Essentials in Ophthalmology
Series Editor: Arun D. Singh

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Editors

Innovative Approaches in the Delivery of Primary and Secondary Eye Care

Springer

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Foreword

Why Do We Need Comprehensive Eye Care?

Recent years have witnessed a major shift in countries' approach to the development of improved health services. A health system approach, summarized and evidenced in the WHO World Health Report entitled *Health systems: improving performance* which was published in the year 2000, became a major milestone in the global efforts of healthcare policy and decision makers to progress towards the provision of universal health coverage through improvements in the six areas of health systems (leadership and governance; human resources; financing of healthcare; essential medicines, technology and consumables; healthcare delivery; and monitoring and evaluation).

How did the global eye care agenda benefit from this development? For several decades, the engagement of governments and international partners in preventing avoidable vision impairment has been growing since late 1990, by establishing the VISION 2020 Global Initiative and by having WHO Member States repeatedly enlisting eye health in the global public health agenda of the World Health Assemblies. By doing so, prevention of avoidable vision impairment was addressed by several World Health Assembly resolutions, including the most recent one adopted in 2013 which endorsed the *Universal eye health: a global action plan 2014–2019*. The eye health action plan was designed from the perspective of health system strengthening in the area of comprehensive eye care services with the ultimate objective to secure universal coverage by essential eye care globally. The issue of comprehensiveness was particularly leveraged, making the opportunity for refinement of eye care service provision applicable for all countries and communities. The intention is to provide a continuum of care, ranging from prevention of eye diseases and their risk factors to the provision of low vision services and rehabilitation. This approach should facilitate actions that progress towards the vision articulated in the eye health action plan of a world in which nobody is needlessly visually impaired, where those with unavoidable vision loss can achieve their full potential, and where there is universal access to comprehensive eye care services.

How can the lasting positive change in eye care services globally be attained? While in the past vertically managed health interventions were routinely used to address major public health concerns in a speedy and focussed manner, for long-term results and to enhance sustainability, integrated approaches have proved to

have greater impact. Increasingly, needs assessment and planning for appropriate targeted interventions are done through a detailed examination of all the six areas of a health system, looking into their capacity to support provision of comprehensive equitable eye care and designing strategies and interventions to strengthen needy areas. The newly developed *WHO eye care service assessment tool (ECSAT)* provides a formulated approach for taking stock of the current eye care service at country level and for identification of gaps and needs. Using the findings from ECSATs and also evidence from population-based surveys such as Rapid Assessment of Avoidable Blindness (RAAB) studies on the prevalence and causes of vision impairment, countries can develop eye health plans that are based upon evidence and which identify achievable focussed priorities.

Along with the health system approach, additional conditions are being taken into account while planning for the provision of eye care services. One of those is the changing pattern of causes of avoidable vision impairment which increasingly drifts towards chronic non-communicable eye conditions associated with ageing. The eye care services will have to adjust, and the capacity to deal with chronic eye conditions such as glaucoma, age-related macular degeneration, and diabetic retinopathy, for instance, will trigger additional demands in all the areas of a health system, including policy development, availability of adequately trained eye care professionals, appropriately equipped eye care facilities, provision of essential medicines, availability of sustainable financing mechanisms, and monitoring mechanisms to assess impact and trends. Two additional eye conditions, cataract as the major cause of blindness globally and uncorrected refractive errors, the major cause of vision impairment globally require intensified action as do the specialized eye care services for children. While experiences in high volume eye care provision in various geographic and socio-economic settings are rapidly growing, the quality of services is critical for the ultimate outcome of eye care interventions. Quality and patient safety are becoming a major concern while planning for eye care service provision at national and district levels. Quality assurance support entails various aspects, and the way to enhance it is to provide adequate support to eye care professionals in their efforts to continuously improve their knowledge and skills, their motivation and desire to dedicate their efforts to their professional growth, to improving results of their eye care establishment and ultimately to contribute to joint improvements at national level. High-quality eye care services are a major public awareness tool as happy patients are the best advocates in their communities to informally advise and encourage others to seek eye care services. Access to services and their geographical coverage have been a major challenge in many communities around the world. While eye care professionals typically establish themselves in major urban areas, rural communities often lack adequate eye care services. Best practices in retention strategies, tested models of eye care service delivery, and mechanisms to support affordability of eye care services need to be further documented and made available to those searching for inspiration and expertise while developing their own eye care services. Experience sharing requires

further efforts, ultimately supporting efficient use of available resources and advancing the work and efforts towards universal coverage of integrated comprehensive eye care services in the world.

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Preface

The global initiative 'VISION 2020: The Right to Sight' was launched in 1999 with the realization that eye care providers across the world were fighting a losing battle against the rapidly increasing prevalence blindness and vision impairment. This initiative led to greater alignment across all stakeholders and a targeted approach towards the leading causes of blindness. As an outcome of this combination, we are witnessing for the first time, a reduction in the prevalence of blindness and vision impairment against the backdrop of a rapidly ageing population, especially in the developing countries. While we have something to celebrate, we are still very far from the goal of 'eliminating needless blindness'. Conditions like cataract, uncorrected refractive errors, diabetic retinopathy, etc. continue to be the leading causes of blindness and vision impairment. These are all conditions for which there are effective interventions, and a number of sustainable and replicable models across the world have demonstrated the success of these interventions. Hence the urgent need is to propagate such models to generate a greater understanding on how they work, what makes them work, the challenges faced, how they were addressed, and so on.

This book will provide eye care partners an understanding of these innovative approaches and models and the lessons to be learnt from them. It has 12 chapters focusing on innovative models for conditions such as childhood blindness, cataract, diabetic retinopathy, age-related macular degeneration, and refractive errors. It also presents models for integrated eye care services and highlights the importance of the health system approach in eye care as well as comprehensive eye care. The key pillars for any successful programme are human resources (HR) and finances. Strategies to address the current challenges related to HR in eye care and ways to ensure financial sustainability in the delivery of eye care are discussed in detail. Each chapter is adequately illustrated and provides easy-to-read tables and text.

We are grateful to the Advisory Board members, Mr R D Thulasiraj, Dr Serge Resnikoff, Dr Suzanne Gilbert, Prof Kovin Naidoo, Prof Jill Keeffe, and Dr Van Lansingh who gave their valuable time along with intellectual inputs to make the content meaningful for the readers. Without their support, this book would not have been possible.

We also thank the contributing authors and their co-authors and also all the reviewers, who withstood the pressure of time and other work commitments to complete the job on time.

We hope the readers find this book useful, and it will help them to apply the learning from this book to improve their day-to-day practice in delivery of eye care services.

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Abbreviations

ACGME	Accreditation Council for Graduate Medical Education
AECS	Aravind Eye Care System
AI	Artificial Intelligence
AMD	Age-related Macular Degeneration
AREDS	Age-Related Eye Disease Study
ASHA	Accredited Social Health Activists
BCCC	Bangladesh Childhood Cataract Campaign
BDES	Beaver Dam Eye Study
BHVI	Brien Holden Vision Institute
BMES	Blue Mountain Eye Study
BMI	Body Mass Index
BOOST	Better Operative Outcomes Software Tool
BPY	Blind Person-Years
Cat QA	Cataract Quality Assurance
CBM	Christoffel-Blindenmission
CDC	Centers for Disease Control
CL	Contact Lenses
CNV	Choroidal Neovascularization
COECSA	College of Ophthalmology of Eastern Central and Southern Africa
CSC	Cataract Surgical Coverage
CSCR	Central Serous Chorioretinopathy
CSF	Child Sight Foundation
cSLO	Confocal Scanning Laser Ophthalmoscopy
CSME	Clinically Significant Macular Edema
CSR	Cataract Surgical Rate
CSR	Corporate Social Responsibility
DALK	Deep Anterior Lamellar Keratoplasty
DALYs	Disability-Adjusted Life Years
DANIDA	Danish International Development Agency
DBCS	District Blindness Control Society
DCCT	Diabetes Control and Complications Trial
DHIS	District Health Information System
DM	Diabetes Mellitus
DME	Diabetic Macular Edema

DR	Diabetic Retinopathy
DVI	Distance Vision Impairment
ECCE	Extracapsular Cataract Extraction Surgery
ECSAT	Eye Care Services Assessment Tool
EFH	Eye Foundation Hospital
EHIS	Eye Health Information System
FONASA	Fonda Nacional de Salud
FPGC	Fund for Protection Against Catastrophic Expenditures
FV	Fundación Visión
GDP	Gross Domestic Product
GNI	Gross National Income
GSI	Global Sight Initiative
GSKZN	Giving Sight to KwaZulu-Natal
HCI	Hilton Cataract Initiative
HECS	He Eye Care System
HIC	High-Income Countries
HMIS	Health Management Information System
HMS	HelpMeSee
HReH	Human Resources in Eye Health
IAPB	International Agency for the Prevention of Blindness
ICD	International Classification of Diseases
ICEH	International Centre for Eye Health
ICO	International Council of Ophthalmology
IDF	International Diabetes Federation
IdV	Instituto de la Visión
IFC	International Finance Corporation
ILEV	Latin American Lions Vision Institute
IMCI	Integrated Management of Childhood Illness
IMF	International Monetary Fund
IOLs	Intraocular Lenses
ISRO	Indian Space Research Organization
KIDROP	Karnataka Internet-Assisted Diagnosis of Retinopathy of Prematurity
Kim	Key Informant Method
KIs	Key Informants
KPI	Key Performance Indicator
LA	Latin America
LAHU	The Leadership Academy of He University
LAICO	Lions Aravind Institute of Community Ophthalmology
LHWs	Lady Health Workers
LMIC	Low- and Middle-Income Countries
LRBT	Layton Rahmatullah Benevolent Trust
LVPEI	L V Prasad Eye Institute
LVR	Low Vision Rehabilitation
MAILOR	Mexican Advanced Images Laboratory for Ocular Investigation of the Mexican Institute of Ophthalmology

MCH	Maternal and Child Health
MCSP	Million Cataract Surgeries Program
MEMO	Model of Excellence in Modern Ophthalmology
ML	Machine Learning
MLOP	Mid-level Ophthalmic Personnel
MRSS	The Macular Risk Scoring System
MSICS	Manual Small-Incision Cataract Surgery
MSVI	Moderate or Severe Vision Impairment
NES	National Eye Surveys
NGO	Non Governmental Organizations
NICUs	Neonatal Intensive Care Units
NIURE	National Intervention on Uncorrected Refractive Errors
NPCB	National Programme for Control of Blindness
NPCS	Nonphysician Cataract Surgeons
NPDR	Nonproliferative Diabetic Retinopathy
OA	Ophthalmic Assistants
OCOs	Ophthalmic Clinical Officers
OCT	Optical Coherence Tomography
OCT-A	Optical Coherence Tomography Angiography
OOPS	Out-of-Pocket Expenditure
PCV	Polypoidal Choroidal Vasculopathy
PDM	Portable Digital Meniscometer
PDR	Proliferative Diabetic Retinopathy
PDT	Photodynamic Therapy
PEC	Primary Eye Care
PEEK	Portable Eye Examination Kit
POD	Postoperative Day
PPP	Public-Private Partnership
PRECOG	Prospective Review of Early Cataract Outcomes and Grading
PSC	Posterior Subcapsular Cataract
PVA	Presenting Visual Acuity
QFFD	Qatar Fund for Development
RAAB	Rapid Assessment of Avoidable Blindness
RACSS	Rapid Assessment of Cataract Surgical Services
RANZCO	Royal Australian and New Zealand College of Ophthalmologists
RARE	Rapid Assessment of Refractive Error
RBF	Result-Based Financing
RCO	Royal College of Ophthalmologists
REACH	Refractive Error Among Children
REAP	Rural Education Action Program
ROP	Retinopathy of Prematurity
RRC	Residency Review Committee
SC	Secondary Center
SCB-SiB	Standard Chartered Bank through its Seeing is Believing Program
SD-OCT	Spectral Domain OCT

SERI	Singapore Eye Research Institute
SICS	Small Incision Cataract Surgery
SiDRP	Singapore Diabetic Retinopathy Program
SSA	Sub-Saharan Africa
TADDS	Tool for the Assessment of Diabetic Retinopathy and Diabetes Management Systems
TARSS	Tool for Assessment of Rehabilitation Services and Systems
UI	Uncertainty Intervals
UKPDS	United Kingdom Prospective Diabetes Study
UNDP	United Nations Development Programme
URE	Cataract and Uncorrected Refractive Errors
URE	Uncorrected Refractive Error
UWF	Ultrawide-Field
VAO	Vision Aid Overseas
VC	Vision Center
VEGF	Anti-vascular Endothelial Growth Factor
VG	Vision Guardian
VHA	Veterans Health Administration
VI	Visual Impairment
VOSH	Visiting Optometry Services to Humanity
VSS	Vietnam Social Security
VT	Vision Technicians
VTDR	Vision-Threatening Diabetic Retinopathy
WACS	West African College of Surgeons
WDF	World Diabetes Foundation
WESDR	Wisconsin Epidemiologic Study of Diabetic Retinopathy
WHO	World Health Organization
YLDs	Years Lived with Disability

VISION 2020: Past, Present and Future

1

Gullapalli N. Rao

Over the past nearly two decades since the launch of the Global VISION 2020: The Right to Sight programme, the efforts to control blindness and vision impairment have yielded notable success.

While much progress was made during the past two decades, a lot more is still to be done to achieve the aspiration of equitable eye health to all.

Many countries in the world are in active discussion about providing universal health coverage to their people, and efforts should be made to get universal eye health as part of such a development. The formation of a Vision Loss Expert Group led to a systematic review of both published and unpublished data on the prevalence and causes of vision impairment over a 22-year period from 1990 to 2012 covering all people and those aged 50 years and above. As per this, several factors came to light.

Prevalence of Vision Impairment and Blindness

(a) In 2010, it was estimated that 32.4 million people were blind, and another 191 million had moderate or severe vision impairment (MSVI).
(b) The greatest proportion of the problem was in the population aged at or above 50 years – 84.6% blind and 77.5% with MSVI, respectively.
(c) Women, while constituting 49.6% of the population had around 60% of blindness and 57% of MSVI.
(d) The prevalence is 25 times greater in the low-resource regions compared to high-resource regions, ranging from 0.3% in North America to 8.3% in South Asia. Overall 90% of the problem is in low-resource populations.

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(e) The global age-standardized prevalence of blindness among adults aged 50 years decreased significantly from 3.0% to 1.9% and MSVI from 14.3% to 10.4%. This was observed in all the regions of the world with North Africa, Middle East and South Asia recording the largest absolute decreases for MSVI and blindness and in sub-Saharan Africa and Southeast Asia, for blindness.

Causes of Blindness and Vision Impairment

(a) Cataract and uncorrected refractive errors (URE) remain the major causes of both blindness and MSVI respectively. There has been a significant decrease in cataract with a marginal decline in URE. Chronic problems such as diabetic retinopathy, age-related macular degeneration and glaucoma, while significant in some regions of the world, contribute to a smaller fraction of the problem globally. For these chronic conditions, a robust model of providing some aspects of care at primary and secondary levels has to be identified. Appropriate levels of human resources and leveraging technology are critical for this. The problem of trachoma has declined significantly in most of the endemic regions. While both cataract and URE have cost-effective treatments, control of cataract blindness has received a lot more attention. For URE, successful models around the world have to be replicated and scaled up.

(b) Childhood blindness, while small in terms of magnitude, is very significant because of the "number of blind years." Many effective strategies and models are in place in different parts of the world in prevention, treatment and vision rehabilitation that need to be scaled up and employed in all parts of the world to control this problem. URE, cataract, corneal opacity and retinopathy of prematurity (ROP) stand out as major causes contributing to childhood blindness and vision impairment with the relative proportions varying in different parts of the world dependent on economic status. The prevalence is several times higher among the low-resource countries compared to high-resource countries. Preventive measures against Vitamin A deficiency have resulted in control of blindness from this cause in many parts of the world. Another example is the many successful models to control blindness from ROP. Recently evolved myopia prevention strategy is against the rapidly escalating problem particularly among Asian countries. The mandatory "1 to 2 hours outside the classroom" exposure each day for school children in some countries based on evidence may have beneficial effects. Such simple measures may go a long way in producing significant benefits.

(c) Low vision rehabilitation is a major requirement as a component of comprehensive eye care, and these services are very scarce among low-resource countries. Significant investment is required to develop these services. All the requirements such as infrastructure, trained professionals and access to low vision devices need to be looked into in the creation of these services.

Universal Eye Health Coverage

The 66th World Health Assembly through its resolution 66.4 endorsed the Global Action Plan 2014–2019 on universal eye health, with special emphasis on improving access to equitable eye care services that are integrated into general health to achieve a measurable reduction of 25% of avoidable vision impairment by 2019.

In order to achieve this objective and covering all major eye health problems, models of comprehensive eye care has to be developed in all parts of the world. This would encompass prevention, promotion, treatment and rehabilitation components.

Special emphasis should be placed on equity and quality of services.

Several innovative and effective models of eye care delivery exist around the world. The application of these on a larger scale globally with appropriate modifications to meet the local needs is required. Clear segmentation of care to community, primary, secondary, tertiary and advanced tertiary levels of care with vertical integration among these levels of care makes it more comprehensive, universal, accessible and cost-efficient. The success of these models used in diverse ways has already been demonstrated in different parts of the world.

An important factor for achieving universal eye health coverage is well-trained human resources. This is a major challenge confronting most developing countries. Development of competencies of different cadres based on the needs and deploying them accordingly provide better coverage and higher quality of care. This also ensures greater availability. All good HRD principles should be applied. All these add considerably to better coverage of currently disadvantaged geographic regions and promote equity.

Financing

Eye care has not received its due share of attention from policymakers in most parts of the world with the consequence of grossly suboptimal or no support for these services from many governments in the world. The same situation applies even in the case of other major funding sources. Through advocacy efforts at both global and national levels, progress was made in securing support for eye health in many countries. Several of the World Health Resolutions were very favourable and prompted some governments to give priority to eye health; many individuals and organizations at country level convinced the national governments to allocate resources for eye health in their budgets leading to positive outcomes in different countries. These efforts also secured funding from bilateral and multinational agencies such as the World Bank, DFID, AusAid and others. The funding for many of the international NGOs has improved too. The cumulative impact of all these helped in significant capacity building for eye health in several parts of the world. Substantial resources from Standard Chartered Bank's Seeing is Believing programme, Queen Elizabeth Diamond Jubilee Trust and other foundations have further stimulated or strengthened several programmes which are producing impact. The International Agency for the Prevention of Blindness (IAPB) played a pivotal role in these advocacy efforts.

Equally successful were the models of self-sustainability practised in many countries, most notably in India allowing the not-for-profit, non-governmental sector playing critical roles in eye health. The model of cross subsidization that was developed in India promoted the availability and accessibility of high-quality comprehensive eye care equitably. Innovations in this area continue to make them even more impactful. This model is being adapted in many other parts of the world with appropriate adjustments to the local environment. Also becoming increasingly popular is the optical supply business as part of eye care centres, the profits from which add to the sustainability of the programme. Local philanthropy contributes for the creation and upgradation of infrastructure, both physical and equipment in many parts of the world. Human resource development is another attraction for potential donors, and several education programmes have received support. Social impact funding is yet another new area that supported eye health. The Eye Fund I, developed by IAPB in partnership with Ashoka and funding from Deutsche Bank, was a successful example that helped in the capacity building of a few organizations in Africa, Latin America and China.

Human Resources

Appropriately trained human resources of all cadres in adequate numbers and of required standards remain a major barrier for the initiation as well as scaling up of eye health programmes in most parts of the world. Limitations in the number of education programmes, competent faculty, systems of education and access to high-quality education materials contribute to this unfavourable situation. Very often, the ratio between ophthalmologists and mid-level ophthalmic personnel is grossly imbalanced. There is too much dependence on ophthalmologists that makes the situation worse.

Proper human resource planning to build a well-balanced eye health team with required competencies for the tasks assigned to that particular cadre will ameliorate the situation considerably. Departure from traditional methods may have to be considered to make the system-efficient and cost-efficient. Adoption of modern methods of education practised in other disciplines will help to a great degree to improve the quality, reach and impact.

During the past two decades, notable progress has been made in building or strengthening educational institutions and programmes that has produced a salutary effect on the overall care. The role of many international professional organizations has helped in catalysing these efforts. Training opportunities, increasing availability of education materials, volunteer faculty and assistance with enhancing the education system are some of the examples.

Technology and Eye Health

The rapid advances in all forms of technology have contributed to the quality, reach and scaling up of eye health systems across the world. Leveraging information and mobile technology have made high-quality care available and accessible to

populations in remote geographic locations. Early diagnosis and prompt treatment, better follow-up care, the ability to analyse massive data and translate that into better planning and the ability to predict the course of diseases are some of the examples. Increasing application of artificial intelligence (AI) and machine learning (ML) is adding yet another dimension to enhance care. The combined potency of these different technologies will transform the care. Innovations in lower-cost but higher-technology solutions are shown to be possible making it affordable to all parts of the world.

Equally significant is the role of technology in education augmenting the strength of many educational institutions with low resources. Distance learning is possible, and this allows education for a larger number of students and thus a rapid solution to the problem of inadequate human resources.

The Way Forward

To realize the vision of achieving universal eye health, high-quality comprehensive eye care encompassing prevention, treatment and rehabilitation employing a health system approach is the best way forward. A well-trained eye health ream, using good-quality infrastructure and operating systems, can meet this objective in an efficient and cost-efficient manner. Proper segmentation of work to different levels of care, namely, primary, secondary and tertiary with vertical integration for appropriate referrals, will ensure quality and equity. The primary eye care model with commitment to a defined community closer to the doorstep of people with community involvement will contribute to success. Human resource development systems need scaling/strengthening to meet the current and future needs. Proven and innovative models of financing have to be adopted to achieve financial sustainability. Leveraging technology, both for care and education, will enhance scale and reach with better quality. Strong partnerships, both local and global and inter-sectoral have proven to produce good outcomes and are worthy of replication. Advocacy efforts with policymakers will have to continue both at national and global levels to pursue the priority for eye health in national and global health plans and thus ensure necessary support. Equally important is to meet the ever-increasing need for public awareness for eye health to create demand. A community activated and supported healthcare system is more likely to yield desirable outcomes that can realize the aspiration of "VISION 2020: The Right to Sight."

Compliance with Ethical Requirements Gullapalli N. Rao declares no conflict of interest.

No human or animal studies were performed by the author for this chapter.

2 Prevalence and Causes of Vision Impairment and Blindness: The Global Burden of Disease

Jill Keeffe and Serge Resnikoff

Introduction

In the Global Action Plan 2014–2019 the World Health Organization (WHO) has stated the importance of data on the prevalence and causes of vision impairment and blindness to monitor and plan eye care services to reduce the avoidable causes of vision loss. The first of the three objectives *addresses the need for generating evidence on the magnitude and causes of vision impairment and eye care services and using it to advocate greater political and financial commitment by Member States to eye health..... In all countries it is crucial to assess the magnitude and causes of vision impairment and the effectiveness of services* (WHO 2013) [20]. It is important to ensure that data on the prevalence and causes of vision impairment are collected at more than one point in time in order to assess change over time which allows the effectiveness of eye care and rehabilitation services to be evaluated. Information from monitoring and evaluation should be used to guide the planning of services and resource allocation.

Data on the prevalence and causes of 291 diseases and injuries in the 7 major world regions, 21 subregions and countries are now available from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) reviews [5, 15]. The GBD construct is health loss where diseases, injuries and risk factors are compared by location and given time periods by age and by sex. Years lived with disability

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(YLD) are determined from the prevalence of a disease and the disability weight for the four levels describing the effect of the disease. Greater weights are given to deaths compared to non-fatal health loss and especially premature mortality at younger than 5 years of age. For each of the health states for the 2010 data, disability weights were obtained from large surveys of the general public across a number of countries [17].

Vision impairment was one of the 291 diseases studied in the GBD. A Vision Loss Expert Group of 79 eye care practitioners and researchers was established to perform a systematic review of all published and unpublished data on the prevalence and causes of vision impairment over a 30-year period, from 1980 to 2012 [1]. Vision impairment was defined in two major categories according to the International Classification of Diseases (ICD 10): blindness as presenting visual acuity (PVA) of <3/60 in the better eye; moderate vision impairment as PVA of <6/18–6/60 in the better eye and severe vision impairment as PVA <6/60–3/60 in the better eye. The latter were combined as moderate and severe vision impairment (MSVI) as <6/18–3/60. Eligibility for inclusion of papers required that cross-sectional population-based studies of representative samples of the population reported prevalence and/or incidence of vision impairment and/or blindness [1]. A systematic review of the literature was undertaken and unpublished studies that met the criteria were added. The first stage identified 14,908 articles from databases, and after title and abstract review, full text articles were obtained ($n = 1334$). After review of each article, 252 papers from 243 studies were eligible and thus used for the meta-analysis to calculate data on prevalence and causes of vision loss. Approximately one third used the rapid assessment of avoidable blindness (RAAB) methodology [13].

Modelling of data used DisMod-MR which is a Bayesian multi-level regression model that incorporated age, country, year of the study, sex, cause of vision loss and visual acuity [1]. Total prevalence and prevalence by causes were estimated from data on presenting and best corrected visual acuity. The difference between presenting and best corrected visual acuity produced data on the prevalence of uncorrected refractive error. There were data on prevalence for 84 countries with very few eligible studies providing data on vision loss in children. For countries where no data were available, three covariates were trialled to provide estimates of the prevalence of blindness. The best model used mean years of adult education and access to health care but gross domestic product per capita was dropped from the model [1, 2]. This approach provided prevalence data and estimates for 190 countries and 21 subregions.

Data on the prevalence of blindness and MSVI by cause were age standardised using the WHO reference population for each country. Uncertainty intervals for prevalence represented the 2.5th and 97.5th percentiles of the distribution of the data. Data were analysed and presented in 5-year age groups providing whole population data and also for the population aged ≥50 years where vision loss is more prevalent.

Prevalence of Vision Impairment and Blindness

The number of people blind in 2010 was estimated to be 32.4 million ((95% confidence interval (CI), 29.4–36.5)), and another 191 million (95% CI, 174–230) had moderate or severe vision impairment (MSVI) (Table 2.1) [18]. Data were reported for all ages and for people ≥50 years. The greatest proportion blind or with MSVI was in the population aged ≥50 years – 84.6% and 77.5%, respectively. Of the total population that were blind, 19.5 million (95% uncertainty intervals (UI) 17.7–22.1 million) were women (60%), and 109 million women (UI 99–130 million) or 57% had MSVI, whereas women are 49.6% of the global population (http://wdi.worldbank.org/table/1.5).

Across the 21 sub-regions, there were very large differences in prevalence of all vision impairment (<6/18) in people aged ≥50 years (Fig. 2.1). There was a 25 times greater prevalence in vision impairment in the low-resource regions compared with high-resource regions, ranging from 0.3% in North America to 0.8% Australasia to 5% in North Africa and the Middle East to 8.3% in South Asia. Papers were published in the *British Journal of Ophthalmology* with the 21 subregions combined into 7 regions [3, 8, 9, 10, 12, 14, 16, 19].

