Innovative Approaches in the Delivery of Eye Care: Cataract

8

Varshini Varadaraj, Rohit C. Khanna, and Nathan Congdon

Epidemiology of Cataract: Burden and Distribution

Cataract today remains the leading cause of blindness and a significant cause of vision impairment worldwide, contributing to 33.4% of all blindness and 18.4% of all moderate to severe vision impairment, as reported by the Vision Loss Expert Group of the Global Burden of Disease Study [1, 2]. Recent literature from the same study on cataract trends shows that this high cataract prevalence is in spite of a prominent age-stratified decrease and less prominent crude decrease in the prevalence of cataract since 1990 [1]. Studies have also shown that cataracts are linked to poorer survival and an increased risk of mortality [3, 4]. There exists a great deal of inequality in distribution, with low- and middle-income countries (LMIC) bearing the brunt of the cataract burden [5]. Cataract contributes 30.7% of eye-disease-related disability-adjusted life years (DALYs) in LMICs as compared to 7.9% of

V. Varadaraj (✉)
Johns Hopkins University School of Medicine, The Dana Center for Preventive Ophthalmology, Wilmer Eye Institute, Baltimore, MD, USA
e-mail: vvarada2@jhu.edu

R. C. Khanna
L V Prasad Eye Institute, Hyderabad, Telangana, India
e-mail: rohit@lvpei.org

N. Congdon
Translational Research for Equitable Eyecare (TREE) Centre, Centre for Public Health, Queen's University Belfast, Belfast, UK

State Key Laboratory of Ophthalmology and Division of Preventive Ophthalmology of Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou, Guangdong, China

ORBIS International, New York, NY, USA

R. C. Khanna et al. (eds.), *Innovative Approaches in the Delivery of Primary and Secondary Eye Care*, Essentials in Ophthalmology,
https://doi.org/10.1007/978-3-319-98014-0_8

DALYs in high-income countries (HIC) [5]. Consequently, more than 90% of cataract-related DALYs fall in developing countries [6].

There also exists geographic and racial variability in the epidemiology of cataract, for example, in the Indian subcontinent, cataract is more prevalent at younger ages [7], appearing to develop close to a decade earlier compared to Americans [8, 9]. Prevalence estimates from migrant studies looking at Indian immigrants in the UK have similarly found an earlier age of onset compared to the Caucasian population [10]. It has also been noted that Indians have denser cataracts, [11] and higher rates of significant nuclear opacity and cataract surgery at a younger age when compared to people in Italy, [12] and Australia [13]. This difference has been linked to environmental factors, as well as nutrition [10, 14, 15] and extent of exposure to sunlight [16] and potentially, genetics [10, 17].

Risk Factors

While various forms of cataract exist, the most prevalent and visually important type is age-related cataract. Age-related cataract can be classified into three types based on the region of the crystalline lens that is affected: nuclear, cortical, and posterior subcapsular cataract (PSC). The etiology of age-related changes has not been fully elucidated and is likely caused by multiple factors in all forms of cataract [18]. Of the several risk factors identified, aging is the main non-modifiable one [19]. Gender plays a role as well, with women being at a greater risk than men [2, 20]. Longitudinal studies have examined the effect of refractive errors on cataract and have suggested that myopia is associated with increased incidence of PSC and nuclear cataract [21, 22]. There also exists substantial evidence showing that smoking is associated with nuclear cataract [23]. Robust evidence from population-based studies suggests that diabetes is associated with PSC [24] and cortical cataract [25]. As the prevalence of diabetes mellitus increases around the world [26], cataract is likely to increase as well. There is some mixed evidence of the impact of hypertension on cataract development [24, 25, 27]. A growing body of research has shown the increased risk of high body mass index (BMI) for all types of lens opacities [28, 29]. Systemic [24] inhaled [30] and topical [31] corticosteroid use has been implicated in increasing the risk of PSC cataract [24]. Genetics may play a significant role in the development of cortical [32, 33] and nuclear cataracts [34, 35]. Exposure to sunlight has been linked to the presence of cortical cataract, with a dose-response relationship [36, 37] and to a lesser extent with PSC cataract [27], apparently secondary to oxidative damage from ultraviolet (UV)-B radiation.

Since oxidative damage is thought to provide the impetus for cataract development, there has been much interest in oral antioxidant supplementation for cataract prevention. However, there is inconsistent supporting evidence, with supplementation seemingly beneficial in undernourished populations in developing countries [38], and contradictory results in more developed areas [39–41].

Of these risk factors, only reduction in sun exposure with the use of protective sunglasses and hats, and smoking cessation provide viable prevention strategies [42,

43]. While prevalence of smoking is still increasing in LMICs, smoking cessation programs are also becoming widespread [44]. This could potentially contribute to a reduction in the incidence of cataract. However, given the other major health effects of smoking [45], such programs are unlikely to be targeting cataract reduction specifically [46].

Indicators for Monitoring Cataract Surgery Programs

Cataract surgical rate (CSR) and cataract surgical coverage (CSC) are key performance indicators that aid in the evaluation and monitoring of cataract services. CSR is the number of cataract surgeries performed annually per million population and serves as a proxy indicator for the provision of eye care services [47]. CSR varies widely across the world, ranging from 4000 to 8000 in HIC and some middle-income countries like India, to as low as <100 in the least developed parts of the world [47, 48]. CSC measures the proportion of individuals with vision impairing cataract who have received cataract surgery and is an indicator of the extent to which services are meeting needs [47]. The World Health Organization (WHO) suggested a target CSC of >85% (with a post-operative visual acuity (VA) of at least 6/18) in order to prevent a cataract backlog in the 2006–2011 action plan [47]. However, the more recent WHO action plan 2014–2019 does not include specific targets for CSR or CSC but rather suggests collectively using these indicators of cataract surgical service delivery as one of three indicators along with (1) the measurement of prevalence and causes of vision impairment and (2) the number of eye care personnel in a country to measure national-level progress and assess overall performance of a country's health system [49].

CSR and CSC data are obtained from population-based surveys like the rapid assessment of cataract surgical services (RACSS) [50] and more recently, the rapid assessment of avoidable blindness (RAAB) [51]. RAABs provide a relatively inexpensive and accurate means to collect data on CSC and outcomes which can be extremely helpful in planning eye care programs. The RAAB repository as of 2016 [52] lists some 270 individual studies providing contact information for investigators, tables, and even raw data for a portion of them. Software packages are available on the RAAB website for sample size calculations, data entry, and analyses as is information on how to conduct a study.

Quality is critical to the success of cataract surgical programs everywhere in the world. Measuring quality is the only way to determine whether training has been effective. The WHO-recommended metrics in the recently published Global Action Plan mentions the importance of monitoring quality of surgical output and recommends integration of monitoring into existing national systems [49]. In spite of this, the quality of cataract surgery currently does not receive the emphasis it warrants. A major reason for this is the absence of simple and accessible tools to measure quality, coupled with low rates of post-operative follow-up among patients in many areas [53].

Limburg and colleagues developed [54] and pilot tested [53] a system for monitoring visual outcomes following cataract surgery at multiple centers in Asia and

Africa. Using a computer-based or manual paper-based method, operative complications, surgical outcomes based on WHO criteria of postoperative VA [55] (good outcomes ≥6/18; poor outcomes <6/60), and causes of poor outcomes were monitored at discharge from the hospital and up to 8–25 weeks after. Poor follow-up rates raise the question of whether vision measured immediately after surgery reflects VA 8–25 weeks later [53].

