenges [10] like costing the services, reimbursement for the services, data safety. Research should be encouraged in view of the rapidly changing nature of telemedicine tools for heart failure remote monitoring etc. [7, 11, 12]. Publicity and awareness programs should be organized and innovation and cultural taboos should be addressed.

Cardiovascular *Data Science Institute*: Several studies have combined cloud computing and mobile computing to facilitate better storage, delivery, retrieval, and management of medical files for telecardiology [10]. With the rapidly increasing amount of data generated, it is predictable and generally agreed that wearables and tele-echocardiogaphy will eventually generate "BIG DATA" which may lend to the application of big data analytic methodology and data mining to the data sets amenable to artificial intelligence methods. Indeed, Hsieh et al. [10] predict that in the future, the aggregated ECG and images from hospitals worldwide will become big data, which should be used to develop an e-consultation program helping on-site practitioners deliver appropriate treatment. The project that with information technology, real-time teleconsultation and tele-diagnosis of ECG and images can be practiced via an e-platform for clinical, research, and educational purposes. With the power of computers together with the rapid improvement in information technology, the large quantity of data generated by all these devices will be exploited by artificial intelligence, possible gateway to predictive and precision medicine. A lot of research in this direction is ongoing [9, 10] cited by [13]. This novel approach to medicine and cardiology should therefore be advantageously exploited to develop artificial intelligence and precision medicine. All this can be smoothly integrated into a *Cardiovascular Data Science Institute*.

Innovative methods should be adopted taking into account the realities of the country [6]. For poor communities in remote areas, a number of recommendations can be made. A small district health center can own just one or two ECG wearable devices which can be used for several patients who call at the clinic with a cardiovascular problem. A patient reporting at such a clinic with severe palpitations for example can have an ECG done with a wearable device in 1 min and the ECG tracing immediately sent to the doctor programmed on the device or to any other doctor; the doctor himself can send the same ECG to a senior colleague for opinion; the doctor, after interpretation of the ECG sends a report back to the nurse or appropriate instructions are given to the nurse for the next action to take. Clinical scenarios leveraging telecardiology could enable a patient in a remote village have consultation and treatment guidlines from a remote specialist otherwise not currently available in that community. A patient with impending tamponade in a district health post can have an echocardiogram done by a nurse and uploaded and made available to a remote specialist with immediate instructions to nurse to organize an ambulance to transfer the patient immediately to a nearby hospital for pericardiocentesis thus saving the patient's life.

Remote Monitoring Technology: There are many studies on heart failure monitoring at distance [2, 6, 11–15].Remote monitoring technology was accelerated during COVID19 pandemic with patients with chronic heart failure partients benefitting the most. Newer wearables devices that incorporate vital signs like temperature, pulse, BP, oxygen saturation, blood sugar ect… enabled patient to be follow up at distance. Studies of cardiovascular signals continuously sensed by implantable devices provide unique insight into detailed pathophysiology as patients progress from stable to symptons of congestive heart failure. These data suggest that volume expansion, autonomic adaptation, and pulmonary interstitial edema begin several weeks before patients develop symptoms or demonstrate changes in daily weight. Monitoring physiologic signals from implanted devices may provide earlier warning of impending decompensation, thereby allowing changes in medical therapy to prevent worsening heart failure [11]. Despite current therapies and disease management approaches, rates of heart failure rehospitalization remain high. New tools are needed to assess preclinical (asymptomatic) pulmonary congestion to enable outpatient management. Hence, a novel monitoring system based on noninvasive remote dielectric sensing (ReDS) technology was developed [12] and findings suggest that ReDS technology accurately quantifies lung fluid concentration and has potential for monitoring heart failure patients through hospitalization and possibly at home.

Future Technologies:

Wearable bioimpedance monitors can measure transthoracic impedance [14] by surface electrode application and have been shown to have reasonable correlation with intrathoracic impedance (ITI). The degree of ITI is inversely correlated with the level of intrathoracic fluid. Changes in ITI are shown to precede worsening congestive heart failure prior to standard clinical parameters like weight gain [15]. Distance monitoring can therefore be used to follow up heart failure patients from their homes to adjust therapy before the patient has symptoms.

Ventricular heterogeneity is the substrate of many lethal arrhythmias. Many conditions leading to heart failure and heart failure itself lead to ventricular heterogeneity. Antzelevitch et al. [16] suggest that the amplification of spatial dispersion of refractoriness in ventricular myocardium, particularly when due to augmentation of transmural dispersion of repolarization, can predispose to the development of potentially lethal reentrant arrhythmias in a variety of ion channelopathies and also in hypertrophic and dilated cardiomyopathies. The patient in Fig. 36.5 with hypertrophic cardiomyopathy suffered two episodes of ventricular tachycardia but cannot afford to pay for an implantable cardioverter- defibrillator (ICD); his test ECG (first recording) with the WIWE wearable (April, 2021) shows normal QT interval but severe ventricular heterogeneity (red circle) confirming that a normal QTc can coexist with ventricular heterogeneity. Future wearables for continuous monitoring should therefore include ventricular heterogeneity functionality, ST segment analysis, heart rate variability, blood pressure, blood sugar body temperature and other vital signs.

Long duration Holter monitoring can be ideal particularly for patients at high risk of sudden cardiac death. Cardioskin https://www.cardioskin.com/en/auth/login recently introduced by Servier could revolutionize long term holter monitoring. It is a wearable innovation that would allow heart patients to more easily accept to monitor their cardiac rhythm for long periods because patients can interrupt the recording temporarily to have their bath or shower, or change the battery without disturbing the recording process. It is a T shirt which can be removed and worn at will. It is fitted with 13 electrodes to generate 15 lead ECG (including V7, V8, V9 making posterior myocardial infarction diagnosis easier). Another important feature is that patients can interact with the recorder during monitoring period and communicate with the Cardiologist. The cloud platform also makes possible rapid consultation of cardiac electrophysiologists if necessary. I think that it should be possible to add other features such as BP measurement, body temperature, oximetry, blood sugar, thoracic bioimpedance by slightly increasing lengths of the garment to the femoral artery at the groin, or synchronizing a medical bracelet with Cardioskin or a Cardioskin equivalent. This will need collaborative efforts from different research groups or industry.

Novel technologies described are expected to improve telecardiology in particular and telemedicine in general, and facilitate home monitoring ideally if implemeted within a national telemedicine strategy. Synchronous data from from one patient in a pool of data from many patients would be the source of 'BIG DATA' necessary for predictive and precision medicine with its invaluable health care cost reduction, improvement and accessibility of quality health care to all, saving lives. Doctor-patient face to face interaction is still possible and very relevant when necessary because telecardiology does not to replace doctor- patient relationship but rather gives the doctor more time to give patient the required attention by augmenting quality cardiovascular care

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37 Developing a Sustainable High-End Cardiovascular Surgery Program in Emerging Economies: The Narayana Health (NH) Model Structured on Affordable, Accessible, Tertiary Level Care

Varun Shetty, Anesh Shetty, and Devi Prasad Shetty

Abstract

In this India story of capacity building for cardiac surgery in India, the authors present the case of Narayana Health (NH) as a model that has evolved successfully and replicated in the Caribbean region. Leveraging on the volumes, the costs of procedures are reduced. A large population gains access to advanced tertiary care through micro health insurance paying a tiny premium amount. Adoption of technology has helped digitize patient health records and electronic health systems in open APIs for flexible interoperability. SaaS and Cloud have minimized capital investment. Data intelligence and analytics have helped in informed decision-making supplementing clinical observation. Aided by Artificial intelligence and deep learning the costs are closely monitored, detection and interpretation of images, MDR and antibiotics use are also tracked. Communication between the doctors in patient care, online consultations with patients have enhanced the reach and convenience of healthcare delivery. A practical oriented approach to training has produced employable surgical support workforce that is hands-on and productive from day one. The approach has also helped in efficient healthcare delivery and outcomes. With a globally recognized accreditation programs, developing countries can be a major supplier of skilled workforce to the world.

Keywords

Cardiac surgery in LMIC · Capacity development · Training health workforce · Health information technology · Health system model · NH · Narayana health

37.1 Introduction

If a solution isn't affordable it is not a solution worth considering."
—Dr. Devi Shetty

Narayana Hrudayalaya Institute of Cardiac Sciences was founded in 2000 by Dr. Devi Shetty as a 150 bedded heart hospital which eventually grew to 1,000 beds performing 8,000 cardiac surgeries and 17,600 cardiovascular interventions annually. Today, Narayana Health (NH) runs 21 hospitals and performs 14% of the cardiac surgeries in India. NH has pioneered numerous strategic interventions, such as reducing the unit price of surgeries to make them affordable, introducing micro-health insurance to cover uninsured cooperative communities, and

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_37

using technology to leverage expertise across lower-skilled manpower.

Dr. Devi Shetty completed his cardiac surgical training in England and started his career in Kolkata as part of the founding team of the B.M Birla Heart Research Centre in 1989. Most Indian cities at the time lacked doctors, nurses and paramedical personnel trained to care for cardiac surgical patients and the B.M Birla team had to simultaneously teach, train and successfully treat patients requiring heart surgery. The hospital established the first cardiac critical care nurse program and the first perfusion training program in Eastern India. Over the course of 9 years, Dr. Shetty's team at B.M Birla completed over 7000 heart surgeries, including the first neonatal Total Anomalous Pulmonary Venous drainage correction and the first Extra Corporeal Membrane Oxygenation in India.

Up until recently, the typical Indian super-specialty hospital was built to serve mostly affluent patients. Only 25% of the bed capacity would cater to patients from lower socio-economic strata. NH was founded by like-minded individuals who believed in the mission of delivering high quality super-specialty care for every Indian. The goal was to develop a sustainable business model that would offer subsidized care to patients who could not afford the list price of surgeries, by reducing operational inefficiencies, standardizing clinical protocols, and lowering cost of medicine, implants and consumables. To this day, NH has never needed to turn away a patient for lack of money.

37.2 Economies of Scale (Micro Health Insurance, Assembly Line Surgery)

India is the second most populous country in the world yet public expenditure on healthcare is one of the lowest at 1% of GDP [1]. As of 2014, only 15% of the population has insurance coverage [2], and a recent survey [3] showed that financial catastrophe from out of pocket expenditure for healthcare amongst vulnerable groups is at an all-time high. This is because most Indians opt for treatment in private hospitals because of deficiencies in the public health system [4]. This unfortunately leads to over 40% of patients having to borrow or sell assets to cover healthcare expenses [5].

The average cost of an open-heart surgery (CABG) at a private hospital in India is around $5,500 compared to $150,000 in the United States. However, this is unaffordable for most Indians as the per capita income for 2019 was $2,104. NH can cross subsidize the cost of a heart operation and lower it to $1,519 USD. For patients who cannot afford to pay out of pocket, their costs are borne by the government through healthcare reimbursement schemes.

In 2004, NH created the first micro health insurance program in collaboration with a farmers cooperative society in the southern state of Karnataka. In the first year, Yeshaswini health scheme covered the cost of all surgeries for 1.7 million farmers and their families. The scheme had a monthly premium of $0.11, half of this was borne by the farmer and the other half by the state government. By 2018, a total of 3.4 million farmers were covered and 1.21 million surgeries were conducted, including 131,000 heart surgeries. This self-managed program was eventually discontinued as states opted to directly pay for healthcare expenses without collecting premiums.

The most important model that NH has adopted towards its mission of reducing the cost of surgeries is optimal utilization of healthcare workers and infrastructure. The NH way has been compared to the Ford model of assembly line production [6]. As an example, the average number of cardiac surgeries performed by a cardiac surgeon in the United States is between 100–200 whereas NH ranges between 400–600 [7]. The flagship Narayana Institute of Cardiac Sciences has 16 operating theatres with a daily average volume between 30–34 cases per day. In 2019, a total of 7,827 cardiac surgeries were performed, out of which 5,538 were performed on adults and 2,289 on children. With the annual increase in volumes there is a reciprocal reduction in the cost of the operation (see Fig. 37.1).

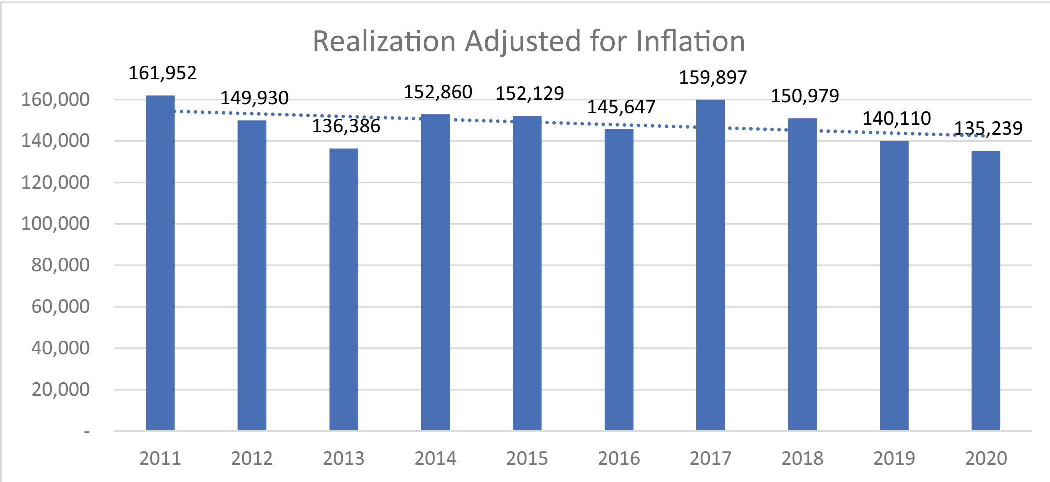

Fig. 37.1 The cost of coronary artery bypass grafting has remained almost the same for the last 10 years at INR 160,000 or USD 2,200 USD

37.3 Converting Atoms into Bytes (Telemedicine, Holter Monitoring and Portable EHR)

As technology advances, it has an intrinsic ability to lower costs. The ENIAC was completed in 1945 at $6.3 million in today's costs, versus a modern cell phone which has 1,300 times the processing power and costs around $500. Medical devices of the past were bulky mechanical devices. Today's medical devices run on software and printed circuit boards, making them cheaper, portable, and more efficient. However, medical costs have continued to outpace inflation for several reasons—regulations, reliance on specialized manpower, high barriers to entry. Skilled manpower is a finite quantity that cannot grow exponentially but can be resolved through software. The internet has shown that knowledge and expertise can transcend physical boundaries and allow common interest groups to collaborate for the betterment of society.

NH started a telemedicine program in 2002 in collaboration with the Indian Space Research Organization. NH Telemedicine program has collaborations with over 55 countries and has treated 53,000 patients to date. In addition to tele consultation NH remotely manages coronary care units (CCU) across the state of Karnataka. These CCUs are equipped with ECG machines, video conferencing equipment, medicines and managed by local general practitioners and nurses. The cardiologists at NH advise the General Practitioners via video conference for the initial management stabilization and transfer in case needed. Between 2001-04, NH treated 7,047 inpatients remotely through tele medicine [8].

The death rate from cardiovascular disease is 272 per 100,000 population, and 52% of deaths occur before 70 years of age [9]. There is no reliable data on incidence of heart failure amongst Indians, however it is estimated to be between 300,000 to 1.75 million [10]. The incidence of arrhythmia in patients with heart failure is high and 46% of patients require implants such as Implantable Cardiac Defibrillator or pacemaker [11]. NH is working on democratising arrhythmia management because patients needing a Holter test, need to travel to big cities and waiting upwards of 1 week for a Holter study.

NH, in collaboration with Cardiac Designs Labs [12], a Bangalore-based start-up has developed a Holter device that transmits heart data wirelessly. The data is interpreted by an algorithm that is then certified by a cardiac electrophysiologist. The plan is to distribute these devices to participating organisations for free and charge them for the interpretation and tele consultation with the cardiac electrophysiologist. This will deliver tertiary level cardiac electrophysiology in rural locations.