Changes in the Prevalence 1990–2010

The global age-standardised prevalence of blindness among older adults aged ≥50 years decreased significantly from 3.0% (2.7–3.4) in 1990 to 1.9%

Table 2.1 Prevalence and numbers of people with vision impairment worldwide by age and sex in 2010

	Blind		Moderate and Severe Vision Impairment (MSVI)	
Age range (years)	Prevalence (%)	No. (millions)	Prevalence (%)	No. (millions)
Males				
0–49	0.08 (0.07–0.09)	2.2 (1.9–2.5)	0.72 (0.63–0.91)	20 (18–26)
50–69	0.85 (0.74–0.97)	4.5 (3.9–5.1)	6.6 (5.9–7.9)	34 (31–42)
≥70	4.2 (3.7–4.8)	6.2 (5.5–7)	18.8 (17–22)	28 (25–33)
Total male		12.9		82
Females				
0–49	0.1 (0.09–0.12)	2.7 (2.4–3.2)	0.9 (0.78–1.1)	24 (21–30)
50–69	1.1 (1–1.3)	6.2 (5.5–7.1)	7.9 (7.2–9.5)	43 (39–52)
≥70	5.3 (4.8–6)	10.6 (9.6–12.1)	20.9 (19.2–24.6)	42 (38–49
Total female		19.5		109
Total		32.4 (29.4–36.5)		191 (174–230)

Table adapted from Stevens et al. [18]
95% uncertainty intervals shown in brackets

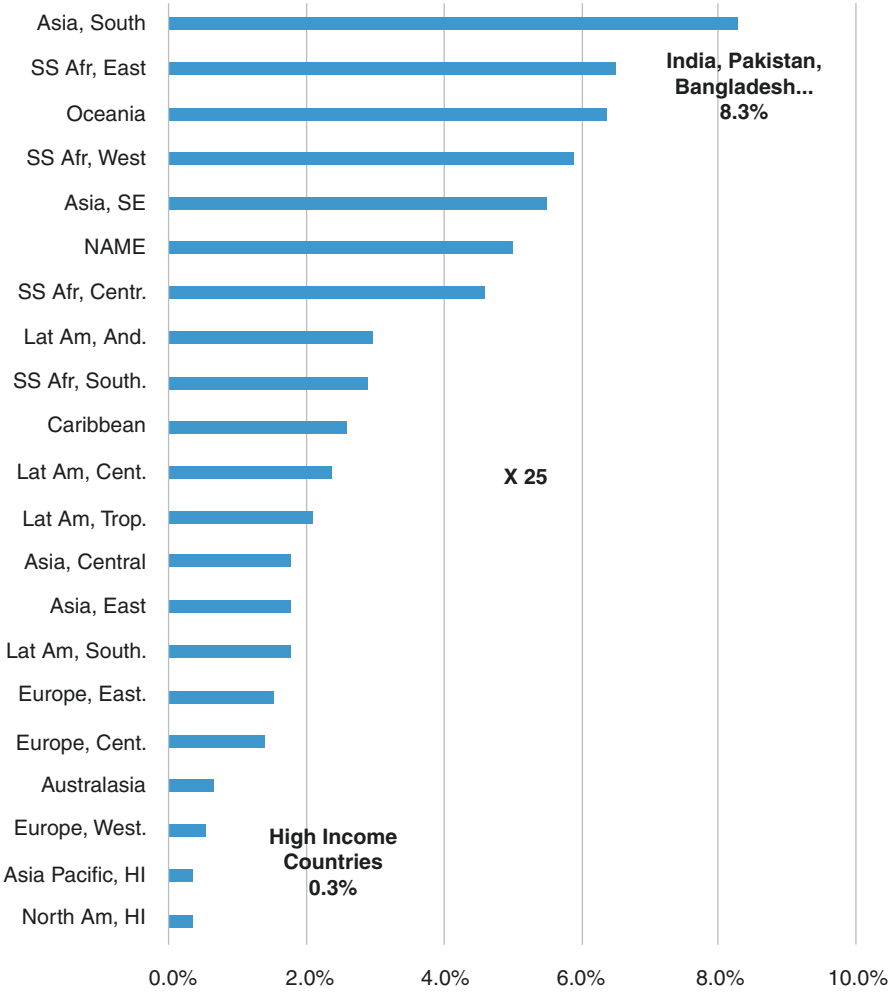

Fig. 2.1 Age-standardised prevalence of vision impairment (presenting VA <6/18) in people aged ≥50 years in the 21 regions. Key: *SS* sub-Saharan, *NAME* North Africa and Middle East, *HI* high income, *Lat Am And* Latin American Andean

(1.7–2.2) in 2010, a decrease of 0.5% (0.4–0.8) per decade. During the same period, the global age-standardised prevalence of MSVI among older adults decreased from 14.3% (12.1–16.2) to 10.4% (9.5–12.3), a decrease of 2.0% (0.4–2.8) per decade. A statistically significant decrease in the age-standardised prevalence of blindness and MSVI among older adults was observed in all regions, with the largest absolute decreases being in North Africa and the Middle East and in South Asia for MSVI (≥4.0% per decade) and in the same two regions plus Southeast Asia and all sub-Saharan African regions for blindness (Fig. 2.2) [2].

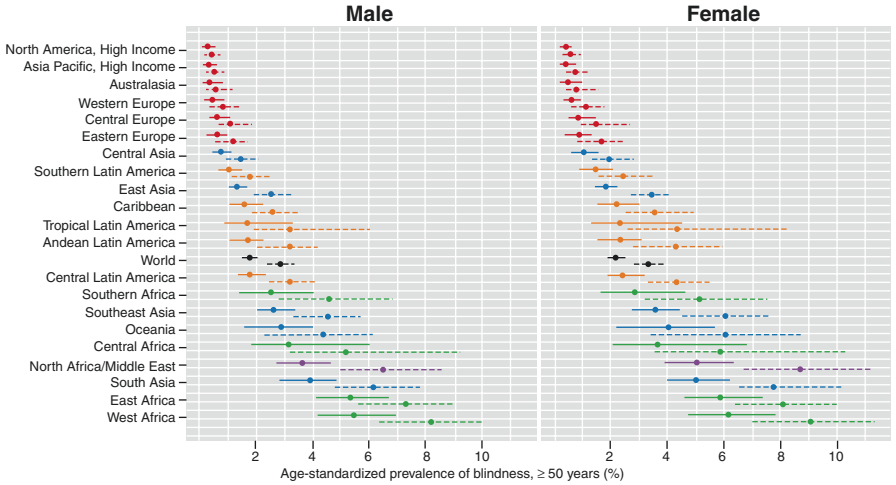

Fig. 2.2 Age-standardised prevalence of blindness in adults ≥50 years for males and females in 1990 and 2010 in the 21 subregions [18]

Table 2.2 Proportion of blindness and moderate and severe vision impairment by major causes globally, in 1990 and 2010

	Cataract	Uncorrected refractive error	Macular degeneration	Glaucoma	Diabetic retinopathy	Trachoma	*Other
Blindness							
1990	38.6	19.9	4.9	4.4	2.1	2.8	27.4
2010	33.4	20.9	6.6	6.6	2.6	1.4	28.6
Moderate and severe vision impairment							
1990	25.6	51.1	1.9	1.2	1.3	1.3	17.6
2010	18.8	52.9	3.1	2.2	1.9	0.71	20.8

Bourne et al. [2]
*Other: Includes a range of causes such as unspecified posterior segment diseases, corneal opacity, congenital defects, neurological disorders and optic neuropathies

Causes of Vision Impairment and Blindness

The greatest proportion of blindness and MSVI is due to cataract and uncorrected refractive error (Table 2.2). Whilst there has been a reduction in the proportion of both blindness and MSVI due to cataract, this has not occurred for uncorrected refractive error. The relative importance of trachoma significantly decreased for both blindness and MSVI. The chronic diseases are responsible for relatively small proportions of both blindness and MSVI with very little change over the two decades. Macular degeneration, glaucoma and diabetic retinopathy are all responsible for relatively small proportions of both blindness and MSVI, with low prevalence. One reason for the relatively small proportion of vision loss due to posterior

eye diseases is the methodology used in assigning causes in epidemiological surveys, in which the most easily treatable or preventable causes are assigned to a person if there are multiple causes of vision loss within and between eyes which are judged to contribute equally to vision loss. For example, cataract or uncorrected refractive error is assigned as a cause when a person might also have diabetic retinopathy.

For cataract the age-standardised prevalence in adults ≥50 years was virtually half in 2010 of that in 1990 – 46% reduction in blindness (from 1.3% to 0.69%) and 50% for MSVI (from 4.4% to 2.2%) [2] (Table 2.3). Trachoma was the only other cause of vision loss to show significant reductions in both blindness and MSVI. There was lower prevalence in both blindness and MSVI due to uncorrected refractive error (URE) but neither was significant. Diabetic retinopathy, macular degeneration and glaucoma [4] all had relatively small increases in prevalence of MSVI but small decreases in blindness with none of the changes being significant.

Regional Differences in Changes and Causes

Whilst there have been changes across the two decades in the prevalence and number of people with MSVI and blindness, the changes in the cause specific prevalence have not been as consistent across regions. There has been a significant decrease in the prevalence of cataract [11] and trachoma across all regions, but this has not occurred in the chronic diseases – macular degeneration, glaucoma and diabetic retinopathy. The prevalence of URE has also decreased across all regions but to a lesser extent, possibly because of the increasing prevalence of myopia [6] (Fig. 2.3).

In a number of regions there has been an increase in the prevalence of MSVI due to glaucoma and macular degeneration (Fig. 2.3). Whilst the prevalence of MSVI due to diabetic retinopathy has reduced in most regions except in East and West sub-Saharan African regions, Oceania and South Asia where there has been an increase in the prevalence. The change in prevalence of blindness shows marked differences to that of MSVI, with all regions except South Asia showing decreases in all the major and "other" causes of blindness; South Asia had relative increases in the prevalence of blindness from glaucoma (19%) and macular degeneration (6%). The regional changes for URE have been relatively small, commonly in the range of 16–35% for MSVI but higher for blindness (25–48%). The prevalence of URE was similar across income regions and the prevalence for all ages was similar to that of people >50 years.

In those regions with vision loss from trachoma, the picture was very positive with a relative reduction in the prevalence of blindness of 57–76% in East, West Central and Southern sub-Saharan African regions. In Southeast Asia there was a similar picture with relative reductions of 64%, 76% and 81% in South, Southeast

Table 2.3 Prevalence of causes of blindness and moderate and severe vision impairment (MSVI) globally in people aged <50 years in 1990 and 2010

	Cataract	URE[a]	Macular degeneration	Glaucoma	Diabetic retinopathy	Trachoma	Other
Blindness							
1990	1.3 (1.1, 1.5)	0.58 (0.41, 0.74)	0.19 (0.16, 0.23)	0.16 0.14, 0.19)	0.07 (0.06, 0.08)	0.09 0.07, 0.1)	0.66 (0.56, 0.77)
2010	0.69 (0.6, 0.78)	0.4 (0.28, 0.51)	0.15 (0.13, 0.19)	0.14 (0.12, 0.17)	0.05 (0.04, 0.07)	0.03 (0.02, 0.03)	0.47 (0.41, 0.56)
Moderate and severe vision impairment							
1990	4.4 (3.6, 5.2)	6.9 (5.6, 8.0)	0.39 (0.31, 0.49)	0.22 (0.18, 0.27)	0.21 (0.17, 0.26)	0.2 (0.14, 0.2)	2.0 (1.5, 2.4)
2010	2.2 (1.0, 2.7)	5.3 (4.5, 6.5)	0.42 (0.36, 0.57)	0.27 (0.23, 0.37)	0.22 (0.18, 0.31)	0.08 (0.07, 0.1)	1.9 (1.6, 2.4)

Bourne et al. [2] Appendix

[a] *URE* uncorrected refractive error

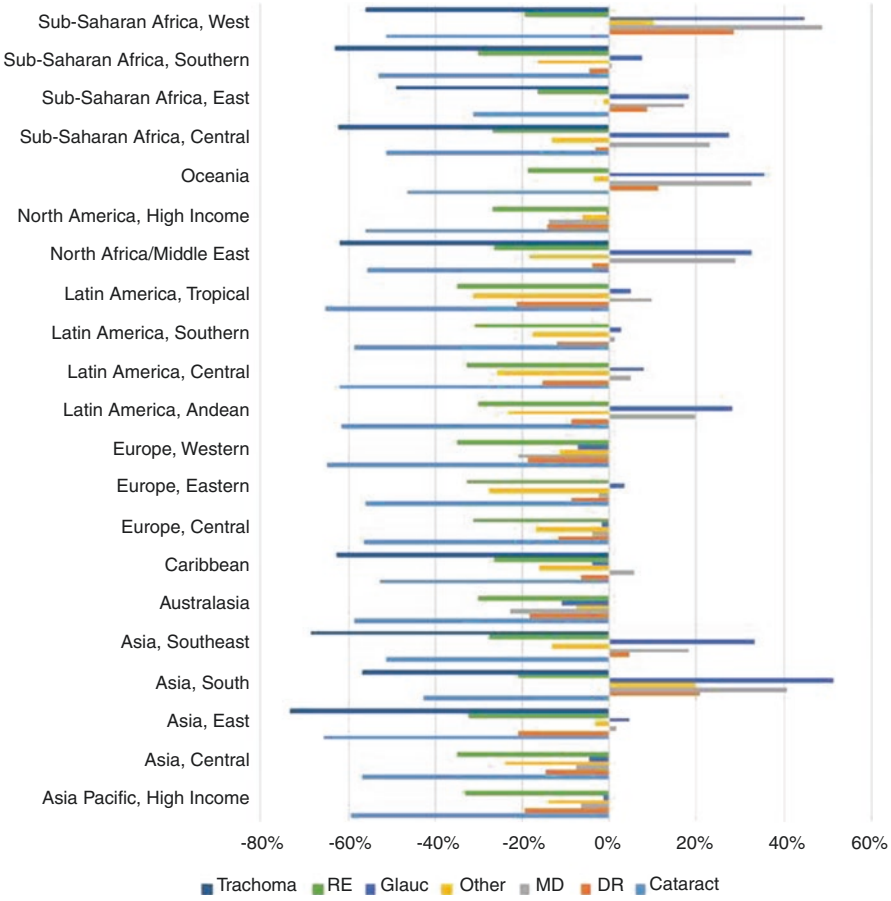

Fig. 2.3 Relative changes in age-standardised prevalence of moderate and severe vision impairment in adults from 1990 to 2010

and East Asia, respectively. The other region with blindness due to trachoma, North Africa/the Middle East, saw a relative reduction of 72% in the prevalence of trachoma blindness.

The prevalence of MSVI due to diabetic retinopathy was lower in most regions but had increased in some (Fig. 2.4). In West sub-Saharan Africa, the change in the adult age-standardised prevalence of MSVI was from 0.39% (0.27, 0.58) in 1990 to 0.50% (0.32, 0.92) in 2010. The changes in MSVI were in contrast to the picture seen for blindness where all regions showed a decrease in prevalence. Oceania region made up of countries with relatively small populations has very high rates of

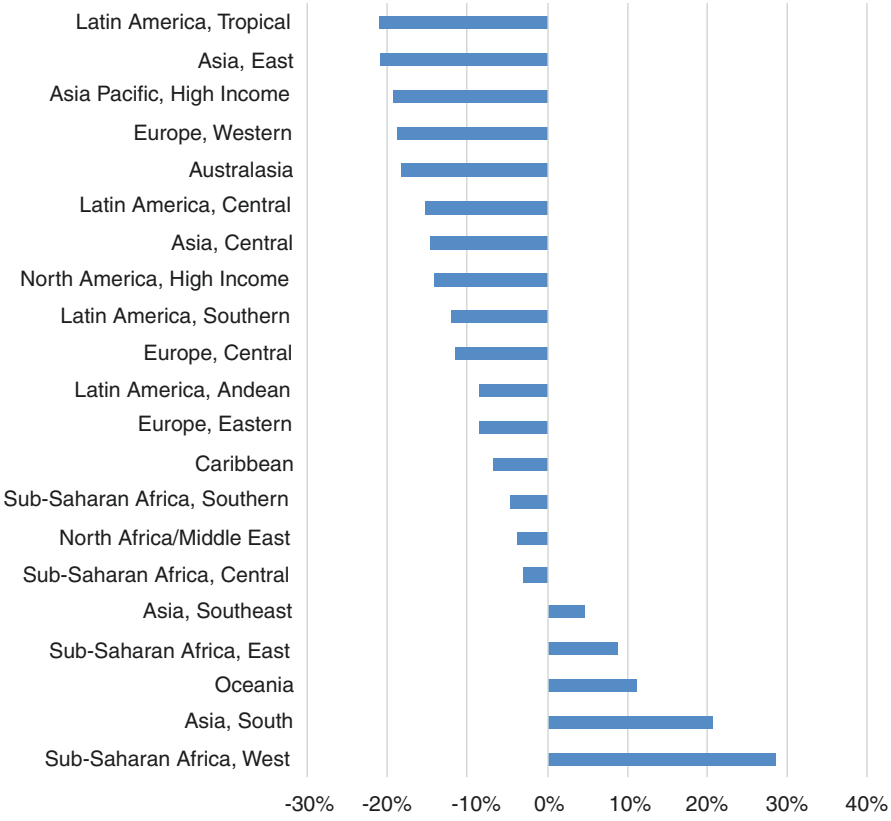

Fig. 2.4 Relative change in the adult age-standardised prevalence of MSVI due to diabetic retinopathy between 1990 and 2010 in all subregions

diabetes – Tokelau has the highest prevalence of diabetes (30% among adults aged 30 years and above), and in four other countries, over 20% of the adult population has diabetes [7] (IDF Diabetes Atlas).

It is only the higher-income countries where the prevalence of macular degeneration has decreased but by relatively small amounts, i.e. a decline of 3% in Eastern Europe and 23% in Australasia (Fig. 2.5). The greatest increase in prevalence of MSVI due to macular degeneration are in South Asia of 40% (from 0.25% in 1990 to 0.35% in 2010) and almost 50% (from 0.53% in 1990 to 0.80% in 2010) in Western sub-Saharan Africa. It should be noted that "macular degeneration" includes not only age-related macular degeneration but also other causes such as myopic macular degeneration, macular holes and Stargardt's disease. Glaucoma has very similar trends to macular degeneration.

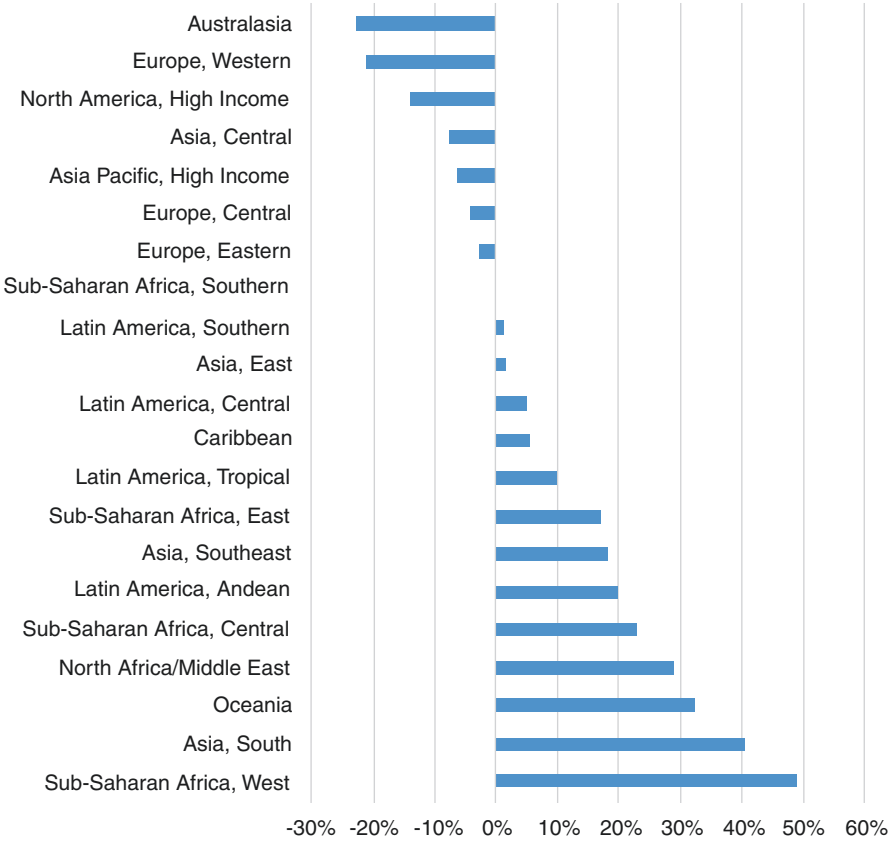

Fig. 2.5 Relative changes in adult age-standardised prevalence of MSVI due to macular degeneration between 1990 and 2010 in all subregions

The crude prevalence of vision impairment due to cataract has declined by 37% over the 20 years (average of 1.9% per year) and the decline for URE was 12% (average 0.6% per year) over the same period (Fig. 2.6).

Disability Related to Vision Loss

The years lived with disability (YLD) for a cause by age-sex groups uses the prevalence of the condition times the disability weight for that condition. A disability weight is ranked from 0 (perfect health) to 1 (death) to make comparisons between causes of disability. For the weights used in the 2010 data in the GBD, the method used in the Disability Weights Measurement Survey to derive weights for YLD was to present people with scenarios and ask them to say who they thought was the healthier [17]. The question related to vision asked "imagine two different people – the first person is completely blind and the second person is completely deaf. Who

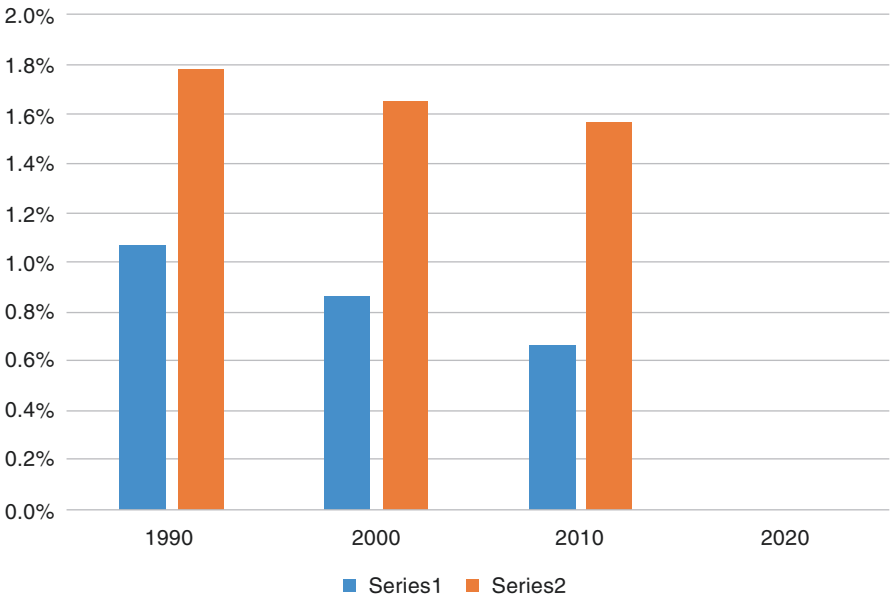

Fig. 2.6 Relative changes in cataract and uncorrected refractive error crude prevalence of vision impairment (PVA <6/18), 1990–2010) [2]

is healthier overall?" It was thus a comparison of health states rather than disability. For vision loss there were categories that ranged from mild, moderate and severe VI to blind with a category for near vision. The weights using health outcomes resulted in low weights for categories of vision loss: mild distance vision impairment (DVI) 0.004, moderate DVI 0.033, severe DVI 0.188, blindness 0.193 and near-vision impairment 0.013.

The data for YLD for vision loss were calculated in 5-year age groups from 0 to ≥80 years for MSVI and blindness using the major causes of vision impairment. In children disability due to vitamin A deficiency contributes to the total. From teenage to older ages, the majority of YLDs are due to cataract and uncorrected refractive error. Both diabetes-related and glaucoma MSVI contribute a relatively small proportion but show the long-term disability, whereas macular diseases are of later onset. Increasing life expectancy is associated with an increase in YLDs particularly for chronic causes of vision loss. The pattern is quite different for blindness with cataract responsible for approximately half of the YLDs.

Challenges in Eye Care

The good news is that there has been a reduction in the global prevalence of vision loss over the two decades. This has been due to the reduction in prevalence of cataract and, to a lesser extent, trachoma, whilst the chronic diseases have seen little change especially in MSVI. Life expectancy increased to 65 years in 2010 in

India and Bangladesh in contrast to countries such as the UK, Canada, Australia, and Japan which have a life expectancy of ≥80 years. As a result, despite a 30% growth in the global population, the numbers of blind grew by only 2% and MSVI by 11%. Based on projected population ageing and growth and no change in the prevalence of blindness and MSVI, the number expected to be blind in 2010 and those with MSVI were projected to be 50.9 million and 268 million, respectively [18]. Instead only 32.4 million people were blind, and 191 million had MSVI in 2010, with a total reduction of 96.5 million from the earlier projection.

A major aim of the VISION 2020 strategy was to eliminate avoidable blindness and MSVI, but there has been only a small change in the proportion of people with preventable or treatable causes between 1990 and 2010 [2]. The proportion of blindness that is avoidable declined from 68% of the 31.8 million people blind in 1990 to 65% of 32.4 million in 2010; the change in avoidable MSVI was from 80% of 172 million to the current rate of 76% of the 191 million in 2010. Even in the highest-income countries, there is a residual proportion of avoidable vision impairment. Cataract and URE still represent, respectively, 13% and 15% of blindness and 43–45% of vision impairment in high-income countries of North America, Asia Pacific, Australasia and Western Europe.

Challenges for the provision of eye care lie in three major areas – URE, chronic eye diseases and the length of time people live with vision loss. There was very little change in the prevalence of URE over the two decades from 1990 to 2010. Whilst effective services exist to the challenge is to expand coverage of services especially in low-income countries. Chronic eye diseases are relatively small proportions of the total numbers of people with vision loss but present challenges in eye care and rehabilitation services as they require long-term care. Eye care for these diseases that cover early detection and ongoing service delivery require integrated services across primary, secondary and tertiary levels. The projections for the increase in the number of people with diabetes provide challenges for the prevention of vision loss from diabetic retinopathy.

Conclusion

One of the limitations of current data is that there have been very few population-based surveys that provide reliable data on the prevalence and causes of vision loss in children. Country or regional surveys are needed to provide these data, but very large sample sizes are required given the relatively low prevalence of vision loss in children.

The meta-analysis of available data and modelling for regions and countries has provided data by region and for countries where in many cases few data were previously available. The Vision Loss Expert Group is continuing to collect data from published and unpublished studies to provide an update of the prevalence and causes for 2015. Avoidable causes still account for a considerable proportion of vision loss, but much has been achieved over the last two decades. The ongoing analysis and

provision of data at national and global levels will aid in the planning and evaluation of eye care programmes to track progress towards the VISION 2020 target of eliminating avoidable vision impairment.

Compliance with Ethical Requirements Professor Keeffe and Professor Resnikoff declare that they have no conflict of interest.

No human studies were carried out by the authors for this article and no animal studies were carried out by the authors of this article.

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Best Practice Integrated Approaches in Eye Care Service Delivery

3

Muhammad Babar Qureshi and Ismat Chaudhry

Introduction

For 2015, WHO has estimated that globally 253 million people were visually impaired, of whom 36 million are blind and 217 million have moderate to severe vision impairment. Eighty-one percent of the people who are blind or have moderate or severe vision impairment are aged 50 years and above. With an increasing population of older people, more people will be at risk of vision impairment due to chronic eye diseases [1].

Globally, chronic eye diseases are the main cause of vision loss. Uncorrected refractive errors and then unoperated cataract are the top two causes of vision impairment and blindness. Unoperated cataract remains the leading cause of blindness in low- and middle-income countries. The prevalence of infectious eye diseases, such as trachoma and onchocerciasis, has reduced significantly over the last 25 years. Over 80% of all blindness/vision impairment can be prevented or cured.

An estimated 19 million children are vision impaired. Of these, 12 million children have vision impairment due to uncorrected refractive error. Around 1.4 million have irreversible blindness, requiring access to vision rehabilitation services to optimize functioning and reduce disability [2].

Recognizing that, globally, 80% of all vision impairment can be prevented or treated and that about 90% of the world's visually impaired live in developing countries, the 66th World Health Assembly through its resolution 66.4 endorsed the Global Action Plan 2014–2019 on universal eye health, with special focus on improving access to equitable eye care services that are integrated into general health to achieve a measurable reduction of 25% of avoidable vision impairment by 2019.

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In order to achieve the objective of universal coverage, different concepts of innovation in health delivery systems can be considered such as public-private partnerships, marketing innovation concepts, financial innovation, technology-based innovation and operational innovation. These approaches make it possible to extend the health delivery system to incorporate new forms of innovation in order to deliver accessible, affordable and quality health service [3].

Over the years of learning from various programs designed on affordable and quality eye care which have had been implemented especially in the far flung rural communities by different organizations across the globe through innovative scales of economy that generate income for the program and its sustainability while ensuring the treatment opportunities for the poorest of the poor; some strategies adopted were quite result oriented ensuring sustained and integrated development. Here are some best practice strategies which sound more promising for the readers.