In order to examine the correlation between early post-operative and final (40 or more days post-operatively) vision in settings of poor follow-up, the Prospective Review of Early Cataract Outcomes and Grading (PRECOG) [56] was undertaken in 40 centers across Asia, Africa, and Latin America. Early visual assessment was found to be predictive of final vision irrespective of type of cataract surgery performed (ECCE, SICS, or phacoemulsification). PRECOG validated two methods of assessing outcomes where few patients return. An assessment of early VA (≤ post-operative day [POD] 3) in all patients and final VA (≥ POD 40) in only those returning without any prompting were both found to provide a measure of an institution's operative quality. While these are extremely useful surrogates in areas of poor follow-up, it has been suggested that it is imperative to increase follow-up to address late post-operative complications and provide refraction when needed [57]. However, subsequent analyses of data collected in PRECOG suggest that most patients who are willing to accept and pay for the interventions that improve VA postoperatively (spectacles and treatment of complications) return spontaneously (Meltzer ME. Zhongshan Ophthalmic Center, Guangzhou China, Personal communication, March 14, 2016). Thus the cost-effectiveness of interventions such as phone contact and transport subsidies to increase post-operative follow-up rates as a means of improving vision outcomes is questionable.

Existing literature shows that cataract surgical quality improves when there is routine assessment of surgical outcomes [53], and reliable quality assessment tools are vital to this process. A cataract surgery outcome monitoring software system has been developed by Hans Limburg from the International Centre for Eye Health (ICEH) [58]. The Aravind Eye Care System (AECS) has also developed a cloud-based platform, the Cataract Quality Assurance (Cat QA) tool that allows hospitals and individual surgeons to monitor their surgical quality and also compare their performance with other participating hospitals/surgeons (Babu G. Senior Manager IT & Systems, AECS, Personal communication, Dec 17, 2015). In an effort to increase ease of use and accessibility of such software, a consortium of NGOs and AECS have developed a freely available cloud-based application, the Better Operative Outcomes Software Tool (BOOST) [59]. BOOST is based on the data collection protocol validated in the PRECOG study and seeks to create a single monitoring system where users can benchmark their performance against those of global data in the cloud.

Success Stories

Wang et al. recently examined the relationship between CSR and indicators of economic development in countries across the world and found that both increasing per capita gross domestic product (GDP) and gross national income (GNI) were closely

related to increasing CSR [60]. This clearly illustrates the remarkable impact that resource availability has on the delivery of eye care services in any given country and the need for innovative approaches in the delivery of low-cost cataract services and the strengthening of existing health infrastructure in LMICs.

Strategic cataract surgery programs, successfully employed so far, can be attributed to reasons ranging from successful primary eye health services covering cataract in Sri Lanka, good insurance coverage for eye health in Maldives, strong community participation and insurance coverage of eye care in Thailand, and good public-private partnerships (PPPs) in eye health in India and Nepal (Sapkota Y. International Agency for the Prevention of Blindness [IAPB] Regional Coordinator – Southeast Asia, Personal communication, Mar 18, 2016). Strong integration of eye care into the primary healthcare system in Sri Lanka and Bhutan has also ensured favorable results (Sapkota Y. IAPB Regional Coordinator – Southeast Asia, Personal communication, Mar 18, 2016). Following sustained advocacy efforts by nongovernment organizations (NGO) and private sectors, cataract surgery is now commonly covered, partially if not entirely, by national insurance programs in many countries (Philippines, Vietnam, Cambodia, and China in the Western Pacific Region and Indonesia and Thailand in Southeast Asia) (Facciolo D. IAPB Regional Program Manager – Western Pacific, Personal communication, Mar 29, 2016). This is a good recognition of the universal health coverage approach with countries trying to avoid single-disease programs (as with cataract) and trying to focus on strengthening the entire health system. Now that staple reimbursement by insurance coverage has been achieved and financial bottlenecks are being addressed in many LMICs that have high burdens of unoperated cataract, attention needs to be paid to develop newer strategies aimed at increasing service provision.

Focusing more closely on some countries, India has fairly good programs in place to tackle cataract blindness. Some of the key reasons for success is the involvement of the ophthalmology leadership coupled with international funding, as well as collaborative efforts between the government, NGOs and the private sector. The formation of the District Blindness Control Society (DBCS) was one such initiative that led to decentralization of planning as well as program implementation resulting in increased output. Collaboration between all the individual components is integral to creating an effective eye care system [61, 62]. The World Bank-assisted cataract blindness control project made effective in 1995 provided a credit of USD 117.8 million to the Government of India in an effort to improve the quality of cataract services and assist the National Programme for Control of Blindness (NPCB) to expand its coverage [63]. This project significantly improved cataract surgery services in the country taking the CSR from 1,342/million in 1995 to 3,620/million in 2002 [64]. The program not only helped solve the resource crunch at the time but also brought about technological advancement in the nation's eye care services. The government and ophthalmology leadership in India have since assumed a greater level of responsibility in addressing the cataract blindness problem, and the CSR has further risen in many parts of the country [65]. The efforts of the NPCB had also previously been fortified by support from the WHO and Danish International Development Agency (DANIDA). Financial and technological support from these

organizations plays a critical role in strengthening existing health systems in developing countries like India, following which the country is better equipped to improve the delivery of quality eye care services.

Within India at an institutional level, there are some well-recognized models of cataract surgical training and delivery. One such prominent model is the AECS. What started as an 11-bed hospital in 1976 has since expanded into an extensive network [66] comprising 5 tertiary, 6 secondary, and 53 primary care centers in Southern India (Ravilla T. Executive Director of AECS, Personal communication, Jan 25, 2016). Their mission is to eliminate needless blindness in areas of limited resources [67] by addressing bottlenecks at both the demand and supply ends [68]. Critical components of the Aravind model are achieving high patient volumes and offering affordable services while maintaining a financially sustainable system. Intensive community screenings and outreach activities, coupled with excellent outcomes, ensure high patient volumes [69]. AECS focuses on actively reaching out to the "non-customer," typically impoverished patients in rural areas that are most in need of care but are least likely to present spontaneously for care. As a result, 34% of the free cataract surgeries performed in 2014–2015 were on patients that were reached via community screenings (Ravilla T. Executive Director of AECS, Personal communication, Jan 25, 2016).

Services are made affordable through cross-subsidization where revenue generated from paying patients is used to support free or low-cost eye care for poor patients, thus ensuring financial sustainability for the enterprise [67]. There are also strategies in place to reduce surgery-related costs for patients and their families, such as provision of free transportation, ensuring that the entire care cycle is completed in a single visit, and elimination of waiting lists so that surgical slots are provided as soon as surgery is indicated [67]. In 2014–2015, 96,072 paying cataract surgeries and 195,981 free/subsidized surgeries were performed throughout the entire AECS (Ravilla T. Executive Director of AECS, Personal communication, Jan 25, 2016). Reducing provider costs also allows AECS to remain financially self-sustaining. Recognizing that ophthalmologists are an expensive commodity, a task-shifting approach is employed where mid-level ophthalmic personnel are trained to complete routine tasks that do not require an ophthalmologist [67]. Additionally, Aravind manufactures its own ophthalmic consumables such as intraocular lenses (IOLs), sutures, surgical equipment, and medications, making it self-sufficient and able to control pricing. High-quality, low-cost consumables required for cataract surgery including IOLs, are in fact increasingly being locally manufactured in other LMICs like China and Nepal [70]. However, these locally produced consumables are underused, and efforts to encourage their optimal utilization could significantly reduce cost of services and encourage high volume programs.