Most Indians have their health records on paper, often amounting to incomprehensible and disorganised information. NH is working towards digital personal health records using a mobile application. The user needs to take a photo of the health records and sort it according to lab report, radiology, prescription, and discharge summary. Using optical character recognition, the app picks out keywords and sorts the co morbidities, creating a trend value for lab parameters and re-creating a timeline for major health events. This data will be cross verified by a registered nurse and will be stored on the users own phone, who can then present it to the next doctor he sees.

37.4 Data Intelligence

Narayana Health is improving clinical outcomes, operational efficiencies and driving productivity gains by harnessing the power of data analytics and artificial intelligence. Our platform Medha has been developed by a team of data scientists, doctors, engineers, coders, nurses and statisticians. Over the past three years, Medha has been analysing mountains of data to deliver insights that are reshaping the way NH makes key decisions.

Born out of a skunkworks project, our data intelligence program gradually evolved into an exercise to standardize and refine the data acquisition processes. Once we amassed sufficient data from all patient touchpoints, we began to unlock value from this treasure trove. Medha presently consists of a catalogue of purpose-built dashboards that empower the clinicians and administrators to take more informed data-driven decisions. These dashboards have evolved through iterative refinement in consultation with diverse users, from CFO's to neurosurgeons. The resulting product is tailor made to each end user's requirements. The cardiac surgeon has a mobile optimized dashboard displaying information about his patients, real time risk score analysis on the patient's current status, which allows the care team to focus on high risk cases. Another dashboard displays MDR organisms, antibiograms, and tracks antibiotic usage (see Fig. 37.2). Ongoing projects include using AI to interpret X ray images to pneumothorax, cardiac tamponade, position of the endotracheal tube and pickup foreign bodies in the chest following heart surgery.

The Business Intelligence tool was developed to a monitor the input costs of an individual procedure. The software provides a detailed analysis of the cost of consumables, medicine, and manpower, this is in turn compared across the group. It is also used to track key quality indicators like average length of stay, intensive care stay and re-admissions for an individual doctor. The main purpose of the tool is to provide doctors with the information to self-govern their expenses and to establish clinical benchmarks. See Fig. 37.3.

37.5 Electronic Health Systems (EHS)

Most EHS today are siloed structures of information with restricted access across systems. At NH, we believe that data portability is the most important function of an EHS that makes high quality care accessible. Driven by a need to develop a technology platform to drive the next level of improvements in clinical outcomes and operational efficiencies, NH embarked on a journey to reimagine and rebuild the EHS.

NH's hospitals run on a technology platform that has been built by an internal software development team consisting of both clinical end users and developers. The platform, named ATHMA, has been built using the latest interoperability standards and with a software as a service platform architecture. Clinicians are embedded within the engineering teams and NH aims to create a frictionless sandbox for developers to interact with end users in a clinical environment. The goal is to create software solutions that empower clinicians to safely treat

Fig. 37.2 The antibiogram dashboard on the EHS, providing regular updates to the clinicians on the antibiotic sensitivity patterns and location of multi drug resistant bugs

patients while continuously improving clinical outcomes and reducing costs.

ATHMA has been designed around portability and openness. The platform works seamlessly for physicians using tablets in their outpatient clinic, or intensivists rounding from a desktop at home or surgeon doing a video consultation from his mobile phone. ATHMA was built with the intention of creating an open API ecosystem upon which other developers can build their products. We believe this will foster better collaboration between different healthcare technology providers and grow the industry as a whole.

ATHMA has a separate mobile application named AADI (ATHMA Application for Doctor Insights) meant for both doctors and patients.

Fig. 37.3 The BI tool can track consumables by procedure, the summary shows doctor-wise consumption for coronary balloon angioplasty

Back to Report | DOCTOR - CONSUMPTION SUMMARY

Doctor	Mean	1st Quartile	Median	3rd Quartile	Volume
	49,367	28,648	42,928	57,085	817.0
	43,977	30,197	36,802	54,290	650.0
	42,099	33,043	38,029	44,589	312.0
	56,330	34,496	43,586	69,098	252.0
	45,117	31,092	39,184	57,300	494.0
	42,321	28,447	36,257	55,233	606.0
	49,953	34,175	40,000	62,838	229.0
	36,507	25,706	30,694	49,171	473.0
	41,855	27,739	41,501	52,818	437.0
	46,858	34,588	40,732	56,468	196.0
	39,915	27,704	33,030	51,516	417.0
	41,864	27,571	36,358	51,980	349.0
	38,258	28,628	35,137	43,209	375.0
	53,920	36,840	45,641	70,253	147.0

AADI for doctors is a mobile interface which doctors can use to access patient medical records remotely. Doctors can also prescribe medicines, order investigations and type notes while in the hospital premises (Fig. 37.4). We have found that AADI is a very effective medium for doctors to efficiently communicate and collaborate in the patient care. Doctors can also use AADI to conduct video consultations with their patients while having complete access to their medical records.

AADI for patients is a dedicated application to access medical records and investigation reports. When the patient is in the hospital, it provides real-time alerts for the patient attenders and is their primary communication tool with doctors.

37.6 Training for the Future

The global healthcare market is expected to reach USD 11.2 trillion by 2022 [13]; estimates put the shortage of healthcare workers at 7.2 million which will exceed 12.9 million by 2035 [14]. India has a shortfall of 1.94 million nurses, a number that is only growing. The primary reasons for poor nursing retention are subpar pay and working conditions across most public and private hospitals. Large number of skilled and experienced Indian nurses will emigrate to developed countries as soon as they acquire the requisite work experience [15]. This problem is not unique to India, mass emigration has proven to be detrimental to the healthcare delivery

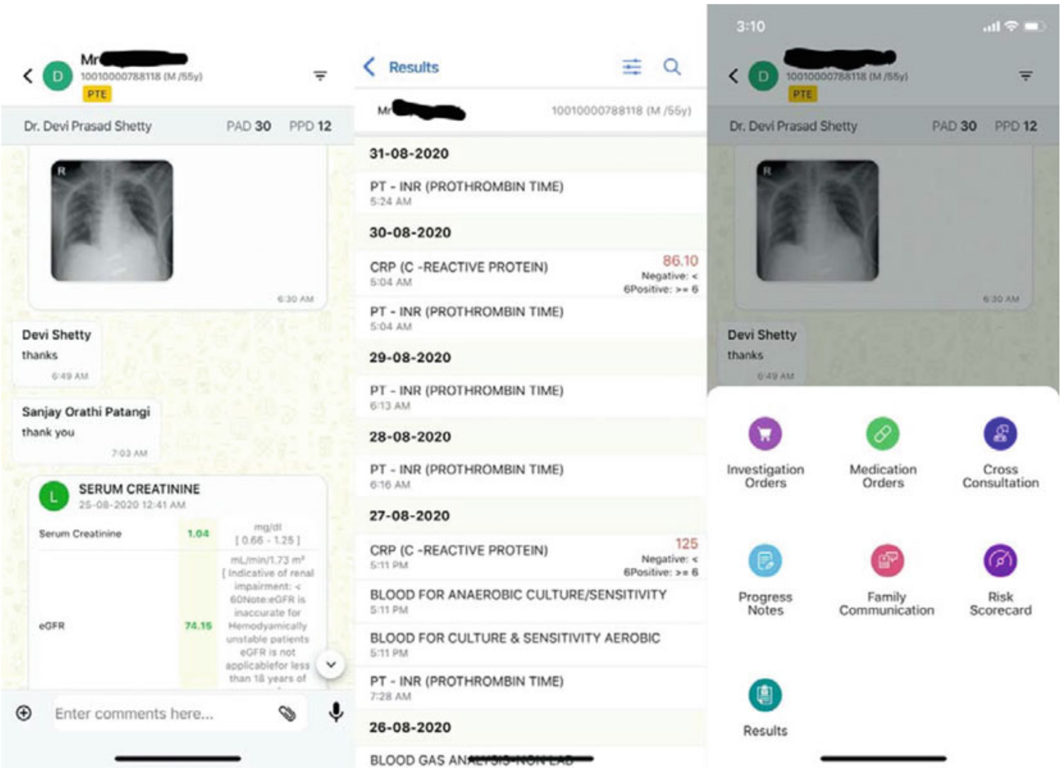

Fig. 37.4 Screenshots from the AADI mobile app, explaining how to doctors have access to the patient's medical records and use AADI as a communication tool between doctors

system in the Philippines [16]. However, this migration does have some benefits, as remittances from nursing is a huge economic driver for some Indian states and nursing as a career is an attractive aspiration for children from deprived backgrounds [17]. The magnitude of these remittances is almost $16 billion every year, and this impacts spending on healthcare infrastructure and training. Migration of nurses does have a negative social impact, but data from the National Health Service, Ireland shows that remittances are useful for families back home as they are a steady income for unemployed members [18].

The world must create coordinated solutions that provide a sustainable supply of healthcare workers. Developed countries facing a declining growth rate have declining enrolments of healthcare workers and they must look towards the developing world to fill this void. These jobs and foreign exchange can be a large economic driver and opportunity for tomorrow's youth. By proactively structuring training and migration of skilled manpower in developing countries, the host countries can avoid shortages that can be detrimental to its healthcare delivery.

The NH College of Nursing and Allied Specialties was started 20 years ago and runs 24 accredited training programs. NH College of Nursing prioritizes field training on the hospital floor. Our nurse trainees are posted in the Intensive Care Unit on day one, where they shadow a trained nurse. They learn physiology by monitoring cardiac intensive care patients and adjusting the ventilator based on the arterial blood gas. Pharmacotherapy by preparing and titrating vasoactive infusions and the skills expected of a nurse by managing the invasive lines, feeding and analgesia. Qualified nurses who have completed 3 years in the intensive care

are eligible for in the house nurse practitioner program in the specialties of cardiac and medical intensive care and anesthesia. At the end of the program, these nurse practitioners are assigned independent responsibility in the intensive care and operating rooms. Our training programs are a hybrid of didactic, simulation and problem-based approaches.

The number of graduates from existing perfusion training programs in the country could not accommodate for the increase in our cardiac surgery volumes, and most of the graduates lacked the requisite experience to independently run a bypass machine. That was when we decided to start our own perfusion school in 2002, to date 250 perfusionists have graduated from our program. Our students are made to work on the bypass machine after just 3 months of joining, by the end of their training most graduates have done over 100 cases independently. The perfusion training program is heavily based on hands on training alongside lectures and simulator-based learning.

The onus of providing skilled manpower to the world should be borne by developing countries with a large population who are young and employable. The world needs a global accreditation program that recognizes their training and provides free migration to the healthcare systems in the developed world. This will prevent asymmetries in the pattern of employment between developed countries. The Philippines and India currently provide majority of nurses to the developed world, and this opportunity should be extended equally to all similarly positioned countries.

37.7 Scaling into Other Territories (the Caribbean Story)

While NH was actively considering the next location for geographical expansion, various observers were wondering if NH's model of high volume, affordable care could be replicated in the Western Hemisphere [19]. While looking for a suitable location near the U.S, the NH team was introduced to the Government of the Cayman Islands (CIG). CIG was aiming to add a third pillar to the economy in addition to the existing tourism and financial services industry. The Cayman Islands had advantages such as a stable developed economy, advanced infrastructure, and proximity to the United States.

NH built a tertiary care hospital in the Cayman Islands with the aim to export its model of affordable care to the developed world. Today, Health City Cayman Islands (HCCI) is the largest JCI accredited hospital in the Caribbean and performs the entire spectrum of tertiary care procedures at a fraction of the price as those offered an hour's flight away in the U.S. To minimize operational costs, the team established a global supply chain network that leveraged NH's procurement strengths in India. HCCI was the first hospital in the Caribbean to perform complex procedures such as Left Ventricular Assist Device implantation and Transcatheter aortic valve implantation. The team also started an Extra Corporeal Membrane Oxygenation program and they presently have an 86% discharge to home rate. With a focus on building both a regional medical centre of excellence and a medical tourism facility, HCCI has treated patients from over 20 countries.

This has served as a showcase hospital for the region and NH is currently looking to expand into neighbouring Caribbean countries.

37.8 Conclusion

Sustainable healthcare programs need to be based on certain guiding principles. The Program:

- needs to understand the needs of the population it serves
- must remain accessible and affordable to most people
- should recruit as much local talent to remain self-serving
- should form the basis of employment, education and training for the population
- must use the economies of scale to reduce cost, maximise efficiency and record year-on-year growth

- must embrace the reciprocal effect of technology in leveraging talent and minimising cost
- must not refrain from technology that renders incumbent processes obsolete.

Acknowledgements The doctors would like to acknowledge the efforts of Mr Nagaraja Pani and Mr Vivek Rajagopal for their assistance in the compilation of data and editing of this document.

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38 Cardiac Surgery and Interventional Cardiology Capacity Development: Insights from Ethiopia and Côte d'Ivoire

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Abstract

In this chapter, the global surgery research team of the JW LEE Center for Global Medicine, Seoul National University College of Medicine, introduced the cardiac surgery and interventional cardiology workforce training programs in Ethiopia and Côte d'Ivoire. A team-based collaborative capacity-building model was implemented in both countries, and details of program design and delivery are documented. The research team shared their experiences and identified achievements, lessons, and challenges for cardiac surgical interventions in Sub-Saharan Africa. Future directions were put forward to advance and strengthen the LMICs' "Safe Surgery."

Keywords

Global surgery · Health services · Capacity building · Health workforce · Sub-Saharan Africa

38.1 Introduction

Access to health services, as defined by Levesque (2013) as "the ability to reach and obtain appropriate health care services in situations of perceived need for care," is limited for children with congenital heart disease (CHD) in low and middle-income countries [1]. According to previous studies, there is a critical need for access to surgical care for children with CHDs in Ethiopia and Côte d'Ivoire, as CHD can cause permanent disabilities or death if not treated promptly. To better meet people with CHD's needs, the public health agenda must learn and succeed in overcoming the barriers associated with prevention, intervention, and post-care.

The JW LEE Center for Global Medicine (CGM), Seoul National University College of Medicine from South Korea, acts as a global surgery Asia Hub advocating for the advancement and strengthening of the LMICs agenda for "Safe Surgery.' To this date, the Pediatric Cardiac Surgery Team at the Seoul National

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_38

University, led by Dr. Woong-Han Kim, a director of CGM, has collaborated with East Asia (Mongolia, Uzbekistan, Nepal, China, Lao People's Democratic Republic) and Sub-Saharan Africa (Ethiopia, and Côte d'Ivoire) to promote cardiac surgery and intervention cardiology in pediatric patients through the dissemination of knowledge and technology. Annual to biannual visits are made by Korean medical staff as a team (cardiac surgeons, perfusionists, cardiologists, intensivists, anesthesiologists, intensive care unit (ICU) nurses, scrub nurses) to conduct cardiac surgery alongside local medical staff in order to transfer expertise and skills and expand medical services. Furthermore, local medical staff is invited to South Korea to begin their training in a Korean hospital setting. This chapter aims to introduce the cardiac surgery and interventional cardiology workforce training programs in Ethiopia and Côte d'Ivoire. The CGM researchers shared the experiences and identified achievements and limitations to provide lessons for future cardiac surgical interventions in Sub-Saharan Africa.

38.2 Background: Ethiopia and Côte d'Ivoire at a Glance

Development Indicator

Ethiopia is the 15th largest nation in the world, with an estimated population of 104,957,400, with children under 15 comprising 43.5% of the total population [2]. The birth rate is 32.3 per 1,000, but the mortality rate under 5 is 50.7 per 1,000, with a population increase of 2.6% annually. The Gross domestic product (GDP) is $2,100 per capita, and the overall health expenditure is 3.3%, the low-income country average being $5 and the global average being 9.2%. The Human Development Index (HDI) stands at 0.463 for 2017 and places the nation as a low human development group. According to the latest World Health Organization (WHO) statistics, Ethiopia's estimated life expectancy is 65.5 years in 2018 [3].