Primary Eye Care Attributes

Primary eye care or first-level contact for eye care embodies the principles and practice of primary healthcare which includes eye health promotion, prevention, treatment, referral, and record keeping. It should not be a stand-alone intervention. It is anchored in the community and is delivered by a trained health workforce and community volunteers. About a fifth of all patients seen by a primary healthcare service have eye problems [4].

To ensure the widespread coverage, it must essentially have close liaison with secondary and tertiary levels of eye healthcare alongwith an inbuilt proper and an adequate systematic referral system. Cataract surgeries account for about two-fifths of all major surgeries at secondary hospitals providing eye care and about a quarter at tertiary hospitals when cataracts can very easily be identified and could be referred by a primary healthcare worker [4].

Primary eye care remains an important factor in healthcare in both the developed and developing world in terms of its underpinning values of universal access, equity, and community participation. The aim is to develop service delivery mechanisms that encourage continuity of care for an individual in terms of health conditions, across levels of care, and over a lifetime. While keeping its focus on the community and first-level contact care, preventive eye care programs in the developed and developing nations develop the capacity of the primary healthcare workforce to diagnose, treat minor ocular ailments, and refer eye conditions which will cause vision impairment and blindness if left untreated or unoperated [5].

Reaching the unreachable and overcoming the barriers of non-affordability and inaccessibility to eye care, different variants of primary eye care service packages can be developed offering regular provision of primary eye care or through outreach services in remote communities backed up with well-established secondary eye care. This is particularly important in developing countries where the scanty infrastructure and human resources have led to piecemeal approaches to blindness control and which more often have failed to produce substantial results [6].

Trust in a particular service provider, as generated by repeated outreach screening camps in the same vicinity and good outcomes reported by peers, have been found to be an important factor increasing the uptake of eye care services. Providing continuous services of good quality might be a way to considerably increase cataract surgery uptake. Reaching the unreached in remote rural areas is a major problem due to the lack of proper road connectivity and transportation services and long distances from base hospitals [7].

Conducting regular outreach camps from base hospitals or opening of vision centers in communities having catchment populations up to 50,000 is feasible and sustainable. The services rendered will ensure that all segments of society especially the women, elderly and children can access eye care. Outreach eye care services must be brought to the patients at a health post or central place in communities which are about one hour from the local eye clinic or beyond. Aravind Eye Hospital has set up Internet- and telemedicine-enabled vision centers staffed with ophthalmic technicians. These vision centers help to reduce time and expense for health service to rural areas by eliminating hospital visit [8].

The primary eye care practice models can primarily be divided into two broad categories based on their working operations which may be through fixed facilities or mobile services. Fixed facility primary eye care in primary healthcare (PHC) centers is commonly provided through fixed or permanent structures available under the government health delivery system. Nongovernmental organizations have adopted different models involving stand-alone primary eye care through fixed facility or mobile units.

Integrated Primary Eye Care Services Within Primary Healthcare

Primary eye care services are delivered as an integral part of integrated healthcare delivery system through the infrastructure and human resources available at the primary health centers and also through the primary healthcare workers in the communities. The primary health centers/community healthcare facilities are established for a population of 100,000 or at basic health centers for a population of 30,000 where there are no surgical specialist services available.

Stand-Alone Primary Eye Care Services

Outside the public health infrastructure, many eye institutes provide community-level eye care through either stand-alone primary eye care centers or outreach services. L V Prasad Eye Institute (LVPEI) in Telangana, India provides primary eye care services in over 150 fixed facility vision centers through vision technicians (VT) each serving a population of 50,000. VTs screen the population for blinding eye conditions, conduct refraction, and refer patients to higher-level centers (secondary or tertiary hospitals) for further management [9].

Sadguru Netra Chikitsalaya, Chitrakoot (SNCC), Madhya Pradesh also has 24 vision centers to provide primary eye care services for a rural population. Aravind Eye Care System (AECS) [10] has 40 vision centers in various districts of South

India. Layton Rahmatullah Benevolent Trust (LRBT) hospital system across Pakistan has developed 55 community eye care centers and 4 outreach (satellite) clinics (http://www.lrbt.org.pk/).

The model of stand-alone primary eye care services has been performing well regarding the strengthening of the primary-secondary referral eye care complex, good replacement of the regional eye camps, provision of refraction and primary eye care services and follow-up of the operated cases to enable the base hospitals to focus on secondary and tertiary eye care [10]. One can witness this eye care model successfully operational in many countries like Cambodia, Ghana, India, Nigeria, Pakistan, Solomon Islands, Sri Lanka, Tanzania and Vietnam.

Key Informant Method (KIM)

Key informants (KIs) are unpaid volunteers (local council leader, social worker, youth volunteer, retired personnel from forces, community health worker, retired teacher, etc.) who work in or belong to a local community and have a social role.

Local key informants act as volunteers for case detection after getting a short training in "how to recognize common blinding eye conditions." The key informant method (KIM) is very effective way of early detection of persons or children with disabilities inclusive of visual impairment and childhood blindness in low-resource settings. The role involves counseling and mobilization of identified patients or the parents of children with eye conditions for getting examination by the doctor/ophthalmologist and accordingly referrals to an appropriate level of eye care or rehabilitation centers.

This method is quick, cost-effective and sustainable, and involves community participation. This novel method of obtaining population-based data on disabilities and childhood blindness has been piloted in Bangladesh, Ghana, Malawi, Iran, and Pakistan [11–13].

Case Study: In Bangladesh, under the childhood cataract campaign (BCCC), community-based KI methodology was adopted for active case finding (children having cataract or vision impairment). Recently, an independent evaluation was accomplished on BCCC, and it was concluded that the campaign was highly relevant and effective as it has addressed a known public health issue of childhood cataract blindness with high impact and good visual outcome of cataract surgeries [14, 15].

This community-linked pediatric eye care program has already had a huge impact directly on thousands of blind children in Bangladesh and through the local organization of Child Sight Foundation (CSF) [16].

Tele-Ophthalmology

Telemedicine can be defined as the use of information communication technology with medical science [17] to provide healthcare, exchange of healthcare information and digital transmission of medical imaging across distance [18]. It has been used

to reduce patient transportation costs [19, 20] and hospital and clinic waiting times [21] and to provide super specialty hospital-based services available in urban settings to rural and remote settings [22, 23].

The Indian Space Research Organization (ISRO) initiated a SATcom-based telemedicine program in 2001 to provide healthcare to the unserved and the underserved population in India [24]. In South Africa, a national telemedicine system was planned in 1998. The initial application modules of that telemedicine system were teleradiology, tele-ultrasound for antenatal services, telepathology, and tele-ophthalmology [25]. The Santa Catarina State Department of Health has developed an integrated telemedicine network in Southern Brazil.

Telemedicine can be implemented at primary, secondary and tertiary levels in the public healthcare network [26]. Tele-ophthalmology has become one of the latest tools to be utilized in diagnostic and therapeutic management of eye conditions such as diabetic retinopathy and glaucoma.

Tele-Ophthalmology for Screening and Management of Diabetic Retinopathy: In people with diabetes, onset of diabetic retinopathy is usually symptomless. Most people with diabetes only present themselves for an eye examination when a complication or vision loss is noticed. The major barrier in the management of diabetic retinopathy has to do with reaching people with diabetes in a cost-effective manner in early stages and then scheduling their comprehensive eye examination every six months, annually, or twice yearly as indicated by the stage of diabetic retinopathy.

Case Study: Aravind Eye Hospitals and Sankara Nethralaya have been pioneers in practicing tele-ophthalmology which was facilitated by the Indian Space Research Organization (ISRO) and the World Diabetes Foundation (WDF). A bus fitted with a fundus camera, slit lamp, telemedicine equipment, and all the controls required for a V-Sat connection used to go to preselected locations where people with diabetes were brought together for the screening.

The vehicle staffed by an ophthalmic technician would take fundus images and transfer them through the V-Sat link to the tertiary-care facility where images would be read and graded and a report sent back immediately. The patient would then be counseled on appropriate follow-up examination scheduling or taken to an ophthalmologist immediately for clinical management. These practices helped in establishing remote diagnosis of diabetic retinopathy thus leading to timely management of the condition.

Tele-Ophthalmology for Screening of Retinopathy of Prematurity: Worldwide approximately 10% of the births or about 13 million deliveries a year are estimated to be preterm (less than 37 weeks of gestation) [27]. With improving neonatal care, the survival rates of the premature babies have gone up from 75% in the past to over 90% now [28]. Many of these premature babies are at risk of developing retinopathy of prematurity (RoP). RoP is another condition which is highly amendable to image-based diagnosis, thus offering an opportunity for telediagnosis.

The tele-ophthalmology practices utilize internet-based information technology wherein the healthcare providers can facilitate a patient to have contact with an ophthalmic specialist at base hospital via video conferencing [29]. Since this facility can be made available at the fixed center as well as from the mobile vans which could help patients consult a specialist without traveling and thus bridges the gap of inaccessibility of services.

Ophthalmic assistants (OA) at primary eye care centers examine the patients and send information to the ophthalmologist at the base hospital. One of the best examples under government public health system practicing tele-ophthalmology services is that of Tripura [10], where 40 vision centers are linked to tele-ophthalmology mobile services. The project has decentralized the eye care system and has also reduced the burden of secondary-level hospitals.

Case Study: Narayana Nethralaya in the state of Karnataka, India has taken the initiative to link up with maternity centers where at-risk children assemble on a scheduled date each month. A technician with a portable RetCam captures images of the retina of these at-risk premature babies and transfers these images to the tertiary-care facility from where an immediate report is sent if further management is indicated.

Till the end of 2010, Narayana Nethralaya had screened 17,550 at-risk children, identified 3,258 cases, and provided laser treatment to 392. Recognizing the importance of this initiative, the Government of Karnataka has adopted it under its rural health scheme and plans to have the entire state covered within the next 3 years [30].

Public-Private Partnership (PPP)

This is being increasingly encouraged as an important aspect of an inclusive and sustainable eye health delivery system [31]. The need for public-private partnership arose against the backdrop of inability and inadequacy of the public health delivery system [32].

On the other hand, the private sector could facilitate this goal through the provision of resources and technical expertise. This partnership creates a powerful mechanism to overcome different challenges by the public and private health sectors leveraging on their strength [33, 34].

Case Study: In Nigeria, the Eye Foundation has been running a community-based public-private tripartite eye care system since 1993. The foundation's private sector activities have been carried out through five private eye care hospitals in different states outfitted with modern ophthalmic equipment and under public-private partnership have been rendering services to the less privileged along a sliding scale. Over 67% of these services are subsidized, and 33% of the services are provided at no cost to patients who are unable to pay.

Under public-private partnership, the Eye Foundation has also established a Deseret Community Vision Institute since January 26, 2006 in Ijebu-Imushin of

Ogun State with the mandate of human resource development and provision of high-quality eye care services to the underserved. The institute's community outreach program serves disadvantaged populations in all the states. The outreach is conducted free of cost with subsidy from the private sector of the eye foundation.

The Eye Foundation Hospital (EFH) Group offers free eye screening and cataract surgeries. Screening is accomplished in an outreach mobile clinic followed by cataract surgery at the hospital. Between 1993 and 2011, more than 20,000 cataract surgeries were performed. The center also undertakes regular visits to vision centers managed by community ophthalmic nurses to reach the rural population [35, 36].

Subsidized Cataract Surgical Services in Latin America

Latin America (LA) is a region rich in resources, talent, and culture but struggling with political instability, the worst economic inequality, and rural marginalization [37]. Cataract is the leading cause (60%) of blindness in LA, and coverage of eye care services is only 10% of the rural areas and surgical output is below minimum, leaving more than 60% of the region's population without access to eye care [38].

Cataract Business Model in Guatemala

Guatemala is a low-income Central American country where more than 50% of the population is living below the poverty line with 13% in extreme poverty [37]. The Cataract Surgical Rate (CSR) is about 800, and there is no government support or budget provided for cataract surgeries.

Visualiza is a private program that was successfully implemented with donor support and financial planning with special focus on its sustainability. Dr. Mariano Yee and his brothers opened an outreach clinic in Peten in 1998 with the support of the Volunteer Optometric Service to Humanity of Pennsylvania and Lions Clubs International Foundation. Approximately 20% of the patients treated were private-paying patients, 80% subsidized, and 10% received free treatment. The income generated by the private clinic, optical labs, eye drops and medications cover the costs of the social clinic. From 2002 to 2007, the number of patients attended grew by an impressive 344% from 6,312 to 28,040 patients. Today, Visualiza performs more than 2,000 cataract surgeries, which is more than 16% of surgical output in the country or 33% in Guatemala City [39].

Cataract Outreach Services in Paraguay

Paraguay is a lower-to-middle income, South American country. Approximately 15% of the population is aged 50 years or older, and 61% of the population is urban. Approximately 19% of the population is below the poverty line [37]. The CSR is about 1,351, and the government financially supports up to 800 cataract surgeries per year.

Fundación Visión (FV) in 2010 inaugurated its new Latin American Lions Vision Institute (LALVI) in Asuncion. In 2011, the FV carried out 3,700 cataract surgeries, 250 of which were financed by the state. Patients, their families, and the active fundraising department of the FV paid for the rest of the surgeries. Patients also have

the options to take out credit through a microcredit business that is on-site at FV. The FV adopted the Aravind sliding scales which allow them to operate on 17% of their patients for free. Up to 68% are subsidized, and 15% pay all the costs [40].

Subsidized Cataract Surgery Business Model in Mexico

Mexico is a middle-income country with a population of 116.4 million. Approximately 17.4% of the population is aged 50 years or older, and 78% of the population is urban [37]. The CSR in Mexico is about 1,720. A national insurance program reimburses for cataract surgery but not evenly, and rural areas in particular are still without access to basic eye care.

Instituto de la Visión (IdV) (*Vision Institute*) in Montemorelos, Mexico is an example of a successful cataract business model that combines the sliding scale of costs with advocacy and resource mobilization from public-private partnerships. The IdV receives additional support from private partners such as CBM, IEF and Lions. The IdV is rendering services approximately 20% to private patients and 80% to social patients. The services are free for people having no economic resources, the patients having scarce income would pay a small contribution, patients with some resources would receive a discount for treatment, and patients having sufficient economic resources would need to cover 100% of the cost of their cataract surgery/treatment [41].

Integrated Secondary and Tertiary Eye Care Services: Attributes

A secondary-level eye care facility should have infrastructure which can support specialized comprehensive eye care services and diagnostics, medical and surgical management of the anterior segment, medical retina and pediatric ophthalmology, low vision assessment and rehabilitation services. The consultant ophthalmologist(s) is the pivot around which secondary-level eye care services revolves. Optometrists, orthoptists, ophthalmic technicians, nurses, and operating room technicians contribute to the clinical ophthalmic team. There must be a specialized training of ophthalmologists working at secondary level in eye health planning, implementation, management and evaluation of eye care programmes and services, in addition to their regular program of continuous medical education and training in clinical updates.

The *secondary eye care facility* provides an effective and efficient delivery of specialized comprehensive and quality eye care services that are equitable, universally accessible, and sustainable for all people with a strong, sequential referral system to the tertiary level. Secondary eye care centers are designed to render comprehensive eye care services to a population of 0.3 to 1 million depending upon the eye care needs in different countries, through a well-trained and skilled ophthalmic team composed of different cadres of clinical and nonclinical personnel which are equally important [42].

The operational sustainability of the secondary center depends on several factors, including the skill level of the ophthalmologist and the corresponding

reputation he or she develops in the community, the demand and supply dynamics in the surrounding region, the presence of other large eye care service providers within a 100 km radius, and the location of the secondary center.

Quality assurance is a crosscutting issue for all delivery systems. Quality assurance must remain part of planning and implementation, starting from service delivery to the management procedures necessary for the efficient operation of systems, and should focus on four aspects of quality assurance: (1) institutionalizing quality assurance systems, (2) improving patient safety, (3) enhancing clinical practice, and (4) improving management systems.

Financial Innovation in the Eye Health Delivery System: The eye healthcare system cannot be sustainable without an effective and efficient financial system. Financial innovation leads to generating revenue over the medium to long term that improves financial performance [43]. It also reduces out-of-pocket funding for service users by redesigning cost structures in such ways that allow services to be more accessible and affordable for poor people [44].

In some outreach or at satellite clinics, patients are not charged for the eye examination, as they generate funds to pay for operational costs through sales of spectacles. Similarly, secondary centers offer tiers of service delivery for paying patients (two tiers of service for paying outpatients and three tiers for paying inpatients) [45].

Research and evidence generation has always been the hallmark of any development initiative, be it for national planning, advocacy, or monitoring. The World Health Organization (WHO) has developed assessment tools to undertake situation analysis to generate baseline data using the Eye Care Services Assessment Tool (ECSAT) [46] or the Tool for the Assessment of Diabetic Retinopathy and Diabetes Management Systems (TADDS) [47].

The epidemiological surveys such as Rapid Assessment of Avoidable Blindness (RAAB) are very cost-effective as they are based on very simple methodology which can be implemented across a defined population unit like district or region or the country. The results generate data on vision impairment and eye care services for better planning of service delivery and health system strengthening for universal access to eye health [48–51].

The application of the RAAB and the WHO tools ECSAT and TADDS across many countries in different regions with limited financial resources has demonstrated these tools to be very cost-effective, easy to implement, and beneficial for evidence-based advocacy, development of eye care plans, and impact analysis studies. These tools for assessment have already been implemented in many countries including the Eastern Mediterranean Region Member States of Afghanistan, Egypt, Iran, Jordan, Libya, Morocco, Nigeria, Oman, Pakistan, Qatar, Saudi Arabia, Sudan, Yemen, and Mexico [48–51].

The tertiary eye care facilities linked to the secondary centers provides the human resource development in all eye care cadres, program for capacity building, professional development, and continuous medical education of ophthalmologists and allied

health professionals in clinical updates and eye health planning and development, research, and strategic development program. The provision of advanced diagnostics and availability of the backup of sub-specialties of advanced anterior segment surgeries, reconstructive and oculoplastics surgeries, medical and surgical retina services, pediatric ophthalmology, and visual rehabilitation services must be ensured. There should also be a mechanism in place for the monitoring and clinical auditing of secondary eye care facilities with 360° operational integrated eye health information system.

The secondary eye care services in a manageable and optimal service units at district level are strengthened for a population size of 0.3 to 1 million comprising of an adequate infrastructure and essential technology and essential human resources (eye care team and administration).

Integrated District Comprehensive Eye Care Program in Pakistan

Pakistan has a relatively large primary healthcare infrastructure of 5,300 basic health units, 600 rural health centers, 7,500 other first-level care facilities, and over 100,000 lady health workers (LHWs) providing a range of services related to maternal and child health including promotion of childhood immunization, growth monitoring, family planning, and health and hygiene promotion.

LHWs are involved in supporting the implementation of multiple public health programs inclusive of primary eye care as part of integrated primary health care. They are capable of identifying people with eye conditions, can treat minor ailments and injuries, and refer more serious cases to appropriate level of specialized care for the medical or surgical management.

A network of 989 secondary care hospitals at sub-district and district levels having there in place the provision of district comprehensive eye care program catering more than 80% of specialized eye care, with the referral backup of 37 tertiary facilities and 7 centers of excellence for eye care in public sector along with 58 tertiary facilities in private sector for specialized or sub-specialized comprehensive eye care and rehabilitation services [52]. This holistic approach of primary-secondary-tertiary- center of excellence referral eye care complex is impacting hugely at national level in reducing the burden of needless blindness and visual impairment [53] (Fig. 3.1).

L V Prasad Eye Institute-Model of Holistic Eye Care

This very well integrated eye care model works in a structural format like a pyramid that at the base of the pyramid are the “vision guardians” who are trained people who keep a close vigil on the eye health of about 5,000 persons within the communities. The vision centers constitute the next upper level and serve the primary eye care needs of an area with a target population of about 50,000. The vision centers are linked to the secondary eye care centers which have been developed to serve a population of about 500,000 people. These centers provide diagnostic and medical or surgical management of the complete range of eye conditions especially of high-quality cataract surgical services, the most common cause of blindness.

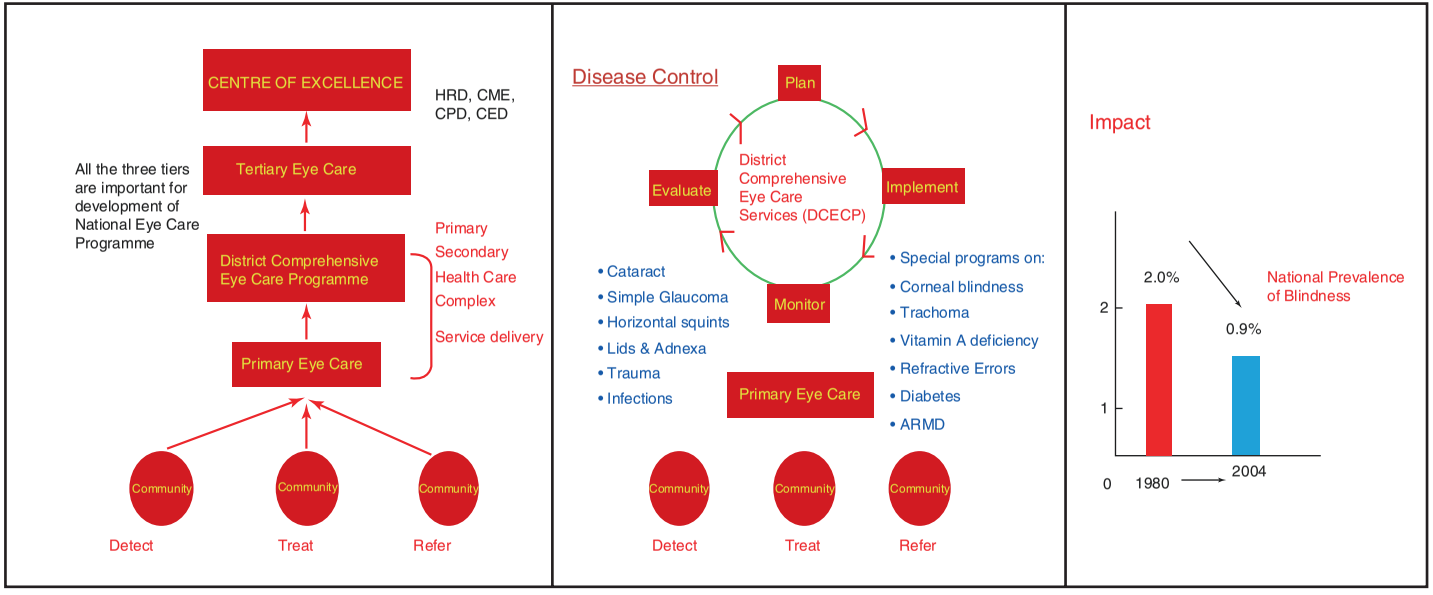

Fig. 3.1 The primary-secondary-tertiary referral eye care complex and its impact on reducing prevalence of blindness in Pakistan [53]

Fig. 3.2 Shows a "bottom-up" pyramid representing LVPEI's model of holistic eye care – creation of sustainable permanent facilities within communities, staffed and managed by locally trained human resources and linked effectively with successively higher levels of care

The tertiary eye care facilities/training centers provide backup to the secondary eye care centers, and each serves a population of five million persons. These centers provide comprehensive eye care and vision rehabilitation services along with teaching and training for the human resource development of different eye care cadres and capacity building of the ophthalmic teams working at secondary centers. Then, top on the pyramid is the center of excellence which is linked to tertiary centers and serves a population of 50 million persons. This center treats complex diseases, trains the trainers in sub-specialties and rehabilitation, and engages in advocacy. The Government of India has adopted LVPEI's pyramid as a model of eye care service delivery in its current 5-year strategic plan, and the model will be implemented in all states in a phased manner [54] (Fig. 3.2).

Aravind Eye Care System

Aravind Eye Care System consists of a chain of eye care hospitals in India. It was founded by Dr. Govindappa Venkataswamy at Madurai, Tamil Nadu, in 1976. It has grown into a network of eye hospitals and vision centers and has had a major impact in eradicating cataract-related blindness in south India [55].

Aravind began performing surgeries on a large scale with treatment being free or heavily subsidized for the poor or cross-subsidized by the paying patients. Aravind established an outreach program wherein doctors reach out to remote villages to conduct eye camps sponsored by various organizations like Sathya Sai Organization, Lions Clubs International and Rotary International [56]. These organizations take care of the costs of the camps, transporting the patients for surgery, and their rehabilitation, while Aravind does the surgery free of cost.

Per surgeon productivity in Aravind is 5 times the productivity of an average cataract surgeons in India and 16 times more than that of the average surgeon in the United States [57]. Aravind established its own lens manufacturing facility Aurolab and a blood bank to reduce costs. As of 2012, Aravind has treated nearly 32 million patients and performed 4 million surgeries, the majority of them being cheap or free making it the world's largest and most productive eye-care service group.

Aravind established the Lions Aravind Institute of Community Ophthalmology (LAICO) in association with Lions International in 1992. The institute offers training for hospital administrators, hospital operations managers, and other management professionals [58]. Currently, LAICO works with over 270 hospitals across the developing world replicating the Aravind model of high-quality, low-cost eye care service delivery.

Layton Rahmatullah Benevolent Trust (LRBT) -Three-Tier Network of Eye Hospitals and Clinics in Pakistan

Layton Rahmatullah Benevolent Trust (LRBT) is the biggest non-governmental organization working in Pakistan to fight against avoidable blindness across the country through its network of 19 fully equipped hospitals, 55 community eye care centers, and 4 outreach clinics. Out of 19 eye care facilities across Pakistan, 17 are secondary level and 2 state-of-the-art tertiary eye hospitals. Except its three hospitals (Karachi, Lahore and Quetta), the remaining 16 eye hospitals are in small towns and rural areas where poverty is greatest and other facilities the poorest.

LRBT through its purpose-built hospitals provide comprehensive eye care through a three-tier service delivery system whereby free diagnosis and treatment is available for all from simple refraction to the most advanced retinal surgery and corneal transplants. The community eye care centers are functioning as fixed satellite clinics with added outreach program of screening for diabetic retinopathy and identification of patients with common eye diseases in far-flung areas and referral to the state-of-the-art base hospitals for diagnostic services and medical or surgical management. Virtually all Pakistanis are now able to access high-quality, free eye treatment from LRBT hospitals within 200 km of their residence.

The management of LRBT hospitals ensures that the majority of those admitted cases are treated the same day. The same level of care and attention is available to all patients, rich and poor, young and old, men, women, and children on a first-come-first-serve basis. There is no discrimination on grounds of religion, gender, class or ethnicity (http://www.lrbt.org.pk/).

Al-Shifa Trust Eye Hospitals in Pakistan

Al-Shifa Trust is a not-for-profit non-government entity that seeks to provide high-quality eye care diagnostic and treatment services to the general population, especially to the needy and less affluent portions of society. It has a backup of a state-of-the-art tertiary eye care hospital and a chain of three secondary-level specialized eye care hospitals in different locations across Pakistan.

Program components include a comprehensive outreach program as well for screening and identification of patients with eye diseases through eye camps and at satellite clinics in far-flung areas and provision of diagnostic services and medical or surgical management at state-of-the-art base hospitals. Al-Shifa Trust also runs a high standard teaching and training facility (Pakistan Institute of Ophthalmology) at the tertiary hospital complex for the development of different eye care cadres especially in specialty of ophthalmology, sub-specialty of pediatric ophthalmology and vitreo-retina. The hospital uses cross subsidization to finance eye care for those not able to pay (http://www.alshifaeye.org/).

Conclusion

Therefore, the key principles for inclusion of services at secondary and tertiary level of eye care should be based on a primary health/eye care model with emphasis on high-impact, evidence-based interventions, integration of services, and standardization of protocols, guidelines, and procedures with inbuilt elements of comprehensive package to create a more holistic three-tier (primary-secondary-tertiary) eye healthcare system approach. Health promotion, being a crosscutting issue, should be strengthened at all levels of eye care through improved coordination between different stakeholders with consideration of urban and rural differences.