"Vision centers," conceptualized by L V Prasad Eye Institute (LVPEI) in India [71] have been another means for AECS to reach the rural poor (Ravilla T. Executive Director of AECS, Personal communication, Jan 25, 2016). These centers are permanent facilities in rural regions that are primarily staffed with trained technicians that are easily accessible to local residents. Strong referral systems are in place that link patients requiring surgical care to the main facilities where cataract surgery can

be performed. LVPEI employs a comparable pyramidal approach with strong community outreach for rural eye care delivery [71]. With a network of 1 main "Centre of Excellence," 3 tertiary care, 16 secondary care, and more than 150 vision centers, the LVPEI Eye Health Pyramid has addressed the issues of availability, affordability and accessibility of comprehensive eye care services, including cataract services in an equitable and sustainable basis. Similarly, Dr. Sanduk Ruit and his team at the Tilganga Institute in Nepal maintain high surgical volumes by utilizing community screenings to recruit patients for surgery [72].

While these centers provide much needed eye care in underserved areas, perhaps this model is most appropriate when these eye care services can be integrated with primary healthcare services as suggested by the WHO Global Action Plan [49]. The successes of these models also calls into question its generalizability and applicability in other parts of the world. In the Indian subcontinent, high population density and good transportation infrastructure [67] make community screenings with transport of surgical patients to higher centers a feasible option. Also, the comparatively high prevalence of bilateral cataract in the working years [20] makes it possible to more easily sustain programs through user fees. China for example, has a different geographic and demographic landscape and a decentralized health system that creates a different situation. While the same Aravind model cannot be replicated, the He Eye Care System (HECS) has successfully adapted components of the Aravind system to the Chinese context [69].

Founded in 1995, HECS is currently a network of 10 eye hospitals and 50 primary eye care centers in China [73]. Community outreach is an integral component of HECS, with daily on-site screenings conducted at the primary care centers linking patients to the main hospitals for surgery. This is supplemented with regular monthly community screenings in remote rural areas lacking eye care services. HECS is moving toward making these primary care centers independent bodies able to offer cataract surgery among other services to people residing in the surrounding areas, eliminating the need for long commutes and transport to higher centers [72]. This will be accomplished by staffing each center with a team including an ophthalmologist trained to perform cataract surgery, essentially creating small autonomous hospitals (He X. Secretary General, Center of Strategic Planning & Globalization He Eye Care System, Personal communication, Jan 25, 2016). Additionally, HECS recognizes that effective management [74] and building organizational capability are integral components of creating a successful model of eye care delivery [68]. The Leadership Academy of He University (LAHU), a management school part of the He system provides educational management courses explicitly for healthcare administrators. A potential limitation of the HECS model is that it creates a parallel structure alongside existing government hospitals without utilizing them effectively or working to strengthen them. This is a potential waste of resources in a country such as China with a relatively robust and complete government system.

One of the constraints to scaling up the Aravind model in China is related to a lack of trained ophthalmologists. In an effort to address the shortage of ophthalmologists in the country, the He Postgraduate Institute of Ophthalmology and Visual Sciences was established in 2001 [73]. An in-built research facility and an industrial

unit that manufactures intraocular lenses (IOLs) and other consumables both add to the self-sufficiency of the He system. In essence, HECS has a business model comprising a well-integrated system including education, training and management for effective delivery of eye care services in the Chinese setting.

If we were to look at interventions in China that have been implemented at a national level, the National Health and Family Planning Commission in an effort to reduce the prevalence of cataract blindness launched the Million Cataract Surgeries Program (MCSP) under which a million operations were performed mostly in rural regions between 2009 and 2011 [75]. It was a solution to a problem unique to China, a very low CSR of 900/million [76] compared to other parts of Asia [64, 77]. While the MCSP succeeded in raising awareness and increasing volumes, there have been some concerns about relative lack of emphasis on capacity building as compared to service delivery, quality and outcomes, [78] and continued slow increase in the CSR. A repeat program might be considered in the near future (Facciolo D. IAPB Regional Program Manager-Western Pacific, Personal communication, Mar 29, 2016).

There is some interesting work led by the government in Malaysia to eliminate the cataract backlog with a commitment to reaching their CSC and CSR targets. Unlike other countries in Asia, Malaysia has had very limited NGO involvement in the eye care sector, with the responsibility almost solely resting with the Ministry of Health's National Ophthalmology Service. The government's work on cataract has been spurred by the results of the National Eye Surveys (NES). The NES II [79] was conducted in 2014, and based on the results there was development of a national plan with strategies to mobilize resources through insurance and the private sector, address barriers to access to cataract services, and ensure doctors keep a focus on cataract rather than other eye conditions (Facciolo D. IAPB Regional Program Manager-Western Pacific, Personal communication, Mar 29, 2016). The Cataract-Free Zone Project 2015–2019 was launched in an effort to increase awareness of cataract in the community and case detection through outreach activities. An integral component of the initiative is the Cataract Finder Programme involving active participation from government hospitals and community organizers to identify all individuals ≥50 years of age with cataract, appropriately referring them and arranging transportation to the closest surgical facility for treatment (Salowi MA. Public Health Ophthalmologist, Ministry of Health, Malaysia, Personal communication, Jun 12, 2016).

When looking at programs implemented in countries in Latin America, there have been some favorable outcomes, although the sustainability of many of these programs has been an issue. Chile has a successfully implemented healthcare plan with seven ophthalmic diseases including cataract fully covered by both government and private schemes (Lansingh VC. Medical Officer, Latin America-Mexico, HelpMeSee, Personal communication, Mar 23, 2016). Their CSR is one of the highest in the region [80] having increased substantially from 1,511/million in 2003 to 3,202/million in 2013 (Fernando B. Chilean Society of Ophthalmology, Personal communication, Jun 13, 2016). While the more expensive private insurance is available for those who can afford it, every citizen is eligible and covered by the

government's insurance plan, headed by the agency Fonda Nacional de Salud (FONASA) [81]. There exists a national healthcare system called the Explicit Guarantees in Healthcare (GES) plan that has special guarantees in league with both private and government insurances [81]. GES covers 80 diseases that have been identified as health priorities which include cataract and has established guidelines that prescribe maximum caps for preset waiting times for care and out-of-pocket expenses. The government also has mechanisms in place for the provision of care to indigenous populations living in the far southern and northern regions of the country. Those needing cataract surgery are transported to hospitals in the two main cities, Santiago and Puente Alto or the government compensates surgeons to commute to the remote areas and operate in clinics available there. The Ministry of Health has cataract surgery guidelines published and distributed to all participating providers [82]. There are however, continued issues with a lack of monitoring of the implementation of the protocols, and different regions in Chile have made varying progress, with some areas having more difficulty with implementation of these programs than others (Fernando B. Chilean Society of Ophthalmology, Personal communication, Jun 13, 2016). The European mindset of the Chileans with heavy investment in education and health, and a proactive ministry of health with stringent laws and policies in place, coupled with the advantage of being a wealthy country with a relatively low population [83] and a well-organized government, sets it apart from other Latin American countries. Hence, the replicability of their success in other regions in Latin America is questionable.