Côte d'Ivoire's population is 25,716,544, with children under the age of 15 accounting for 41.7% of the number [4]. According to the World Bank data, the birth rate is 35.7 per 1,000, but the death rate for children under five is 79.3 per 1,000, amid a 2.6% annual population growth. The data reported the Gross National Income (GNI) per capita is $2,290, and current health spending accounts for 4.2% of GDP. As of the most recent United Nations Development Program (UNDP) statistics, Côte d'Ivoire's HDI is 0.538, putting the country in the low human development category, and the average life expectancy is 57.8 years [5].

Congenital Heart Disease in Ethiopia and Côte d'Ivoire

CHD is the most common etiology of heart failure among children in Sub-Saharan Africa (SSA) [6]. In 2019, approximately 13 million people worldwide lived with CHD, with nearly 3 million of these people living in SSA [7]. The pattern of CHD is similar across SSA countries, with the most common CHDs being ventricular septal defect (VSD), atrial septal defect (ASD), patent ductus arteriosus (PDA), and Tetralogy of Fallot (ToF), as observed in SSA [8]. Congenital heart surgery is performed SSA by pediatric heart surgeons in a small number of cardiac centers [9]. In Ethiopia, the true prevalence of CHD in the general population is unknown, and it is most likely due to a lack of structured perinatal diagnostic capabilities [10]. According to a few community-based studies, heart failure accounted for approximately 11% of pediatric admissions at an Ethiopian referral teaching hospital [11]. Heart disease has been the subject of very few studies in children in Côte d'Ivoire as well, and all of these studies have been conducted in Abidjan, so the national prevalence of childhood heart disease is unknown. One retrospective study from a few hospital-based studies found a total of 49,760 admissions, including 228 infantile heart disease cases, with a prevalence of 4.6 percent [12]. Another retrospective research studied open heart surgery between 1978 and 2013, in which the most frequent CHD were VSD (n = 240), ASD (n = 200), partial atrioventricular sepal defect (n = 30) and ToF (n = 220), and rheumatic heart disease (RHD) was 1,475 cases [13].

38.3 A Brief History and Current Status of Cardiac Service in Ethiopia and Côte d'Ivoire

Ethiopia

Ethiopia has a relatively new history of cardiac surgery and interventional cardiology. Cardiac services were first provided to Ethiopians in 1995 on a limited scale, with help from western organizations [14]. According to Leuner and Weldegerima (2018), some foreign cardiac surgical and interventional cardiology teams reached Addis Ababa University during specific times of the year to treat primarily children for free.

The Ethiopian Federal Ministry of Health (FMOH) recognized the health system's need for better cardiac services and identified the resource shortfall of needed human resources as a significant barrier to reaching that need. The FMOH launched the Saving Lives Through Safe Surgery (SaLTS) initiative in 2015 [15]. The FOH has issued a call to action to expand the size of trained health professionals in emergency surgical care at Addis Ababa University's Tikur Anbessa Specialized Hospital (TASH) [6]. TASH is an Ethiopian tertiary referral hospital located in the heart of Ethiopia's capital, Addis Ababa. CHD patients may be referred to one of the eight special units in the Department of Pediatrics, where the hospital has an average of 170 pediatric beds, with 25–30 of those beds occupied by pediatric cardiac admissions [16]. Because the hospital is the country's largest tertiary referral center, patients came from all over Ethiopia.

While Ethiopia's national surgical plan emerged the importance of surgical care, further action is required to meet patients' surgical needs. According to a recent hospital-based study on cardiac care in Ethiopia, Ethiopia lacks early CHD diagnosis and timely surgical intervention for children with CHD due to an inefficient and fragmented health care system [17]. The study qualitatively investigated navigating experiences to access cardiac surgical services from interviews of 13 caretakers of patients with CHD who underwent heart surgery. It also showed that caregivers faced financial challenges, a segmented medical delivery system, and low-quality medical services during the treatment process. Consequently, the study addressed the needs of a regional screening test and surgical system in Ethiopia.

Cote d'Ivoire

As early as 1977, the initiative of the Republic of Côte d'Ivoire's first President established a national cardiac center, the Institute of Cardiology of Abidjan (ICA). Côte d'Ivoire had its first open-heart surgery, performed successfully on March 11, 1978 [13]. It has been known that since 1978–2013, open-heart surgery has been delivered to patients with several obstacles in terms of new equipment and consumables, affordability and accessibility to open-heart surgery for patients, and sustainability.

Cote d'Ivoire released the findings of the first 300 open-heart surgeries conducted in Abidjan for cardiac valve disease (149 cases), CHD (100 cases), endomyocardial fibrosis (40 cases), and other lesions in 1983 [18]. According to the report, the hospital mortality rate was 13.3 percent, leading to the severity of the condition before surgery. By 1987, Yangni-Angate et al. (2016) had published data on 851 open heart surgeries performed at the same Abidjan hospital [13]. However, recent economic difficulties and civil strife have contributed to the decline of Abidjan's open-heart program [18].

A paper released in 2016 explored the complexities of open-heart surgery in SSA, reporting on experiences from Côte d'Ivoire. It could be considered difficult to provide reliable and full funding for the day-to-day operations of open-heart surgery centers to maintain existing infrastructures and facilities and supply the required supplies [19]. The author pointed out that there is a shortage of trained medical personnel: the number of nurses, physicians, and cardiac specialists available is insufficient to meet current demand, and current health professionals are unequally distributed across national territories, which resulted in a lack of diagnosis, a numerical undervaluation of cardiac diseases with 80 percent of valvopathies diagnosed in hospitals in Côte d'Ivoire at advanced stages of heart failure [19].

38.4 Implementation of a Team-Based Collaborative Capacity-Building Model

Purpose of a Team-based Collaborative Capacity Building model

Interprofessional teamwork is essential at all stages of a surgical patient's journey. Teamwork is the ability to collaborate to achieve a common goal and teamwork characteristics, including open communication, collaboration willingness, mutual performance monitoring, backup behavior, and team orientation [20]. If a hospital develops effective teamwork, the shared goals of medical staff to provide quality care and ensure a positive health outcome will be met. A single surgeon cannot perform surgery. Perioperative holistic care from various medical divisions is provided in order for a patient to successfully receive surgery and live a healthy life afterward. The holistic care includes an accurate diagnosis, a well-trained and skilled surgeon, supportive and effective assistance from the surgeon in the form of a surgical technician, operating room nursing, ancillary services, and intensive care after surgery. At every step of the surgical patient's journey, holistic care cannot be provided unless the health professionals are deeply rooted in clinical knowledge and excel in non-technical skills such as teamwork [21]. As such, the importance of teamwork in a hospital setting is well-described. However, the current understanding of hospital teamwork is exclusive to high-income countries (HICs). A study revealed provider training inadequacy in low and middle-income countries (LMICs) [22]. In response to this gap, a surgical team led by Dr. Woong-Han Kim of South Korea established a team-based collaborative capacity building model in developing countries.

Description of Team-based Collaborative Capacity Building Models

A team-based collaborative capacity building program was first introduced in Tashkent, Uzbekistan, in 2009 to increase the surgical capacity of a local pediatric cardiac surgery team [23]. An annual or biannual visit is made by a group of Korean cardiac surgeons, pediatric cardiologists, anesthesiologists, perfusionists, ICU nurses, administrative assistants, and researchers to a host country. During the on-site visit, the Korean team gives didactic and clinical seminars, discussions, and hands-on training. The Korean and local team handles all aspects of diagnosis, surgical treatment, and pediatric intensive care. Everyone meets for morning and post-operative conferences to review the surgical procedure for children who have had open-heart surgery or interventional catheterization and talk about how to improve the patient's health. Didactics and clinical lectures were provided under the needs of the host team. Contrasting to other HIC mission teams, this capacity-building program was implemented with guiding principles. The first task is to retrieve untreated sicker or more complex patients so that the host team can perform complex surgical procedures collaboratively with the Korean team or independently but under the Korean team's supervision, depending on the complexity and familiarity of the cases. The second obligation is to encourage and promote local team building. Just as importantly, Korean team knowledge and skills transferred between Korean and host teams through team-based activities.

The Ethiopian medical team was the first to participate in the team invitational training in 2015. 9–10 trainees from required divisions for cardiac service are invited to a HIC for a minimum of two months. The goal of invitational training is for trainees to gain in-depth academic knowledge in related fields while experiencing diverse and specialized cardiac and vascular surgery, interventional cardiology, and patient care. Trainees have the opportunity to attend and present at domestic and international academic conferences. The design, processes, and outcomes for the on-site and invitational cardiac surgical capacity-building program are expressed in a project design matrix (see Fig. 38.1).

Impact of the Program

National Level

The establishment of a surgical system at the teaching hospital contributes to the continuing

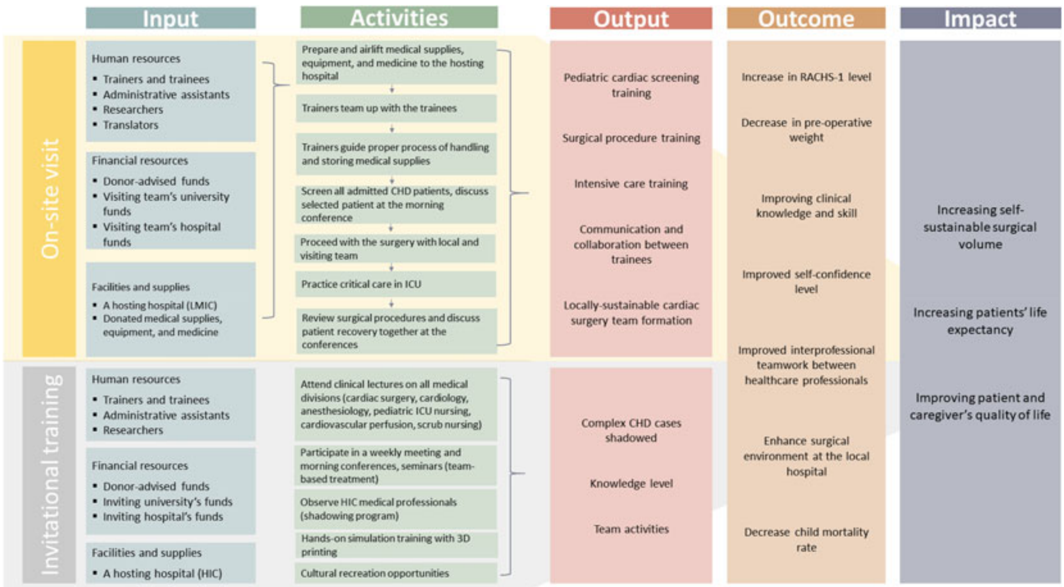

Fig. 38.1 The team-based collaborative capacity building program design

care of CHD and helps to reduce the national disease burden. Furthermore, LMIC teaching hospitals will serve as a representative cardiac center across neighboring countries, where there is no cardiovascular center, equipped with the most up-to-date clinical experience, procedures, and advanced technology, enabling surrounding nations to access a specific health service.

Institution level

The team-based model benefits the local institution in terms of human development and infrastructure expansion. The model includes a training of trainers (ToT), which cascades Korean faculty's knowledge and skills through local trainers and eventually within a health network across a local hospital [24]. The model will increase the overall human resource level at the local hospital. Furthermore, since subspecialty care necessitates substantial infrastructure, other healthcare priorities benefit from its expansion. Improved intensive care unit capacity benefits all critical care patients, and improved anesthesia care advantages all surgical patients. The enhanced screening will facilitate community health as well as primary care [25].

Individual level

Individuals benefit from the team-based program, including not only medical staff but also patients and caregivers. According to the 10-year team-based collaborative capacity collaborative capacity building program evaluation from 2010 to 2019, the average Risk Adjustment for Congenital Heart Surgery 1 (RACHS-1) score increased from 1.9 to 2.78, while the average preoperative weight of patients decreased by 2.8 kg, from 13 kg (2009) to 10.2 kg (2019). In-depth interviews with Uzbek and Korean medical staff, patients, and caregivers show an improvement in Uzbek medical personnel's surgical capacity, an improvement in attitudes toward patients and colleagues, and changes in the quality of life of patients and caregivers [26]. Based on these findings in Uzbekistan, a team-based program proved to be effective as a program to strengthen the pediatric cardiovascular disease treatment capacity in low- and middle-income countries (Fig. 38.2).

38.5 A Team-Based Collaborative Capacity-Building Model in Ethiopia

Program description

Since 2015, six cardiac surgery training and two interventional cardiology training sessions in Ethiopia, and two visiting training courses in Korea have been held. This program has received financial support from the Korea Foundation for International Healthcare (KOFIH), a public affiliated organization of the Ministry of Health and Welfare. In 2016, the Ethiopian counterpart organization changed from Myungsun Christian Hospital (MCM), a private hospital, to TASH, a public university teaching hospital under AAU for long-term sustainability and impact (Fig. 38.2).

As part of the team-based capacity building model, the HIC team used the "sandwich program" (see Fig. 38.3). The Sandwich program has been used by Swedish International Development Cooperation Agency (SIDA) and other global fellowship programs, and it is well-known for connecting the fellow's step-by-step advancement with the development of institutional capacity in order to build an enabling environment for professional growth, which enhances patient care [27].

Rotation 1: First on-site visit

For about a week, ultrasound diagnosis, surgery, and post-operative care are performed at the host institution, TASH. Ultrasound diagnosis is performed during the first 2–3 days of training, and the final surgery target is chosen based on the ultrasound diagnosis record. Following that, 1–2 surgeries are performed per day for about ten surgeries. At the same period, transcatheter treatment for several CHD such as atrial septal defect, patent ductus arteriosus, pulmonary stenosis was completed with a Korean pediatric cardiologist and a pediatrician (see Fig. 38.4). Local medical staff participation is maximized to the greatest extent possible by including local medical staff in all surgery and post-operative intensive care processes, resulting in the implementation of local staff-led clinical skills rather than Korean team-led clinical skills (see Fig. 38.5). By doing so, local medical personnel is encouraged to participate in hands-on training. During the on-site training period, 1–2 lectures are provided for about 1 hour. The selection of topics is based on local personnel's needs or at

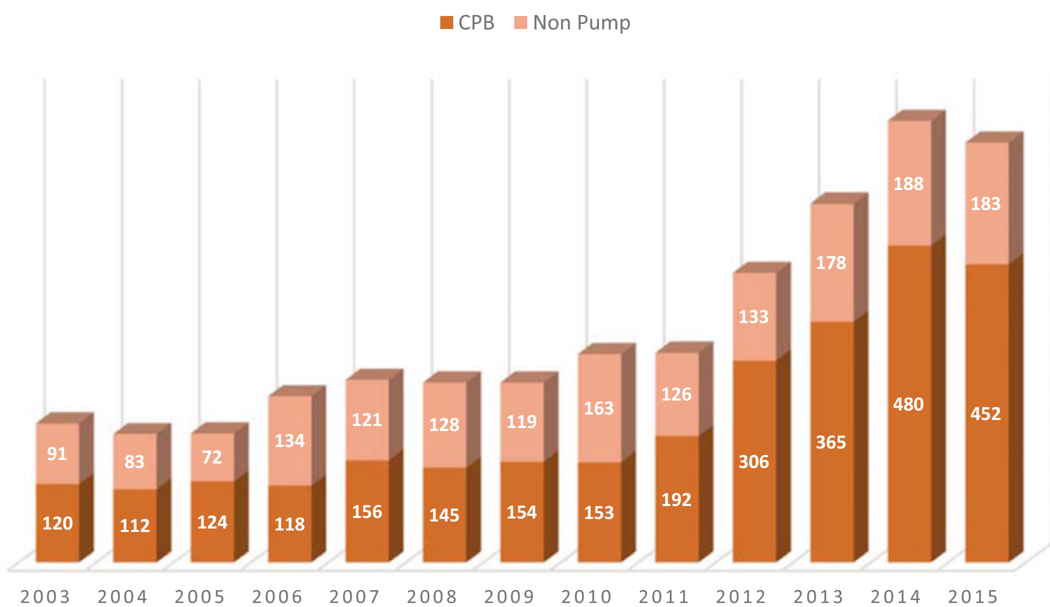

Fig. 38.2 Pediatric cardiac operation counts of Tashkent pediatric medical institute, Uzbekistan

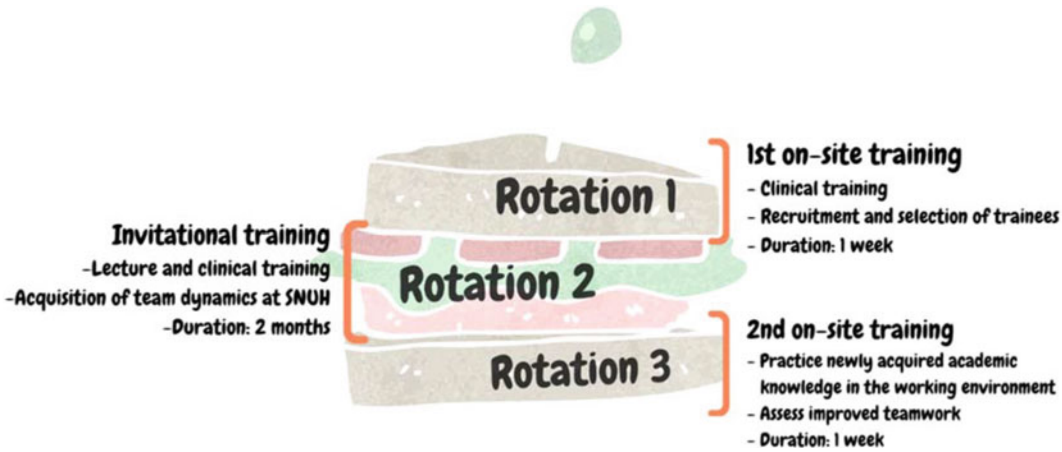

Fig. 38.3 The Ethiopian team-based collaborative capacity building model in a sandwich design

the discretion of Korean medical staff. Conferences are based on ultrasound diagnosis records and surgical records at the beginning of the on-site training period. Through a conference based on the patient's surgical records and progress, Korean medical staff and Ethiopian medical staff discuss treatment strategies and the expected progress.