Considering the inequitable provision and delivery of eye healthcare, poor infrastructure and system gaps, the scarcity of human and financial resources, demographic situation, and human development index in developing countries; the comprehensive eye healthcare services should be planned in a multi-tiered system in line with the WHO framework for health system strengthening and giving emphasis on incorporating:

- Community level services in countries where primary healthcare programs are provided.
- First referral level/first level care facility which is usually a basic health post/unit or primary health center.
- Second referral level/secondary level care facility, usually a big hospital at sub-district, district, or regional level where specialized eye care services are available with a strong systematic sequential referral system to the tertiary level.
- Third referral level/tertiary level care facility attached with medical institution for human resource development of different medical and eye care cadres. These are usually a university hospital at regional or provincial level where specialized and

sub-specialized ophthalmologic diagnostic, medical and surgical eye care, and visual rehabilitation services are available with a strong systematic sequential referral system to the center of excellence for more advanced sub-specialized eye care and rehab services. This center also serves as the training center for allied health personnel, mid-level eye care personnel, ophthalmic nurses, and other auxiliaries.

- Fourth referral level/center of excellence which is usually a university hospital having sophisticated infrastructure and highly skilled expertise in sub-specialties, well equipped with advanced technology and visual rehabilitation facilities. This center also serves as the teaching and training center for fellowship and post-fellowship programs in different ophthalmic sub-specialties like vitreo-retina, pediatric ophthalmology, oculoplastics surgery, rehabilitation, etc.

In this context, the innovative approaches emphasizing on strengthening primary-secondary-tertiary referral eye care complex with a good backup of comprehensive specialized and sub-specialized eye care act as a supportive tool to overcome the challenges of inaccessibility, non-availability, and non-affordability of eye health-care especially in remote underprivileged communities. The different innovative concepts can benefit and positively impact on the performance of health delivery system and improve eye health outcomes.

Therefore, there is a need to develop and implement innovation-based eye health delivery systems which could provide equitable, accessible, affordable, inclusive, and quality health services to all individuals. The outcome of such a comprehensive eye care program would depend upon social marketing along with financial and technology backup, operational innovation and partnership in the health sector, which would certainly play an important role to improve the efficiency and effectiveness of health delivery system within any setting. Innovation-based eye health delivery system and diverse strategies would add value or rectify the inadequacy in inclusive, integrated and sustainable eye care service delivery process.

The innovative and diverse strategies would add value or rectify the eye care service delivery process through implementing technological and management techniques to deliver inclusive and integrated health services. Innovation-based health delivery systems perform as models of inclusive, sustainable and scalable health service delivery systems.

Compliance with Ethical Requirements Muhammad Babar Qureshi declares no conflict of interest.

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Expanding and Optimizing Human Resources for Eye Care

4

Suzanne S. Gilbert, Paul Courtright, and Dhivya Ramasamy

"No Health without a workforce" – Global Health Workforce Alliance

The development of a strong global health workforce is the focus of increasing efforts by the World Health Organization and other bodies. A landmark review documents the shortage of health workers with more shortages forecast [17]. The challenges of the aging workforce, the need for replacement, and better balancing of skills mix persist. Sufficient breakthroughs in attracting and retaining health workers, keeping them motivated, well supervised and supported remain elusive. Performance assessment, quality of care and information systems required to estimate future needs and design evidence-based solutions all are issues requiring substantial additional investment. This work has been developed further as the global strategy on workforce 2030 to better support achievement of the UN Sustainable Development Goals better [18].

This is the greater context for the production, recruitment, deployment and sustaining of human resources for eye health.

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Global Need for Human Resources in Eye Health

Human resources constitute a key pillar of the World Health Organization and International Agency for the Prevention of Blindness VISION 2020: The Right to Sight [48]. The need for a well-trained and equipped eye health workforce is acknowledged, and requirements for human resources are embedded in global as well as regional plans [20, 21, 40, 52].

This situation has been recognized in the WHO Global Action Plan for 2014–2019 [50]. The second objective of the plan is to "develop and maintain a sustainable workforce for the provision of comprehensive eye care services as part of the broader human resources for health workforce." The actions called for include planning of human resources for eye care within wider human resource planning, engagement with other relevant sectors, provision of training and career development, retention strategies and sharing of best practices.

This chapter addresses these priorities and others which are critical to the establishment of an eye health workforce which provides quality services where, when, and to whom they are needed.

Human Resource Gap and Goals of Global Action Plan

Global plans target optimal ratios of human resources in eye health (HReH) to population by cadres and region. These targets are indicative of the levels of personnel required but rarely suffice to produce the service levels required [50]. Consortium calls for increasing professional development and service delivery are taking on prominence as with the Durban Declaration on refractive error and service development [49], the Cambridge Declaration to ensure high-quality capacity development and skills of eye care teams [7], and Miami Declaration building capacity for training in eye health in Latin America [24].

The size and composition of the eye health workforce have been documented through a series of global, regional, and national surveys over time. Ophthalmologists are the most thoroughly studied. The results are sobering. A comprehensive study of data from 193 countries documents the poor geographic distribution and uneven practice patterns of the world's 200,000 ophthalmologists [44]. The growth in the number of ophthalmology trainees is not keeping pace with population growth trends. An in-depth analysis of the status of ophthalmic education and eye health workforce in selected South Asian countries documents severe imbalances in ophthalmologists and allied ophthalmic personnel (referred to there as allied eye health professionals [4]. Regional HReH surveys such as those conducted by the Eastern Mediterranean Region office of [52] chart progress made and the wide gap to be tackled (see also [5, 11]).

Presumed solutions to HR needs that focus on simply increasing the number of personnel in isolation from their working context are of questionable value. All too often, training programs are established in isolation from eye care system planning.

Least beneficial are those that set broad HR training and funding policy without investment in any context-specific study to evaluate these simplistic solutions.

Little is known about productivity of HReH in relation to the population need. Eye care programs and health programs in general have made insufficient investment on the study of HR issues in their jurisdictions. Beyond increasing numbers of personnel, strategies are needed to increase the efficiency of personnel to more effectively serve the preventive, clinical, and longer-term rehabilitative eye health needs of the community. Some models, such as Masnick [33], have been suggested to improve the match between training and needs.

Planning for Human Resources for Eye Health

Practical planning for human resources for eye health (HReH) is done at the national level rather than global or regional level. Regional targets for HReH have been promoted in the past, but these have less relevance today as there is much more information which can be used for setting targets and for planning [9]. At the national level, factors that should be considered for the purpose of target setting and planning include as follows.

Understanding the Epidemiology of Eye Disease in the Country

Research carried out in the last decade has demonstrated considerable variation in the age- and sex-adjusted prevalence and incidence of cataract, even within the continent of Africa [32]. Although the reasons for the variation are still not well understood, it appears that populations in the Sahel areas of Africa have an incidence of cataract about twice the incidence in populations further south. Indications are that populations on the Indian subcontinent have an incidence of cataract higher than the African Sahel populations. The implications of this for HReH are clear: the HReH needed to manage cataract in different populations will not be the same.

Similarly, there is considerable global variation in the prevalence of uncorrected refractive errors, particularly myopia. East Asian populations generally have a high prevalence, and African populations generally have a low prevalence [15, 46]. Setting targets for HReH to provide optometric services will need to reflect these differences.

Some conditions, such as trachoma, tend to be focal in distribution. Planning human resources for trichiasis surgery is generally based upon the burden of trichiasis in each "district." Since the goal is trachoma elimination, HReH plans for trachomatous trichiasis generally only span the years until elimination is reached. At the other end of the spectrum is the growing burden of diabetic retinopathy and other non-communicable diseases that produce blinding ocular sequelae. All countries will need to develop comprehensive HReH plans for managing these chronic conditions which often require lifelong care. The implications for eye health workforce are considerable.

Need by the Population

National planners for HReH also need to consider the needs of the population. The extent of the need is often linked to the epidemiology of disease.

In countries where the incidence of (vision impairing) cataract starts at a younger, working age, the demand for surgical intervention is often prior to severe vision impairment. This has two implications for planning for HReH: (1) more surgeries means more surgeons need to be trained per million population, and (2) the quality of the service provided (e.g., achieving improved visual outcome) must be high. Demand for surgery prior to the onset of severe vision impairment from cataract is challenging. HReH planning in African countries involve training of non-physician cataract surgeons (NPCS) [9]. Most NPCS only perform cataract surgery on eyes with 6/60 or 3/60 cataract when, in fact, a growing number of people wish to have surgery earlier [8]. National HReH planning is best informed when there is a thorough review of evidence of the demand of the population.

Legal Considerations

Legal parameters related to human resources for health are generally developed without specific consideration of eye care. Restrictions on non-physicians doing eye surgery, such as the case in 14/31 (45%) countries in Africa [30], were adopted for a wide range of reasons including patient safety and professional protection. In some countries, legal restrictions on the practice of optometry by non-physicians were a result of a desire by physicians to protect their field of work. Systematic research and advocacy in some parts of the world is promoting optometry as a recognized profession. In other settings, such as in sub-Saharan Africa, the low prevalence of uncorrected refractive errors has likely been the reason for a lack of inclusion of optometry within the HReH frameworks in many countries. Distribution of eyeglasses to children is often perceived as politically attractive even if there is minimal evidence to support the activity.

Multitude of Cadres in an Evolving Field

National planning for HReH needs to continually advance as the field of eye care evolves. As the goal of universal access to eye care broadens to include a more comprehensive range of vision needs, more skill sets are required, often for new cadres of staff. Recommendations for the establishment of highly productive mid-level personnel are succinctly presented by du Toit [11]. More comprehensive eye care often brings with it the requirement for new technologies which mean that new skills need to be learned. In advanced eye care delivery settings, specialization has become common. While this may not be ideal in most developing country settings, some specialization is necessary. The training and deployment of low vision technicians is an example of a growing trend to meet more comprehensive needs,

particularly in settings with a Child Eye Health Tertiary Facility. Some countries have been challenged by having two or more cadres that have similar skill sets: an example is the training of ophthalmic nurses and ophthalmic clinical officers in many sub-Saharan African countries [22]. A lack of structured career progression pathways is often a constraint in HReH management. This can lead to confusion and unnecessary competition. National planning, based upon a thorough assessment of clinical and non-clinical skills desired, can reduce these challenges.

Consider HR Needs for Sustainable Service Delivery

Another factor for planning is to consider HReH needs as they relate to sustainable service delivery. Advances in making programs more resilient organizationally and financially rely heavily on rational allocation of responsibilities across team members [6]. To ensure high volume or at least optimally structured services, there is a growing emphasis on the need for well-trained and supervised non-clinical staff [47]. These include program managers who have expertise in planning, financial analysis, and human resources; community outreach workers to bridge the gap between patients and the eye center; patient counselors to encourage follow-through on recommendations for surgery or other treatment; repair and maintenance experts to ensure that much needed, expensive equipment is kept in good working order; and staff for hospital management information systems which enable data-based decision-making to improve efficiency and effectiveness of services [12]. As programs mature, sustainability is further strengthened by building internal capacity for research and training plus development of library resource centers to support both. Sustainability includes consideration of attracting and retaining motivated staff to serve the community. A well-designed plan for a sustainable eye care program is only as good as the ability to staff it [10].

National planning for HReH needs to be forward-thinking; plan now for a future that is 5–10 years distant. Training is time-consuming and costly, and shortcuts will likely limit the long-term development of appropriate HReH.

Effectiveness of Our Current HReH

While considerable effort has been given to advocating for increasing HReH at the global, regional and national levels, less effort has been directed toward improving the efficiency and effectiveness of our existing HReH. Palmer et al. noted that while Africa-wide targets for surgeons (ophthalmologists and non-physician cataract surgeons, (NPCS)) have been reached in some countries, the cataract surgical rate (CSR) remains very low [39]. This raises the question: what is the point of training more people if those people have very low levels of productivity? This particular question has been posed regarding NPCS. A recent review showed that 69% of the NPCS trained in Eastern Africa do less than 200 cataract surgeries in a year [14]. Low productivity often leads to poor quality of surgery and a frustrated workforce.

Effective national planning for HReH is strengthened by an assessment of productivity and, ideally, quality of care.

Currently most training programs are cadre-specific with little attention given to how that cadre works as part of the eye care team. Improving quality, efficiency, and patient safety requires teamwork with effective communication and clarity on skills, roles, and responsibilities. Systematic training, coaching, and use of checklists have been demonstrated to reduce surgical mortality within Veterans Administration Hospitals in the Unites States [38]. National-level task shifting initiatives are best based upon a clear set of skills and roles within the context of the eye care team. Shifting national training programs to become team-oriented is challenging, and, as noted below, approaches may best be undertaken at the implementation level.

Although ideal, in reality, there are few comprehensive pediatric team training programs available. In some settings, such as selected sites in Africa, Kilimanjaro Centre for Community Ophthalmology (KCCO) has organized training in planning, counseling, management, and coordination as part of the development of Child Eye Health Tertiary Facilities. There is a good evidence from both Asia [36, 37] and Africa [2, 28] on the importance of the team approach to effective pediatric eye care.

Pediatric Eye Care Team Training

When pediatric eye care became a focus, service providers quickly noted that the program intervention required an approach very different from adult eye care. Right from screening the children by key informants in the communities or in the schools, the skills and roles necessary are very different.

A comprehensive pediatric program would include special cadres that play specific roles in this program:

- Pediatric ophthalmologist
- Pediatric anesthetist
- Optometrist/orthoptist
- Ophthalmic assistant
- Pediatric counselor
- Childhood blindness and low vision coordinator

This approach to training where the entire team for a program is developed is essential to ensure a cohesive workforce. Team training is a more effective method as it is designed with the program in mind rather than training one specific cadre alone.

General tenets of desired productivity are best discussed and agreed at a national level; however most actual planning for improving the effectiveness and efficiency of HReH is carried out at the level of the VISION 2020 “district” (populations of about one million). Improving HReH effectiveness and efficiency is a key component in a district VISION plan and includes:

Setting Productivity Targets Where Practical

All plans need targets or goals, and all people working within an eye care team work best if they have agreed-upon productivity targets. While this may not be practical for all aspects of eye care, it has been successfully used by programs in many settings as follows:

1. Number of cataract surgeries per ophthalmologist per year
2. Number of spectacles dispensed per optometric staff member per year
3. Number of people screened per outreach visit day
4. Number of people identified to have a certain condition
5. Number of trichiasis surgeries done per trichiasis surgeon per surgical outreach day

Review of targets is often undertaken annually with revisions made accordingly.

Defining Specific Roles and Responsibilities Within the Eye Care Team

A basic tenet when defining roles and responsibilities of members of the eye care team is to use trained people to the best of their ability [41]. This can be translated to mean that the ophthalmologist should be spending his or her time doing the actual surgery rather than assisting patients on/off tables, giving injections, etc. The Aravind Eye Hospitals have championed efficiency for nearly 40 years, and many countries have learned from their experience. Every single member of the eye care team has a clear set of tasks, and each one knows that by fulfilling their tasks they help the team run smoothly and provide services for more people.

Task Shifting at Aravind Eye Hospitals

In a country like India, given the backlog of the cataract blind and a large underserved population in need of eye care, it is essential to ensure that the capacity of the eye care service providers meets this large need.

This is achieved by ensuring sufficient human resources but also ensuring its efficiency. Productivity can be compromised, for example, if surgeons drape and prepare the patient for the surgical procedure or if doctors perform routine investigations and tests in the outpatient clinics. These tasks can be "shifted" to well-trained and supervised lower-level staff.

At Aravind, doctors focus on diagnosis and surgery. All other routine tasks are shifted to mid-level ophthalmic personnel (MLOP) who perform tasks such as refraction, tonometry, and patient counseling. This enables Aravind's surgeons to average over 1500 surgeries per year, compared to a national average of about 500.

However, this "shifting" requires that the lower-level staff are well trained and supervised. Aravind's MLOPs are typically young rural women who undergo a 2-year MLOP training program in one of eight streams: refraction, medical records management, outpatient and ward assistance, operating room assistance, patient counselling, spectacle dispensing, and housekeeping. Aravind's management systems ensure that the quality of outcomes of the team is continuously monitored and improved.

Key Learning Points

Staff with higher qualifications should not perform tasks that can be done by those with appropriate training and supervision yet with lesser qualifications. Task shifting is context-specific and requires the staff cadres to be defined by the required roles. Training and supervision of the lower-level staff is critical to ensure quality of outcomes.

Ensuring that the Eye Care Team Works Well Together

At the VISION 2020 implementation level, team development can help the hospital eye unit run more effectively and efficiently. Clinical team development needs to be matched with management/administrative team development [43]. The importance of improving leadership and management systems within eye units is well-recognized but often under-resourced. Government eye units, in particular, have often not benefitted from change management and mentorship although experiences from Aravind's work in India and KCCO's work in some countries in sub-Saharan Africa suggest that investment in leadership and management strengthens the entire program and helps build teamwork. The process of building teams is both an art and a science. There are now increasing strategies for the training, certification, and accreditation for eye teams [19, 26]. Developing teams can be more challenging in government institutions if there is no eye care management system. Furthermore, a hospital eye team may work well but may have little interaction with other units within the hospital or with eye care personnel based outside of the hospital. Engaging the eye care personnel from outside the hospital as part of the "district" HReH team improves both effectiveness and efficiency of all eye care services provided.

Role of Managers

To ensure that an eye care institution carries out its core clinical activities requires that the various resources and tasks are managed effectively. Hospital managers and administrators play a critical role in ensuring the smooth functioning of an institution through ensuring HR management, logistics and planning, timely supply of material, infrastructure management, organizing outreach, handling accounting and reporting requirements, etc.

They can also support strategic decision-making as well as continuous improvement by overseeing productivity, quality, and financial performance.

Having HR Plans that Enable Good Access to Service Delivery

By their very nature, effectiveness and efficiency require having patients to whom one provides service. In many rural settings in developing countries, the barriers that limit utilization of eye care services have been well-researched [1]. Investing in addressing these barriers, most notably the need for transport to hospital, is often critical to increase the effectiveness and efficiency of the eye care team. Good community outreach and management staffing can contribute substantially to bridging this gap [31]. The importance of the clinical and community interface has been reinforced in the training curriculum in community eye health of the International Council of Ophthalmology [16].

In addition to helping patients come to hospitals, there are numerous emerging structures for bringing more services closer to the patient's doorstep. One such modality is the community vision center which can be staffed by personnel who receive specific training to meet the new demands [29]. While there is evidence of need for treatment of ocular morbidity [27, 45] at the community level, there is inadequate evidence to suggest that providing training in diagnosis and treatment of eye conditions to general health center staff (who have other healthcare responsibilities) will lead to improved eye care service at the community level. Ensuring that these cadres provide services in eye health promotion and referral still requires investment in the health system.

Retaining Motivated and Productive Personnel

There is a growing recognition of the need for systematic and active efforts to retain current HReH. These strategies address motivational factors such as clear personnel policies with career ladder opportunities, financial and professional rewards, assurance of continuing professional education, and other contributors to professional satisfaction. Some of the factors that contribute to staff longevity also produce benefit for the institution. Most notably, these can include engagement in conducting training and research that builds personal competencies while also strengthening the program and knowledge base. Recruitment and retention of ophthalmologists is generally strengthened when there are mechanisms for enterprising young professionals to obtain benefit from their efforts to provide a high-quality, high-volume service. It is important to study the factors that counter staff depletion and promote retention so as to address them comprehensively. Some influential factors go beyond the institution and require improvement of policies at the national level governing range of practice, retirement requirements, and others.

Improving the productivity of existing HReH entails limited training inputs yet can achieve huge gains in services provided to patients. This is the natural place to start national HReH planning.

Below, a case study from L V Prasad Eye Institute (LVPEI) also demonstrates how the issues of recruitment, training, career development, and retention at all levels of its eye health pyramid are addressed [42].

Case Study

The L V Prasad Eye Institute (LVPEI) rural eye health pyramid serves a population of 0.5–1 million which is the typical population of a district. It comprises a secondary center (SC) for 0.5–1 million populations linked to vision center (VC) for 50,000 population and a vision guardian (VG) for 5,000 population. LVPEI has addressed the issues of recruitment, training, career development, and retention at all level of its eye health pyramid [42].

The dearth of ophthalmologists in rural areas is addressed by recruiting newly graduate ophthalmologists for a fellowship program. This program ensures that they have good comprehensive ophthalmology skills. Similarly, recruitment of eye care managers is through advertisement in local media. Other staff members are recruited from the region where the SC or VC is proposed.

Training for staff is more based on the competency needed for performing a task rather than providing a generalized training. The focus is not on individual training but on training of the eye care team, and the roles and responsibilities of each team member are clearly defined. The concept of this team approach is based on principles of working together, task shifting, and ensuring continuity of care. Also, it ensures that the team members are available, have all the required competencies, ensure maximum productivity, and are responsive to the need of the population.

There is also a clear career pathway for each cadre of staff as well as provision for continuing professional development for most cadres of staff. All this along with attractive salaries and perks, fair appraisal systems, ensures retention for most of these cadres.

Training Strategies and Resources

Throughout the field of training and development, there is a growing recognition that training alone is not sufficient to prepare the next generation of HReH. A systems approach is needed to ensure that each trained person is equipped to perform optimally. Training must be conducted with clear understanding of the skills required to meet the service needs, the fit of the professional within the team, and the facilities and tools that are necessary. Ongoing supervision and support are required to ensure application of what has been learned. Increasingly, training focuses on building demonstrable competencies required for quality patient care rather than rote learning to pass the next test.

Since the early 1980s, there has been a push to create training opportunities that are locally available in developing countries. This accomplishes multiple goals: training is more likely to be relevant to the service setting as it often is more affordable and accessible and reduces brain drain. Initially, training programs in eye health focused on ophthalmologists. Over time, structured programs for optometrists, allied ophthalmic personnel, managers, and community eye health workers have been designed and have proliferated.

Training takes place in a variety of settings including universities, vocational schools, and within programs conducted by eye care institutions themselves. Training in some cases is sponsored by a government, a non-government organization, the training institution, or the candidates themselves. The structure and financing of the training are closely related to the system for providing eye services.

Candidate Selection Matters

Selection of candidates to be trained has a powerful influence over the likelihood of their staying on the job and doing well. Given the focal nature of many eye care needs, increasingly candidates are sought from those regions to which they may return to work. The importance of reducing barriers to care for women can be addressed in part through recruitment of women among the trainees [35]. These selection features are particularly relevant in the many parts of the world where HReH, especially the wide range of ophthalmic medical assistants, are recruited and trained by the eye care institution in which they will work.

Assessment of Training Needs

A movement in the field of training is to adopt a "learner-centric" approach. This process begins with an assessment of the entry-level skills, knowledge, and attitudes of the people to be trained. This assessment is considered in light of the competencies the staff member will be expected to gain during training and apply on the job. Pre-training assessment of HReH has been demonstrated to be effective. A growing array of assessment tools are available at low or no cost from major professional societies at the international, regional, and national levels.

Focus on Required Competencies

Given the recognition that service delivery and thus also staffing patterns vary from region to region, country to country, and sometimes within country, there is a move to focus training on required outcome competencies. Targeting the particular skills and other attributes needed by staff makes training more efficient. Competency-oriented training also lends itself to improved monitoring of the learner's progress toward pre-specified goals. The clarification of competencies enables rational organization and allocation of skills across team members to optimize their contribution toward eye care [22]. Definition of competencies is not limited to clinical training but also includes management training [13]. Finally, the careful identification of competencies enables the development of detailed training curricula with accompanying teaching materials, testing pro forma, and other assets.

Array of Training Opportunities

The settings and strategies for training are as varied as the eye health workforce. Information sharing regarding training opportunities and how to access them is increasing. This applies to training both for the entering eye health professional as well as to those seeking continuing professional development. While comprehensive review of training opportunities crosscuts disciplines and regions [51], databases within regions offer more granular detail on type, duration, cost, and location of training [23].

Formal academic training is becoming more available in many countries, thanks in part to the government efforts and the support of global professional societies including the International Council of Ophthalmology, World Council of Optometry, and Joint Commission on Allied Health Personnel in Ophthalmology, among others. National and supranational entities including the American Academy of Ophthalmology, the Asia-Pacific Academy of Ophthalmology, and their sub-specialty counterparts further support the growth and strengthening of training. These organizations share the goals of clarifying the scope of practice, competencies, preferred practice patterns, and development of systematic professional education required for quality service delivery, research and training. Recognizing the value of hospital managers and a wide array of allied ophthalmic personnel, the number of training programs internationally is growing at the undergraduate and graduate levels. These professional training programs need a strong link with service delivery settings to ensure relevance and application of learning.

On-the-job vocational training is an available gateway that is chosen by some allied ophthalmic personnel. These candidates generally enter training upon completion of high school and perhaps several years more education. This is one of the multiple entry points that can lead to a profession. Other opportunities involve hospital-provided training which can lead to employment within the eye care institution.

Blended learning is on the upswing in training programs for HReH and frequently involves a blend of in-person and distance learning. Tailoring the choice of learning content to the educational method can enable more people to get trained more effectively. A wide range of educational materials are being developed by professional societies and universities for computerized self-study via DVD or the Internet [34]. Self-study makes best use of relatively less frequent classroom and other instructional opportunities.

Online options for exposure to the world's eye health training materials are mushrooming. The American Academy of Ophthalmology's ONE (Ophthalmic News and Education) [3] Network offers on-demand access to resources useful for the clinician, trainer, and researcher. Courses such as EdX and the Global Blindness Prevention series offered free of charge by the International Center for Eye Health, London are but a few examples.

ICEH Global Blindness Course Online

The first two times in 2015 that the ICEH offered the massive open online course (MOOC) in Global Blindness: Planning and managing eye care services, a total of 5,232 people participated in the course. Of them 2,849 from 109 countries completed all the activities in the 6-week course including the associated quiz content. Participant comments highlighted the importance of having the course available online.

For 83% of participants this was their first online experience and comments included:

- "The course materials were useful and adaptable for local application."
- "Course changed my attitude towards engaging with the community."
- "Impact on practice – including monitoring cataract surgical rate and outcome."
- "Downloaded the content to share with students and team."

The ICEH team is now developing courses on global issues as well as specifically within regions of Africa. The aims are to localize online training and embed it within an accreditation system specific to the region, as well as to strengthen digital literacy across ophthalmic training programs.

Systematic Efforts to Increase Availability and Quality of Training

Professional societies and leading academic centers play a major role in identifying priorities for training and developing print and digital training materials for use within programs worldwide. In many cases these groups also dedicate considerable effort toward improving the quality of training. The International Council of Ophthalmology's (ICO) Center for Ophthalmic Educators, the World Council on Ophthalmology, and the International Joint Commission on Allied Health Personnel in Ophthalmology offer state-of-the-art training materials for programs around the world [25].

Twinning programs such as the International Center for Eye Health Links network and university-to-university exchanges make available guest faculty from more mature training programs to help those with fewer resources. Eyexcel: Expanding the Global Eye Health Workforce through Excellence in Training, a 4-day course offered by Aravind Eye Hospitals, Seva Foundation and the ICO have helped more than 85 eye hospital teams to launch or strengthen their institutions' training programs in 24 countries.

Priorities for Moving Forward

To meet the growing and as yet unmet global need for eye care, there must be a systematic effort to better utilize the existing HR as well as scaling up the number, mix, and caliber of eye care personnel.

- Focus on how to improve efficiency of existing HR (investments in improving productivity of existing staff are essential).
- Encourage countries to shift away from independent training programs to more systematic team training. This would require that a country identify what the "eye care team" consists of, determine what training is needed, and then plan HR needs and training around it.
- Encourage countries to carry out a systematic review of existing HR (competency, productivity etc.) and epidemiology of eye conditions and demand of the population so evidence-based planning can be undertaken.
- Equip training programs with tools including curricula, instructor guides, learner assessment tools and course evaluation strategies.
- Build training in management, leadership, community engagement, and others in addition to clinical training required for strong service delivery programs.
- Encourage all groups (government, NGOs, others) to engage with the private sector and include them in HReH planning efforts.

Compliance with Ethical Requirements Suzanne S. Gilbert, Paul Courtright, and Dhivya Ramasamy declare they have no conflict of interest.