On the other hand, Uruguay is an example of a country whose health system has prevailed despite a corrupt and disorganized government. Over the past decade, with capable and committed leaders at the helm of the National Uruguayan Association of Ophthalmologists and at the university training center, the Ophthalmological College of Uruguay, the country has seen the CSR rise from 2,000/million in 2006 [80] to 4,000/million in some pockets. Also, the prevalence of blindness due to cataract is under control at 10%, coming close to 0 in some regions (Lansingh VC. Medical Officer, Latin America-Mexico, HelpMeSee, Personal communication, Mar 23, 2016).

Mexico is one of the primary proponents of the Universal Eye Health: A Global Action Plan 2014–2019 (GAP), which has an ideal of a 25% reduction in prevalence of avoidable vision impairment by 2019, with tackling the cataract burden being a central component [49]. The country has some mechanisms in place that help address the problem. Mexico has a public insurance scheme called the *Seguro Popular* or People's Health Insurance [84], financed by taxes levied primarily on alcohol and tobacco (Lansingh VC. Medical Officer, Latin America-Mexico, HelpMeSee, Personal communication, Mar 23, 2016) that provides healthcare to all citizens not covered by other insurance programs, i.e. approximately half the population. It guarantees access to a comprehensive list of interventions targeting most (>90%) diagnoses requiring care in outpatient clinics and hospitals [84], including cataract services. Under the insurance plan, there exists a Fund for Protection Against Catastrophic Expenditures (FPGC), a package of specialized interventions for conditions deemed likely to result in catastrophic health expenses [84]. Diseases

are selected based on their prevalence, epidemiological impact, and the social acceptability and financial feasibility of the intervention [85]. Not surprisingly, cataract is one of the conditions covered by the FPGC. This ensures that the formerly uninsured, economically disadvantaged are not excluded from receiving cataract surgical care. The number of surgeries being performed under the People's Insurance scheme has been growing with about 80,000 surgeries in 2015. However, this program is by no means lacking in problems. It has been abused by the providers, and the government has clamped down with controls being brought into place so that only certified hospitals can participate in the scheme, with resources and operating rooms having to meet international standards for cataract surgery (Lansingh VC. Medical Officer, Latin America-Mexico, HelpMeSee, Personal communication, Mar 23, 2016).

In the Pacific Islands, compared to other specialties, ophthalmology is relatively well developed and well equipped. Efforts in the region have been primarily coordinated by an NGO, the Fred Hollows Foundation New Zealand with active involvement of the local government. In the past, the island nations depended heavily on expatriate visiting surgical teams from Australia, New Zealand, the USA, and Japan for the treatment of cataracts. This was costly and unsustainable with poor follow-up. In the last decade, a training base, the Pacific Eye Institute, has been established in Fiji [86, 87] (and a new one in Solomon Islands) serving the entire region. Local doctors and nurses are trained, and services are delivered in public hospitals and clinics using primary healthcare networks, with outreach teams visiting the various islands on a regular basis.

A noteworthy establishment providing eye care across the Middle East and Africa is the Magrabi Hospitals and Centres, a large network of private hospitals founded in 1955 [88]. The Magrabi Foundation was consequently created in 1992 under the umbrella of the main medical group largely as a charitable organization [89]. One of Magrabi Foundation's "low-pay hospitals" in Cairo has fundamental similarities to the Aravind model where highly standardized, high-quality surgery is offered using a multitiered pricing scheme based on an individual's ability to pay. Approximately 60% make financial contributions, while 40% benefit from free surgery. They also have outreach caravans and local vision centers to enable the rural residents of Egypt to seek care [89].

While Magrabi and other hospitals are increasingly providing eye care in sub-Saharan Africa (SSA), the literature shows that acceptance and uptake of cataract surgical services are low even when made available [90–92]. Overall, when considering SSA, it has been noted that when compared to Asia, it is lacking in both surgical and management capacities [74]. The former is related to a shortage in trained ophthalmologists and the latter relates to a lack of leadership and structure in the existing programs, together resulting in inadequate service delivery. Compounding the problem, SSA has low population density, inadequate transportation infrastructure [74], and relatively low cataract prevalence due to the younger population [93], making it more challenging to capture high volumes. Further, it has been noted that there exists a lack of motivation among many existing ophthalmic personnel in SSA that adds to the low productivity in the region. It is in this

context that the Hilton Cataract Initiative (HCI) was designed to capitalize on the interest and dedication of a few highly motivated local ophthalmic actioners/hospitals in an effort to improve cataract services in the region [94]. The HCI is a collaboration between the Hilton Foundation (providing financial support), the AECS (providing mentoring), and the Dana Center for Preventive Ophthalmology at Johns Hopkins University (providing educational support) working together with five hospitals in SSA to strengthen existing infrastructure and increase cataract surgical output [95]. These select SSA hospitals are supported by the HCI in training and employing new ophthalmologists and expanding their existing services. However, it is still early to assess whether this initiative has demonstrated tangible results.

As others have suggested [72], models like AECS, LVPEI and Tilganga have succeeded because they are highly standardized (specifically assigned roles for surgeons, nurses, support staff), have tightly monitored quality control [74], are financially self-sufficient, and are modeled to serve the needs of the local community [96]. A delicate balance between the two core principles, (1) provision of low-cost, high-quality care to all those in need and (2) maintaining financial viability has to be struck for this model to succeed [67]. While these fundamental guidelines remain the same, it is imperative to understand the local geographic and demographic patterns, cultural norms and attitudes, and availability of resources and human capital. All these factors need to be taken into consideration to effectively implement systems that are relevant to the region in question.

Leveraging existing platforms such as those mentioned above, the Global Sight Initiative (GSI), a consortium of leading eye care NGOs and hospitals worldwide was launched in 2008 [97]. GSI is dedicated to partnering with local hospitals to build capacity, improve service quality, and increase surgical output to an additional one million cataract operations per year by 2020. Thus far, from 2010 to 2014, there has been an average increase of 69% in surgical output in a group of 25 eye hospitals in 16 countries (Judson K. Seva Foundation, Personal communication, Sep 01, 2016).

It is to be noted that while singular institutions and collaborations such as the GSI have had great impact in many countries in the developing world, design and delivery of cataract surgery programs have to happen at each individual country's national level to have maximum influence and produce successful and sustainable solutions. Integration among the various components of the healthcare system with the fostering of relationships between the government, the private sector and NGOs, with mobilization of political will, can go a long way in creating a viable solution to tackling the cataract problem.

Training

High-quality training of adequate numbers of surgeons is crucial to relieving the cataract burden. An International Council of Ophthalmology (ICO) survey conducted in 2010 estimated that there are 5.6 residents in training per million

population globally, ranging from less than one resident per million population to more than ten residents per million population based on the region's economic development [98]. While these data highlight a deficiency of ophthalmologists in a majority of the developing and some parts of the developed world, there are few available data on the quality and skill levels of existing ophthalmologists. Also, there are limited data providing an overview on global resident training standards, including information on the primary cataract surgical technique taught (phacoemulsification, extracapsular cataract extraction surgery [ECCE], small incision cataract surgery [SICS]), and existing mandatory minimum number of cases required for graduation.