Fig. 38.4 Proceeding and training interventional procedures with local medical staff in Ethiopia (2018) From left: Dr. Gi-Beom Kim is doing hands-on training with an Ethiopian cardiologist

Fig. 38.5 Surgery and patient management led by local medical staff in Ethiopia (2018) Dr. Woong-Han Kim in a green scrub watching over the Ethiopian surgical team. The main surgeon is Ethiopian, and the first assistant surgeon is a Korean surgeon

Rotation 2: Invitational training

A total of 9 trainees were chosen for invitational training after passing the competency assessment and interview conducted by Korean medical staff in its first on-site training: 2 thoracic surgeons, one anesthesiologist, one pediatrician, three intensive care nurses, one operating room nurse, and one perfusionist. The invited trainees attended the Seoul National University Hospital Pediatric Heart Center's weekly meeting and engage in the actual patient care plan (see Fig. 38.6) for two months to understand team dynamics in HIC setting. All trainees participated in all lectures, regardless of workforce type, and this increased mutual understanding between professions, which is vital for developing their teamwork.

Rotation 3: Second on-site visit

During the second on-site visit, the HIC team evaluated trainees' ability to apply their newly acquired skills in their home country hospital setting. Under the HIC team's guidance, the trainees led the procedure and patient care during the training period. The local team was trained to the point that they could operate without the HIC team's assistance.

Program evaluation

In 2018, after successfully implementing all the rotations, we evaluated the program using the following criteria: change of the individual competencies, changes in self-confidence in basic skills before and after the invitational training, and satisfaction level overall invitational training. As a result of comparing the evaluation scores of trainees on detailed abilities related to clinical skills, most trainees' scores improved during the 2nd on-site training. In particular, there was feedback from Korean medical staff that the active participation attitude and improved skills of the trainees were outstanding in the 2nd on-site training. The self-confidence of detailed abilities required for clinical techniques was conducted before and after the invitational training, respectively. The majority of the trainees have increased their self-confidence (see Fig. 38.7). The score increased dramatically in clinical procedures linked explicitly to surgery, particularly to operational process roles during operations. Since surgery is not conducted on a regular basis in the area, it is assumed that the increased confidence is due to exposure to numerous surgeries, either directly or indirectly through invitation training. Most of them showed

Fig. 38.6 Invitational training in South Korea (2018). From left: A Korean ICU nurse explains patient care to an Ethiopian ICU nurse. A Korean anesthesiologist explains to an Ethiopian anesthesiologist before placement of a central venous catheter

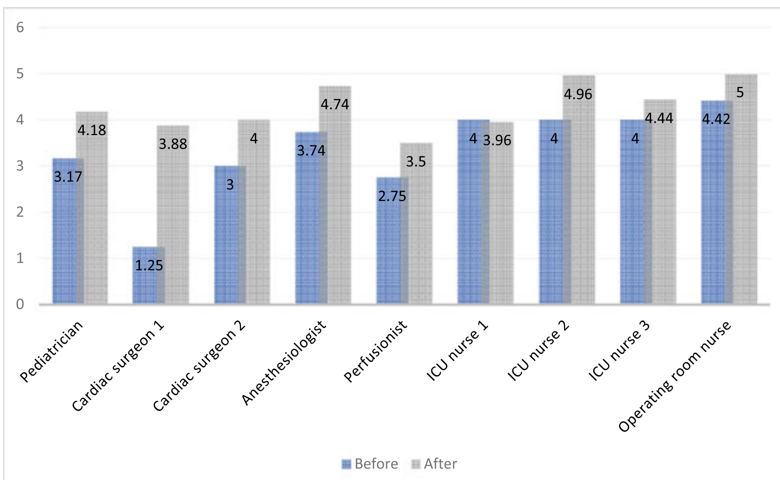

Fig. 38.7 Changes in self-confidence in basic skills before and after the invitational training

high satisfaction in the five sub-areas of the overall training course (see Fig. 38.8).

In 2019, during rotation 1 from December 16, 2019, to December 22, 2019, the local team's teamwork was measured by social network analysis, using baseline data for evaluating communication. Quantitative data were collected from 31 Ethiopian medical workers, and the survey looked at the level of contact between medical staff (1-never, 5-frequently). Network density, degree centrality, and betweenness centrality were calculated as Freeman's degree of centrality. The network density was highly scored (0.802), and the average path length of communication was short (1.206) (n = 31). It means that there was a great deal of direct interaction and communication between each of the members. As for the centrality index, first of all, a head ICU nurse showed the highest level of total weighted degree (296), followed by a

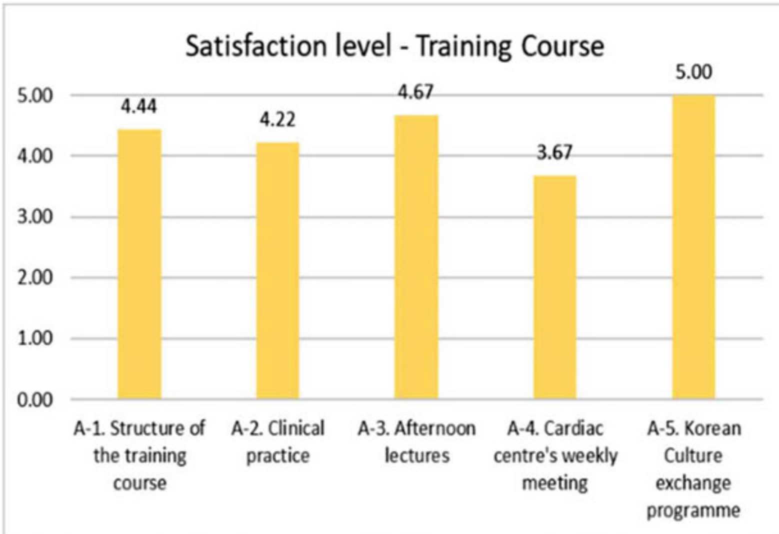

Fig. 38.8 Satisfaction level of the overall training

cardiac surgeon (269) (n = 44). The head ICU nurse was at the center of the network.

A milestone achievement was reached after five years of program progress. February 13, 2020, Addis Standard, a private magazine registered with the Ministry of Trade and Industry of the Federal Democratic Republic of Ethiopia, twitted that a surgical team from TASH conducted the first open heart surgery with full Ethiopian health workers for a left atrial myxoma excision procedure [28]. This accomplishment implies that the local surgical team has obtained operative autonomy facilitated by the team-based collaborative capacity-building program.

38.6 A Team-Based Collaborative Capacity-Building Model in Côte d'Ivoire

Program description

The interventional cardiology training program in Côte d'Ivoire began in 2014 in response to a request, and invitation from ICA that had previously worked with a Korean doctor assigned to Côte d'Ivoire as part of the Korea International Cooperation Agency (KOICA)'s medical staff dispatch program. In 2016, 13 patients were treated, 11 were completely treated with the procedure, one was treated with post-procedure surgery, and one was followed by surgery. On-site PDA obstruction was the second procedure performed in this country following the last one, and ASD instrument obstruction was the country's first procedure (using transesophageal ultrasound). Local medical personnel participated together to experience the procedure in person, and education and lectures were organized to perform the procedure. In the following year, ten patients were treated, and all of them were successful. Advanced echocardiography was performed on 12 patients who had previously undergone the procedure, and no abnormalities were found. Five patients with complex cardiac malformations were asked to undergo echocardiography, express their thoughts, and be consulted on future treatment policies. Stent in CoA (the first local procedure) is a complicated procedure to perform even in Korea; however, it was successfully treated. On the final day, didactic lectures on CHD interventions were delivered to medical professionals in response to a local request.

A pediatric cardiologist was invited to Korea for a one-year term on the condition that local hospitals actively support and cover a portion of the travel and expenses. In January 2019, the team from Korea visited the ICA and performed nine cardiac surgery for children with heart disease and four patients with cardiac intervention, and about 50 patients underwent ultrasound examination at the local hospital's request. In 2020, the team again visited the local hospital and performed eight cardiac surgery for CHD children, and ten interventional cardiology was performed.

During the on-site visit in 2019, the local medical staff's involvement and engagement in surgery grew, and improvements in their attitudes were observed. While local medical staff actively engaged in the operation and conducted surgery alongside Korean medical staff, extracorporeal membrane oxygenation (ECMO) was used for open heart surgery for the first time since the hospital's founding. This action offered a constructive incentive to local medical personnel by showing that treatment and care could be performed adequately with the available equipment. Clinical education and patient care were given, and expertise was revitalized through the distribution of related educational materials and the practice of assigned tasks. The local team and the visiting team gathered every morning to improve interdisciplinary communication and patient outcomes (see Fig. 38.9). Experts addressed potential medical infrastructure projects in Côte d'Ivoire during a meeting with the representative of KOICA's Côte d'Ivoire office. Besides, the program's direction was discussed in an interview with Côte d'Ivoire's Minister of Health and government funding and cooperation. Opinions on the project's feasibility were gathered, and coordinates were outlined through meetings with the hospital director and local medical staff.

Formative evaluation

In 2020, the researchers of CGM conducted a formative evaluation study to collect and analyze information to confirm the need for enhancement of pediatric cardiac surgical capacity in Côte d'Ivoire. The aim was to develop a sustainable model by collecting and evaluating data using the Practical, Robust Implementation and Sustainability Model (PRISM) implementation methodology that prioritizes the organizational and patient levels to improve the educational program. Through interviews with Côte d'Ivoire medical staff (n = 28) and health care personnel, opinions on the necessity of pediatric heart surgery and educational content were investigated.

Fig. 38.9 At a morning meeting with the local and visiting team

About 34.5% of medical professionals said they work part-time outside their primary employment. The need for pediatric heart surgery education was 3.9 out of 5 points, and the need for team-based education was 4.5 out of 5 points.

According to the stakeholder interview, training pediatric cardiac intervention and care was in high demand. The interview included hospital stakeholders as well as funders. The current state of pediatric heart surgery, according to all interviewees, is at a very low level or is continuing to deteriorate. Since the number of pediatric heart surgeries was limited to around ten last year, both in terms of quality and surgical capacity, it is very weak. There are few opportunities for pediatric heart surgery training in Cote d'Ivoire, according to one hospital stakeholder. Although education and training are available in French-speaking countries, most courses concentrate on adult heart surgery. All interviewees responded that the first goal is to educate medical professionals in all fields related to pediatric cardiac surgery.

38.7 Lessons and Challenges

(1) **Desirable attributes for other HIC & LMIC teams**

Required competency for a HIC team

Evidence-based medicine competency: Members of the HIC team must have the appropriate level of expertise to translate knowledge to local staff. It is critical to have competent evidence-based medicine practitioners who can figure out how to use the materials at hand to provide the best care for their patients and teach local medical staff to do the same. Medical staff in HICs, particularly those in positions of leadership, should critically examine their knowledge base and practice in the field of global surgery.

Global health competency: Through strengthening global health competency, a HIC team must be prepared for the unexpected situation of a resource-limited surgical system. Visiting trainees may be unfamiliar with surgical diseases or presentations in hosting communities and their added complexity; visiting trainees may lack understanding or preparation to deal with cultural and linguistic challenges in unfamiliar settings. Furthermore, the HIC team must work in facilities that lack basic infrastructures such as water, electricity, adequate supplies and equipment, and ancillary services, making it challenging to work within one's scope of practice. The level of discomfort can be overwhelming if HIC members arrive without prior global health experience or understanding.

Listen to the frontline surgical providers: The implementor should fulfill teaching, research, and service missions while giving the local frontline surgical provider a voice in their potential needs. The frontline health providers play a key role as brokers (usually as patient advocates) between patients and the health system at the point of care. Thus, understanding their perspectives and actions can strengthen planning and provision of future surgical services [29].

Identify a key champion: Engaging local champions is one of the four critical components to making global health programs effective and sustainable, according to Howell [30]. Because the local champion, who believes strongly in the cause, will align himself or herself with the intervention and understands local ecosystems. Thus, the role of local champions in keeping everything on course should not be underestimated. So the program implementor needs to reach out to local champions who dedicate their effort [31].

Required competency for an LMIC team

Team leadership: The performance of the team members depends on the behavior, knowledge, and interpersonal and leadership skills of a team leader [32]. A local champion (a surgeon) should be constantly conscious of the implications of keeping the entire healthcare team in a proper, grounded context. Through the leadership of a ‘safe surgery champion,’ the initiative will quickly gain momentum in the early stage of development [33].

(2) **Building effective partnerships**

It should be emphasized that cooperation and successful development of programs can be achieved with the full support and interest of local governments, especially for capacity building and human resource development programs that need a long-term solution. A long-term program needs new sustainable funding and supportive administrative process comparatively to a short-term program. Therefore, local government commitment should be allocated to a global surgery partnership to support these long-term placements.

The institutional university and hospital partnerships are also critical: a network of governments and organizations that have made an institutional commitment to foster effective and long-term academic partnerships. Collaboration between universities and teaching hospitals can promote research and advocacy to support progressive policy agendas, advance medical education, and retain healthcare workers in economically marginalized areas [34].

(3) **Essential infrastructure and equipment**

For cardiac surgery, in particular, a stable cardiopulmonary bypass machine and an oxygenator for open heart surgery must be continuously supplied. A fluoroscopy machine for cardiac catheterization and angiography, as well as a variety of devices for septal defect closure or vessel dilatation, should be available for transcatheter intervention. During on-site visits, the HIC team frequently brings appropriate technology that may be unavailable or unaffordable at the host institution or country. Those are intended to be used in future surgery cases; however, donated equipment frequently becomes inoperable. According to a WHO report on medical device donations, “only 10–30% of donated equipment becomes operational in developing countries” [34]. Ultimately, the hospital must devise a reliable supply chain for critical surgical devices. Further research into how to develop supply chains and advanced health technology management systems in LMICs to maximize the impact of the surgical capacity building program should be conducted.