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Technology and Innovation for Eye Care

5

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Introduction

Technology development and innovation have surged recently within the global realm of medicine as an industry. This expansion has at times disrupted existing technologies and related costs within the practice of medicine. Ophthalmology practice has particularly been affected by this technological surge in a number of ways. This chapter discusses how technology has enabled the delivery of immediate

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timely medical services at the doorstep while achieving relatively low cost. The three areas of technology which are necessary for making the comprehensive eye care system accessible to everyone are:

1. Technology to improve access to eye care systems for remote screening and diagnostics
2. Technology to improve delivery of remote eye care (real-time delivery of treatment)
3. Technology to build monitoring capacity for global eye care

In all areas, due to different perspectives, technology development continually evolves. Many have started from relatively simple technological platforms suitable for screening onto more complex systems capable of diagnostic and interventional treatment parameters [1–3]. While there exists a host of eye care-related technology, there are both new and existing platforms which are constantly improving with research and development. Several technologies have surfaced which strive to improve global high-quality access and capacity to eye care. This chapter is limited to technologies.

Technology for Improving Access to Eye Care Systems for Remote Screening and Diagnostics

The ongoing spectrum of non-communicable diseases, such as diabetes, age-related macular degeneration (AMD), and others which are age, lifestyle, and nutrition related disorders affecting the global population, have driven technology to detect diseases earlier using both remote and on-site resources. In this scenario, current technology can enhance earlier pathology detection on-site. This is helpful in reduction of clinic burden and can help reduce the barrage of patients being summoned back to clinics on the basis of diagnostic suspicion.

The above arguments, combined with efficient sensors and light sources, smartphone and tablet displays, and improved computational power chips have directed the efforts of improving and building portable diagnostic devices. This technological development has helped in several ways: by saving valuable resources a patient spends on getting needed medical treatment and allotting on the ground resources for medical care providers. This remains important for developing countries and within systems having limited resources. Device portability has also opened up another area for development and opportunity as usage in the realm of population screening tools within public health off-site settings. Many complexities involved in large population screening programs and studies have been effectively reduced as a result of availability of these devices. These screening devices are also capable of helping provide effective counseling for people “at risk.”

Significant development has also occurred in high-quality fundus photograph device capability, especially non-mydriatic devices. Other specific areas include cataract grading, tear film evaluation and anterior segment imaging. In parallel, development of devices with good specificity and sensitivity has enabled screening, while they couldn’t

be used for diagnosis, but leveraged within the low-cost segment for mass patient usage. To allow enhanced capability, multifunctionality has been incorporated which has added affordable, accessible medical care capability, such as merging of anterior and posterior segment imaging, cataract grading and acuity measurements.

In a study of telemedicine undertaken at MAILOR (Mexican Advanced Images Laboratory for Ocular Investigation of the Mexican Institute of Ophthalmology), 5,628 patients were evaluated using images sent to the center from portable non-mydriatic cameras over a period of four and a half months. A total of 4,803 (85.34%) had a previous diagnosis of diabetes mellitus. In the group of patients with diabetes mellitus, 898 (18.69%) patients with diabetic retinopathy damage were found, among whom 49.77% had signs of bilateral observable diabetic retinopathy based on the examined photographs. From the 7,812 eyes of patients with diabetes mellitus, 561 eyes (7.18%) presented some data of diabetic maculopathy. In the control group, in contrast, a recommendation was made for evaluation for diabetic maculopathy and diabetic retinopathy in 669 patients (13.92%) with diabetes mellitus. These results suggest that the use of a reading center significantly improves the sensitivity of submissions to ophthalmology.

An ongoing challenge for the development of both diagnostic and screening devices has been to create a viable stand-alone entity capable of reliably detecting, storing, and sharing information in a variety of environmental conditions, including climatic variations and fluctuations in the electrical grid. Another challenge has been to provide sterility, safety and ease of use so that untrained and semi-trained people can appropriately utilize devices in nonclinical settings. These objectives are the yardsticks for adding value in portable screening/diagnostic devices for global ophthalmology.

With imaging capability development, this area has experienced technological surge using small camera sensors, better light sources and microchip computing power. These additions have enabled many devices to have functionality comparable to a conventional diagnostic system. On the basis of functionality, these devices can be segregated into varying groups such as visual acuity measurement, anterior segment imaging, cataract grading and tear film evaluation. A brief overview of devices that are commercially available is presented in the following sections.

Taking Visual Function Testing Beyond Primary Eye Clinics

Visual function can be affected by either refractive errors or eye diseases. Vision is the universal first step of the clinical eye workup, and every primary care facility has the infrastructure to do so. However, the global demand volume is often too high, and a large segment of underprivileged society cannot attend for this basic testing to the primary centre. Hence, to make this service accessible and affordable, appropriate and affordable visual function technology should be available for each patient by a person with minimal training, globally.

Due to its importance, visual acuity measurement was among the first tests developed in the realm of portable devices. One is the VizMeter, which is a portable device for measuring visual acuity and defining subjective refraction by means of personal devices such as a smartphone [4]. Titmus (Amplivox limited) [5] is another

device, which can measure acuity, depth perception, color vision and peripheral vision. Another method of such testing is through the software apps built for smartphones and tablets called the Portable Eye Examination Kit (PEEK) Acuity [6]. It can also do refraction by displaying the letter E ("the tumbling E") and using PEEK SightSim™ which can also run a live simulation of how the patient sees the world. It relies on data storing and sharing capability among smartphones. It also tests for color blindness (blue, green, and red) using the high-definition smartphone screen, as well as contrast sensitivity testing.

Portable Anterior Segment and Cataract Diagnosis

For remote cataract detection and grading, handheld devices using tablet and smartphone capabilities with add-ons for imaging are being built. The PEEK [6] project is one such smartphone-based tool. PEEK Retina is an attachment that slips over the built-in camera of the smartphone or iPad. With the PEEK app, it can focus on the retina or cataracts and display images on the screen.

While the smartphone-based technologies are serving global patients on their doorstep, parallel updating in technology used at primary vision care centers is also undergoing continual change. One such multipurpose device is a bench top-mounted 3nethra [7] (Forus Health) which is equipped with an objective auto refractometer to measure both spherical and cylindrical eye powers, a non-mydriatic fundus camera, anterior segment imaging, as well as dry eye imaging. It is also claimed to be affordable and can be operated by a minimally trained person.

There are several other products such as Keratron Scout [8] and pachymeters [9] such as Pachmate 2 (DGH Technology, Inc.), SP-100 (Tomey, Japan), and iPac® Pachymeter (Reichert® Inc.) for keratometry and thickness maps. For corneal topography [10], EyeSys Vista, 3nethra, and others are being developed for creating axial, tangential, refractive, surface distortion maps, and keratoconus detection at the primary eye care level.

It is also felt that dry eye is the most common global eye disease and is often underdiagnosed [11]. It has also been observed that "Given a complex presentation and a variety of signs and symptoms, it would be beneficial if there was an inexpensive, readily available and reproducible diagnostic test for dry eye" [12–16]. The Portable Digital Meniscometer [17] (PDM) using image processing on iPod touch, LacriPen™ (LacriScience, LLP) osmometer using osmolarity as a biomarker [18–20], and InflammaDry® (Rapid Pathogen Screening; Sarasota, Fla.) using levels of matrix metalloprotease 9 [21, 22] are a few such devices.

Fundus Imaging for Disease Detection

According to available World Health Organization statistics, the number of people with vision loss worldwide, as of 2010, was in excess of 285 million [23]. Vision loss to some extent can be controlled by allowing easy and timely fundus screening. To make fundus imaging accessible and affordable, there are four hurdles: the bulky

system, skilled personnel, high resource requirements being restricted to high-end non-remote clinical settings, and device complexities added to overall ongoing costs.

Several fundus-imaging devices have undertaken meaningful design improvements. Hence, spectrums of devices with different capabilities, functionalities and cost have arrived. An overview of meaningful fundus-imaging devices such as Portable Eye Examination Kit (PEEK), 3nethra, Pictor Plus, etc. and a summary of their features are presented in Fig. 5.1 [24]. While the basic functionalities of all devices are similar, there should be clarity among the users about the various features which help customize selection. Another helpful buyer resource of features could be considered desirable for remote eye care access devices. Concepts, for example, could include durability, handheld, data management, external power dependability, reliability, user friendliness, cost-effectiveness, live display of parameters being recorded, resolution of the image if acquired, colored fundus/anterior segment photos, field of view and non-mydriatic. Such specifications remain unclear and subjective even now. Nonetheless, Fig. 5.1 gives a brief overview of the capabilities that are identified and how different devices can be compared.

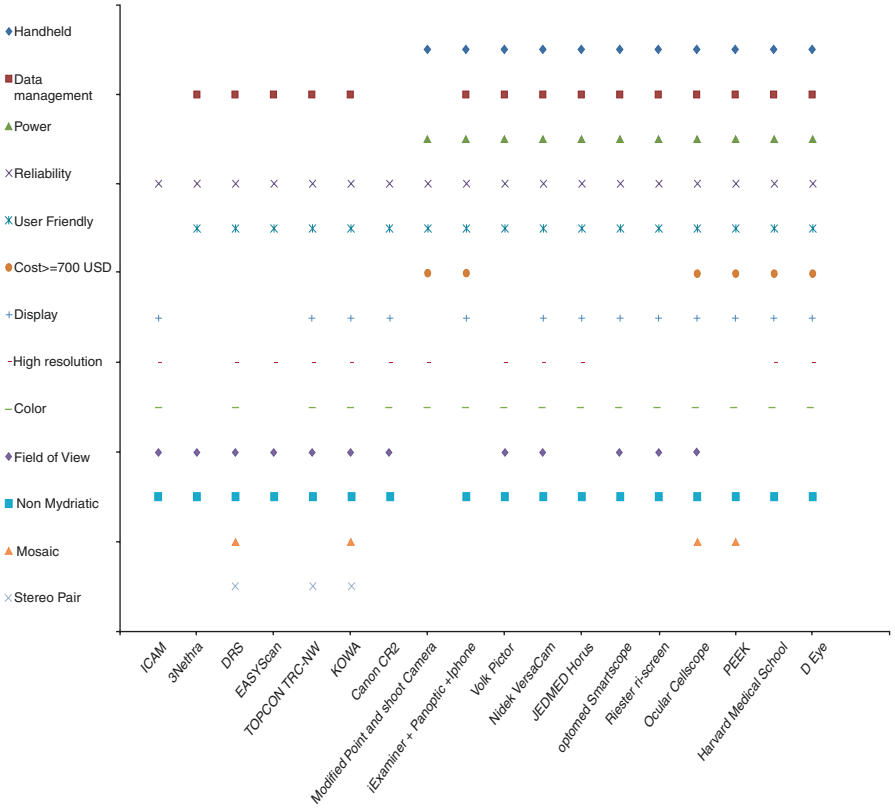

Fig. 5.1 Overview of the features in the commercial portable devices for diagnostics in ophthalmology

Technology to Improve Delivery of Remote Eye Care

Virtual interface exists now between patients and ophthalmologists, thus enhancing remote eye care delivery systems globally. Presently the majority of teleophthalmology concepts work on the precept of offline store-and-forward systems which capture medical data and then forwarded to physicians via e-mail and e-file systems [25]. However there are also online systems which provide real-time examination of eyes and allow direct online consultation and communication channels between patients and ophthalmologists.

The earliest use of teleophthalmology started in the late 1990s for diseases like diabetic retinopathy and glaucoma [26–28]. This was found to be useful both in developing and developed countries [29–31]. With the development of smartphone technology and efficient sensors, new techniques are being reported almost everyday [32–34].

The teleophthalmic slit lamp is one such product being used in clinics. A regular slit lamp has been robotized with precision stepper and servomotors to motorize all the slit lamp functions. The slit lamp's ocular lenses have been replaced with two Charged Coupled Device (CCD) video cameras. The robotized slit lamp can be operated from any remote location with an internet-connected computing device.

Placing such slit lamps at the vision centers located at a primary village level would function nicely as screening tools, whereby patients can be seen "just in time" and "on the go" by ophthalmologists stationed in off-site secondary centers and receive sight saving-guided treatment to include faster referral to the secondary or tertiary centers by the vision technicians manning the primary center. This can also be used for follow-up of post-operative eye whose procedures were performed within off-site secondary or tertiary centers.

Figure 5.2 shows a patient at teleophthalmic slit lamp at primary eye care center (left) and an ophthalmologist at tertiary eye care center – 375 km from the patient's location (right).

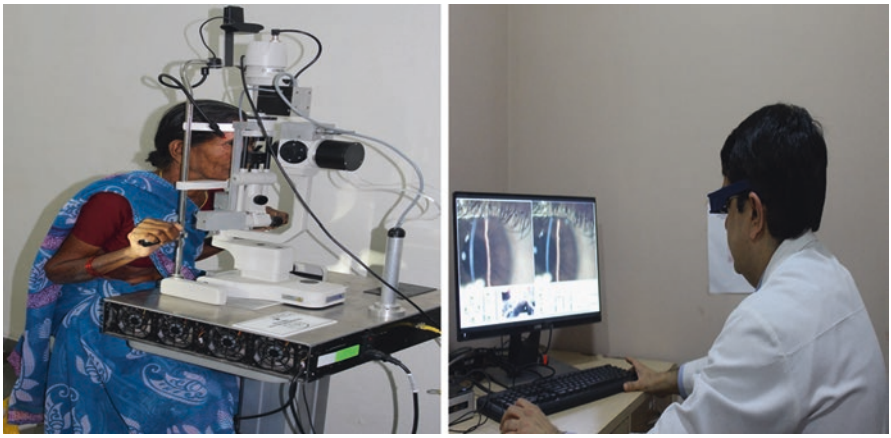

Fig. 5.2 (Left) A teleophthalmic slit lamp at primary eye care center. (Right) Ophthalmologist at tertiary eye care center – 375 Km from the patient's location

Placing such units at local secondary or tertiary centers allows for cross consultation in critical situations and permits improved follow-up of clinically critical patients who cannot travel to specialist location.

While the initial establishment-related costs are high for such portable devices, these can be highly cost-effective solutions in the long run [35, 36]. These savings come in three variables: cost of travel, time, and energy of the patient (and clinician); ability to cover clinical services to larger demographic areas; and cost of tertiary care by reducing the number of people arriving for follow-up which is instead displaced to closer proximity (Table 5.1).

The use of technology is highlighted by this case of an existing teleophthalmology pilot project at L V Prasad Eye Institute (LVPEI), where a number of teleophthalmology slit lamps are built and installed at several remote locations in rural areas of Telangana state of India. These are adaptations of slit lamps built by Ophthalmic Biophysics Center at the University of Miami. An example is a case of a 7-year-old female child hailing from a village near Paloncha, Khammam District, in Telangana. She developed a corneal scar in her left eye following an episode of fungal keratitis, severely affecting her vision. Paloncha has a LVPEI's secondary eye care center about 375 Km from the main campus of LVPEI in Hyderabad.

The general ophthalmologist at the secondary center consulted cornea specialist at the main campus of LVPEI in Hyderabad for further evaluation and management of the scar. With the help of the teleophthalmic robotic slit lamp, the cornea specialist sitting in Hyderabad performed a detailed slit lamp examination on the patient who was there in the secondary center. Through this the patient was diagnosed with an anterior stromal scar and was advised for deep anterior lamellar keratoplasty (DALK) surgery.

The surgery was performed in the main LVPEI hospital in Hyderabad. However, following the surgery, all the follow-up examinations were being performed through the tele-ophthalmic slit lamp. With timely treatment, the corneal scar has been treated successfully saving patient's eye from going into amblyopia. Due to this technology, her parents do not have to travel to Hyderabad for frequent post-op examinations. This surely has saved the family the trouble of frequent visits and the travel expenses that they would have otherwise incurred.

Table 5.1 Cost-benefit comparison of use of technology for optimal utilization of resources

Resources needed for delivery of treatment	Change in utilization against standard practice
Clinical facility and resource usage	More optimally utilized
Clinician's time spent for each consultation	Decreased
Clinician's effort for consultation	Decreased
Facility or new technology cost	Increased
Patient's effort for consultation	Decreased
Patient's time spent for consultation	Decreased
Patient's cost for consultation	Decreased

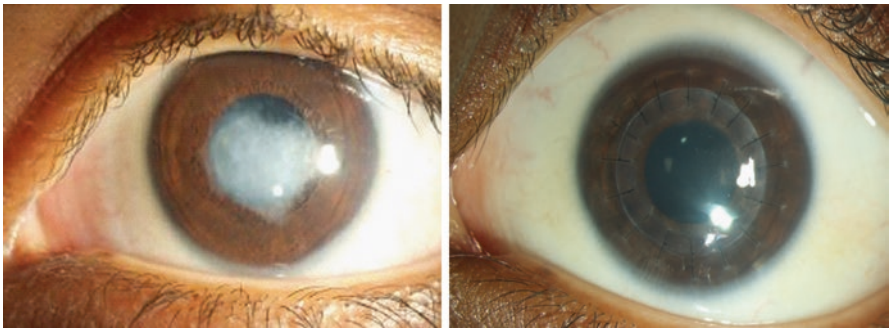

Fig. 5.3 (Left) Pre-op condition of patient as seen by teleophthalmic slit lamp. (Right) Post-op condition of patient as seen by teleophthalmic slit lamp

Figure 5.3 shows pre-op condition of a patient as seen by teleophthalmic slit lamp (left) and post-op condition of the same patient as seen by teleophthalmic slit lamp (right).

This demonstrates that the timely intervention for detection and management of an eye ailment enables the ophthalmologist to restore a patient's vision. All referral and post-surgical follow-up cases can be examined at the remote vision center, and treatment and follow-up care based on the complexity and severity of the patient condition(s) can be appropriately referred to the secondary or tertiary center.

Technology to Build Capacity for Delivery of High-Quality Eye Care

In addition to disease diagnosis infrastructure development, it remains important to "on the go" manage, analyze, and share critical healthcare information. As the patient base continually increases, the number of reports required from clinicians also increases exponentially. To help the clinicians offer high-quality services to a larger number of patients at low cost, several technologies are currently being used. These technology developments are focused on several areas: organize, communicate, and update data as well as data analysis.

In an effort to improve organization, communication and storage Internet services, there are secure memory chips and clouds with database management systems and electronic medical record systems. Millions of records are now available online and can be accessed by authorized users from remote locations of their choice. These databases can store large masses of healthcare information with patient history, exam findings, operative reports and demographics being securely accessible at any point of time.

To enable the clinician to remain efficient as well as reduce the underlying skill set requirements for electronic patient record analysis, automated tools for analysis of data, segmentation of disease indicators, and automated decision support systems are available [37]. These technologies are widely used in fundus image analysis for detection of diabetic retinopathy as well as other retinal disorders, cataract grading,

visual morbidities and functional vision measurements. They detect diseases and can also raise an alarm for the clinician to see specific diagnostic features. Image analysis and segmentation are also aiding clinicians to do high-quality efficient eye examinations and conclude with disease progression, treatment outcomes, and analysis of complications.

Advances in technology are also impacting the quality of service delivery by improving surgical skills training. Improved realism in non-biological materials and models such as the surgical ocular simulation system (UK) has reduced the cost of alternatives to the traditional animal eye wet lab. Combined with utilization of advances in skill-training methodology, these models have improved the effectiveness of pre-surgical cognitive and psychomotor training.

The world of virtual reality (VR)-based training is exploding into the field of global ophthalmology and as a result increasing access of clinicians to world-class training. The gold standard for VR training includes both the look and feel of live surgical experiences for a complete training solution [38, 39]. The full-immersion virtual surgical training environment is an appropriate goal given the demand for reduction in the dependence on animal eyes and the priority of improved safety and efficiency in training.

A review of existing VR simulators including the Virtual Phaco Trainer/MicroVisTouch (ImmersiveTouch; Chicago, IL), EyeSi simulator (VRmagic; Manheim, Germany), and PhacoVision simulator (Melerit Medical; Gothenburg, Sweden) highlight the progress being made as well as the opportunity for new development. Only a few years ago, Young and Greenburg [40] suggested "Widespread implementation of VR simulation in ophthalmology graduate medical education programs has been limited by concerns about simulator realism fidelity, lack of evidence for surgical skills transfer (VR-to-OR), and startup costs."

Construct validity studies suggest that the potential for the technology as a training tool is high, but its efficacy for improving operating room performance has yet to be proven. Studies show a small reduction in task performance time (capsulorhexis) for the beginning surgeon, and Lowry et al.'s review of costs suggests that VR cataract surgical training for resident cataract surgeons is not yet cost-effective especially for smaller programs [41]. Despite these limitations there is widespread acceptance of VR training systems as the future of training because of its potential to improve training trajectories and trainee surgical outcomes [42].

The potential for further development of affordable virtual training environments, using high-fidelity simulation remains attractive for both safety and effectiveness. The aviation industry has for years now successfully embraced development of and deployment of level-D simulation in their industry, which is now the standard requirement for all commercial and non-commercial training [43, 44]. Based on this aviation model, simulation development of an alternative approach was proposed by HelpMeSee [45], a humanitarian organization formed to address the problem of cataract blindness using a virtual training environment as the cornerstone of a scalable training system for MSICS (manual small-incision cataract surgery) cataract surgeons.

Conclusion

Recent technological advancements have enabled our global capability to access eye care in many ways. Most products are new and constantly being updated; hence the available options are ongoing. Lastly, with improved technical capabilities, current products and technologies at the time of this writing will rapidly become obsolete as further improvements and more technologies come to the global market.

Compliance with Ethical Requirements Ashutosh Richhariya, Mukesh Taneja, Glenn Strauss, Matthew Walden, Jean Hausheer, Van C. Lansingh, and Rohit C. Khanna declare no conflict of interest.

No human studies were carried out by the authors for this article.

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Affordability and Financing for Eye Care

6

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Money isn't the most important thing in life, but it's reasonably close to oxygen on the 'gotta have it' scale
– Zig Ziglar

As implied in the quote above, finance, though a tool or a resource, is an essential determinant of eye care service, pretty much on all dimensions. It determines the scale, scope and depth of coverage, quality as well as the sustainability of the programme. Since most aspects of eye care interventions are elective, it does not by itself generate a priority or commitment in funding as maternal child health does. It is in this context that we have to fully understand who the providers of eye care in any given country are, how they are funded and the funding options. We need to understand funding towards both the infrastructure development and the ongoing delivery of care. Funding also has to be ensured for all other enablers of care such as the human resource pipeline that is essential to staff growth as well as attrition, which is inevitable in all settings.

How much funding is required is broadly defined by two factors. When it comes to infrastructure development, the overwhelming influence comes from the scope and design of the services. While in the case of ongoing delivery of care, it is the number of patients served, efficiency and quality that drive the cost and thus the funding. From this perspective, it is also necessary to understand

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these aspects of eye care delivery to the extent it relates to financing or funding. This chapter aims to explore this in order to give the readers a comprehensive and holistic understanding of financing of eye care services in developing country settings as well as the dynamics on the ground that affect or influence financing.

Provider Mix

In almost all countries, there is a mix of providers of eye care, though the proportions may vary very widely. The major providers can be broadly grouped as:

- *Government health system:* In countries where private entrepreneurship in healthcare is not encouraged or not developed, the essential provider tends to be the government health system. This is true in many of the Southeast Asian countries, China, Africa and Eastern European countries.
- *Private health providers – for profit:* Oftentimes, the doctors in the government health system would also have their own private practice through which they account for a significant amount of care. In countries where this space has been opened officially to non-government providers, there is a significant amount of care being provided by private eye hospitals or practitioners and the not-for-profit sector. This is largely true in countries like India, Nepal, Bangladesh and Latin America. In countries which have national health insurance, such as China, Vietnam and the Philippines, insurance reimbursement for ophthalmic services, surgery and procedures has supported the growing private practice sector. In the Philippines, 90% of eye care is provided by the private sector with reimbursement coming from PhilHealth, the national healthcare insurance scheme.
- *Non-government health provider – non-profit:* The mission hospitals and the charitable eye hospitals fall under this category. The reason to start such hospitals and their purpose have been to provide health and eye care services to the community, and in most instances the focus has been on the poor and vulnerable segment of the community.
- *Periodic overseas eye care "expeditions":* In several countries where there is an acute shortage of ophthalmologists and thus the eye care service, it is not uncommon to see surgical expeditions from other countries often done with some form of local partnership with the government or the community. Such expeditions often come from the West, but increasingly they are also done by developing countries like India and Nepal.

Financing Investment Versus Operations

Financing capital investment and financing the operations have very different dynamics and sources of financing. The implication of funding varies significantly on who the provider is and what the overall mix in the country is. In countries where

the government is the major provider, it becomes the government's responsibility to provide such funds either out of its tax revenues or from bilateral funds, grants and donations often from other countries and agencies. In the private sector, financing for investment is left to the individual or the private hospital, and the most common approach has been either funding from saving or debt finance. The user fees from the patients or insurance covers the ongoing delivery of care. The NGO providers often look up to external grants and donations for both investment and provision of care. The sporadic overseas missions almost always finance their work through cash and in-kind donation often from the country of origin of such missions.

(i) *Financing the establishment of an eye care programme and capital expenses*: The sources of funding and their outlook tend to vary depending on who the provider is. Table 6.1 summarizes the most common funding sources for the broad categories of providers.

Because of the differing mandates of the various providers, their vision or purpose varies and that in turn has implication on the financing. In the case of government, the mandate always tends to be for the country as a whole, and thus the scale is determined by the population of the country. While they may choose to phase out the investment with a pilot programme, the overall design of eye care services tends to be the single largest influencer of the quantum of investment. More often than not, a standardized uniform model or package of space and equipment is applied across all identified locations regardless of the local context and need. So it is not uncommon to see this resulting in duplication or non-use of resources.

In the context of private providers, the financial pressures brought on by the investors or the providers own personal aspirations, drive investment and pricing decisions. In recent years, there have been instances of eye hospital chains coming up in several countries, notably in India and China. These are often funded by venture capitalists with the intention of exiting the investment by going public at a later date or being bought out. These investments are driven by the goal of rapidly creating a large customer base, a delivery network as well as profitability. However, the private sector in developing countries is still essentially characterized by single practitioner or small group practice. So, by design, these often tend to be small and often compete for the same pool of patients who are accessing eye care with a willingness to pay for the same.

Table 6.1 Providers vs. source of capital financing

Provider	Source of financing
Government	Budgetary allocation from government (tax) revenues, bilateral loan/grant arrangements with other countries, World Bank, International Monetary Fund (IMF), International Finance Corporation (IFC), etc.
Private	Self (including friends and relatives), debt financing from banks and financial institutions, investments from venture capitalists, equity, etc.
Non-profit (NGO)	Self and through grants and donations
Overseas surgical campaigns	Cash and in-kind donations

In the non-profit sector, the design often is for serving the poor, either for free or at low rates. Hence the facilities tend to be rather basic and scope of service limited to the most common conditions. Many of these programmes are supported by international non-governmental organizations for their operating expenses. Each year they have to "reinvent" themselves through garnering sufficient donations locally and internationally to continue service delivery. Many of these programmes are located in areas with sufficient population density and income. With the proper planning and support, they could become financially self-sufficient. International and local NGOs need to study their programmes to determine which ones can be made self-sufficient, so that they can reallocate a greater percentage of resources towards "start-up" capital by not having to spend so much on ongoing operating expenses.

While there are these differences, when it comes to investing in an eye care programme, there is one common theme that tends to cut across all providers. In making such investment, the providers have a strong or almost an exclusive "input" orientation. In simple terms, an eye care programme seems to translate into building and equipment. In some instances, this may extend to include human resources where again the focus is often limited to ophthalmologists. It is rare to see providers taking into account the entire care delivery process and ensuring that all needed resources are in place. Building an eye care programme ought to include resources and processes to enable proactive demand generation, ensuring efficiency as well as quality. While these are all in the realm of operational stage, all of them have investment implications by way of technology, strategic directions, orienting and training the staff to ensure alignment to purpose and the required basic competencies. This focus towards just creating the "input" – the physical facility – is probably one of the reasons why we tend to see lots of facilities that are suboptimally utilized.