Some countries have regulating bodies that stipulate a minimum number of cataract surgeries to be completed during ophthalmology training. Programs in the USA accredited by the Accreditation Council for Graduate Medical Education (ACGME) [99] are required by the ophthalmology Residency Review Committee (RRC) for graduating residents to have served as the primary surgeon on at least 86 cataract surgeries during the course of the 3 years [100]. While data show that 90% of US residents perform more than a 100 surgeries [101] and 86% of graduates are comfortable with their surgical training [102], it has been suggested that the required minimum be raised to 121 to allow for enhanced surgical proficiency [103].

Similar to the USA, 86 cataract surgeries are required for residents in Singapore [104]. In the UK, the Royal College of Ophthalmologists (RCO) requires 350 cataract cases to be completed during the 7 years of training [105]. In Australia and New Zealand, no numbers for surgical cases are currently stipulated, though most residents complete approximately 400–500 cataract operations (almost all phacoemulsification) during their 5-year training coordinated by the College of Ophthalmologists [106]. At the Pacific Eye Institute in Suva, Fiji [87], which trains ophthalmologists for the whole Pacific region, trainees undertaking their first year of training (which gives them a Diploma) are required to have completed at least 100 SICS cases and have the results audited (Green C. ICO, Personal communication, Dec 19, 2015).

In some countries, there are no mandatory regulations, but there are suggested guidelines that are not always followed. A study comparing the differences in training between Chinese and Hong Kong ophthalmology residents found that while in Hong Kong the required 100 cataract surgery case target is often achieved, reflected in the median number of 100 cataract surgeries reported by residents, the median number of cataract surgeries performed by residents in China was zero, well below the minimum 15 case target set by the Chinese Ophthalmological Society [76].

Data from India show that a resident performs anywhere between 3.5 and 2,489 cataract surgeries per year [107] depending on the training program. While there are some renowned institutions like AECS and LVPEI, many programs in the country are found not to meet the criteria considered essential for resident training [108], and many recent graduates are not surgically competent and must seek additional surgical training [109]. In some countries there are regional training centers and NGO-supported hospitals present to supplement the surgical training that the national systems are not able to provide (India, Africa, Myanmar) (Green C. ICO, Personal communication, Dec 19, 2015). There are instances where industry has

stepped in to provide such supplemental training. For example, Alcon has launched the Phaco Development Program in China, India, and Vietnam where phacoemulsification training is made available to ophthalmologists in practice [110].

Working with local government and educational institutions with adequate resourcing best achieves sustainability of any training program. This is the approach that the Royal Australian and New Zealand College of Ophthalmologists (RANZCO) takes with its international development work, with partnerships in the Pacific, Cambodia, Vietnam, and Indonesia [111].

There is a dearth of data on training standards in Africa. Data from a survey conducted by ICO shows that SSA has the lowest average number of ophthalmologists (2.7) per million population [98]. Initiatives to address the shortage in ophthalmologists have led to the development of training programs in some countries for non-physician cataract surgeons [91]. While this has contributed to an increase in the number of cataract surgeries performed in those regions, productivity of these surgeons has been shown to be relatively low [112]. Other strategies include formation of the College of Ophthalmology of Eastern Central and Southern Africa (COECSA) to tackle the chronic shortage of ophthalmologists and plans exist to develop a shorter, 1-year diploma in ophthalmology under the direction of West African College of Surgeons (WACS), so as to increase the rate of production of trained personnel [113].

A structured residency program with clear guidelines and standards is required to produce capable ophthalmic surgeons. As some have suggested [114, 115], significant reforms in ophthalmology training may be required in many parts of the world.

The role of simulation technology in cataract surgery training has been explored as a medium for providing much needed training in some parts of the world in a fail-safe, stress-free environment that supports learning [116]. One such US-based NGO, HelpMeSee [117] is leveraging its experience in aviation training by adaptation and implementation of best practices in simulation-based training to develop a proficiency-based SICS simulation-based training program. HelpMeSee training will provide over 4 months, an estimated surgical practice equivalent of about 300 cases, where various surgical complication scenarios can be recreated followed by live mentored training (Walden M. Clinical Research Coordinator at HelpMeSee, Personal communication, Dec 17, 2015). Trainee performance will be evaluated by objective measures adapted from ICO standards of practice (Ophthalmology Surgical Competency Assessment Rubric). Pre-sterilized surgical kits will be provided to all qualified surgeons completing their training in an effort to standardize the process. While exciting, such simulator-based training methods still remain to be validated.

Way Forward

While global annual cataract surgical output has doubled from 10 million to 20 million in the past decade, the elderly population (≥65 years) has also doubled in the past two decades in some developing countries [118]. With the increase in the aging population, there has been little reduction in the prevalence of cataract blindness,

with indeed, an increase in the numbers requiring surgery in many parts of the world. Hence, successfully dealing with the cataract problem would require a comprehensive, multi-dimensional approach encompassing innovative strategies for prevention (smoking cessation program, limitation of UV-B exposure, etc.), as well as improving surgical output and outcomes.

In many LMICs insurance programs are now available that cover the cost of cataract surgery partially, if not fully. This means that the pivotal challenge currently is to make available services more accessible. One way to accomplish this is through use of newer technologies for aiding in large-scale assessment of visual function and screening for unoperated cataract in settings with large backlogs and limited ophthalmic personnel. Smartphone-based applications like the PEEK test have been shown to be a reliable measure of VA that can be administered by non-healthcare personnel and may be of value in resource-limited areas [119].

Principles from some of the models mentioned in this chapter could be adapted to suit local geographical/cultural needs and replicated in other institutions/countries, to increase surgical output quantity and quality. It is imperative to strengthen existing training programs across the globe and ensure basic minimal training standards to equip countries with skilled ophthalmic personnel. Monitoring of surgical outcomes should be a routine practice that is regularly reviewed rather than the occasional manner in which it is currently conducted.

Compliance with Ethical Requirements Varshini Varadaraj, Nathan G. Congdon, and Rohit C Khanna declare that they have no conflicts of interest.

No human or animal studies were carried out by the authors for this chapter.

References

1. Khairallah M, Kahloun R, Bourne R, Limburg H, Flaxman SR, Jonas JB, et al. Number of people blind or visually impaired by cataract worldwide and in world regions, 1990 to 2010 worldwide prevalence of cataract, 1990–2010. Invest Ophthalmol Vis Sci. 2015;56(11):6762–9.
2. Bourne RR, Stevens GA, White RA, Smith JL, Flaxman SR, Price H, et al. Causes of vision loss worldwide, 1990–2010: a systematic analysis. Lancet Glob Health. 2013;1(6):e339–e49.
3. Knudtson MD, Klein BE, Klein R. Age-related eye disease, visual impairment, and survival: the Beaver Dam Eye Study. Arch Ophthalmol. 2006;124(2):243–9.
4. Khanna RC, Murthy GV, Giridhar P, Krishnaiah S, Pant HB, Shantha GPS, et al. Cataract, visual impairment and long-term mortality in a rural cohort in India: the Andhra Pradesh Eye Disease Study. PLoS One. 2013;8(10):e78002.
5. Ono K, Hiratsuka Y, Murakami A. Global inequality in eye health: country-level analysis from the Global Burden of Disease Study. Am J Public Health. 2010;100(9):1784.
6. Rao GN, Khanna R, Payal A. The global burden of cataract. Curr Opin Ophthalmol. 2011;22(1):4–9.
7. Vashist P, Talwar B, Gogoi M, Maraini G, Camparini M, Ravindran RD, et al. Prevalence of cataract in an older population in India: the India study of age-related eye disease. Ophthalmology. 2011;118(2):272–8. e2
8. Group EDPR. Prevalence of cataract and pseudophakia/aphakia among adults in the United States. Arch Ophthalmol. 2004;122(4):487.