38.8 Future Direction

Prepare for an unprecedented crisis: E-learning Program

Because of the unprecedented pandemic, international travel was restricted, so that direct face-to-face exchange between the Korean surgical team and the overseas surgical team was not possible. As a result, with the remarkable rise of e-learning, team-based training was undertaken remotely and in a virtual setting. Korean supervisors provided all online materials to satisfy the needs of local staff. In December 2020, the e-learning program on cardiac surgery and interventional cardiology was first offered to all medical staff at TASH in Ethiopia. The program consists of approximately 37 lectures and discussion sessions, and case study simulations with 3D printing led by Korea's most experienced medical staff. The program ran for eight weeks, and participants were required to watch five to seven lectures per week and take part in case studies. Certificates were distributed at the end of the program to participants who had completed all lectures.

With this sudden move away from face-to-face programs, online learning technology played a key role, with promising outcomes. Educational didactics have strengthened, and this will remain a component of the team-based curriculum in the post-COVID-19 period. Additionally, the offered translation and subtitles aided in bridging the language gap between the local and Korean teams. However, there are alternatives to an online program. While 3D printed simulator activities were provided for trainees’ clinical practices, there are still limitations compared to receiving direct hands-on training in the local health care setting. As a result, it is incumbent upon global surgery practitioners to thoroughly exploit its potential and find ways to fill the gap, as the online program will continue to exist after the pandemic.

Develop sustainable academic partnership: academic global surgery

Academic institutions should facilitate academic cooperation by rebuilding the bilateral education program. In order to improve surgery in LMICs, the surgical education system must be strengthened as well. However, according to one rapid review of academic global surgery programs, the existing academic global surgery programs are highly skewed toward HIC residents [35], and concerns raised that similar opportunities for LMIC medical staff are not frequently available [36]. Furthermore, LMIC medical personnel must acquire learning autonomy and eventually replace visiting faculty. To close the gap, HIC academic institutions and LMIC academic institutions should cooperate in the future to provide opportunities for advanced certificates or academic degrees.

Acknowledgements We gratefully acknowledge all the medical volunteers and researchers who participated in the program. We would also like to thank the Korea Foundation for International Healthcare (KOFIH), Seoul National University College of Medicine, and Seoul National University Hospital for supporting and promoting the capacity-building program.

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39 Global Cardiac Surgery in China: 23 Years of Mission Work

Lee Errett and Muhammad Uzair Khalid

Abstract

The Global Surgery Program at the University of Toronto aims to increase surgical expertise in underserved communities around the world, with a focus in low- and middle-income countries. On the suggestion of our colleagues and in the footsteps of the world-renowned Canadian surgeon Dr. Norman Bethune, we realized that China, with an increasing cardiovascular disease burden and a population exceeding 1.2 billion, offered an opportunity like no other. In this chapter, we reflect on our 23 years of experience in the region, recounting how we began in 1998 as a small initiative to increase access to cardiac surgery in areas that had little of it, but have now evolved into a multidisciplinary effort across 160 medical institutions and 29 subspecialties. In doing so, we have established cardiac surgery training programs at 11 centers, mimicking the "Competency by Design" curriculum implemented here in Canada by the Royal College. We also successfully advocated for health coverage for over 95% of Chinese citizens, while additionally welcoming 142 trainees for observerships to Canada. Not only have these experiences taught us many invaluable lessons, we have also been very fortunate to witness one of the most remarkable socioeconomic developments in recent Chinese history.

Keywords

China · Global surgery · Cardiac · Cardiovascular · Growth · Healthcare access · Surgical training · Residency · Competence by design · BMDAC

The mission of our Global Surgery Program has been to provide service, educate, and create something sustainable to leave behind. Although we work in low- and middle-income countries, we are fully aware that some of the criteria we use to decide where to travel could be applied to our homeland. However, colleagues whose homeland was China made a compelling case to visit their country. Twenty-three years ago, the decision was made to travel to China whereby all measures, the need was staggering beyond imagination. Like a fellow colleague from the University of Toronto from long ago, Dr. Norman Bethune, I decided China offered the opportunity and challenge like no other [1]. The intention was first to introduce cardiac surgery into areas of China that had little of it, but our work quickly progressed to all cardiovascular care and more.

This chapter will outline our experiences in China from 1998 until our last visit in November

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_39

of 2019. The twenty years have certainly been an evolution for us, but the Chinese have also been witness to one of the greatest expansions ever known.

39.1 Growth in China

Since we first ventured to China in 1995, the population has grown by almost two hundred million people [2]. China has an older population that is growing faster than almost any other country [3]. This is due to improvements in health care and social assistance. Life expectancy went from 43 in 1960 to 75 in 2015 [4]. The "one child" policy was changed to allow two children in 2015 to "balance" the uneven growth [5]. From 1979 when the "one child" policy was introduced, it has been estimated that over four hundred and twenty million more Chinese may have been born [2]. It now appears that the age dependency ratio (people 65 and older: people 15–64 years old) will reach a staggering 43.5% by 2050 [6]. This net imbalance would lead to an aging population dependent on a shrinking younger work force [3, 7].

Over the past 30 years China has been the only major economy in the world to maintain a growth in annual GDP over 6% [8]. It is most likely the only economy not to experience a contraction due to the COVID-19 pandemic [9]. This growth is evident to visitors year over year. New buildings, roads, and airports along with the famous high-speed rail service have changed the face of China. Growth and rapid development has been seen in hospitals as well. Indeed, we had the opportunity to witness the growth in all these aspects of Chinese growth as well.

China has 23 provinces, 5 autonomous regions, 4 municipalities and 2 special administrative areas. In 2019, the population was estimated to be 1,400,050,000 [2]. There is a wide distribution of wealth but a concentration of higher per capita income in the eastern coastal areas [11]. Poverty remains a major issue in the country that the current government has directed an extraordinary effort to rectify. There has been a massive input in the agricultural sector which has had a positive effect [12]; however, as of 2018, 17% have remained in poverty, as defined by the World Bank to be individuals living below USD$5.50 per day in upper-middle income countries [13]. Extreme poverty being defined as income less than USD$1.90 per day changes the picture, such that the China government can claim that 748.5 million people have been lifted from these dire straits [14]. Regardless of the method of defining poverty, these people are poor when considering the costs of health care.

In 2011, the Chinese government implemented a basic coverage that included almost 95% of the population [15, 16]. This basic care covers some, but not all, of the needs for medical care. For example, surgical procedures may be covered but not the cost of an implanted device like a heart valve. Consequently, care usually must be supplemented by other insurance plans or directly from the pockets of patients. The gap therefore continues to exist for many who do not have coverage or limited coverage. To be sure, that gap is also present in countries like the United States for a sizeable portion of the population. A total of 27.5 million American citizens do not have medical coverage or about 8.5% of the population [17]. This statistic further inc reases to 43.4% when under-insured are included [18]. Because the coverage is relatively new in China, changes can be expected to evolve so that more of the people will be covered in a more fulsome way. For now, many will not be treated or not provided the necessary treatments.

39.2 Cardiovascular Disease Burden

In the western world, there is 1 cardiovascular surgery center per 120,000 people; in contrast, Asia has 1 center per 25 million people [19–21]. Mortality in China as a result of CVD was 296 per 100,000 people in rural areas and 262 per 100,000 people in urban settings in 2014 [22]. It follows that the maldistribution also prevails with cardiac surgeons, with 27 surgeons per million people in the Western world and 2.6 surgeons per million in China [21, 23, 24]. Obviously, if medical care were to keep up with other parameters of growth, there will be significant emphasis placed on cardiovascular care. The mortality from cardiovascular disease is higher than cancer or any other disease, and the prevalence of CVD results in over 290 million with a diagnosis within the spectrum of surgical treatable conditions in 2017 [25–27]. One example is rheumatic heart disease, which is present in over 7 million people and had 72,600 deaths in 2015—second only to India [28]. Another is an estimate of over 11 million people with coronary heart disease [26]. Expansion of the cardiovascular workforce is obviously key to addressing the issues of care. Our story that follows demonstrate how the medical community has responded in the past twenty years.

39.3 First Visits

In the spring of 1998, I travelled to Jinan in Shandong province. The connection I had was with a perfusionist at my hospital that had trained at Shandong University. At that time, all perfusionists were considered cardiac surgeons as they branched out late in their careers. There were 8 surgeons on staff, performing about 150 cases per year in total. The preponderance was for valve surgery, then for paediatric procedures, and then finally coronary artery bypass. The head surgeon decided who and when each patient would be operated upon. It was he who did the actual surgery while the others opened, closed, and looked after the patient.

Having visitors from abroad was not common. The interest in having me there was to teach and do some off-pump surgeries. At the time, there was a great deal of interest in beating heart surgery in western countries. Proponents felt that not using the heart lung machine would limit neurologic complications, be equivalent in vascularizations, use less blood, and, most importantly, be cheaper. The Chinese felt the cost savings would be reason enough to allow far greater numbers to have CABG. At that time, we were interested in looking into beating heart surgery but found the disposables for devices created by medical supply companies to be cost-prohibitive. My partners and I had teamed up with an engineering firm to evaluate a re-usable system that could be sterilized between cases. This turned out to be practical and cost efficient.

My Chinese counterparts were as much interested in this device as they were in having me there. At the end of every day, I noticed someone gather up the device and whisk it away to somewhere outside the confines of the operating rooms. On our final day of a ten-day stay, the young surgeons proudly came with a copy of the device I had brought from Canada. They even had the trademark copied!

Teaching beating heart surgery is a challenge with English-speaking residents on its own but add in a language barrier and it becomes exceptionally difficult. We filmed the 9 operations we did so that the staff would be able to study the steps. One of the operations was under very strong lights. It so happened that the patient was a newscaster who wanted to see what we did, and so he had the operation professionally filmed. This helped us get welcomed back to various institutions in the area as it was broadcast openly. During his post-operative recovery, filming continued where the patient looked much better than his surgeon with the proper lighting and a bit of make-up.

The logistics of travel in China have dramatically changed since our first visit. We were treated graciously, but every aspect was less than ideal. Travelling from Beijing to Jinan by train took all night. The first-class cabin had four other guests in an area I thought was for two. The hotel had a communal washroom with only cold water. On our final night of our stay, we ate at Jinan's best restaurant where I recognized lettuce but little else. The hotel locked the doors at ten in the evening, so we had to climb in through the window. I shared a room with the perfusionist but also with a few critters that I heard but did not see.

The work in the operating room and lecture halls taught us some valuable lessons. Just like almost everything else, these experiences have changed progressively and positively. The operating room in Jinan was set to be renewed so they wanted our input as to set up and design. There are experts at operative suite re-development, and I did not qualify as one. However, there are certain aspects that are typically on anyone's list to satisfy requirements: adequate space, safe environment for all concerned, proper lighting, good flow patterns for the most efficient care, and limitations on any possible infections. A latrine right outside the operating room would definitely be discouraged. Advising the hospital officials was not always easy, and the suggestions that I gave were not actually mine at all but based on our new facility at home. The process that we went through to help design the surgical suites was certainly educational and, in the end, extremely rewarding. When I returned just eighteen months later the new operating rooms were in full use. The surgeons were grateful and proud to being working in the new rooms with the latest in equipment. It was clear that this project had been on the minds of the administration for some time before our arrival.

Funds were also allocated for new equipment. Most of the equipment was over thirty years old —well beyond their best before date. We were tasked to give lists of our scissors, retractors, needle holders, and larger devices like operating tables and anesthetic machines. The Chinese colleagues made it clear that they would accept anything we could offer. For several years, we could carry old instruments in "hockey bags" that our hospitals were discarding to help in the rebuild. There were never any issues upon landing.

To coincide with our second visit a cardiac conference was going to be held. This time, the group consisted of two anesthetists, a cardiologist, a perfusionist, and a cardiac surgeon. It had been less than a year, but a lot had changed. A new hotel near the hospital was a significant improvement. The facade of the hospital had changed, and the operating rooms were partly remodeled. In between lectures, I was asked to see a patient who had a ruptured mitral valve. Exam was by clinical exam and 2-D echo to confirm the diagnosis. I suggested a cardiac catheterization in the 64-year-old man. Unfortunately, "the machine was not working", so I asked if we could put an intra-aortic balloon to help stabilize him prior to operation. They had never placed this device before—a device which helps in failing ventricles and was particularly useful in this situation. I had seen a new model IABP at the conference, so I suggested to get the company to allow us to use it. They agreed so we set up to go ahead. The operation would be a mitral repair, if possible, or a replacement. At that time there had not been a mitral valve repair done in this hospital, and they did not have the ring that are usually used in such repairs. So, we went ahead to replace the valve—something which we would have had to do anyway, at least in my hands, because the valve was heavily calcified. Little did I know that this operation would receive notoriety as well as the conference.

The patient turned out to be a very prominent businessman in Shandong Province. The operation was presented the following day at the conference with multiple intraoperative pictures that I did not even remember being taken. All this was covered by local media. In translation, it appeared that this Canadian surgeon was flown in to do this operation and the hospital had acquired new equipment to do it. This was all good publicity for the hospital, and it helped cement our relationship with this area of China.

One lesson was taught to me from a nurse who explained that almost every staff had someone in their life who needed or would have benefitted from modern heart surgery or care. To see the opportunity of bringing that to the community excited them all. Our work represented that possibility, thereby teaching me another lesson. In the past, I had travelled to many places, operated, then left never to go there again. Instead, I realized that to make real difference requires a sustained effort. This first visit was setting the stage for our future missions.

Our lectures were designed for those interested in operative cardiac surgery. This was a mistake. Although there were surgeons in the audience, there were also cardiologists, nurses, anesthesiologists, other surgical specialties, traditional medicine doctors, and government officials. To make these types of symposiums worthwhile, the lectures should be proportioned to answer questions for all attending groups. After reflecting on that, I decided to cover a lecture topic that would be appropriate for the audience at a hospital or university, and more in-depth seminars with more specific groups. For example, when there were hundreds in the audience, it was assured most were not cardiac surgeons and so the topics were outlined by how the diagnosis is made, pre-operative assessments, the operation, and what are the essentials in post-operative care. My frame of reference would also outline what the costs would be in Canadian dollars, but this was deemed "not necessary" as there would be no comparison in the Chinese system. The next step would be to organize a type of program that would ensure everyone was on the same level—at least in the "trainees" population in the cardiac surgical program.

39.4 Expanding the Scope

After several visits, we began to get more invitations to come for conferences and training sessions. We also began to attract other specialties to join us beyond cardiac surgery. These included general, vascular, thoracic, and urologic surgery. This variety was attractive to a large number of hospitals because many had programs in these specialties that were just beginning or wanting to expand.

From 2000 to 2008, our group travelled as one at least once per year, increasing our profile as an educational source. Also, during this time, we began organizing a teaching program which was predominantly in cardiovascular specialties. There was great interest in our residency program, and so our efforts were towards creating a similar gradation in the cohort of surgeons "in-training" at the various centers in Shandong. At the time, the Royal College of Physicians and Surgeons of Canada was just developing a new style of residency that was called "competence by design", which basically individualizes the progression of trainees [29, 30]. For instance, when a resident mastered a certain task/operation in the evaluation of several staff, they would move on to more advanced procedures and responsibilities. Because we were beginning with a group of young surgeons at varying stages of their own knowledge and skill, we had to evaluate each one in as objective of means as possible. I feared this would create some hard feelings, but it was accepted remarkably well. First, we made the assumption that each resident was already at year two of a five-year program. Second, we had to have contact with the trainees. Finally, we had to convince the chief who would delegate the cases instead of always being the primary surgeon. The program was a success at one place and then another, with 11 centers participating over the 8 years. This type of structure seemed to arrive at the right time.