"Impact investing" has found eye care in recent years. Acumen Fund financed a diabetic retinopathy management programme in Nairobi, Kenya. The Deutsche Bank Eye Fund, done in collaboration with the International Agency for Prevention of Blindness and Ashoka, is a $15 million debt financing fund that supports three programmes in China, Africa and Latin America. This is an affordable debt financing at 5.5–6% interest that has a 3-year grace period of interest-only payments and full repayment in 7 years. Eye Fund One has achieved sufficient proof of concept to the extent that Deutsche Bank is now planning a larger $50 million fund for eye care.

(ii) *Financing ongoing delivery of care*: This aspect of financing has turned out to be the most significant determinant of eye care services in terms of how much eye care gets delivered. Free care, insurance and user fees are the front-end mechanisms that the patients interface with. In the back end are the government budgets and (tax and other) revenues, grants, donations, bilateral aid, insurance premiums and sometimes quotas on how much care can be provided. This varies somewhat from provider to provider (Table 6.2).

While the private sector depends almost entirely on user fees paid out of pocket or health insurance reimbursement, in the government sector, this is supplemented from

Table 6.2 Providers vs. source of operation financing

Provider	Source of financing
Government	Budgetary allocation from tax revenues, bilateral loan/grant arrangements with other countries, World Bank, International Monetary Fund (IMF), International Finance Corporation (IFC), etc.; user fees
Private	User fees (out of pocket) or health insurance
Non-profit (NGO)	User fees (out of pocket) or health insurance, grants and donations

the health budget based on its policies. In many government hospitals, the number of people served especially those receiving surgery, is limited by the budgetary allocation. In the case of the non-profit sector, revenues from user fees often have to be supplemented by donations and grants. The proportion of donations and grants to the total revenue varies widely with many non-profits being heavily dependent on them. In such institutions the quantum of care gets limited to the extent of donations or grant funding. However, there are a few emerging models wherein the non-profits are fully self-reliant through user fees even while providing a significant amount of care either for free or below cost. The financial viability is largely a reflection of the services provided, outcomes and its attractiveness to the general community.

There are several Latin American models of state intervention in the health sector:

- *Unified Public*: In this type of system, the government regulates finances and provides services through a vertically integrated system. In its most extreme version, it can only be found in Cuba. It is also in force in Costa Rica but in a less rigid manner as it allows you to choose other service options. Countries that implement this system manage to establish equity, but do not necessarily ensure the quality of care nor coverage. Also, the centralized public administration negatively impacts efficiency.
- *Public Procurement*: This model consists of a financing private provision where the separation of functions is achieved by hiring public or private providers by the state. In cases where this system is implemented, companies have more choices to compete. Often there is an overall budget that is directed to providers based on criteria of productivity and quality. This was in vogue in Brazil. This model failed owing to coordination problems and lack of appropriate control mechanisms to prevent unfair exploitation of the scheme.
- *Segmented*: This system which is common in Latin America covers three different subsystems of provision: one of social security which covers workers in the formal area; one public through a ministry serving the rest of the population; and one private that provides services to those who pay a monthly fee. As there is no integration between the three, there is a lot of duplication and waste of resources. The services that cater to the poorest sectors have to face a shortage of resources.

Insurance is emerging as a significant mechanism for financing the cost of care by individuals. Until less than a decade ago, the penetration of health insurance was quite limited in developing countries. When the regulatory framework became more enabling, private health insurance became an option. However this was largely used by the more affluent segment of the society and white collar workers with reliable monthly incomes. This has changed in recent years with many countries recognizing that healthcare costs especially the catastrophic conditions (trauma, accidents and heart attacks) drive the disadvantaged into irretrievable poverty. Many countries have now introduced health insurance schemes targeting the poor or to bring about universal coverage from an affordability perspective. In some countries, the individual has to contribute a small premium, while in others, the government pays the entire premium.

In some countries, such as Rwanda, the government has instituted comprehensive health insurance that successfully covers many aspects of primary and secondary eye care service delivery. Cataract surgery, provided at a government facility is included in the nationwide programmes. Through the community-based health insurance scheme, the current amount that can be billed for cataract surgery is around US$47 inclusive of all consumables. Rwandans pay the equivalent of US$4–9 per year into the programme, which is supported by a combination of government income as well as international donor support [1]. Non-government facilities are not covered by the community financing scheme but are covered by the social health schemes that cover all public servants and military personnel, pensioners and their dependants in Rwanda (Rwanda Social Security Medical Scheme). Hospitals can bill up to US$600 for cataract surgery inclusive of all consumables. Workers pay 7.5% of their basic salary, and the employer contributes a similar amount. While Rwanda's health insurance scheme covers the entire population, health insurance schemes in most other African countries only cover small segments of the population or have limited benefit packages that may not include eye health services. That said, in some settings, reimbursement rates are sufficient to provide some "profit" for the eye unit.

Two Case Studies: Financing of Eye Care in Vietnam and the Philippines

Health Insurance in Vietnam and How It Affects Eye Care Delivery

On the face of it, Vietnam's health insurance system appears well structured to help the country meet the challenges of universal eye health. Enshrined in the Law on Health Insurance (No. 25/2008/QH12), a single-payer national health insurance is in place which is administered by Vietnam Social Security (VSS). At present, 72% of the population is covered (with 97% of the poor covered via tax-financed subsidized premiums). Most inpatient services are covered, including eye care treatments. Premium payments are broadly progressive (within and across cohorts), with

mandatory contributions from formal sector workers. Formal sector workers comprise 16% of the membership but contribute 39% of funds. Non-contributing members, such as the poor and children under 6, represent 49% of the membership but only 34% of funding [17].

Coverage is not yet universal, and access to services is still on the way to becoming equitable. Lower-income households still face the threat of going into poverty as a result of having to spend a disproportionate percentage of their income on health. As has been noted elsewhere, this study has shown that service access in eye health is not presently equal for all in Vietnamese society [11]. Cost sharing is inbuilt into the Vietnamese health financing system through mandated patient co-payments. This means that all patients, both poor and rich alike, are required to contribute a relatively small share of their healthcare costs at the point of service. A general under-provision of services in rural and remote areas can increase out-of-pocket costs further for patients as they need to travel to where services are available. Perceptions of poor quality in the existing district and provincial hospitals can also increase costs as patients bypass referral pathways and present directly at tertiary hospitals in major cities. This is despite official mechanisms in place to discourage such behaviour in which patients' co-payments rise in line with the level of bypass.

Such cost sharing, coupled with rising costs for services, provides some explanation of why out-of-pocket expenditure on health remains high in Vietnam, accounting for roughly 37% of total health expenditure in 2014.[1] This high percentage of out-of-pocket expenditure places an inordinate burden on people with low income.

In the case of eye care, and in particular cataract surgery, out-of-pocket expenses rise further when doctors convince patients to purchase higher-priced consumables, which increases the overall cost of surgery beyond what insurance reimburses.

Health Insurance in the Philippines and How It Affects Eye Care Delivery

The Philippines has one of the longest histories of social health insurance in Southeast Asia [18]. On the face of it, the system, known as "PhilHealth," has the features required for universal eye health: coverage across a very high proportion of the population, inclusion of most health services and a case-based system of fixed payments that provides reimbursement for service providers. For instance, for cataract removal, payments of $16,000 (approximately $350) are provided, which is generally high compared to reimbursement for other Asian countries such as China and Vietnam. Equity provisions are built into the system to ensure that indigent people can be covered for health services. National and local governments sponsor, fully and in part, insurance coverage of target groups such as the poor (known as the 'indigent') and those aged over 60 and children. The national government aggressively expanded coverage rates between 2010 and 2014 by enrolling poor households, using funds from the proceeds of a consumption tax on cigarettes and alcohol

[1] Out-of-pocket expenditure (OOPS) as % of total health expenditure (THE); Viet Nam; 2014. Source: WHO Health Accounts. Available from http://www.who.int/health-accounts/en/.

(known as the "sin tax"). Public hospitals also sponsor eligible patient's first annual contribution to the scheme at the point of care if they have fallen through the cracks of coverage. Indigent patients are prohibited by *PhilHealth Advisory No. 09-01-2011*, from paying any additional out-of-pocket co-payments in accredited public facilities for service covered under the insurance package.

In reality, however, the health system is grappling with the problem of meeting the needs of many at the lower end of the socioeconomic spectrum. This is particularly the case with eye health where the large outstanding backlog of untreated cataract cases, which are concentrated among the poor, is an indication that people are not accessing eye health services in the volumes needed to eliminate avoidable blindness.

Since public hospitals are the only facilities required to provide services free at the point of service for indigent people, access for low-income people is often limited to urban areas where government facilities are located. Care is therefore less available in areas of lower population density. By forcing patients to pay additional costs for treatment (either directly or indirectly in travel, for instance), it is also failing to offer financial protection for vulnerable people who are blind or vision impaired. A lack of financial autonomy in government facilities makes improvement a challenge for public hospitals. A complex system of revenue sharing between professionals and facilities and transfer of hospital income to the local and central government level restricts the autonomy of eye departments and influences budgeting decisions.

Conversely, relatively lucrative PhilHealth reimbursement rates for cataract surgery provide the private sector, where it exists, with a strong incentive to increase volumes of indigent patients. The revelation of misdiagnosed need and fraudulent claims for cataract surgery, however, has shown the importance of upholding rigorous eligibility guidelines and quality standards. In response to the fraudulent claims in July 2015, PhilHealth imposed a daily and monthly cap on the number of cataract surgeries surgeons can claim in non-training hospitals [15]. While this is designed to prevent abuse in claiming benefits for unnecessary surgery, and may make sense for private providers, it also has the effect of rationing services in public facilities. This undermines patient access in a country that needs to greatly increase its cataract surgical volumes among the poor.

The revelations have also drawn considerable attention to how eye health is financed and the sustainability of the system in its current form. The total estimated operable cataract in 2016 is 970,236. In 2014 PhilHealth reimbursed 128,331 cataract removals, which was the fourth highest procedure PhilHealth paid for, comprising 2.5% of total outlays. Surgical volumes therefore need to increase dramatically to meet the goals as set out in *Universal Eye Health: A Global Action Plan 2014–2019.* The implication is that the total amount of PhilHealth spending on cataract surgery must rise to accommodate any increase in surgical volumes. The growing elderly population, along with the recent inclusion of the elderly in automatic lifetime-sponsored coverage, is only likely to intensify these spending pressures.

The key for PhilHealth is to find ways to extract as much value for money as possible from expenditure on eye health – including targeting of the neediest. There is a clear risk that, without some reform, a re-evaluation of how eye health is financed in the Philippines may be imminent. Caps imposed on surgical volumes (due to the recent issue of unnecessary cataract surgery being performed) are an ominous

portent of how sweeping regulatory changes to improve the effectiveness of government spending may actually run counter to public health goals of reaching those in need of cataract surgery.

Organizational and institutional reform of public health facilities could help unlock the considerable potential underutilized capacity in the system and increase the availability of quality affordable eye care treatments. Reducing the overall cost of cataract surgery, while maintaining quality will aid in rationalizing and extending limited healthcare insurance funds. Providing eye departments within public hospitals with the autonomy to control decisions on purchasing, investment and staffing should assist in increasing both the efficiency and equity in the public eye health system.

The private sector can, and should, also play an important role in increasing accessibility of affordable services. As has been demonstrated in a number of other countries, private facilities can sustainably provide low-cost services to the poor while remaining profitable by combining high volumes and low costs. A similar model could be developed in the Philippines using the PhilHealth reimbursement as a revenue source.

Social Impact Funding

Today we also see a lot of corporate bodies making philanthropic commitments for various causes in the society, and this is opening up the opportunity for eye care as well. In some countries like India, this is mandated by law. Corporate social responsibility (CSR) is becoming an accepted deliverable, and many of the corporates are now subscribing to the philosophy of "Triple Bottom Line" – social, environmental (ecological) and financial. Probably as an outcome of the corporate involvement in the social sector and for other reasons, there is an emergence of the new type of funding called social impact funding or development impact funding. This vocabulary and the funding platform are still emerging with initiatives like "Social Impact Bonds" or "Development Impact Bonds". In this approach, funding is done towards measurable beneficial social impact or "result-based financing". Some of them also expect a nominal financial return as well when there is a viable business model. In the case of eye care, for example, this could translate into funding "successful sight restoring cataract surgeries". These are nascent times for this type of funding, though some eye care programmes are negotiating funding under this paradigm. If this grows, which we hope it does, it will bring about the much needed focus on quality, performance and a much higher level of accountability.

Trends and Ground Realities in the African Context

Financing of eye care services in sub-Saharan Africa continues to undergo change with a multitude of models across the 56 countries that comprise the continent. While there is no single model that can define how eye care is being financed, there

are some clear trends. Three general trends that have been noted in the last 5 years are:

- The adoption of nationwide health insurance schemes that cover eye care services
- Growth in private practice in rural as well as urban areas along with, out-of-pocket financing
- Greater willingness by international non-governmental organizations and others to invest in eye care service delivery models that focus on improving organizational and financial sustainability

Private practice ophthalmology in the African continent, once limited to capital cities and non-surgical ophthalmology, has evolved in many places into a model that is starting to resemble private practice found in developed countries: high-tech equipment, global standards of quality of care and sophisticated marketing of services are becoming the norm. In countries like Kenya, the large number of well-trained ophthalmologists and the saturation of ophthalmic services in the capital Nairobi have led to expansion of private practice to many of the smaller towns in the country. In countries like Burundi and more recently in Congo Republic and Malawi, innovative approaches to developing and operating private, for-profit community eye centres that also aim to meet community needs suggest that running costs can be recovered within 6–12 months of opening and start-up costs (primarily infrastructure and equipment) can be recovered within 3 years. In settings where government contribution to eye care services is minimal, private practice is generally the only eye care financing model available.

External support for eye care, often through partnerships between international NGOs and individual hospitals or eye units, continues though there are some differences from the mission hospital model of the past. While financing 20 years ago was generally focused on either direct support to a mission hospital or for government eye units – equipment, instruments, consumables and staff training – this has changed. Some large mission hospitals now are financially sustainable, and external support is limited to specific projects. Governments, particularly in Anglophone Eastern Africa where decentralization of health-related decision-making has been most prominent, have allowed eye units in government hospitals to start on a path of organizational and financial sustainability. While contributions by various stakeholders vary [5], it appears that external financing for eye care in many rural African settings will remain essential for some time into the future. Financing by international NGOs and international service clubs has shifted to creation and mentoring of management and organizational systems necessary for (eventual) financial sustainability.

While there have been many financing changes across the continent, it remains a patchwork, between countries and even within countries [3]. Some countries, such as Uganda, continue to claim that eye care is to be provided “free of charge”; as government does not prioritize eye care within healthcare funding, this has resulted in no eye care services in some areas of Uganda. Attempts to institute even limited

cost recovery have achieved limited success due to many factors, including low willingness of the population to pay for eye care services [7]. Some international NGOs donate consumables and support outreach, but when this support ceases, programmes tend to fall apart. Researchers in Ghana noted that the more complex the eye care activity, the lower the compatibility of the activity within the health system, and the lower the observability of the activity led to the least likelihood of being sustained after external funding ended [2].

Generally, government health budgets have supported the personnel costs to provide eye care services. It has been noted that the number of ophthalmologists and/or nonphysician cataract surgeons is near to the VISION 2020 target of four per million population in Africa, yet the cataract surgical rate remains stubbornly low in many countries [13]. While there are many reasons for underutilization it does illustrate the fact that simply training more eye care providers, as recommended by some [14], will not lead to improved eye care services (quality and quantity) by the population. While some governments (e.g. Kenya) have routinely supported purchase of ophthalmic equipment, this has not been the norm. Equipment purchase, when government supported, tends to be a "one-off" in response to a political agenda rather than based on a long-term strategic plan. External financing of more specialized eye care, such as the development and running of Child Eye Health Tertiary Facilities and diabetic retinopathy programmes, is necessary given the high cost of comprehensive services [6].

Multiple authors have noted that the lack of transport to hospital for cataract surgery remains a significant barrier to use of existing services, even when these services are provided free or within the capacity of the population to pay [8, 12, 16]. Accordingly, successful programmes often package the cost of transport into their financing models [10].

Financing of eye care service delivery throughout Africa will continue to evolve; providers, governments, donors and NGOs will all benefit from a growing body of evidence of effectiveness on different financing models in the coming decade. Low population density, inadequate road infrastructure and public transportation will continue to pose challenges in making eye care affordable and accessible.

Ground Realities in Latin America

The system of medical services in Latin America is overloaded with technical and organizational deficiencies and deteriorating infrastructure: the problem of healthcare is perhaps one of the most complex issues faced by any public administration, because what the people demand is greater than the resources available. Due to the complexities of insurance schemes and social security, public hospitals forego these two possible forms of payment and treat these patients for free or subsidized rates. This results in high expenses for the hospital and often low-quality surgeries for the patients.

The administrative expenditure is high as there are no controls in place and no prioritization of resources. This problem could be solved with proper resource

allocation, redefining the system so that the vast amount of human, technological, financial and community resources can be used appropriately.

While a section of the population has privileged access to good care, the rest must do with the inadequate coverage and care. They have to contend with care that has little accountability and a medical practice pressured by the market or discouraged by the lack of financial and professional incentives, coupled with low wages.

Private care is provided by individual doctors, and those with the ability to pay form their major clientele. Many of these private practitioners work in the morning in the public sector and in the afternoon go to their private clinics. These doctors with private practice don't have an easy way to make capital investments for infrastructure. Some of these private clinics were founded by families of ophthalmologists and have been passed from generation to generation. Most ophthalmologists tend to have supplier credit and mortgage loans to grow their practices.

Public hospitals do not invest in primary or preventative healthcare – they instead focus on health conditions that could have been prevented. In addition, these hospitals do not focus on high-quality or volume services because there is no incentive to do so. The aim is to change this philosophy and encourage the public sector to care about these issues. State intervention is necessary because, in a completely private system, the lower strata of the population cannot afford the costs of medical care payments. So the government must ensure equity of health services in both comprehensiveness of care and access.

Those responsible for this are the political representatives who should ensure that resources are not wasted and that the production cost is minimized.

Cost

The other dimension of financing which is much less discussed is the cost aspect. In most instances the prevailing costs are taken as the benchmark and the financing is driven by it. There is seldom a reflection on whether such costs necessarily have to be incurred or on ways to bring them down. When such reflection and necessary changes are not factored in, the cost continues to rise owing to inflation, inefficiency and newer technologies. This is most acutely felt in developed countries, many of whom are spending well above 10% of the gross domestic product (GDP) on healthcare with the USA leading at over 18% (World Bank http://data.worldbank.org/indicator/SH.XPD.TOTL.ZS) [19]. Even in some low and middle income countries (LMIC), governments tend to subsidize cataract surgeries at very high levels without any introspection or wider benchmarking to see whether costs at such high levels are justified. Figure 6.1 broadly describes the aspects of the eye care delivery that are amenable to cost-containment mechanisms and financing the services including user fees.

Overall the drivers of cost could be grouped into two broad buckets – one as *internal drivers* of cost and the other as *external drivers* with an overarching concept of *cost containment.*

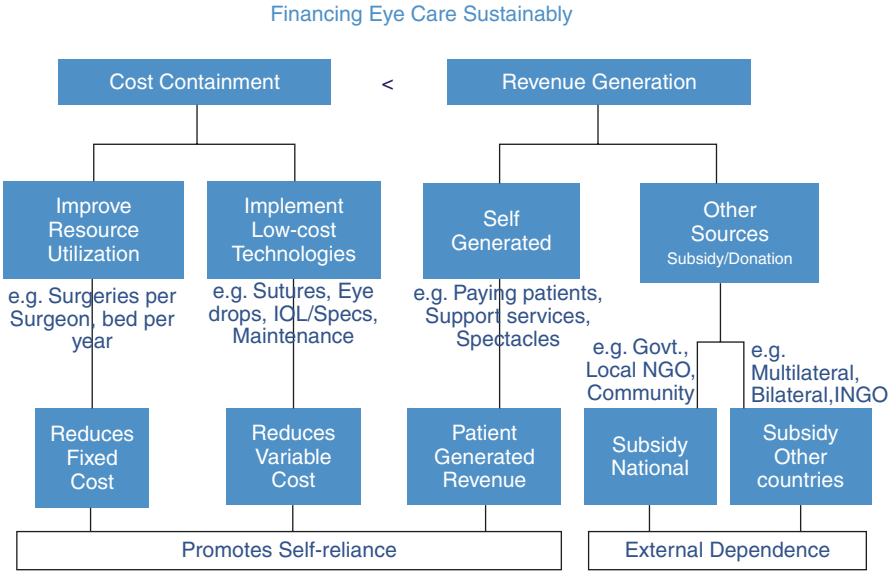

Fig. 6.1 Financing eye care sustainably. (Modified from Foster and Thulasiraj [20])

(i) *Internal Drivers of Cost*
The internal drivers of cost can be listed as:

- Efficiency
- Clinical and patient flow protocols
- Quality

As in many service organizations like hotels or airlines, eye care also tends to be heavily "fixed cost" driven, i.e. most of the expenses are incurred regardless of the level of utilization or output. For instance, the salaries, utility expenses, maintenance contracts and depreciation are incurred whether they are used optimally or not. Thus, it becomes very critical to ensure high level of resource utilization especially given that in all developing countries, only one in four to five people needing eye care is being reached [9]. If one uses average surgeries by an ophthalmologist per year as a metric of efficiency, we can see a huge variation between countries. In most Latin American and African countries, this would be less than a hundred or at best in the low hundreds. In Nepal, it is well over a thousand, and in several institutions, the productivity of an ophthalmologist is well over 2,000.

Such variation is a reflection of many factors such as pricing of service, level of proactiveness in generating demand from the community and patient flow protocols. In some institutions, undergoing a cataract surgery may involve four to five prior visits, while in more efficient ones, it could be on a single visit or at best two visits. The clinical protocols which define what consumables and technology are used and how they are used defines the variable cost per surgery or procedure.

Governments or funding agencies which don't question this cost tend to reimburse this at high levels, which in some ways institutionalize the low productivity levels and the current protocol as the norm.

(ii) *External Drivers of Cost*
The broader ecosystem within which eye care operates is also a big determinant of financing, both for investments and ongoing delivery of care. This ecosystem from a financing perspective is a result of

- Government policies, regulations and import tariff
- Guidelines and rules around establishment and running of hospitals
- The practice of the trade especially when it comes to pricing, incentivizing purchases and service support for equipment
- The availability of trained human resources as well as the regulations around certification, accreditation and how the eye health personnel are used
- The outlook of the association of the professionals such as association of ophthalmologist or optometrist towards the eye care needs of the community

Most countries including small ones with five million population or less tend to have their own regulations around registration of imported pharmaceutical products. This is in the context of almost complete reliance on imports. While in principle such guidelines are necessary, how they are framed and the cost involved in such product registration severely affect the availability of surgical supplies and pharmaceuticals in those countries. In some countries even for existing and widely used products (in other countries), the registration process can be as elaborate as the registration of a product for first time use. In some countries, the fee for registering for a product is quite high, and its validity is limited to a few years. While the industry might be willing to put in the required effort and pay the registration fee for large markets like China or India, they are unlikely to do this for smaller countries where the population is small and the market itself is very underdeveloped due to several reasons including availability of supplies. The import regulation as well as the tariff is also another barrier in terms of the effort and cost. As a result in several of the African countries, the consumables are brought in through the donation route with special import dispensation. Quite often the institutions or individual practitioners tend to stock at least a year's worth of supplies. The combination of all this ultimately leads to the much needed medical supplies including intraocular implants and sutures becoming very expensive, sometimes even more than the Western prices. For example, it is not uncommon to see the intraocular lenses or pharmaceuticals from India costing five to six times more in several African markets. The economies of most of these countries are not positioned to afford such escalated prices.

The industry also sometimes manipulates the price to their advantage. Though not official, many companies tend to incentivize individual providers and hospitals to prescribe and use their products sometimes at significantly marked-up prices. Companies which supply equipment often bundle supplies to go with the equipment. Under this scheme, the equipment are given literally free, while the buyer is

under legally binding obligation to buy certain minimum quantities of consumables at prices which are significantly marked up. While such practices are disallowed in the USA and other Western countries, they are very common in developing economy as this offers an easy alternate for financing the equipment but results in much higher ongoing cost of delivery.

This type of purchasing paradigm engenders expectations on the part of eye care providers that such payments are the status quo and to be expected. Doctors who are paid low wages in government hospitals feel entitled to augment their low salaries with such inducements in order to make a reasonable living.

On the human resource front in many countries, the professional bodies such as the ophthalmologist associations are very protective of the eye care services and seem to be reluctant to develop other eye care professionals who could support and enhance their own performance. This comes out of concern that such professionals may start treating patients directly and gain from resulting economic benefits. There is a reluctance to develop a cadre of ophthalmic assistants or technicians to carry out routine tasks such as refraction, biometry or intraocular pressure measurement, etc. As a result, the ophthalmologists end up doing all such routine and time-consuming tasks. This inappropriate use of highly trained ophthalmologists leads to fewer people being served, thus at a much higher cost than it needs to be. In countries like Nepal and India where such mid-level ophthalmic personnel are widely engaged, we see much higher productivity and the cost of care being significantly lower.

Present Purchasing Paradigm for Ophthalmic Consumables

In countries like Vietnam, China and the Philippines which have universal coverage, 50% or more of the cost of cataract surgery is comprised of surgical consumables. The high reimbursement for cataract surgery has led to cataract surgery being rationed in China. In Vietnam, the poor are not reached due to high co-payments which go primarily to consumables. Clearly, the high cost of consumables is a key constraint to growth in cataract surgery volume in many country markets with a few examples are elaborated upon below.

In Vietnam, a combination of hospital autonomy in procurement and pricing, limited competition in supplier markets and the general lack of transparency in how services and consumables are priced results in a system in which the price of consumables is high relative to international benchmarks. This is largely due to the price of the intraocular lenses (IOLs) – the key consumable in cataract surgery – which range from US$100 to $150 and comprise approximately half to one-third of the total insurance reimbursement.

That these high prices are passed through to both the insurance provider and patients helps explain why “cost” is most often identified in Rapid Assessments of Avoidable Blindness (RAAB) as the primary barrier for patients in accessing cataract surgery despite the broad coverage of the insurance system. The high price for services clearly undermines most acutely the access of the most poor and vulnerable to eye health services and further erodes the financial protections purported to be built into the insurance scheme.

The current high-cost operating framework for eye health also represents poor value for money for the population of Vietnam – both as a consumer of products and financiers of the insurance system. The Vietnamese people rely on the insurer to act as an agent on its behalf to get the best value for money for their contributions. At present this is not happening because of the lack of price competition and transparency in the current system.

The total cost of healthcare in all nations will increase dramatically over the next decade as progress continues towards universal health coverage. Growth in the aging population will also result in increased demand for cataract surgery. It is likely that as these spending pressures grow, countries that provide health insurance will look for ways to rationalize the health budget. There is a risk that this will include a focus on containing health costs on "big ticket" items that take up a large proportion of overall spending, such as cataract surgery and other device-driven procedures (in the USA, cataract surgery receives the highest amount of reimbursement for any surgical procedure from Medicare, the government insurance system for people aged 65 and older).

The main challenge in these countries is to find ways to improve value for money in spending on eye care services and other similar device-driven procedures that does not further reduce the availability of services. Lower-cost options for consumables are an obvious first choice, as they are readily available. With competitive procurement practices, working in concert with measures that target the availability of services and the quality of patient outcomes, equity in the system can be improved, and eye health can be placed on a more sustainable financial footing.

The public sector in Latin America spends around 7% of GDP on health [4]. The health sector in the region is subject to a flexible regulatory framework that allows free performance of companies. This feature allows the participation of foreign companies in the market.

There is a risk to this level of deregulation: the lack of laws and controls results in commercialization of healthcare. Another drawback is that there are no official records and the actual numbers being served are not clear. Within this framework, private clinics are allowed to be built and advertised to the general public with no oversight on the quality of services provided. Within this panorama doctors are unhappy because of the low levels of compensation.