9. Klein BE, Klein R, Linton KL. Prevalence of age-related lens opacities in a population: the Beaver Dam Eye Study. Ophthalmology. 1992;99(4):546–52.
10. Das B, Thompson J, Patel R, Rosenthal A. The prevalence of age related cataract in the Asian community in Leicester: a community based study. Eye. 1990;4(5):723–6.
11. Dandona L, Dandona R, Naduvilath TJ, McCarty CA, Srinivas M, Mandal P, et al. Burden of moderate visual impairment in an urban population in southern India. Ophthalmology. 1999;106(3):497–504.
12. Giuffrè G, Giammanco R, Di Pace F, Ponte F. Casteldaccia eye study: prevalence of cataract in the adult and elderly population of a Mediterranean town. Int Ophthalmol. 1994;18(6):363–71.
13. McCarty CA, Nanjan MB, Taylor HR. Operated and unoperated cataract in Australia. Clin Exp Ophthalmol. 2000;28(2):77–82.
14. Mohan M, Sperduto RD, Angra SK, Milton RC, Mathur RL, Underwood BA, et al. India-US case-control study of age-related cataracts. Arch Ophthalmol. 1989;107(5):670–6.
15. Thompson JR. The demand incidence of cataract in Asian immigrants to Britain and their descendants. Br J Ophthalmol. 1989;73(12):950–4.
16. Javitt JC, Taylor HR. Cataract and latitude. Doc Ophthalmol. 1995;88(3–4):307–25.
17. Nirmalan P, Robin A, Katz J, Tielsch J, Thulasiraj R, Krishnadas R, et al. Risk factors for age related cataract in a rural population of southern India: the Aravind Comprehensive Eye Study. Br J Ophthalmol. 2004;88(8):989–94.
18. Seddon J, Fong D, West SK, Valmadrid CT. Epidemiology of risk factors for age-related cataract. Surv Ophthalmol. 1995;39(4):323–34.
19. Hodge WG, Whitcher JP, Satariano W. Risk factors for age-related cataracts. Epidemiol Rev. 1994;17(2):336–46.
20. Kahn HA, Leibowitz HM, Ganley JPK, Mohandas M, Colton T, Nickerson RS, Dawber TR. The Framingham eye study I. Outline and major prevalence findings. Am J Epidemiol. 1977;106(1):17–32.
21. Kanthan GL, Mitchell P, Rochtchina E, Cumming RG, Wang JJ. Myopia and the long-term incidence of cataract and cataract surgery: the Blue Mountains Eye Study. Clin Exp Ophthalmol. 2014;42(4):347–53.
22. Pan C-W, Cheng C-Y, Saw S-M, Wang JJ, Wong TY. Myopia and age-related cataract: a systematic review and meta-analysis. Am J Ophthalmol. 2013;156(5):1021–33. e1.
23. West S, Munoz B, Emmett EA, Taylor HR. Cigarette smoking and risk of nuclear cataracts. Arch Ophthalmol. 1989;107(8):1166–9.
24. Delcourt C, Cristol J-P, Tessier F, Léger CL, Michel F, Papoz L, et al. Risk factors for cortical, nuclear, and posterior subcapsular cataracts: the POLA study. Am J Epidemiol. 2000;151(5):497–504.
25. Leske MC, Wu S-Y, Hennis A, Connell AM, Hyman L, Schachat A, et al. Diabetes, hypertension, and central obesity as cataract risk factors in a black population: The Barbados Eye Study11Members of the Barbados Eye Study Group are listed in the Appendix at the end of this article. Ophthalmology. 1999;106(1):35–41.
26. Amos AF, McCarty DJ, Zimmet P. The rising global burden of diabetes and its complications: estimates and projections to the year 2010. Diabet Med. 1997;14(S5):S7–S85.
27. Bochow TW, West SK, Azar A, Munoz B, Sommer A, Taylor HR. Ultraviolet light exposure and risk of posterior subcapsular cataracts. Arch Ophthalmol. 1989;107(3):369–72.
28. Hiller R, Podgor MJ, Sperduto RD, Nowroozi L, Wilson PW, D'Agostino RB, et al. A longitudinal study of body mass index and lens opacities: the Framingham studies. Ophthalmology. 1998;105(7):1244–50.
29. Glynn RJ, Christen WG, Manson JE, Bernheimer J, Hennekens CH. Body mass index: an independent predictor of cataract. Arch Ophthalmol. 1995;113(9):1131–7.
30. Cumming RG, Mitchell P, Leeder SR. Use of inhaled corticosteroids and the risk of cataracts. N Engl J Med. 1997;337(1):8–14.
31. Urban RC, Cotlier E. Corticosteroid-induced cataracts. Surv Ophthalmol. 1986;31(2):102–10.