In order to start something like this, I recognized that we had to have buy-in from all the stakeholders. The chiefs of the division/surgery had to be supportive. It was them who would carry the idea to the administration, who in turn would seek permission of the government. It was clear that the patient demand was there, as was the strong desire of the young surgeons to master their craft. A massive change was also taking place all over China in creating more hospital facility. I had many meetings with authorities with the sole purpose to convince them that the expansion of cardiac services was not only needed but would also create improvements throughout their hospitals. The labs, blood bank, respiratory care, and ICUs would all improve. Nursing, anesthesia, and intensive care would follow. The timing was perfect particularly because all the parties were on-board to make significant efforts to move forward.

The establishment of training programs with language and cultural barriers is no mean feat. The relationships we developed with government officials and hospital/university administrators was essential. The enthusiasm at the clinical level was the main force behind the success of this endeavor. This re-enforced the principles of global surgery work almost anywhere: government has to be on board, the administration must agree with the plan, and, most importantly, the grass roots clinical teams have to be willing to participate. We were fortunate to have all three.

Expanding our scope also meant other areas which we could never have anticipated. In the spring of 2003, I was outlining what our residency design was to a group of educators in the Beijing region. At the end of the day, I was asked to speak with a group from the Ministry of Health. Initially, I thought this was following up on my presentation regarding the Royal College of Physicians and Surgeons platform on surgical training. I soon discovered it was not. A panel from the ministry informed me about a new concern about which they would like my opinion. They described what turned out to be an index patient who had acquired a pulmonary infection for which they had no explanation. The fear was that this was highly transmissible, deadly, and, most importantly, without a cure. My initial response was that I was a cardiac surgeon and not an infectious disease specialist. Nonetheless, I was asked how our hospital and system would handle such a situation.

It is humbling for physicians to be asked medical questions about which they have no clue how to answer. After considering the question regarding how our hospital would react, I provided what the protocols were on the unit I worked. I prefaced the answer by asking about bed constraints or nursing shortages. The quick answer was that there are no such difficulties, and so what would we do in an ideal situation. Well, first we would place infected patients in private rooms that had limited traffic. Nursing and medical staff must gown, glove and mask upon entering the room. The rooms should be deep cleaned regularly. All linen and food should be kept separate from other patients. What if there were more than six patients? Then I would isolate a ward. What about sixty? I remembered they said the situation was that there were no limitations; so, if the numbers kept on raising logarithmically the patients should be isolated in a single facility. That is exactly what the Chinese did when the case count reached 100 per day [31]. The Xiaotangshan Hospital just north of Beijing had 1000 beds, cost almost $20,000,000 and was built in 8 days by 7,000 workers [32, 33]. I am sure there were many consultations, but that experience was unlike anything I had experienced.

When I returned home to Toronto, SARS was just beginning. The index case was from a couple who had vacationed in Hong Kong [34. By March 26, 2003, the province had declared an emergency [34, 35]. The hospital where I worked was considered one of the main treatment centers by virtue of the large number of ICU beds. Fortunately, I never had any symptoms but had a worry, even a guilt, that I may be a spreader. A total of 178 cases and 24 deaths occurred. By May 14, 2003, the WHO removed Toronto from the list of areas with recent local transmission [36]. My appreciation of communicable infectious disease was forever changed.

Over the next five years we gradually increased our travels to all 23 provinces. Initially the participants were from the faculty of the University of Toronto, but that grew to include clinicians from throughout Canada. Surgical, medical, nursing practitioners, and technicians were included. As we expanded in China, we also expanded in Canada.

Several symposia regarding training and residency programs were held in Beijing over six years. The Chinese Ministry of Health was represented at all our presentations. In late 2008, a number of our group was invited to discuss the future of health care in China. In Canada we have a universal health care plan which most Canadians are proud of and it forms part of what defines us. China at that time was basically fee-for-service—this was surprising to us perhaps due to coming from a country that had a universal health care policy. It was on this background that our opinions were expressed to the Chinese representatives. The main recommendation was to adopt a universal system which would do much to provide much needed care, particularly to the large population of poor people who would never be able to afford private insurance. This was thought to carry such an enormous price tag that it was impossible. This initial conversation veered away from the training of physicians to the support of patients.

Universal care was deemed impossible, so our suggestion was modified. Farmers and their families were mostly amongst the poor so obviously in need of basic care. If health insurance could be given to them, it may alleviate a fear as well as be a disincentive to leave farming. The coverage would have to include the extended family, including parents and children. The idea of this coverage was intriguing to the people we spoke with who would then carry this to a higher level. On our next visit in the spring of 2009, we were delighted to hear that farmers would begin to have at least 80% coverage. Even if it were a small contribution, we were gratified that this level of care was being adopted. By 2011, most Chinese had some form of basic coverage, representing a monumental sea change.

39.5 Getting Organized

Dr. Norman Bethune is revered in China [1, 37, 38]. He travelled from Canada to China during the Second Sino-Japanese war where he was put in charge of Mao Zedong's medical team. In 1939, Bethune died from an infection he contracted while caring for a patient's infected wound. Mao wrote a eulogy that was committed to memory by millions of Chinese school children. He became the best-known surgeon in China and perhaps the world.

It was with this Canadian surgeon in mind that we began the Bethune Medical Development Association of Canada (BMDAC). This non-profit was formed to organize all of our functions in China. From 2010 to 2020, the BMDAC has made 20 trips to China, going twice a year in spring and fall. Each trip had about 30 participants who travelled for about two weeks. Groups of 3–5 travelled to a variety of hospitals that were matched with the hospitals' requests. For example, if a hospital wanted cardiac services, a cardiologist, a cardiac surgeon and an echocardiographer formed the make-up of the group. Service included performing procedures with an emphasis on indications and process. Education included the procedures, seminars, and lectures. In the 160 institutions visited, many close relationships have developed. There was a strong desire to visit our centers expressed in almost every place visited. Observer groups to Canada were arranged so Chinese doctors could see how their specialties were practiced under our system. Over the 10-year period, 142 observers have visited our hospitals. Most importantly, the process of how patients were assessed, treated, and cared for post-operatively was instructive for them. The gratitude expressed was heartening but the changes made in their practices in China have been remarkable.

One illustrative example has been through the echocardiographers. Our cardiologists and echo techs have taught many how to use their echo machines to the greatest benefit. Although the individuals they worked with had the same machines we have in Canada, those individuals had never been given extensive training on them simply because there was no one who could. This literally changed the face of cardiac assessments.

Another non-cardiac example comes from two of our spine surgeons who invited surgeons to come from China to learn how minimally invasive surgery was practiced in Canada. Twenty-one surgeons learned the techniques and subsequently acquired the necessary equipment. It is estimated that over 100 surgeons have learned the new methods, which has ultimately led to more widespread adoption and perhaps enhancement.

Cardiac surgeons from McGill University in Montreal established a Bethune Fellowship that allowed a young surgeon to have a full year of a complete range of surgical procedures. Coronary bypass is by far the commonest procedure practiced—this is not the case in China. On the other hand, angioplasty and stenting (PCI) have been increasing across the world, but not nearly like the expansion in China. Indeed, the ratio of PCI to CABG was 2.7:1 in our province of Ontario in 2012, whereas it was 13:1 in China [39, 40]. Reasons for this may be the advent of a new technology right when the older more invasive procedure was just gaining traction. It may also be part economic as well as part fear that centers that performed less than 100 CABGs per year were not proficient. Surgeons who get a full experience may help change this imbalance.

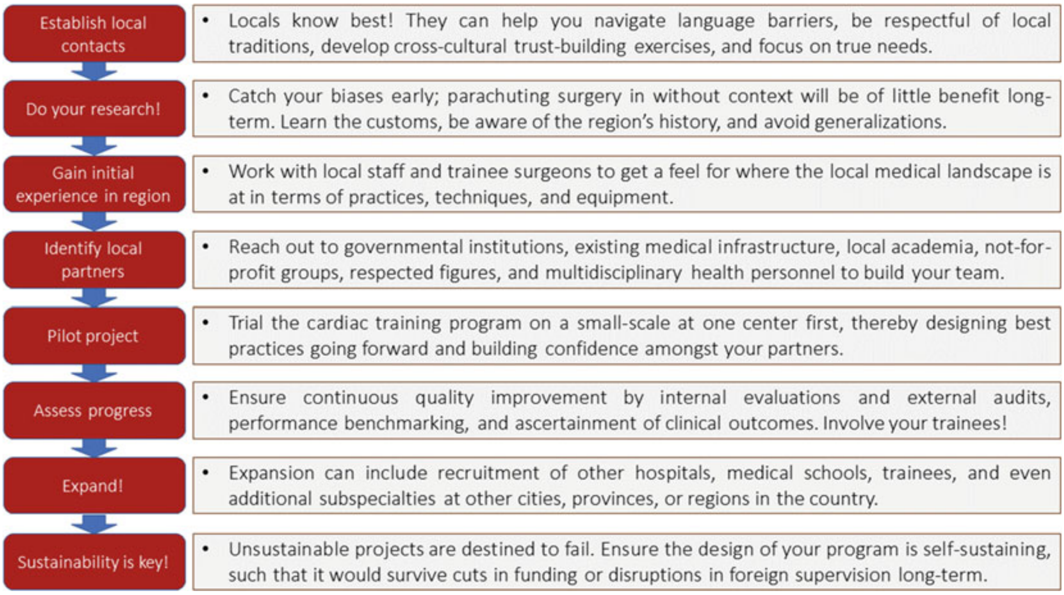

Fig. 39.1 A step-by-step template for building a cardiac surgery training program in a new region is shown here, delineating the important of local partnerships, cultural competency, and inbuilt sustainability

39.6 Training in Cardiac Surgery

Training of a cardiac or cardiothoracic surgeon in the western world has been a structured program for more than 50 years. The Chinese medical education system is hugely complex varying from region to region. Applicants with a Bachelor's in Medicine apply directly to training centers without centralized application streams and no regulation on the total number of surgeons [41]. There is no minimum length of training, with training going even beyond 8 years post-medical school [41, 42]. No annual written in-training exams or oral/written board exams are conducted. Individual institutions confirm a trainee's preparedness. It is not unusual for a "graduate" to continue in an apprentice role for 10 or more years [41]. There is little transfer to other institutions. It is little wonder why quality of care has such variability throughout the country.

Our particular training model was introduced to 11 centers, using an approach that mirrored the steps delineated in Fig. 39.1. As mentioned, the "competency by design" model was instituted [29, 30]. Graduates were then allowed independent practice. This has resulted in some competition for operating time not unlike what we see in our local hospitals. On my most recent trip, I have encouraged a type of practice plan that pools the resources, pays the bills, and then shares the remainder. It is too early to see how this will work out.

39.7 Lessons Learned

China has offered a unique experience in global surgery. Many areas are low income, poorly resourced, and suffer from inattention. In our twenty years of going, we have witnessed probably the most dramatic advances in such a short period of time. We carry no illusions that change was coming in spite of visitors from the West. However, our groups did provide some guidance on how best to take advantage of the new prosperity.

In cardiac surgery, we set standards for surgical training that mirror our own developments. Case selection is key to obtaining successful outcomes. This has been emphasized on every visit. Practicing evidence-based decisions is also a fundamental message that was repeated. The exuberance to publish on a large volume of cases has been tempered to look for a method, technique or finding that may be of interest to the cardiac surgical community. Quantity of cases does not always mean that best practices are being employed. Questioning of techniques which may lead to innovative changes does not seem to have reached the Chinese practices just yet. However, I have seen such advancement that I am confident that clinical trials would answer questions in an expedited way if proper scientific methods are used.

Coronary bypass surgery has not grown in a way that stenting has. The actual ratio suggests an imbalance with the rest of the world. The relationship between cardiologists and cardiac surgeons does not have to be adversarial but should rather be complementary. No doubt our biases have been on display, but the discussion always went back to patient selection based on what is best for a particular patient. The same issues exist in the western world. Economics, industry participation, and patients desires for less invasive procedure obviously play a role.

One glaring difference between our system and that of the Chinese is the lack of family doctors. In a country of 1.35 billion in 2012, there were only a reported 110,000 family doctors [43]. If most doctors are specializing—which can take almost half their career in apprenticeships—the majority will not experience the specialty of general practice. Much of the country's health issues could be addressed at a primary level which, again, may address the patient selection problem. Not every backache should get an MRI, nor should all chest pain receive an angiogram. General practitioners would go a long way in sorting this out.

Many places we travel to in the global surgery world have limited medical help, but most are general practitioners whereas specialists are rare. The opposite is true in China. In an effort to "catch up" to the western world, the priority has been placed on specializing and not general care. This has led to massive hospitals which tend to be the only place to go when sick. The creation and support of the general practitioner seems the next logical step for China.

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40 Establishing a Congenital Cardiac Program-Pakistan Model

Masood Sadiq

Abstract

Pediatric/congenital cardiac services are highly technology dependent and resource intensive; therefore, their availability reflects economic prosperity. Pakistan is ranked 145th in terms of human development index and spends only 1.9% of its GDP on health. These cardiac programs evolved over the last 30-years with pioneering efforts of the Pakistani physicians and surgeons returning from the West. A "piggyback" model on adult cardiac programs was used in all three initial programs. Interventional program took off in late 1990's by "individual visit model" and commitment of the local leadership. Infant and neonatal cardiac surgery evolved once the program developed in a Children Hospital and was again spearheaded by a Pakistani trained in USA. Armed Forces Institute of Cardiology adopted "intermittent visit model" by an international team with variable success. A fellowship program in paediatric cardiology was a major contribution in teaching, training and development of the program. The pioneering institutions and mentors contributed to the local capacity building and cardiac programs evolved at both cardiology institutes and children hospitals. Sindh province has used a model of establishing satellite centers of its major cardiology institute and capacity building of the local centers. There are only 42 cardiologists, 21 cardiac surgeons, 15 public sectors hospitals, 8 private hospitals and one philanthropy program for a population of 220 million. Setting up programs that can deliver outcomes at par with international programs but at an affordable cost requires sustained financial resources, commitment of the government and an ongoing effort on part of the committed professionals.

Keywords

Developing countries · Children · Pediatric cardiac surgery · Congenital heart disease · Pediatric cardiac program

40.1 Introduction

Pakistan with an estimated population of over 220 million is the fifth most populous country on the globe. It has one of the highest growth rates in the world (2%) and the population under 18 years of age constitute 48.7% of the total population [1]. On the other hand per capita income is only US $1,260 (nominal; 2020) $5,230 (PPP, 2020–21) and is ranked at 145 in terms of human development index (HDI) [2].

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-030-83864-5_40

The country spends only 1.9% of its GDP on health. The infant mortality rate is still high at 55.7/1000 births and neonatal mortality is one of the highest in the world at 41.2/1000 live births (2019). In Pakistan, the main causes of neonatal deaths are prematurity (39.3%), birth asphyxia and trauma (20.9%) and sepsis (17.2%) [3]. Congenital anomalies contribute only 5.7% of the total deaths. The health infrastructure is very patchy and there is no established referral system in the country.

The country is composed of four provinces (Punjab, Sindh, Baluchistan and Khyber Pakhtunkhwa), one federal territory—its capital Islamabad and two autonomous territories—Gilgit-Baltistan and Azad Jammu and Kashmir. There is marked variability in terms of HDI within the country—islands of affluence in an ocean of poverty (Fig. 40.1). The paediatric/congenital cardiac programs primarily exist in Punjab and Sindh. The remaining 2 provinces, capital territory or autonomous territories have very limited or no such paediatric/congenital cardiac program.

40.2 Burden of Disease

No birth prevalence studies have been conducted in Pakistan hence the true burden of congenital heart defects (CHD) is not known. There is a high rate of consanguinity and data from Pakistanis living in UK shows a higher incidence of CHD, especially complex congenital heart defects, in the immigrant population as compared to the local Caucasians [4]. In addition to CHD, there is high prevalence of rheumatic heart disease (RHD), even more so in the urban slums and rural population of the country [5, 6]. The incidence of post-viral as well as genetic and metabolic myocardial disease is also high due to a higher ratio of consanguinity in the community [7, 8].