Eye health in Latin America becomes quite expensive for several reasons:

1. For all countries in Latin America, the benchmark tends to be the USA whose health system and costs are not amenable to the characteristics of low- and middle-income countries (LMIC).
2. Many of the health regulations are also based on those in the USA resulting in very expensive investment in infrastructure.
3. Latin America also tends to follow the protocols, techniques and high-cost materials used in the USA, and this makes the cost of care very high for the people.
4. When cheaper inputs from Asia are explored, there is misinformation to the patients that if the products are not from the west, then it would be of poor quality, although this is changing gradually.

In this broader context, the ecosystem in which eye care operates has a lasting impact on cost. It becomes the duty of the government and the professional bodies as well as the industry to take a "purpose-driven perspective" to ensure universal coverage where one of the three critical components is "affordability". When this is done well, the government would be able to ensure good eye health to all its citizens, while the eye care professionals and the industry will also benefit from generous economic returns.

Conclusion

In eye care, there are certain conditions like vitamin A deficiency, trachoma and onchocerciasis which are preventable and through appropriate measures are also amenable to elimination. However, most of blindness, vision impairment and current eye care services are for conditions that fall into either treatable (e.g. cataract, refractive errors) or controllable (e.g. diabetic retinopathy, glaucoma). The implication of this is that, there needs to be ongoing financing year after year, both for maintaining and enhancing the existing capacity and for ongoing delivery of care. Several studies have shown that the economic cost of blindness is in the $billions, and this is likely to increase with the rapid ageing of the population especially in low and middle-income countries. Thus the government, the eye care sector and the industry have to put in place appropriate funding mechanisms as well as processes by which the cost remains affordable and appropriate within the broader economic framework (Fig. 6.1).

Compliance with Ethical Requirements Thulasiraj Ravilla, Paul Courtright, Juan Francisco Yee Melgar and David Green declare that they have no conflict of interest.

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

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Innovative Approaches in the Delivery of Eye Care: Children

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Introduction

The number of children who are blind has declined from 1.4 million in 1999 to 1.26 million in 2010 [83]. Many of the causes of vision impairment (VI) and blindness in children are preventable or treatable; therefore, the control of blindness in children is a high priority of the World Health Organization (WHO) and the International Agency for the Prevention of Blindness (IAPB) VISION 2020 initiative [1, 11, 30]. Blindness in children has a far larger impact on the individual and society compared to adult blindness considering the total number of disability-adjusted life years lost

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(number of years lived after going blind), the difficulties in integrating a blind child socially and functionally, and the long-term economic and psychological impact on affected individuals, families, and society.

The epidemiology of blindness in children is primarly determined by the demography, levels of socioeconomic development and the provision of relevant services of the specific country [24, 54, 62]. In high-income countries, the prevalence of blindness in children aged 0–15 years is approximately 3/10,000 children, whereas in low- and middle-income countries (LMIC), it can be as high as 12–15/10,000 [51, 85]. In high-income countries, there are approximately 600 children with blindness per 10 million total population but can be as high as 6,000 in the poorest countries. The causes of blindness in children can be categorized as preventable and curable; preventable causes include corneal scarring due to measles, vitamin A deficiency, ophthalmia neonatorum, the use of harmful traditional eye remedies and trauma, while treatable causes include cataract, glaucoma, retinopathy of prematurity (ROP), and refractive errors.

The causes of blindness in children vary widely from region to region and can change rapidly over time in response to expansion of services and coverage of public health measures which promote child health. For example, greater coverage of measles immunization and vitamin A supplementation has reduced corneal scarring in many low-income countries. On the other hand, the expansion of services for sick and preterm infants in many middle-income countries has led to a rapid increase in vision loss from ROP, which during the 1990s was the most prevalent cause of avoidable blindness in many middle-income settings. ROP is likely to become an increasingly important cause in low-income countries as they too expand services for preterm babies. As corneal scarring has declined, congenital and developmental cataract have now become the commonest avoidable cause of blindness in children in many low-income countries [25, 37].

In high-income settings, other important causes of blindness are lesions of the higher visual pathways (i.e., optic atrophy, optic nerve hypoplasia, cortical vision impairment), often secondary to prematurity. In the poorest communities, preventable or treatable conditions, like corneal scarring, ophthalmia neonatorum, and the use of harmful traditional remedies, remain important causes [9, 16, 83].

Public health measures to control vision impairment in children must be planned in terms of:

- *Primary prevention*: interventions to prevent the disease from occurring. Preventive strategies directed toward prematurity would reduce ROP and cerebral vision impairment. Other strategies include immunization against measles and rubella, childhood nutritional programs to reduce vitamin A deficiency and ocular prophylaxis to prevent ophthalmia neonatorum. In cases of genetic diseases, counseling may have a role to play in the prevention of hereditary conditions, such as cataract.
- *Secondary prevention*: early detection and treatment of eye conditions causing vision impairment. Screening and prompt treatment of infants with sight-threatening ROP is an example of secondary prevention. Prompt identification

of vision impairment (VI) in children allows the institution of early intervention to optimize the vision outcome. Pediatricians and other pediatric health professionals as well as screening programs, play a key role in the early detection of children with sight-threatening ocular conditions [82, 84].

- *Tertiary prevention*: early detection and treatment of conditions to restore vision and managing the child with an established visual loss to promote normal development, education, and independent mobility and to minimize the socioeconomic impact of VI. An example of tertiary prevention is early surgery for children with cataract. Children who are blind or vision impaired from incurable conditions should be assessed and managed by a multidisciplinary team of professionals including low vision specialists, special educators, and teachers of children with VI, in a comprehensive and integrated intervention.

In this chapter, some of the models for eye care delivery in children will be reviewed, focusing on uncorrected refractive error (URE), congenital and developmental cataract, and ROP.

Refractive Error

There are 12.8 million children worldwide who are visually impaired from URE; half of these children live in China, where the number may reach 100 million by 2020 [76]. Short-sightedness (myopia) is the commonest type of refractive error in children [76]. Although its underlying causes are not fully understood, myopia is likely to be due to complex interactions between genetic, epigenetic and postnatal influences [41, 66]. Given the rapid increase in the prevalence and severity of myopia, particularly in East and Southeast Asia, environmental factors associated with urbanization have been identified as important factors [44, 86]. Reducing prolonged close work and increasing the amount of time spent outdoors are the main forms of primary prevention of myopia [43, 69, 70, 95]. A full-scale, island-wide program in Taiwan called "Daily 120" has added two hours of outdoor time to every school day for all children for this purpose. Less is known about potentially modifiable risk factors for primary prevention of astigmatism and long-sightedness (hyperopia).

Secondary prevention consists in the early and full correction of the refractive error and according to the latest evidence, low-dose topical atropine which reduces the progression of myopia. However, side effects include light sensitivity and near blur, and this medication is not commercially available, so its use is limited and not practical [13, 14].

Tertiary prevention consists of the provision of optical correction, usually in the form of spectacles, which are inexpensive, safe, and effective in improving educational outcomes [55]. Other forms of treatment, such as contact lenses and laser surgery are less commonly used in children.

In some areas of limited resources, as few as 15–25% of children who need refractive correction actually wear spectacles. Reasons include cost (donation of free spectacles doubles the rate of use), fear that spectacles harm children's vision,

lack of awareness about the existence of an underlying refractive error and poor compliance (which can be improved by a range of methods, including allowing children to select the frames they refer and incentives for teachers) [68, 71, 98]. Primary reasons for non-compliance with spectacles include breakage/loss in younger children, disliking the appearance in teenagers, parental disapproval and overprescribing, i.e., dispensing spectacles when there is very little improvement in visual acuity [80, 94].

School Eye Health Programs

Schools are a practical location for carrying out vision screening and follow-up to assess spectacle wearing, often with the assistance of teachers who are familiar with children's needs [80]. In Tanzania, secondary schools were randomized to two arms: in one arm, children needing spectacles were given free glasses; in the other, children were given the prescription for spectacles. At follow-up, a significantly higher proportion of children given free spectacles were wearing them [96].

Several large-scale programs have been developed over the last few years to address school eye health. These include Our Children's Vision [3], Peek Botswana [4], and the Rural Education Action Program (REAP)'s Seeing for Learning social enterprise program, which provided vision screening services and free spectacles to children living in rural areas in China. Similarly, Orbis International and the Qatar Fund For Development (QFFD) are collaborating in a large eye screening program for children, the Refractive Error Among Children (REACH), which includes partners across India, such as Aravind Eye Hospital (Madurai), Sankara Nethralaya (Chennai), Little Flower Hospital (Angamaly), VMA Netra Niramay Niketan (West Bengal), PBMA H V Desai Eye Hospital (Pune), and Sadguru Netra Chikitsalaya (Chitrakoot). More than 2,000 schools in 7 districts and a team of more than 100 ophthalmologists, optometrists, and ophthalmic assistants are involved in this project. The REACH model employs a three-phased approach. Phase I (Preparation) sets the foundation for subsequent service delivery activities:

1. Generate a database of all the schools in the project area.
2. Establish contact with local authorities, schools, and other stakeholders to get the buy-in and necessary permissions.
3. Generate the list of enrolled students in each participating school.
4. Generate an institutional resource database (e.g., human resources, equipment, vehicles, etc.).
5. Plan and schedule service delivery activities with an adequate lead time.

Phase II (Deliver) entails primary screening. The vision screener performs a visual acuity test using a uniformly self-illuminated pocket optotype. Children who fail the screening (cannot read 0.2 LogMAR or can read 0.2 LogMAR with +1.50 D sph), have any other ocular complaints/symptoms, or are already wearing spectacles are sent for evaluation. During the evaluation, the team, which includes an

optometrist or ophthalmologist conduct a detailed visual acuity assessment, refraction (including cycloplegia), and ophthalmic evaluation. All children who require spectacles are given a prescription and are either given the spectacles at the time in school or the spectacles are delivered later. All these children are counseled about the benefits of wearing their spectacles to increase acceptance and promote compliance with wear. Where possible parents are also counseled. Three months after dispensing glasses, a team member visits the school unannounced to check for compliance and to identify any specific factor(s) for non-compliance (Phase III, Consolidation). One year later, a follow-up visit is scheduled for all children investigated in the previous year and to assess any students identified by the teachers who have an eye health issue.

In Pakistan, the Brien Holden Vision Institute (BHVI) has developed a cost-effective school eye health model by defining and delegating appropriate roles and responsibilities to the Ministries of Health and Education with limited additional input from the Institute [97]. The master trainers from the institute trained optometrists in the local government eye units, who in turn trained two teachers in each school in eye health vision screening, and record keeping. Children who failed the eye health and vision screening were referred to the district eye hospital where a team of optometrists provided refraction and appropriate spectacles prescription. Children whose vision could not be improved with corrective glasses or who had other eye care needs were referred to the ophthalmologist at the tertiary care level. All the school teachers and auxiliary school staff also were provided with free eye health screening, refractive prescriptions, and distance and near spectacles. The hospital also provided treatment for eye diseases in teachers such as glaucoma, diabetic retinopathy and cataract if needed. Compliance with the use of spectacles among students was regularly checked and causes for non-compliance were addressed. Health promotion and creation of positive role models among teachers resulted in improved compliance. Moreover, advocacy was undertaken with the social welfare department to fund the provision of spectacles to children who could not afford them. Some success has been achieved in passing the ownership of the program to the district social welfare department.

The BHVI along with Sightsavers and the London School of Hygiene and Tropical Medicine has developed standard school eye health guidelines for middle- and low-income countries [2].

In Nepal, the eye health program uses a holistic approach, i.e., screening, health education as well as inclusive education for children with disabilities. In Sri Lanka, there is a system for mandatory medical testing in schools with provision of free spectacles.

All the above programs outlined show the importance of integrating eye health into school health programs. This process not only addresses the issue of URE, but also takes care of other eye diseases, like squint, cataract, red eye, cornea problems, as well as conditions which require low vision services.

Two studies have recently been undertaken in China and India to assess the utility and cost savings to programs of ready-made spectacles (i.e., they have the same power in each eye, without astigmatic correction). Children with significant URE

eligible for ready-made spectacles were randomized to ready-made spectacles or full-prescription glasses. In China, although visual acuity was better with custom spectacles, no difference was found in acceptability at one month [100]. Similar results were reported in India, where 86% of children with URE were eligible for ready-made spectacles. To be eligible for ready-made glasses, the corrected visual acuity had to be the same as, or not more than one line of acuity worse than with custom made glasses. In this study, the proportion of children wearing ready-made spectacles was not inferior to the proportion wearing custom-made glasses at 3–4 months [61]. These findings suggest that ready-made spectacles could substantially reduce costs for school-based eye health programs without compromising visual acuity or spectacle wear, at least in the short term.

Retinopathy of Prematurity

Retinopathy of prematurity (ROP) is an important cause of blindness in children worldwide [28]. In 2010 it was estimated that 20,000 infants born preterm became blind from ROP and a further 12,300 were vision impaired. The largest number was in the Southeast Asia region. The proportion of preterm infants who develop the different stages of ROP (I to V) as well as the population at risk, are primarly determined by the degree of prematurity and the level of neonatal care the babies receive [10, 31]. Risk factors include inadequate management of supplemental oxygen from immediately after birth, i.e. hyperoxia or fluctuating hyperoxia/hypoxia, sepsis, transfusion of blood products, failure to gain weight and anything which makes a baby unstable during the first few weeks of life such as pain and loud noises. In high-income countries neonatal units provide very-high-quality care, and only a small proportion (less than 10%) of extremely preterm babies (birth weight of <1000 g) develop sight-threatening ROP. In contrast, in LMIC where the level of care may be suboptimal, the proportion can be far higher, and babies with birth weights between 1500 and 2000 g can also develop severe disease [31, 81].

Clinical trials have shown that peripheral retinal laser photocoagulation is highly effective treatment for the sight-threatening stages of ROP (type 1 ROP) as long as it is delivered adequately and urgently [65]. New treatments, such as intravitreal injection of anti-vascular endothelial growth factors (VEGF) are currently being explored for their efficacy and safety in terms of short- and long-term ocular and systemic complications [60, 78]. Currently, these agents should only be used when laser is not possible because the retina cannot be seen clearly or the child is too sick, after gaining informed consent from parents.

Primary prevention strategies for control of visual loss from ROP include interventions to reduce pre-term births (e.g., regulation of assisted fertilization to reduce multiple pregnancies, reduce rates of unnecessary Caesarean sections) and interventions to reduce ROP in preterm infants (i.e., a course of systemic steroids to mothers when preterm delivery is threatened which improves lung function, and high-quality intensive neonatal care from immediately after birth). Secondary prevention involves screening of preterm babies at risk of ROP, followed by urgent treatment if

indicated, and long-term follow-up for early detection of complications such as refractive errors. Complex vitreoretinal surgery for stage IV ROP (i.e., tertiary prevention) can be of benefit, but surgery for stage V ROP does not usually improve visual function. Visual rehabilitation is required for children who are irreversibly blind or vision impaired from ROP.

Many preterm infants with ROP develop high degrees of refractive error, principally myopia, at a very young age. Babies who have had laser treatment develop more severe myopia and at a younger age than babies whose ROP did not require treatment [8, 19, 72]. Anti-VEGF agents may be associated with a lower incidence and severity of myopia during early childhood than laser [27, 59].

To plan a ROP program at a regional level, information on the local context is needed such as the number of neonatal intensive care units (NICUs) in the selected area, the number of premature babies admitted/month in each, the survival rate in babies less than 1500 g, and the availability of clinical staff who could be trained to screen and to treat. All these factors need to be borne in mind when deciding where to start a service for ROP [7].

If no program exists, the first step is to raise awareness through educating neonatologists and neonatal nurses, including an explanation of the role that a neonatal staff can play in preventing visual loss through improvement of neonatal care and supporting screening and treatment. The retinal examination in the neonatal unit by an experienced ophthalmologist using indirect ophthalmoscopy or digital imaging with remote evaluation by an ophthalmologist (teleophthalmology) must be planned on a weekly basis, although some programs prefer to screen newborns even more frequently. Once treatable disease has been diagnosed, laser ablation of the peripheral retina must be done within 72 hours, to minimize the risk of retinal detachment (stage V ROP). Four key elements need attention for ROP programs development in LMIC: (1) epidemiologic and health systems research; (2) building effective teams of caregivers within the institution; (3) improving local capacity in terms of personnel, equipment, and education; and (4) partnerships between institutions. Financial support for the latter is often initiated by non-governmental agencies, however, long-term sustainable programs need the engagement and support of governments [17].

Brazil is among the top ten countries with the highest number of pre-term births in the world. In 2008, 20 years since the publication of the CRYO-ROP study, Brazil passed legislation on a national policy to regulate ROP diagnosis and treatment and this has led to an expansion of ROP screening and treatment. The Unified Health System (Sistema Único de Saúde) provides approximately 76% of free neonatal care in the country. In the city of Rio de Janeiro where the ROP program has been implemented in government neonatal intensive care units (NICUs) over the last two decades, a trained ophthalmologist visits more than two to three NICUs every week, and six NICUs share one laser [102]. The estimated cost of ROP diagnosis and treatment for all at-risk infants in NICUs is 80$ per infant, indicating that providing ROP care is affordable and feasible in the country [101]. Many other countries in South and Central America have programs for ROP, and in some countries such as Argentina, this has led to a marked decline in the number of children blind with ROP [42].

The Indian Twin Cities Retinopathy of Prematurity Screening program was started at L V Prasad Eye Institute (LVPEI) in 1997 in the twin cities of Hyderabad and Secunderabad in the southern Indian state of Andhra Pradesh. The objective of this program was to ensure that no child in these two cities would go blind from ROP, as well as to create awareness among all stakeholders including pediatricians, neonatologists, gynecologists and other health-care professionals. Posters and brochures were placed in many private and government hospitals to sensitize parents about the need for ROP screening within 20–30 days of birth. In this program, a team of one faculty and two trainees visit each neonatal center once a week on a fixed day and time, to provide screening and laser treatment. A ROP diary is maintained at each center for all babies eligible for screening according to the National Neonatology Forum of India ROP guidelines [49]. For smaller units where routine visits are not required, the neonatal staff contacts the team from LVPEI when there is a baby who needs to be screened and the team visits a few days later.

The screening guidelines were based on scientific evidence generated from the prospective ITCROPS database since 1999: all babies less than 30 weeks gestational age (GA) are screened by the 20th day; babies with GA between 30 and 35 weeks are screened by the 30th day (20–30-day strategy) [18].

In addition to screening for ROP in neonatal units, LVPEI also offers a daily ROP screening and treatment walk-in service, and an appointment is not needed for ROP babies less than two months of age. Babies who are stable undergo laser therapy under topical anesthesia within a couple of hours of arriving at the hospital. For unstable babies, treatment is performed after admission to the nearby NICUs. Following laser, the babies are discharged after feeding and checking that their vital signs are stable. A prospective computerized database with Ethics committee approval, was set up to record all data prospectively for scientific analysis [46]. With all these efforts since 2007, 13,654 neonates have been examined under this program in the twin cities of Hyderabad and Secundrabad [45, 48].

Since March 2007, services to care for sick and unstable preterm infants who need ROP management have been established, which include neonatal anesthetists, neonatal nurses, anesthesia equipment, and a mini-neonatal intensive care unit (the first in the country in an Eye Institute) for postoperative care. A neonatologist regularly visits to monitor the overall health of the babies and to give pre- and postoperative support [47]. The program also includes a robust in-house facility for low vision management and comprehensive early intervention for visual rehabilitation which has now been upgraded to include multiple disability services.

Over the years, many ophthalmologists from India and neighboring countries such as Bangladesh, Nepal, Sri Lanka and Indonesia had been trained in ROP management at LVPEI, and many have gone on to develop services for ROP in their own settings, with staff at LVPEI providing a mentoring role [74].

A large-scale telemedicine program has also been established in India in Karnataka state. This approach was adopted as over 3.5 million babies are born pre-term in India every year, mostly in rural areas, but there are less than 100 ROP specialists [90, 93]. Since 2008, the Karnataka Internet-Assisted Diagnosis of Retinopathy of Prematurity (KIDROP) program has been providing screening and treatment to rural special

newborn care units and neonatal units across Karnataka state [89, 90, 92]. The novel aspect of this program is that screening is undertaken by a mobile team where non-physicians (i.e. technicians and optometrists) have been trained and accredited to take retinal images using a portable wide-field camera (RetCam Shuttle, Clarity MSI/Natus, USA or Neo, Forus Health, India). The team travels with a laser unit in a minimally modified vehicle 6 days a week, observing a fixed schedule of NICU visits in a pre-defined geographical area. The imagers are trained to grade the images using a specialized "STAT score" and in reporting images using a priority-weighted algorithm to aid follow-up decisions. The images are reviewed remotely by a ROP specialist in real time. Before the end of the session, the mother is informed about the diagnosis and the date for the next follow-up [91]. Patients who need surgery or further examination are counseled to attend the base hospital and this accounts for about 9% of the 200,000 annual consultations. Babies born in facilities not visited by the team are referred to these "imaging centers" using a low-cost referral strategy called "Red Card for ROP" [88]. Over 100 semi-urban and urban neonatal units (with over 65 million population) are currently visited across 30 districts.

The KIDROP model was validated by the United Nations Development Programme (UNDP) and Planning Commission of India for deployment in middle-income commonwealth countries. Subsequently, a report from Australia validated the program based on the Centers for Disease Control (CDC, Atlanta, USA) template, supporting its "task-shifting" model and advocating for nationwide expansion. In Karnataka state (where the program was initiated), the economic benefit in terms of blind person-years (BPY) saved was USD 9.5 million in 2016. Expanding to nine other states where ROP is a perceived problem would increase the economic benefit to USD 108 million. Improving infant survival and higher admission rates for delivery would add a further USD 106 million in BPY [93]. Pediatrician-led models of ROP screening, with teleophthalmology linked to ROP specialists via an Internet cloud-based platform, provide rapid access to neonatal units without screening in a relatively short period of time. Recently developed, affordable, portable retina camera, automated image analysis and software processing should be integrated into the tele-ROP program for better triaging [50].

Pediatric Cataract

Cataracts are one of the treatable causes of blindness in children [37]. Cataract can be present at birth (congenital) or can develop during the first 2–3 years of life (developmental); they can be bilateral or unilateral and can occur in isolation or with other ocular abnormalities. Congenital bilateral cataract has a birth prevalence of approximately 1 per 2,000 live births.

After excluding trauma, most unilateral cases are idiopathic, i.e. of unknown cause. Bilateral cases can be associated with systemic conditions (Down's syndrome, metabolic disorders) and congenital infections (congenital rubella syndrome and congenital toxoplasmosis) or be familial, usually inherited as autosomal dominant. However, in up to 50% of cases an underlying cause cannot be determined.

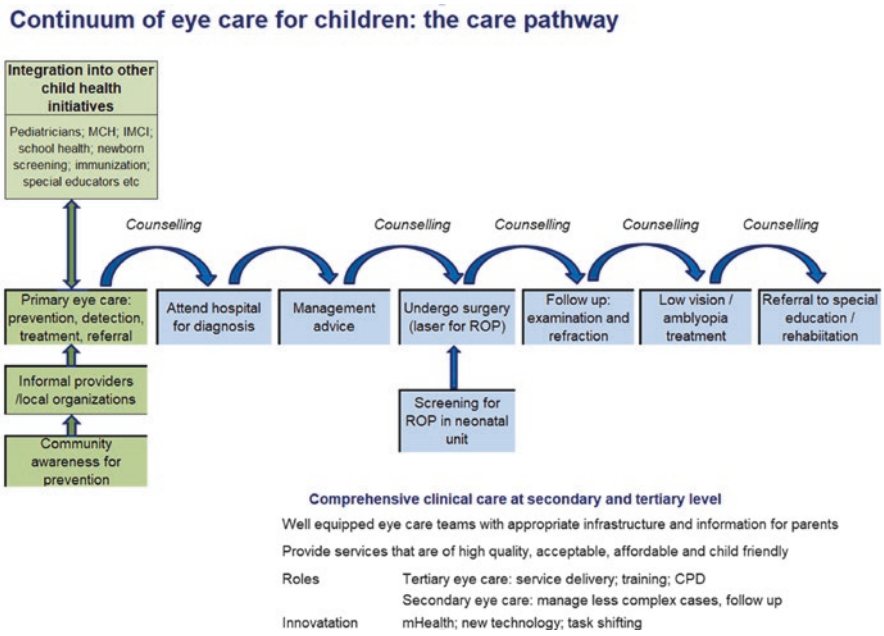

Fig. 7.1 Comprehensive eye care for children with cataract: the care pathway. (From Gilbert et al., adapted from Aravind Eye Care System [29]). MCH: maternal and child health; IMCI: Integrated Management of Childhood Illness

Comprehensive clinical care for children with cataract requires multifaceted interventions including training health personnel who care for newborn infants and young children to recognize cataracts by examining children for a white pupil or loss of the red reflex, easy and quick referral mechanisms to specialists, training of eye care specialist teams in the assessment, surgery, and long-term management of these children, support services including pediatric anesthesia, orthoptics, optometry, low vision specialists, and counsellors; and support services for parents (Fig. 7.1). Services must be high-quality, acceptable, affordable and child-friendly. Counseling at every step along the care pathway is essential to enable parents to realize that surgery is only the first step in optimizing the vision of their child. Some tertiary care eye hospitals have appointed a dedicated childhood blindness coordinator to support parents through counseling and sending them reminders, which can improve compliance with follow-up [5, 53].

Identifying Children with Cataract

In low-income countries, there is often a considerable delay in children undergoing cataract surgery, which means that the visual outcome is not as good as it might be because of amblyopia (“lazy eyes”). Barriers to access include lack of awareness,

cost, distance, poverty, beliefs that blindness from birth cannot be treated, and being given the wrong advice. It is, therefore critical that the programs address community awareness and promote health service-seeking behaviors. Caregivers should know the referral mechanisms and the available services for referral within the health system. In a study conducted on 178 caregivers (mostly mothers of children with cataract) at the Kilimanjaro Christian Medical College Hospital in Moshi, Tanzania, the mean delay between recognition by caregivers and presentation to hospital was 34 months [67]. For this reason, the staff working in primary care represents an important group for early identification and referral in these children [56]. For example, a pilot study in Tanzania showed improvement in the diagnosis and management of children with cataract among primary-level staff providing reproductive and child health services after a 1-day intensive course on primary eye care. This approach is potentially scalable and sustainable.

Another approach is to train key informants to identify children they think are blind or has vision loss and refer them to a temporary clinic setup in the community where they are examined. This method was pioneered in Bangladesh and has since been used in Malawi, India, and many other countries. Key informants should be selected for training on the basis of their role and are individuals who know their communities well, i.e., community health workers, social activists, men and women of faith, traditional birth attendants, paramedics, and anyone with interest and enthusiasm to serve their community [21]. These people are trained to identify children who are blind or has vision loss, which will include those who have cataract. Training is generally short (0.5–1 day), and the work is usually campaign-based [6, 20]. As the prevalence of blindness in children is less than one in a thousand in many parts of the world, this approach is economical and practical. School screening and community-based eye camps – used in Sarva Shiksha Abhiyan – are other examples of case finding. Finally, children in schools for the blind can sometimes have unoperated cataract [39, 33, 87].

Strategies for Prevention and Treatment

Immunization from rubella is one of the strategies for the prevention of cataract in children. The approach adopted (vaccination of all infants at 9 months, selective immunization of school girls or relying on passive immunity without immunization) depends on the local epidemiology of rubella and the resources available to detect seronegative women of childbearing age who should also be immunized. Secondary prevention of cataract is not possible. Tertiary prevention consists of early detection and high-quality surgical management in a tertiary-level facility, with long-term follow-up to ensure optimal optical correction which promotes normal visual development and to detect and manage complications. Tertiary prevention also includes comprehensive low vision care and rehabilitation services.