32. Hammond CJ, Duncan DD, Snieder H, de Lange M, West SK, Spector TD, et al. The heritability of age-related cortical cataract: the twin eye study. Invest Ophthalmol Vis Sci. 2001;42(3):601–5.
33. Congdon N, Broman KW, Lai H, Munoz B, Bowie H, Gilbert D, et al. Cortical, but not posterior subcapsular, cataract shows significant familial aggregation in an older population after adjustment for possible shared environmental factors. Ophthalmology. 2005;112(1):73–7.
34. Hammond CJ, Snieder H, Spector TD, Gilbert CE. Genetic and environmental factors in age-related nuclear cataracts in monozygotic and dizygotic twins. N Engl J Med. 2000;342(24):1786–90.
35. Congdon N, Broman KW, Lai H, Munoz B, Bowie H, Gilber D, et al. Nuclear cataract shows significant familial aggregation in an older population after adjustment for possible shared environmental factors. Invest Ophthalmol Vis Sci. 2004;45(7):2182.
36. Hollows F, Moran D. Cataract-the ultraviolet risk factor. Lancet. 1981;318(8258):1249–50.
37. McCarty C, Taylor H. A review of the epidemiologic evidence linking ultraviolet radiation and cataracts; progress in lens and cataract research. Dev Ophthalmol. 2002;35:21–31.
38. Sperduto RD, Hu TS, Milton RC. The linxian cataract studies. Two nutrition intervention trials. Arch Ophthalmol. 1993;11:1246–53.
39. Christen WG, Glynn RJ, Manson JE, MacFadyen J, Bubes V, Schvartz M, et al. Effects of multivitamin supplement on cataract and age-related macular degeneration in a randomized trial of male physicians. Ophthalmology. 2014;121(2):525–34.
40. Chew EY, SanGiovanni JP, Ferris FL, Wong WT, Agron E, Clemons TE, et al. Lutein/zeaxanthin for the treatment of age-related cataract: AREDS2 randomized trial report no. 4. JAMA Ophthalmol. 2013;131(7):843–50.
41. Age-Related Eye Disease Study Research Group. A randomized, placebo-controlled, clinical trial of high-dose supplementation with vitamins C and E and beta carotene for age-related cataract and vision loss: AREDS report no. 9. Arch Ophthalmol. 2001;119(10):1439.
42. McCarty CA, Nanjan MB, Taylor HR. Attributable risk estimates for cataract to prioritize medical and public health action. Invest Ophthalmol Vis Sci. 2000;41(12):3720–5.
43. Congdon NG, Friedman DS, Lietman T. Important causes of visual impairment in the world today. JAMA. 2003;290(15):2057–60.
44. Abdullah A, Husten C. Promotion of smoking cessation in developing countries: a framework for urgent public health interventions. Thorax. 2004;59(7):623–30.
45. Fielding JE. Smoking: health effects and control. N Engl J Med. 1985;313(8):491–8.
46. Congdon NG. Prevention strategies for age related cataract: present limitations and future possibilities. Br J Ophthalmol. 2001;85(5):516–20.
47. World Health Organization. Global initiative for the elimination of avoidable blindness: action plan 2006–2011. 2007. Accessed Nov 26, 2015. Available from: http://www.vision2020.org/documents/publications/Vision2020_report.pdf.
48. Foster A. Vision 2020: the cataract challenge. Commun Eye Health. 2000;13(34):17–9.
49. World Health Organization. Universal eye health: a global action plan 2014–2019. Geneva: WHO; 2013. Jun 4, 2016. Available from: http://www.who.int/blindness/actionplan/en/.
50. Limburg H, Kumar R, Indrayan A, Sundaram K. Rapid assessment of prevalence of cataract blindness at district level. Int J Epidemiol. 1997;26(5):1049–54.
51. Kuper H, Polack S, Limburg H. Rapid assessment of avoidable blindness. Commun Eye Health. 2006;19(60):68.
52. Rapid assessment of avoidable blindness. Dec 11, 2015. Available from: http://www.raabdata.info/repository/.
53. Limburg H, Foster A, Gilbert C, Johnson G, Kyndt M, Myatt M. Routine monitoring of visual outcome of cataract surgery. Part 2: results from eight study centres. Br J Ophthalmol. 2005;89(1):50–2.
54. Limburg H, Foster A, Gilbert C, Johnson G, Kyndt M. Routine monitoring of visual outcome of cataract surgery. Part 1: development of an instrument. Br J Ophthalmol. 2005;89(1):45–9.
55. World Health Organization. Informal consultation on analysis of blindness prevention outcomes. Geneva; 1998. Nov 26, 2015. Available from: http://apps.who.int/iris/bitstream/10665/67843/1/WHO_PBL_98.68.pdf.

56. Congdon N, Yan X, Lansingh V, Sisay A, Müller A, Chan V, et al. Assessment of cataract surgical outcomes in settings where follow-up is poor: PRECOG, a multicentre observational study. Lancet Glob Health. 2013;1(1):e37–45.
57. Jiang Y, Foster PJ. Quality assessment of cataract surgery in regions with low follow-up rates. Lancet Glob Health. 2013;1(1):e9–e10.
58. Limburg H. Monitoring cataract surgical outcomes: methods and tools. Commun Eye Health. 2002;15(44):51.
59. BOOST (Better Operative Outcomes Software Tool). Dec 5, 2015. Available from: http://www.iapb.org/blog/cataract-boost-story.
60. Wang W, Yan W, Fotis K, Prasad NM, Lansingh VC, Taylor HR, et al. Cataract surgical rate and socioeconomics: a global study cataract surgical rate and socioeconomics. Invest Ophthalmol Vis Sci. 2016;57(14):5872–81.
61. Muecke J, Sia DI, Newland H, Casson RJ, Selva D. Perspective on ophthalmic support in countries of the developing world. Clin Exp Ophthalmol. 2013;41(3):263–71.
62. Johns A. The International Agency for the Prevention of Blindness and non-governmental organisations: an effective network. Int Ophthalmol. 1990;14(3):227–30.
63. Jose R, Bachani D. World Bank-assisted cataract blindness control project. Indian J Ophthalmol. 1995;43(1):35.
64. Murthy G, Gupta SK, John N, Vashist P. Current status of cataract blindness and vision 2020: the right to sight initiative in India. Indian J Ophthalmol. 2008;56(6):489.
65. Murthy GV, Vashist P, John N, Pokharel G, Ellwein LB. Prevalence and causes of visual impairment and blindness in older adults in an area of India with a high cataract surgical rate. Ophthalmic Epidemiol. 2010;17(4):185–95.
66. Natchiar G, Robin AL, Thulasiraj RD, Krishnaswamy S. Attacking the backlog of India's curable blind: the Aravind Eye Hospital model. Arch Ophthalmol. 1994;112(7):987–93.
67. Ravilla T, Ramasamy D. Efficient high-volume cataract services: the Aravind model. Commun Eye Health. 2014;27(85):7.
68. Sommer A, Taylor HR, Ravilla TD, West S, Lietman TM, Keenan JD, et al. Challenges of ophthalmic care in the developing world. JAMA Ophthalmol. 2014;132(5):640–4.
69. Bhandari A, Dratler S, Raube K, Thulasiraj R. Specialty care systems: a pioneering vision for global health. Health Aff (Millwood). 2008;27(4):964–76.
70. Glasziou P, Straus S, Brownlee S, Trevena L, Dans L, Guyatt G, et al. Evidence for underuse of effective medical services around the world. Lancet. 2017;390:169–77.
71. Rao GN, Khanna RC, Athota SM, Rajshekar V, Rani PK. Integrated model of primary and secondary eye care for underserved rural areas: the LV Prasad Eye Institute experience. Indian J Ophthalmol. 2012;60(5):396.
72. Broyles JR, Glick P, Hu J, Lim Y-W. Cataract blindness and simulation-based training for cataract surgeons: an assessment of the HelpMeSee approach. Santa Monica: RAND Corporation, TR-1303-HMI, 2012. Dec 15, 2015. Available from: http://www.rand.org/pubs/technical_reports/TR1303.html.
73. He Eye Care System. Jan 3, 2016. Available from: http://fm.hsyk.com.cn/english/intro.html.
74. Lewallen S, Thulasiraj R. Eliminating cataract blindness–how do we apply lessons from Asia to sub-Saharan Africa? Glob Public Health. 2010;5(6):639–48.
75. Yan X, Guan C, Mueller A, Iezzi B, He M, Liang H, et al. Outcomes and projected impact on vision restoration of the China Million Cataract Surgeries Program. Ophthalmic Epidemiol. 2013;20(5):294–300.
76. Young AL, Jhanji V, Liang Y, Congdon N, Chow S, Wang F, et al. A survey of perceived training differences between ophthalmology residents in Hong Kong and China. BMC Med Educ. 2015;15(1):158.
77. World Health Organization. Blindness as a public health problem in China; global initiative for the elimination of avoidable blindness. Fact Sheet. Geneva: WHO; 2013. Jun 6, 2016. Available from: http://www.who.int/mediacentre/factsheets/fs230/en/.
78. Yan X, Guan C, Tan L, Mueller A, Iezzi B, He M, et al. Outcomes from the China Million Cataract Surgeries Program. Invest Ophthalmol Vis Sci. 2012;53(14):2293.
79. Salowi MA. Report on the National Eye Survey 2014. Kuala Lumpur.