The estimated number of children born with CHD in Pakistan is 40,000–50,000 (with an assumed birth prevalence of 8-12/1000 and annual birth rate of 2%). There is double burden of un-operated CHD in adolescents and adults, which is essentially unknown. Regarding RHD, if we take into consideration the community data available from Pakistan giving an incidence of 5.7 in 1000 for rural population and include those above the age of 15 years as well, the number of RHD patients at all ages exceeds 700, 000 [5, 6].

40.3 Screening

There is no national, provincial or regional program of newborn screening for critical CHD and there are no checks at school entry either. Almost 30% births are still home deliveries, not attended by a skilled health personnel (typically a doctor, nurse, or midwife) putting the health of both mother and baby at risk (https://data.unicef.org).

There is no routine antenatal screening for a four-chamber and great artery view by sonographers or radiologists at national level. Limited fetal echocardiography services are offered by major centers only. Antenatal diagnosis by fetal echocardiography is crucial for recognizing an early CHD and thus preventing neonatal morbidity and mortality. The decision of termination of pregnancy for complex CHD for which treatment is not available will be an ethical dilemma in countries like Pakistan where termination will not be accepted by majority of families for social and religious reasons.

40.4 Diagnosis

The diagnosis of CHD in low and middle-income countries like Pakistan is typically a chance event. The diagnosis is made when a doctor sees the baby for an illness or vaccination as routine postnatal check by a doctor or pediatrician is practiced in limited private sector deliveries. The published hospital data shows that the average age when the diagnosis of CHD is made is usually 6–12 months (median = 8 months), which essentially means that majority of neonates and infants with critical CHD, do not make it to a hospital in time [7, 8]. We have reported one of the highest ratios of delayed diagnosis reported in the literature in recent times (85.1%) [8].

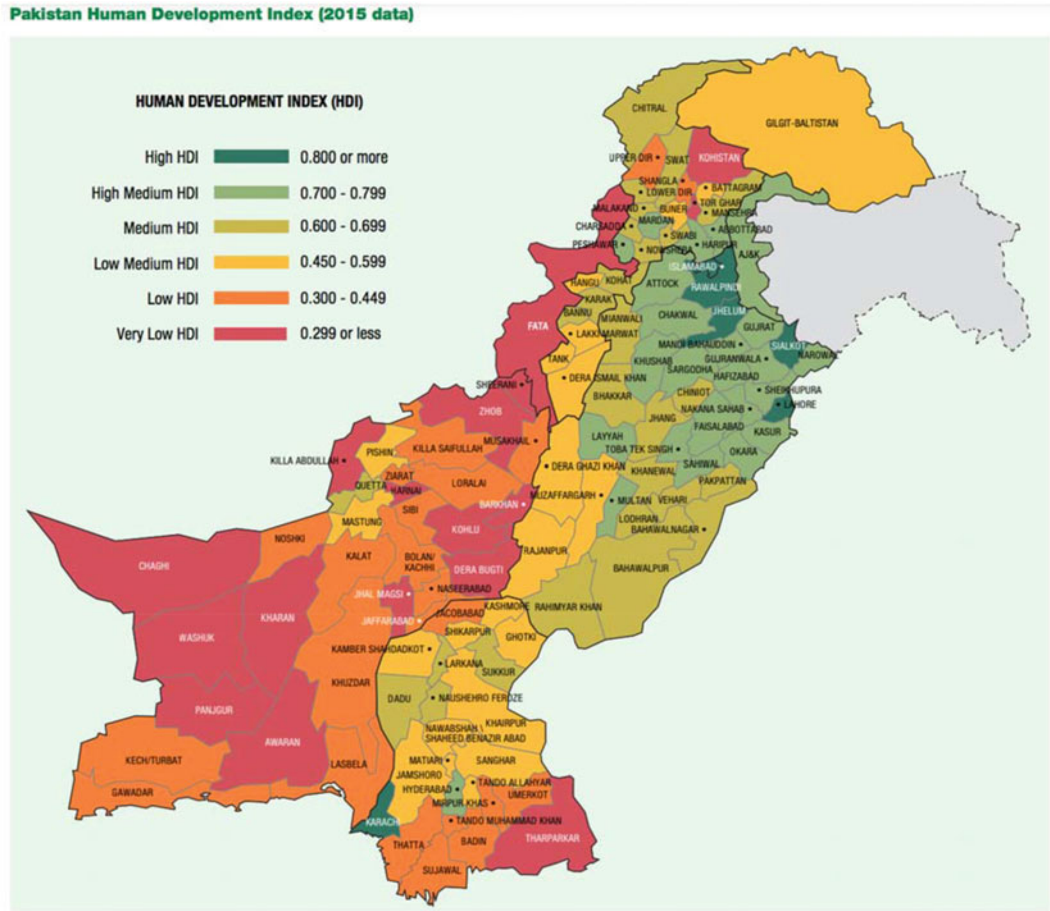

Fig. 40.1 District wise distribution of Human Development Index across Pakistan. Pakistan Human Development Index Report 2017—Due to unavailability of the PSLM 2014/15 data for Gilgit-Baltistan, Azad Jammu & Kashmir, Panjgur and Turbat, most recent available data is used instead

40.5 Limitations

There are many limitations to delivery of care to these patients and the major limitations include:

1. Overwhelming patient burden: At the Children's Hospital Lahore alone (the largest congenital cardiac care center), the waiting list of surgery for patients with CHD runs in thousand and up to 30–40 patients are added in the pool every week.
2. Too few centers: there are only 15 public sector and 8 private sector hospitals in the country offering surgery for CHD. There are very limited intensive care beds, which is a major limitation.
3. Procurement of trained staff at all levels: there are only 42 paediatric cardiologists and 21 cardiac surgeons in the country committed to congenital cardiac work. The situation is even worse when it comes to trained nurses, paramedics like perfusionists, anaesthesia and intensive care staff.
4. Not enough resources: the cost of surgery and intervention in a public sector setting is subsidised by the government and ranges from US$ 2000 to $3500. The cost in a private set up is US$ 3500–5000. Despite this low cost

from a western standard, this is still a lot of money for an average Pakistani. Out of pocket contributions and philanthropic support account for at least 30% of the surgeries being performed.

5. Not enough salaries: the highly trained staff is paid minimally in the government hospitals and has to work extra hours in private hospitals to earn their living. This not only affects the patient care at both government and private set-ups but also affects the quality of life of professionals who get frustrated and leave for the Middle East or return to the West.
6. Lack of antenatal diagnosis- the antenatal services to make a diagnosis of CHD is almost non-existent. Only 2% of mother had the antenatal diagnosis of CHD by fetal echocardiography in one of our studies and all of these had a timely referral with subsequent optimal management [8].
7. Patient related specific factors: like late presentation leading to pulmonary vascular disease, malnutrition, respiratory tract infections, anemia and other contributory factors like tuberculosis and worm infestation.
8. Infection control and emergence of multi drug resistant organisms is a major challenge in intensive care units and theatres.
9. Ethical and religious considerations: One of the major challenges is decision making on managing complex lesions with poor outcome like univentricular heart with atrial isomerism and treating patients with Down's syndrome and other syndromes. Confronted with a large waiting list of fairly straightforward lesions with a good outcome like infants with large ventricular septal defect (VSD), there is a constant fight with your conscience. There is pressure from the system and you become victim of your own successes. Dealing with such situation leads to an ongoing mental torture when you have to make choices.
10. There are no specialized centers for adults with CHD. The exact prevalence is not known but there is a sizable population of unoperated adults with CHD and the number of adults with operated CHD is growing with the availability of treatment at major cities. Major challenges to care of adults with CHD include lack of trained persons, no specialized centers, low levels of awareness about the disease and lack of government interest.

40.6 Current Model and Status of CHD Programs

There are three pioneering programs in the country and all evolved in an adult cardiology set up spearheaded by Pakistani cardiologists in USA or UK returning to Pakistan.

Considered as father of paediatric cardiology in Pakistan, Prof. Kalim uddin Aziz who was a Pakistani working in Chicago USA came to Pakistan under a scheme launched by the government of Pakistan to attract expatriate Pakistani doctors in early 80's. This first program was a "piggyback" on an adult cardiac program at National Institute of Cardiology Karachi. One of the major contributions of this program was start of a fellowship program in paediatric cardiology (FCPS) supervised by College of Physicians and Surgeons Pakistan.

Dr. Shakeel Qureshi, a renowned cardiologist from UK, joined Pakistan Army and tried establishing a CHD program at Armed Forces Institute of Cardiology in Rawalpindi. He however left Pakistan after 2 years and returned to UK. This program did progress subsequently as army got its professionals trained from UK through a training scheme facilitated by Dr Qureshi.

Prof Masood Sadiq trained in UK and returned to Pakistan in mid 90's. He established the first CHD program in Punjab at Punjab Institute of Cardiology, Lahore. This was also a "piggyback" on an adult cardiology program. This program however could not go beyond a critical point as infant cardiac surgery could not be established and it was very hard to attract young doctors to this specialty. The Children's Hospital Lahore was established in late 1998 and his team managed to build the initial 5-bedded cardiac surgery ICU and one cardiac theatre through philanthropic support in 2001. This generated numbers and at the same time paediatric cardiac surgery flourished in India and patients started going to Bangalore India (Narayana Hrudayalaya Institute of Cardiac Sciences) for surgery. A political pressure was generated through media and parents so the government of Punjab decided to establish an "Institute of paediatric cardiology and cardiac surgery" within the Children's Hospital Lahore. The current 120-bedded unit with 3 theatres, cardiac surgery ICU, 2 cath labs, 640-slice CT, 1.5t MRI was set up by the government of Punjab. Human resource was recruited and paid by the government, although on very low salaries. The same team works in 2 private set-ups in the evening to make a living.

In Punjab, the other seven public sector programs include four adult cardiac centers, 2 military cardiac centers and 2 in a children hospital. Except Armed Forces Institute of Cardiology in Rawalpindi, none of them is currently offering surgery to infants and neonates generating a tremendous pressure on the Children's Hospital Lahore and its team.

The Sindh government adopted a model of satellite centers of its major cardiology institute (National Institute of Cardiovascular Diseases Karachi) and established 9 cardiac centers in interior Sindh thus taking the cardiac care to the doorstep. The teams of NICVD are developing these centers through periodic visits and telemedicine services and have already established in-patient and cardiac intervention facility for patients with CHD in 2 of these centers. Capacity building of the local teams and institutions has led to availability of this government funded services to the poorest of the poor.

The current status of the pediatric cardiac services in various parts of Pakistan is shown in Table 40.1.

40.7 Interventional Program

The interventional program in Pakistan took off in late 1990's. Prof. Shakeel Qureshi from the UK (later joined by Dr. Zahid Amin from the USA—both Pakistani origin cardiologists working in the west) led this initiative. Local commitment, leadership and desire to develop the program were key factors to its success. This was a multidisciplinary training and involved invasive and non-invasive cardiologists, technicians and nurses. The visits started in 1998 and would involve both Lahore and Karachi, 2–3 visits per year for the first few years and then one visit a year. Before 1999, the only interventions done were balloon atrial septostomy and balloon dilation of pulmonary valve stenosis, aortic valve stenosis and coarctation of the aorta. From 1999 onwards stenting of different vessels was introduced, including covered stents, device closure of patent ductus arteriosus (PDA), atrial septal defect (ASD) and ballooning in neonates and infants. From 2004 onwards, closure of ventricular septal defect (VSD), coronary AV fistulas and more complex interventions e.g., LV-aortic tunnel and ruptured sinus of Valsalva, were undertaken.

Over a series of visits the number of interventions and complexity was increased and this illustrated the kind of progress that could be made from the combination of a committed international expert and dedicated local leadership (Fig. 40.2). We shared the space, equipment and personnel with the adult cardiology team and used single plane equipment. Sedation protocols were used to avoid anaesthesia where feasible and strategies were devised to reduce procedure time. It was also a practice to reuse certain expired or near expiry disposables brought by the visiting team through re-sterilization.

Table 40.1 A snapshot of the cardiac programs, human resource, cardiac catheterizations, interventions and cardiac surgeries in all the provinces and areas of Pakistan for the year 2019. The Human Development Index (HDI) data is as per UNDP report 2018

Sr. no.	Province	HDI	Cardiac program	Cardiologists	Cardiac surgeons	Total cath	Interventions	Cardiac surgeries
1	Punjab	0.567	**Public Sector**- 8 (Cardiology hospitals-5, Children's Hospitals-3) **Private Hospitals**- 3 (all general hospitals) **Military Hospitals**- 2 (both cardiology hospitals) **Philanthropy unit**- 1 (part of a general hospital)	24	12	3808	2047	4180
2	Sindh	0.533	**Public Sector**- 3 (a cardiology hospital with its 2 satellite centres) **Private Sector-** 3 (all general multispecialty hospitals)	13	7	1366	705	1330
3	KPK	0.529	**Public Sector**- 2 **Private Sector**- 2 (all general multispecialty hospitals)	5	2	295	231	626
4	Balochistan	0.477	None	–	–	–	–	–
5	Gilgit Baltistan	0.593	None	–	–	–	–	–
6	Azad Jammu and Kashmir	0.611	None	–	–	–	–	–
7	Islamabad	0.678	None	–	–	–	–	–
8	Pakistan	**0.561**	–	**42**	**21**	**5464**	**2983**	**6136**

The other significant contributors to this effort included Dr. James L Wilkinson from Australia and Dr. J. V. De Giovanni from UK.

40.8 Cardiac Surgery

Cardiac surgery was much slower to evolve. The adult cardiac surgeons in all three major cardiac centers would operate upon patients weighing 10 kg or more with variable results. Mr. W. J. Brawn, a renowned congenital cardiac surgeon from Children's Hospital, Birmingham UK, visited the Punjab Institute of Cardiology and then later Children's Hospital Lahore along with his team of anaesthesia and nurses in an effort to help develop the local team. This however, halted after geopolitical situation after the September 11, 2001 attacks in USA.