80. Lansingh VC, Resnikoff S, Tingley-Kelley K, Nano ME, Martens M, Silva JC, et al. Cataract surgery rates in Latin America: a four-year longitudinal study of 19 countries. Ophthalmic Epidemiol. 2010;17(2):75–81.
81. Missoni E, Solimano G. Towards universal health coverage: the Chilean experience. World health report. 2010.
82. Guía Clínica 2010 Tratamiento Quirúrgico de Cataratas congénitas y adquiridas [Clinic Guide 2010 for Surgical Treatment of congenital and acquired cataract]. Santiago: Ministerio de Salud [Ministry of Health][In Spanish]; 2010.
83. World Bank. Jun 16, 2016. Available from: http://data.worldbank.org/indicator/SP.POP.TOTL.
84. Frenk J, Gómez-Dantés O, Knaul FM. The democratization of health in Mexico: financial innovations for universal coverage. Bull World Health Organ. 2009;87(7):542–8.
85. Aracena-Genao B, González-Robledo MC, González-Robledo LM, Palacio-Mejía LS, Nigenda-López G. Fund for protection against catastrophic expenses [Article in Spanish]. Salud Publica Mex. 2011;53:407–15.
86. Brian G, Ramke J, Szetu J, Qoqonokana MQ. Cataract and its surgery in Fiji. Clin Exp Ophthalmol. 2011;39(5):449–55.
87. du Toit R, Brian G, Palagyi A, Williams C, Ramke J. Education of eye health professionals to meet the needs of the Pacific. NZ Med J. 2009;122(1291):69–76.
88. Magrabi Hospitals & Centers. Jan 2, 2016. Available from: http://www.magrabihospitals.com/index.php?option=com_content&view=article&id=459&Itemid=100026&lang=en.
89. Magrabi Foundation. Jan 2, 2016. Available from: http://magrabi.org.
90. Chibuga E, Massae P, Geneau R, Mahande M, Lewallen S, Courtright P. Acceptance of cataract surgery in a cohort of Tanzanians with operable cataract. Eye. 2008;22(6):830–3.
91. Lewallen S, Courtright P. Blindness in Africa: present situation and future needs. Br J Ophthalmol. 2001;85(8):897–903.
92. Lewallen S, Roberts H, Hall A, Onyange R, Temba M, Banzi J, et al. Increasing cataract surgery to meet vision 2020 targets; experience from two rural programmes in east Africa. Br J Ophthalmol. 2005;89(10):1237–40.
93. Oye JE, Kuper H. Prevalence and causes of blindness and visual impairment in Limbe urban area, South West Province, Cameroon. Br J Ophthalmol. 2007;91(11):1435–9.
94. Sommer A. Professor of epidemiology and ophthalmology at Johns Hopkins University, Personal communication. 2017.
95. Karumanchi SM, Ravilla T. Increasing sustainable cataract services in sub-Saharan Africa: an experimental initiative. Commun Eye Health J. 2014;27(88):73.
96. Samandari R, Kleefield S, Hammel J, Mehta M, Crone R. Privately funded quality health care in India: a sustainable and equitable model. Int J Qual Health Care. 2001;13(4):283–8.
97. Global Sight Initiative. 09.01.16. Available from: http://globalsightinitiative.org.
98. Resnikoff S, Felch W, Gauthier T-M, Spivey B. The number of ophthalmologists in practice and training worldwide: a growing gap despite more than 200,000 practitioners. Br J Ophthalmol. 2012;96(6):783–7.
99. ACGME Institutional Requirements. Dec 3, 2015. Available from: http://www.acgme.org/acgmeweb/Portals/0/InstitutionalRequirements_07012014.pdf.
100. ACGME. Required minimum number of procedures for graduating residents in ophthalmology. Review Committee for Ophthalmology. Dec 3, 2016. Available from: http://www.acgme.org/acgmeweb/Portals/0/PFAssets/ProgramResources/240_Oph_Minimum_Numbers.pdf.
101. Yeu E, Reeves SW, Wang L, Randleman JB, Physicians AY, Committee RC. Resident surgical experience with lens and corneal refractive surgery: survey of the ASCRS Young Physicians and Residents Membership. J Cataract Refract Surg. 2013;39(2):279–84.
102. McDonnell PJ, Kirwan TJ, Brinton GS, Golnik KC, Melendez RF, Parke DW, et al. Perceptions of recent ophthalmology residency graduates regarding preparation for practice. Ophthalmology. 2007;114(2):387–91. e3.
103. Wiggins MN, Warner DB. Resident physician operative times during cataract surgery. Ophthal Surg Lasers Imaging Retin. 2010;41(5):518.

104. Singapore Country Addendum to the ACGME-I advanced specialty requirements. Dec 4, 2015. Available from: http://www.healthprofessionals.gov.sg/content/hprof/sab/en/topnav/specialist_training/residency/country_addendum.html.
105. Chan W, Saedon H, Falcon M. Postgraduate ophthalmic training: how do we compare? Eye. 2011;25(8):965.
106. Mitchell P. Ophthalmology in Australia. Arch Ophthalmol. 2002;120(10):1375–6.
107. Murthy G, Gupta SK, Bachani D, Sanga L, John N, Tewari HK. Status of speciality training in ophthalmology in India. Indian J Ophthalmol. 2005;53(2):135.
108. Thomas R, Dogra M. An evaluation of medical college departments of ophthalmology in India and change following provision of modern instrumentation and training. Indian J Ophthalmol. 2008;56(1):9.
109. Thomas R, Paul P, Rao GN, Muliyil J, Mathai A. Present status of eye care in India. Surv Ophthalmol. 2005;50(1):85–101.
110. Alcon. Jan 3, 2016. Available from: http://www.alcon.com/corporate-responsibility/emerging-markets.aspx.
111. RANZCO (Royal Australian and New Zealand College of Ophthalmologists). Dec 3, 2015. Available from: https://ranzco.edu/international-development/international-programs.
112. Courtright P, Ndegwa L, Msosa J, Banzi J. Use of our existing eye care human resources: assessment of the productivity of cataract surgeons trained in eastern Africa. Arch Ophthalmol. 2007;125(5):684–7.
113. Bode CO, Nwawolo CC, Giwa-Osagie OF. Surgical education at the West African College of Surgeons. World J Surg. 2008;32(10):2162–6.
114. Congdon NG, Aung T. A tale of two systems: health reform in China and the United States. Ophthalmology. 2010;117(3):407–8.
115. Thomas R. Residency training programs in India. Indian J Ophthalmol. 2008;56(6):525.
116. Choi K-S, Soo S, Chung F-L. A virtual training simulator for learning cataract surgery with phacoemulsification. Comput Biol Med. 2009;39(11):1020–31.
117. Help Me See. Dec 17, 2015. Available from: http://helpmesee.org.
118. IAPB. 09.1.16. Available from: http://www.iapb.org/vision-2020/global-facts.
119. Bastawrous A, Rono HK, Livingstone IA, Weiss HA, Jordan S, Kuper H, et al. Development and validation of a smartphone-based visual acuity test (peek acuity) for clinical practice and community-based fieldwork. JAMA Ophthalmol. 2015;133(8):930–7.