Congenital cardiac surgery did not take off until a Pakistani cardiac surgeon Dr. Asim Khan trained at the Cleveland Clinic in USA returned to Children's Hospital Lahore and started regularly performing neonatal and infant cardiac surgery in 2004. Anesthesia services also greatly improved subsequently and the advent of ultrasonography

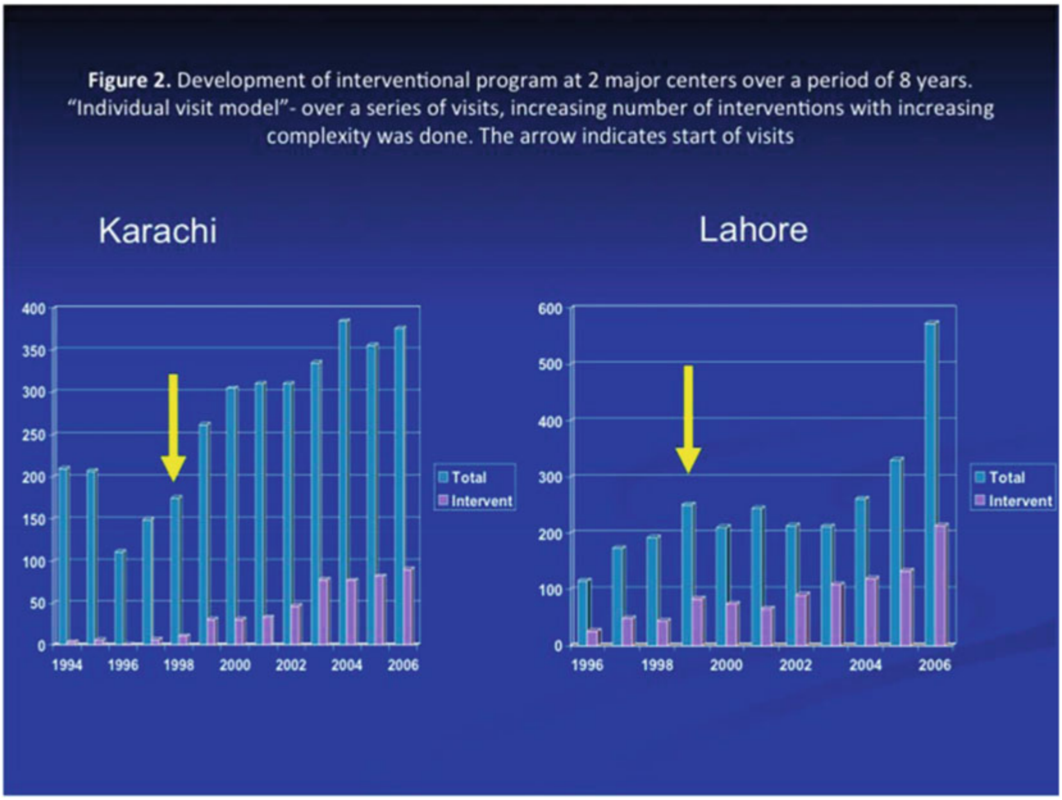

Fig. 40.2 Development of interventional program at 2 major centers, "Individual visit model"- over a series of visits, increasing number of interventions with increasing complexity was done. The arrow indicates the start of visits

guided line placements and video assisted laryngoscopy greatly facilitated the anesthetic care of infants and neonates. The team now has four cardiac surgeons, a cardiac intensivist, seven perfusionists, trained nurses and allied professionals and does over 2500 surgeries a year combined in government, private and philanthropic set up. The team has an acceptable mortality for the neonatal arterial switch operation and acceptable results in infantile and low weight patients with VSD, tetralogy of Fallot, total anomalous pulmonary venous connection and complete atrioventricular septal defect repairs. Selected patients undergo Fontan surgery too. The evolution of cardiac surgery from 2009 to 2020 in terms of the patient's age at operation being performed at children's hospital Lahore is shown in Fig. 40.3.

Dr. William Novick and his team of William Novick Global Cardiac Alliance entered into a contract with the Army and started their assistance in December 2005 at Armed Forces Institute of Cardiology Rawalpindi. Their multidisciplinary team made multiple trips of 1–4-week durations, operated on many patients while training and educating the local team. They helped the local team to develop a surgical and ICU set up by improving the existing site [9]. This was a mixed experience of variable success and was discontinued after few years. Currently the only centers offering infant and neonatal surgery are the Children's Hospital Lahore, Ittefaq Hospital Lahore, Armed Forces Institute of Cardiology Rawalpindi, National Institute of Cardiovascular Diseases Karachi and Aga Khan University Hospital Karachi. All other cardiac centers and private

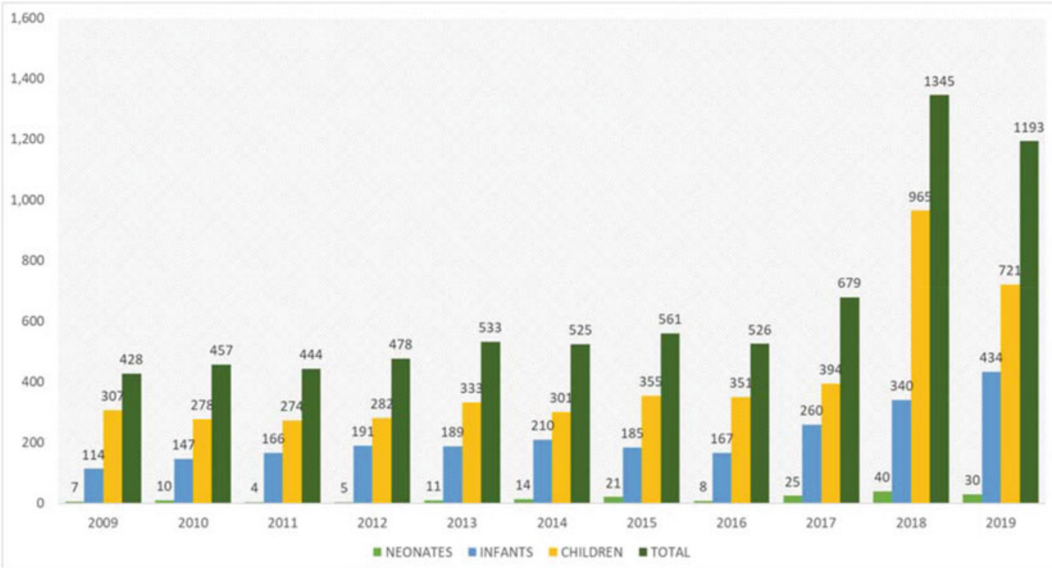

Fig. 40.3 Cardiac surgery procedures performed at children's hospital Lahore from 2009 to 2019 in terms of pediatric, infant and neonatal surgeries

hospitals would still operate upon children weighing 8–10 kg or more primarily due to lack of paediatric anaesthesia and intensive care team to look after neonates and infants.

A complete detail of the cardiac programs, number of cardiologists and cardiac surgeons, cardiac caths including interventions and cardiac surgeries are depicted in Table 40.1 for all the provinces and areas of Pakistan. The HDI data is per UNDP report 2018 [10].

40.9 Financial Model

There is no uniform financial model in the country as surgery and intervention is being done in both public and private set-ups. The cost when compared to any western model is significantly low. In the public sector the major contribution is by the state as there are no hospital or professional charges and the government also supplies a significant proportion of drugs and disposables. The out-of-pocket expenses contribute to almost 20% and philanthropy another 10% or so [11]. Very recently governments of two provinces (KPK and Punjab) have started a universal health card scheme which is likely to impact these services significantly as CHD treatment is covered by this program of "Sehat Card (Health Card)".

Various philanthropic organisations work in close liaison with these centres and contribute to the cost of treatment in various models. Of note is "Pakistan Children Heart Foundation" which supports cardiac surgery and interventions in various hospitals and runs a philanthropic set-up at University of Lahore Hospital where free surgical treatment is offered to non-affording families with the help of donations and contribution of the hospital. This foundation is in the process of building a "Children's Heart Hospital and Research Institute" in Lahore, the first of its kind in Pakistan to provide comprehensive care to patients with CHD irrespective of their ability to pay.

40.10 Brain Drain

This is a judgmental phrase in the first instance and the implicit assertion in the phrase is that it is a bad thing. It is assumed that people involved are somehow neglectful and irresponsible. Our approach has been otherwise, as a significant proportion do return home and these Pakistanis have built the entire congenital cardiac program in Pakistan. Even those who do not return contribute by professional links/ networks, focused training visits and helping and guiding young trainees aspiring for higher training. There are substantial financial remittances from these expatriates too.

Countries like Pakistan that have a large young population need to exploit the human resource. A brain drain is truly detrimental if the best and the brightest leave the country and sever all ties. Using the example of congenital cardiac services where well-trained experts either returned to their country or established working relationships with the local expertise to significantly improve and expand local services can mitigate this. A brain drain then is more a relocation with its losses but benefits too. It does not need to be stopped but more rationalized with local and may be some international bindings.

40.11 Capacity Building

Capacity building although not formally evaluated has been done at all levels by partnerships through individuals, non-governmental organizations, societies (both cardiac and pediatric) and governments. Various models have been used to train and mentor human resource, build institutional capacity, develop and maintain financial resources and system improvements. Sustainability is a major issue in low and middle income countries like Pakistan and an ongoing effort is required to keep the teams motivated and coherent. Leadership at all levels is key to success.

Workforce development has been a multipronged approach. Training program of College of Physicians and Surgeons Pakistan has been a major factor in attracting young doctors into the specialty. Visits by cardiologists/cardiac surgeons/ anesthetists/nurses from developed centers of the world, partnerships/twinning arrangement worldwide (The Children's Hospital is twinned with Royal Hospital for Children Glasgow, UK) facilitating bilateral exchange of professional at all levels, and more recently technology has helped in arranging joint sessions and workshops online.

The pioneering institutions and mentors have played a major role in expansion and capacity building of the newer institutions. Visits by local cardiologists/cardiac surgeons/anesthetists/intensivists/perfusionists/nurses to these newer centers has been a regular feature as the local cardiologists and surgeons were trained in the main units, hence a personal link. Teams were selected in these newer centers and en mass sent to the major canters for a specified period to be trained as a team. The cardiac surgeons and interventional cardiologists would go to these new canters to kick start their programs and be around for first few surgeries or interventions.

An infographic showing the capacity building model of the paediatric cardiac services at Children's Hospital Lahore highlighting the evolution along with future vision is shown in Fig. 40.4.

40.12 Challenge for the Future

Setting up programs that can deliver good outcomes at par with international programs but also at an affordable cost is a challenge. The governmental support is key to the success of any program although support from local and international NGOs can contribute too.

We need to constantly find ways to keep the cost down. Development of indigenous technology (Brazil model), special pricing of devices/ oxygenators/disposables for low and middle income countries and Chinese disposables and devices are some of the ways to keep the cost affordable. Cost effective strategies in cath lab and surgery are very important. Sharing of space, equipment and personnel with adult cardiology team, use of a single plane equipment, sedation

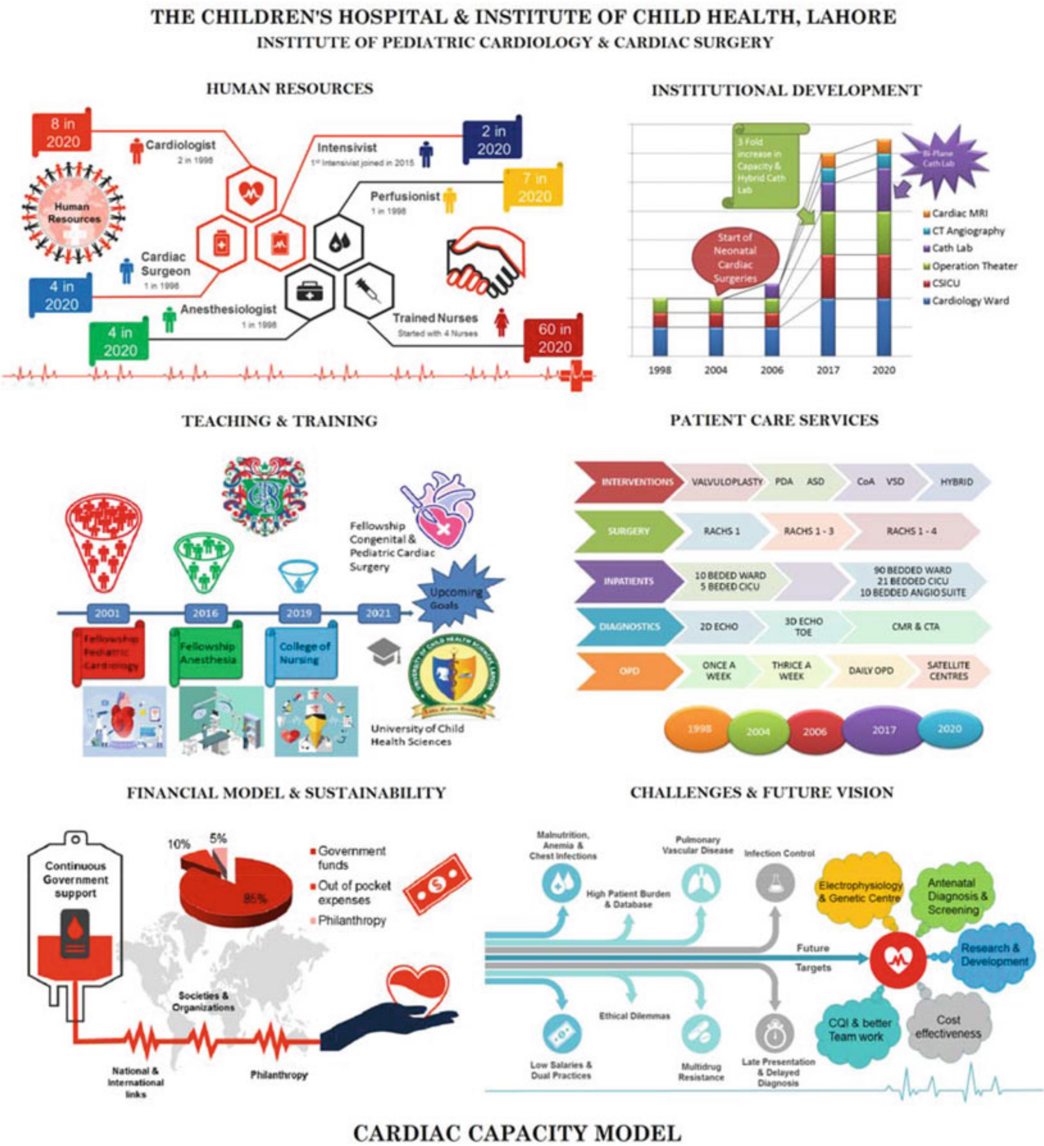

Fig. 40.4 An infographic showing the evolution of the capacity building model of the paediatric cardiac services at Children's Hospital Lahore along with future vision

protocols to avoid anaesthesia, strategies to reduce procedure time, use of adult cardiac catheter hardware and improved alternatives to occlusion device are some of the strategies being adopted in low and middle income countries [12]. Similarly many cost effective strategies are adopted in surgery and intensive care to decrease time of intensive care and hospital stay [9].

Human resource particularly in paediatric anesthesia and intensive care is very limited and restricted to few centers. Expansion of intensive care beds and human resource in these two critical areas is a major task and a challenge.

Antenatal diagnosis by fetal echocardiography is getting universal in developed countries. It is a useful screening tool for recognizing an early

CHD and thus preventing neonatal morbidity and mortality. Training sonographers in a standard four-chamber and great vessels view on routine antenatal scans can increase the yield of a possible CHD significantly. This is another major task as trained radiographers/sonographers are very limited.

Pediatric electrophysiology, a key area in paediatric and congenital heart defects management is still totally absent in Pakistan. There is not a single operator or center doing electrophysiology in pediatric age group. The local adult programs can give a basic training and then an international placement in a high volume center will be required to train a cardiologist in this area.

The limited number of paediatric cardiologists in the country is currently looking after adults with CHD. The adult cardiologists are not trained in looking after these patients and there are no specialized clinics or centers for this growing number of adolescents and adults with both unoperated and operated CHD. There is need to develop a fellowship program in adult CHD where both adult and paediatric cardiologists could be given a path. The adult cardiology centers would be the optimal institutions for establishment of such units.

The quality assurance is a major challenge in countries like Pakistan. Currently infant and neonatal surgery is being offered in only 2 or 3 centers in the country and results although encouraging are not at par with advanced programs in the developed world. Enrolling in the IQIC program was associated with an improvement in the postsurgical outcomes of the CHD surgeries at Aga Khan University Hospital Karachi [13]. Similar initiatives are required at all centers across the country to improve outcomes particularly in neonates and infants.

Teamwork is another major challenge in the low and middle income countries. We tend to be outstanding as individuals but somehow fail as a team. The ability to work within a team is a vital attribute to all pediatric cardiovascular professionals. Today's trainees in individual specialties will need to focus on developing the interpersonal skills required to work with each other [12].

Setting up programs is a challenge but sustaining the program is an even bigger challenge and requires not only sustained financial resources and commitment of the government but also an ongoing effort on part of the committed professionals.

Acknowledgements The author acknowledges the help extended by Dr. Salman Ahmad Shah and Dr Ahmad Usaid Qureshi at Children's Hospital Lahore in the formulation of tables and figures and Dr Umer Waqar Azeem and Dr Aimen Ch for their help in development of the infographic.

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J. Kpodonu (ed.), *Global Cardiac Surgery Capacity Development in Low and Middle Income Countries*, Sustainable Development Goals Series, https://doi.org/10.1007/978-3-030-83864-5