The effective management of cataracts in children requires early detection and prompt surgery to clear the visual axis followed by optical correction, usually by

intraocular lenses in children over the age of 12–18 months. Long-term follow-up is essential as the refractive error changes over time and complications such as media opacification or glaucoma need to be detected and managed. The relatively poor outcome, difficulty in visual evaluation of infants and toddlers, and apprehension on the part of parents and caregivers mean that relatively few children undergo cataract surgery early [22, 63, 67]. Studies from Tanzania, China, and India have shown that there is often a delay of 1–2 years between the diagnosis and surgical management of pediatric cataract [36, 67, 99]. An 18-month delay is the average in many parts of Africa [38]. Distance from the hospital and cost of surgery were reported as the main barriers in Asia and Africa, as well as health system-induced barriers ("I was told to wait for the child to grow older," "the doctor said my child's eyes were okay," "doctors were not sure of the results of the surgery") [38, 79]. Pediatric cataract surgery is also more expensive than adult cataract surgery, not just because of the need for general anesthesia but also for consumables (high-power, high-quality intraocular lenses, small spectacles frames, etc.), surgical equipment (vitrectomy machines) and the need for admission in hospital. As a delay in surgery between the first eye and the second eye can lead to amblyopia in the second eye, both eyes are often operated on a few days apart during the same hospital admission. Some centers operate on both eyes during the same operating session but this needs meticulous attention to infection control, as intraocular infection after cataract surgery can be blinding [34, 35, 73]. Finally, in some Asian countries girls with bilateral cataract do not access cataract surgery at the same rate as boys which needs to be addressed [32].

Unlike adult cataract surgery, childhood cataract management requires long follow-up and postsurgical care, as the refraction error changes over time and amblyopic treatment is often needed. Increasing follow-up requires great commitment by health-care providers as well as families [15, 39]. Strategies that have been tried include: good-quality counseling, ideally with both parents; covering the costs of all aspects of postsurgical care; reminding about all the follow-up visits; mobile phone reminders to the family of the need for follow-up; support for transport costs; reinforcement of the use of the spectacles or low-vision devices prescribed [23, 52, 53, 73].

Over the last two to three decades, many organizations like ORBIS International, Sightsavers, Christoffel-Blindenmission (CBM), the Fred Hollows Foundation (FHF), Rotary International, Standard Chartered Bank through its Seeing is Believing program (SCB-SiB), etc. have supported the development of tertiary eye care facilities for children, on the recommendation that there be one center for a total population of ten million people. For example, ORBIS International, a non-profit organization which supports prevention of blindness in low-income countries, has been working in partnership with the provincial government in KwaZulu-Natal, South Africa. Support included strengthening the pediatric service at the Inkosi Albert Luthuli Hospital with equipment and training the ophthalmic team including a pediatric specialist ophthalmologist, an optometrist and a child blindness coordinator. This has led to an increase in the number of children treated and a 100%

improvement in follow-up. A similar program has also been initiated in Zambia's copper belt region at Kitwe Central Hospital which has also shown success [58]. In Bangladesh, Sightsavers, ORBIS and the Fred Hollows Foundation supported the Bangladesh Childhood Cataract Campaign in which 10,337 children were identified with bilateral cataract. Over the four years of the campaign, eight child eye care centers were strengthened or developed, and over 24,000 cataract operations were performed, almost 9,000 on children with bilateral cataracts. Essential elements of the campaign were community-based approaches for active case finding using key informants and other approaches, training ophthalmologists and other mid-level eye care personnel in pediatric ophthalmology, and developing and delivering a health education strategy [64].

Low Vision Rehabilitation

The goal of low vision rehabilitation (LVR) is to reduce the impact of VI and minimize the ensuing disability. This may include prescription of low vision devices and training in their use, environmental modifications, social and psychological support. Given that one professional group cannot provide all these elements, specialists with different expertise are required to provide comprehensive LVR. While "multidisciplinary low vision rehabilitation services" are now considered the norm, and are being established around the world, there is still a lack of evidence on which is the most effective model [12, 26, 40].

In India, LVPEI has been providing comprehensive LVR services to children and adults through center-based and community-based strategies for over two decades. Community-based rehabilitation is a practical and feasible model for developing countries, supporting full participation and inclusion of children with disabilities into their rural and remote communities. LVPEI has been delivering LVR in children through its pyramidal model (primary to tertiary) across four South Indian states – Telangana, Andhra Pradesh, Karnataka, and Odisha [75]. To date, about 50,000 to 60,000 children with VI and blindness have been provided the comprehensive LVR services across the LVPEI network.

There are several barriers to providing and accessing LVR services [57]. The barriers can be grouped into three categories: health-care system related, person related, and society related. Barriers related to health-care system include inadequate service provision in many areas and/or people are not referred to services or choose not to use them. Lack of awareness and misconceptions about LVR services have been also identified as obstacles and could be the result of limited awareness raising by rehabilitation agencies or the scarcity of printed materials. Moreover, a clearly structured referral system is critical for proper referral of visually impaired children. Barriers that are more specific to parents of children with low vision are that they think they can manage the functional limitations of their child or lack of understanding that child's functional vision could be improved by LVR services. Some of the barriers related to social attitudes include the parents' fear of their

child being stigmatized as disabled and the fear of prejudice and discrimination by other members of the community' [77]. An overprotective attitude is common among parents of visually impaired children as they are worried that their child might be harmed emotionally and physically in the outside world.

Comprehensive Eye Care for Children

There are many challenges in providing comprehensive eye care for children, including the management of cataract with interventions being needed at each level of service delivery:

- Community: increasing awareness about how eye conditions can be prevented and that children with serious eye conditions need to be identified and urgently referred. Rehabilitation of older visually impaired children can be undertaken in the community.
- Primary level such as health centers and dispensaries: health workers at this level can play a key role in preventing eye disease in children and in identifying eye conditions, as young children and their mothers attend these facilities on many occasions during the first few years of life for growth monitoring and immunization.
- Secondary level such as district hospitals: eye care professionals at this level need to be aware of which conditions require urgent referral to the tertiary level such as cataract in young children, and which they can manage.
- Tertiary level, such as regional or national centers of excellence. This level requires a well-trained, well-equipped team of eye care professionals who can manage the more complex cases and provide low-vision services and early visual stimulation for children with irreversible loss of vision.

For the control of blindness and vision impairment in children to be scalable and sustainable, eye conditions need to be included in the training curriculum of staff working at every level and integrated into the health system, with clear referral pathways between the different levels of service delivery. This means that trained staff are supported by the equipment and consumables needed, and eye conditions can be monitored if included in national health information management systems.

There are only a few examples of comprehensive screening for children of all ages in low-income settings. One example was developed by LVPEI in India, which includes primary screening in schools, Anganwadi centers (pre-school) and special schools, screening of newborns, and screening in health centers and in neonatal units. In India, village health workers, called Accredited Social Health Activists (ASHA) workers can also assist in case detection as part of their routine work. There is a clearly defined pathways for referral from primary to secondary, tertiary, and center of excellence.

Conclusions

Global public health measures and increased eye care services for children are having an impact on blindness in children. However, the goal of eliminating avoidable blindness in children is still some distance away and the way forward complex due to the interdisciplinary nature of the services required. Important steps have been identified, such as developing comprehensive child eye health programs from communities through to tertiary level services with referral to rehabilitation and special education, with good coordination among relevant stakeholders. Child eye health needs to be integrated into national child health policies and plans including for the control of ROP. Training and building capacity of health workers is required at all levels, together with sensitization of community personnel, such as teachers and optometrists, on the importance of screening and follow-up as they are often the first to detect eye disease in the general population, including children. Moving forward, more studies are needed to evaluate how better to improve collaboration and communication between professionals involved in child eye health, to assess the effectiveness of integrating eye care into general health care for children, to eliminate service redundancy and barriers and to optimize services for children with VI.

Compliance with Ethical Requirements Rohit C Khanna, Maria Vittoria Cicinelli, Vijaya K. Gothwal, and Clare Gilbert declare that they have no conflict of interest.

No human studies were carried out by the authors for this article and no animal studies were carried out by the authors of this article.

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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

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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.

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Innovative Approaches in Delivery of Eye Care: Diabetic Retinopathy

9

Daniel Shu Wei Ting, Ecosse Lamoureux, and Tien Yin Wong

Introduction

Diabetes mellitus (DM) is one of the world's fastest growing chronic diseases and one of the leading causes of acquired vision loss [1]. According to the International Diabetes Federation (IDF), it is estimated that the total number of people with diabetes will double from 366 million in 2011 to 552 million by 2030 [2]. Diabetic retinopathy (DR), a specific microvascular complication of DM, remains the primary cause of acquired vision loss worldwide in middle-aged working populations [1, 3, 4]. Over the past few decades, there have been major advances in understanding the epidemiology of DR; systemic control of DM to prevent DR development and progression; clinical assessment, diagnosis, and management of DR; and severe stages of DR, including diabetic macular edema (DME) and proliferative diabetic retinopathy (PDR), often grouped together as vision-threatening DR (VTDR) [5]. There is widespread knowledge that screening, early detection, and prompt treatment of VTDR allow for the prevention of diabetes-related vision impairment [6]. Through regular eye examinations and adequate diabetes management, the progression of DR and associated vision loss can be prevented in 98% of cases [6, 7]. Randomized controlled trials have shown that early treatment can reduce an individual's risk of severe visual loss by 57% [8].

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However, much of the advances and research in DR treatment have been focused on tertiary level care of patients with DR (e.g. laser photocoagulation, intraocular application of anti-vascular endothelial growth factor (anti-VEGF), and vitreoretinal surgery). The key solutions to sustainable prevention of vision loss involve developing innovative ways to optimize clinically and economically effective DR care in primary and secondary settings, both in resource-rich and resource-poor countries worldwide. For example, DR screening services in both resource-rich and resource-poor countries remain patchy and are constantly challenged by unclear guidelines on the most appropriate method to screen (e.g. clinical examination versus fundus photography) and the increasing resources needed for implementation and maintenance of comprehensive DR screening programs [9]. Thus, DR is a progressively significant major public health problem, especially in many resource-poor countries where access to trained eye care professionals and secondary and tertiary eye care services may be suboptimal. It is therefore important that public and private stakeholders continue to look for innovative ways of managing DM, improve access to DR screening and plan and optimize cost-effective screening programs within the community.

Epidemiology of Diabetic Retinopathy

There have been many studies on the prevalence, extent, and burden of DR in different countries. A pooled analysis of 22,896 people with diabetes from 35 population-based studies in the United States, Australia, Europe, and Asia (1980–2008) showed that the overall prevalence of any DR in type 1 DM (T1DM) and type 2 DM (T2DM) was 34.6% (95% CI 34.5–34.8), with 7% (95% CI 6.9–7.0) vision-threatening DR (VTDR) and 6.8% (95% CI 6.7–6.9) diabetic macular edema (DME) [5]. For DR incidence among the T1DM, the Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR) showed the 10-year DR incidence among the T1DM in the United States was 74%, increasing to 97% after 25 years. On the other hand, the 5-year cumulative DR incidence among the T2DM in the United Kingdom was 4% rising to 16.4% after 10-year follow-up (from no retinopathy to pre-proliferative retinopathy) [10]. In Australia, the Blue Mountain Eye Study (BMES) reported that the 5-year DR cumulative incidence and DR progression rates were 22.2% and 25.9% respectively [11].

Major Modifiable Risk Factors of Diabetic Retinopathy

The major modifiable risk factors include hyperglycemia, hypertension, and hyperlipidemia. The Diabetes Control and Complications Trial (DCCT) and United Kingdom Prospective Diabetes Study (UKPDS), two landmark clinical trials, showed tight glycemic control (HbA1c value of 7% or less) could reduce the risk of DR development and progression in type 1 DM and type 2 DM patients [12, 13]. For every 1% decrease in HbA1c, there was a reduction in 40% of DR development,

25% progression to VTDR, 25% need for laser therapy, and 15% blindness in people with diabetes [14]. In addition, intensive glycemic control had been shown to reduce the 4-year incidence of DME by 58% [15]. For hypertension, the UKPDS was the first RCT that demonstrated the importance of tight BP control in reducing retinopathy [13]. It showed that every 10 mmHg increase in systolic blood pressure was associated with 10% increased risk of early DR and 15% risk of PDR or DME [16, 17].

The role of dyslipidemia in DR prevention is less clear. Triglycerides had been shown to be associated with the presence of DR, while the low-density lipoprotein (LDL) was related to DME [18]. The DCCT showed that the severity of DR correlated positively with increasing triglycerides and inversely with high-density lipoprotein (HDL) [19]. In the Sankara Nethralaya-Diabetic Retinopathy Epidemiology and Molecular Genetic Study (SN-DREAMS), high serum low-density lipoprotein (LDL), high non-high density lipoprotein (non-HDL) cholesterol, and high cholesterol ratio were related to diabetic macular edema [20]. However, there are no randomized trials that have conclusively shown controlling dyslipidemia will prevent DR progression and associated vision loss.

Controlling risk factors for DR by increasing public education on these risk factors in primary and secondary care settings should therefore continue to be a major strategy to prevent vision loss.

International Council of Ophthalmology Screening Guidelines [21]

The International Council of Ophthalmology has published a guideline on an appropriate screening strategy for DR. The guideline suggests the following elements: (1) history focused on diabetes and other vascular risk factors, (2) physical examination (visual acuity, retinal examination), and (3) fundus examination (using either slit lamp biomicroscopy or retinal photography). In terms of DR grading, the screeners should grade DR severity level using a simplified grading system – the Proposed International Clinical Diabetic Retinopathy and Diabetic Macular Edema Severity Scale. However, the referral level may need to be adjusted based on the requirement of the individual healthcare system. In the setting of low-resource countries where DR grading is not possible, a referral to an ophthalmologist is recommended if patients have these following features: (1) multiple retinal hemorrhages or possible neovascularization, (2) white spots in the retina, (3) ungradable fundus images, and (4) visual acuity below 6/12 (20/40) or symptomatic visual complaints. It is important to educate patients about their conditions and emphasize the importance of maintaining good HbA1c level (<7%) and other vascular risk factors (blood pressure, lipids, stop smoking). For patients who suffered from permanent visual loss, primary eye care physicians should assess the psychosocial situation and make appropriate referrals to the vision rehabilitation, psychology or social services to improve their quality of life.

Diabetic Retinopathy Detection Modalities

Traditionally, DR screening is performed in various ways by different healthcare professionals such as ophthalmic nurses, ophthalmic technicians, optometrists [22, 23], and GPs [23, 24], including direct ophthalmoscopy [25], dilated slit lamp biomicroscopy with a handheld lens (90 D or 78 D) [26], mydriatic or non-mydriatic retinal photography [25], and tele-retinal screening [27]. In addition, the sensitivity and specificity of the number of retinal fields performed during DR screening were evaluated, as well as the type of devices and screeners with variable ophthalmic experience (Table 9.1) [26, 28–33].

Table 9.1 The methods, sensitivity, and specificity of diabetic retinopathy (DR) screening by different practitioners [26, 28–33]

Methods of DR screening	Practitioners	Outcome measure	Sensitivity % (95% CI)	Specificity % (95% CI)
1. Direct ophthalmoscopy [29]	GPs	Any DR	63 (56–69)	75 (70–80)
	Optometrists		74 (67–81)	80 (75–85)
	GPs	Referable DR	66 (54–77)	94 (91–96)
	Optometrists		82 (68–92)	90 (87–93)
2. Dilated slit lamp examination [26, 28]	Ophthalmologist	Referable DR	87 (84–92)	95 (92–98)
	Optometrists	Referable DR	73 (52–88)	90 (87–93)
3. Retinal still photography				
i. Mydriatic				
Single field (35°) – color [29]	GPs	Any DR	79 (74–85)	73 (68–79)
	Optometrists		88 (83–93)	68 (62–74)
	Diabetologist		73 (67–79)	93 (90–96)
Two fields (50°) – color [28]	Retinal photographers	Referable DR	96 (87–100)	89 (86–91)
(Optic disc and macula)				
Two fields (50°) – red free [28]	Retinal photographers	Referable DR	93 (82–98)	87 (84–90)
(Optic disc and macula)				
Three fields (30°) – color [30]	Ophthalmologist	Any DR	95 (87–98)	99 (95–99)
(Optic disc, macula, and temporal)	Medical officer		92 (83–96)	96 (92–98)
ii. Non-mydriatic				
Single field (35°) – color [31]	Trained grader 1	Any DR	72 (66–79)	96 (92–99)
	Trained grader 2		64 (57–71)	99 (95–100)
Single field (35°) – red free [32]	Trained grader	Referable DR	78	86
4. Retinal video recording – color [33]	Ophthalmologist 1	Any DR	94 (84–98)	99 (95–99)
(Optic disc, macula, and temporal)	Ophthalmologist 2		93 (83–98)	95 (89–98)

Of the screening methods, 30° stereoscopic seven-field fundus photography remains the gold standard for DR screening or reference standard against which screening tests are judged [8]. According to the National Institute for Clinical Excellence (NICE) guidelines, DR screening tests should have sensitivity and specificity of at least 80% and 95% respectively with a technical failure rate of no more than 5% [34]. The technical failure rate has been reported to be higher in non-mydriatic and wide-angle field (e.g. 50°) retinal photography [28, 32]. For unreadable or ungradable retinal images, patients will ideally warrant referrals to ophthalmologists due to the undetermined DR state and other coexisting significant pathologies causing vision impairment such as dense cataracts, rubeotic glaucoma with hazy cornea, or vitreous hemorrhages.

Non-mydriatic retinal photography does not require any dilating drops which can potentially blur vision for up to 6 h and precipitate acute angle closure in patients with narrow iridocorneal angles [35]. Hence, it is a popular screening technique in the primary eye care setting. Nevertheless, non-mydriatic retinal photography has drawbacks, including a higher technical failure rate resulting from media opacity or small pupils and difficulty in obtaining stereoscopic views.

Mydriatic retinal photography is more reliable and allows for not only better-quality retinal images but also a lower technical failure rate. It has been shown to have a minimum sensitivity of at least 80% in the detection of any grade of DR [34]. For sight threatening retinopathy, sensitivity and specificity increased to 97% and 92%, respectively. Despite the significant increase in the detection rate of DR for mydriatic compared to non-mydriatic retinal photography, the safety of pupil dilation remains one of the fearful complications among primary eye care physicians. Nevertheless, narrow angles have also been shown to be a poor predictor of the likelihood of mydriatic-induced ACG with an incidence of 6 per 20,000 people in the Caucasian population [36]. This incidence may be slightly higher in Asia but the actual risk still remains unknown.

Economic Burden of Vision Impairment (VI) and Blindness Secondary to Diabetes

Vision impairment (VI) and blindness, as a result of diabetes, impose a substantial cost burden on the community, though such costs are difficult to assess with certainty. According to the World Health Organization (WHO), it is estimated that DR accounts for 4.8% of the number of cases of blindness (37 millions) worldwide [37]. VI and blindness are life-changing disabilities that put a heavy strain on the daily lives of sufferers, their families and society at large. The total financial cost of major visual disorders among US residents aged 40 years or older was US$35.4 billion: US$16.2b in direct medical costs, US$11.1 billion in other direct costs, and US$8 billion in productivity losses. The direct medical cost of DR was US$493 million. It is estimated that the annual cost per patient with DME is approximately twice as high as those of patients with diabetes alone. An additional €11,500 is required from DME patients every year for nonmedical costs, including the outpatient visits, nursing and inpatient care, and non-medicinal therapies.

Apart from the patients, VI and blindness had been shown to cause a considerable economic burden to the family, caregivers and the community. As demands on healthcare continue to increase in all high-income countries, economic evaluations of disease, impairment, and interventions have also become increasingly important. Faced with the increasing demand and limited resources in healthcare, the resources will need to be prioritized and channeled to the appropriate areas. All public and private stakeholders should continue to look for innovative ways of managing DM, improve access to DR screening, and plan and optimize cost-effective screening programs within the community.

Diabetic Retinopathy Screening: Innovative Approaches in the Resource-Rich and Resource-Poor Countries

Nearly all vision loss associated with DR can be prevented through regular eye examination and timely interventions. There is compelling research data showing that most, if not all, of the vision loss associated with DR can be prevented by regular eye screening [6, 7]. This is evident in European nations where annual free eye screening is offered to patients with diabetes, e.g., Iceland [38], Sweden [39], and England [40]. In the Newcastle Health District (England), Arun and colleagues reported that VI and blindness due to DR had been reduced by more than two-thirds as a direct result of this national eye screening program [41]. Similarly, new blindness cases from DR decreased by more than a third in Stockholm County (Sweden) after the implementation of diabetes eye screening [42]. In Iceland, the prevalence of blindness in those with diabetes decreased from 2.4% to 0.5% following the onset of screening in 1980, and this is largely attributable to the public health program [43]. In Singapore, the efficacy of annual eye screening in decreasing VI and blindness from DR has been recognized and implemented by the Ministry of Health (MOH) as part of their 2014 diabetes care guidelines [44].

A successful DR screening program should follow the established quality assurance standards to ensure their services are safe and effective, with regular audits on the key performance indicator (KPI) and quality assurance standards data [45]. In order to set up a successful DR screening program, several factors need to be taken into consideration: (1) magnitude of the disease, (2) validity of the screening tests, (3) effective treatment at preclinical stage, (4) cost-effectiveness of screening program, (5) safety and comfort of screening tests, (6) quality control measures, and (7) sustainability through integration into the healthcare system [46]. At present, various screening models, implemented in resource-rich and resource-poor countries, remain constantly challenged by increasing resources needed for implementation and maintenance of comprehensive DR screening programs [9]. It has been estimated that DR costs $500 million annually in healthcare and associated costs in the United States alone [47]. With the rapidly increasing prevalence of diabetes in resource-rich and resource-poor countries, the financial and manpower resources allocated to training, certification, and accreditation of the professional graders will be untenable. In addition, this human bottleneck can potentially result in undue delay of diagnosis and effectively limits the number of patients that can be screened.

Table 9.2 Innovative approaches for diabetic retinopathy screening and management in the setting of resource-rich and resource-poor setting

	Resource-rich	Resource-poor
1. Focus of treatment	Diabetic macular edema	Proliferative diabetic retinopathy
2. Goals of treatment	Visual improvement instead of visual loss prevention	Visual loss prevention
3. Modality of treatment	Anti-vascular endothelial growth factors	Retinal lasers – most cost-effective treatment
4. Screening models	Tele-ophthalmology screening, automated DR screening	Static and mobile/outreach eye screening
5. Focus of research	Novel therapeutics for diabetic retinopathy, novel imaging devices – e.g., optical coherence tomography, ultrawide-field fundus imaging	Improvement of awareness, systemic control and access to tertiary care services, training of primary care workers

Diabetic Retinopathy Screening Approaches in Resource-Rich Countries

The DR screening models in resource-rich and resource-poor countries can vary widely due to the availability of government healthcare funding, access to DR screening facilities, and trained eye care manpower. Traditionally, the DR screening is usually performed in a routine clinical setting by ophthalmologists, diabetes physicians, general practitioners, or optometrists using direct ophthalmoscopy, slit lamp examination with 78 diopter lens, or retinal still photography captured using a retinal camera. Retinal still photography has become increasingly popular as the DR screening method in various developed, "resource-rich" countries such as the United States, the United Kingdom (UK), Australia and Singapore. Investment of resources should be directed to establish the national tele-ophthalmology DR screening programs and to evaluate the effectiveness of sophisticated DR imaging devices (e.g., automated DR detection software, OCT, and ultrawide-field fundus imaging) (Table 9.2).

Tele-ophthalmology Diabetic Retinopathy Screening

With the advancement of telecommunication technology and improvement in network bandwidth, tele-retinal screening has been widely implemented in both developing resource-poor (e.g. India, China) and developed resource-rich countries (e.g. the United States, the United Kingdom, and Singapore). In the United States, a tele-ophthalmology DR screening program was set up between the Veterans Health Administration (VHA), the Joslin Vision Network, and the Department of Defense and the Veterans Integrated Service Network [48–50]. Similarly, the National Health Service has set out operational guidance (e.g. screening settings, role definition of clinical leads, standardization of grading thresholds, equipment guidance, photographic methods, referral intervals) for diabetic eye screening program in England [45]. In Singapore, the national screening program – Singapore Diabetic Retinopathy Program (SiDRP) is currently implementing Asia's first

telemedicine model with a centralized reading center based in the Singapore Eye Research Institute (SERI). This screening program provides a national coverage of 600,000 persons with diabetes with in-built quality assurance processes. Retinal still photography is interpreted within an hour by professional graders, and a "real-time" feedback is subsequently sent to the primary care physicians. It is a cost-effective program as it not only minimizes the patients' follow-up but also reduces the unwarranted tertiary eye care referrals.

Automated Diabetic Retinopathy Detection Software

More recently, several types of automated DR detection software have been developed to assist in managing the heavy load of retinal images for DR screening. Most automated systems (e.g., Iowa DR detection software, iGrading, EyeArt, IDx, and Retmarker) for detection of DR lesions have been assessed in terms of their performance for detecting the target lesion types [51–56], with sensitivity of at least 80% for any DR, though less specific than manual grading [57–60]. An automated DR grading system can reduce the load of retinal images that need to be graded, hence reducing the running cost of a screening program. Since the implementation of an automated grading system in Scotland, the grading workload has decreased up to 70% [53, 61] with significant cost saving (£200,000/year) [62, 63]. Sensitivity is relatively more important than specificity in a DR screening program. Missing a referable DR (false negative) might result in delayed treatment, potentially leading to vision impairment. While this may be a beneficial DR screening tool in countries or areas where DR screening services are not available, most of the automated DR system worldwide have not achieved comparable diagnostic accuracy as the trained professional graders, and thus they had been utilized as stage 1 grading to detect those with "positive DR" with subsequent manual grading by trained graders.

Optical Coherence Tomography

Optical coherence tomography (OCT) is a non-invasive, non-contact imaging modality that uses low-coherence interferometry to measure optical wave reflectivity and capture cross-sectional image of the retina. Spectral domain OCT (SD-OCT, Spectralis, Heidelberg Engineering, Germany) and swept source optical coherence tomography (SS-OCT, Topcon Medical System, Japan) are the two main OCT devices in the market, and they are useful in detecting diabetic macular edema (DME) and clinically significant macular edema (CSME). State-of-the-art technology has now allowed the macula to be imaged, quantified, and monitored noninvasively using optical coherence tomography (OCT) [64].

The use of OCT may reduce the false-positive referrals of patients suspected with DME/CSME based on the presence of a few microaneurysms or hard exudates around the macula area [65, 66]. Additionally, a UK economic modeling suggested that combining SD-OCT with fundus photographs is likely to be cost-effective in screening for DR [67]. The estimated marginal cost of including SD-OCT within the screening program was low compared with the cost of a tertiary referral and consequent monitoring in the outpatient setting. Furthermore, optical coherence tomography angiography (OCT-A) is the latest OCT device that has the ability to

analyze blood flow and the retinal vascular bed without the need of intravenous contrast. This device is potentially useful to prognosticate the visual potential of people with DR based on the amount of capillary dropout around the macula area [68].

Confocal Scanning Laser Ophthalmoscopy

Confocal scanning laser ophthalmoscopy (cSLO) has also been shown to be a cost-effective tool to screen for DR [69, 70]. It uses laser light instead of a bright flash of white light to illuminate the retina. A focused laser beam scans across the fundus illuminating successive single points in a raster pattern. The reflected light is captured through a small aperture that suppresses light reflected or scattered from outside of the focal plane which otherwise would blur the image. The result is a sharp high-contrast image of the object layer located at the focal plane. The advantages of using cSLO over traditional fundus photography include improved image quality, small depth of focus, suppression of scattered light, patient comfort through less bright light, three-dimensional imaging capability, video capability, and effective imaging of patients who have a poorly dilated pupil. Some cSLO devices obtain images with multiple lasers typically green and red in the Optos systems and blue, green, and infrared in the Heidelberg multicolor providing a pseudocolor image. These images can be viewed separately and can provide additional information on changes at various retinal layers. In diabetes this can be helpful in identifying area of previous macular laser treatment and retinal pigment epithelium changes [71].

Ultrawide-Field Fundus Imaging

Ultrawide-field (UWF) fundus imaging technology has been implemented for DR screening. It is able to capture a 200° wide-field image in a single photograph by combining an ellipsoid mirror with a scanning laser ophthalmoscope. This technology has been incorporated into various devices including Optos (Marlborough, MA), Optomap 200Tx, Daytona imaging systems and Heidelberg Engineering (Carlsbad, CA). As compared to the standard imaging, the UWF imaging was reported to improve DR diagnostic accuracy by 15–17% by detecting more peripheral lesions with a lower technical failure rate of 3% and quicker image evaluation time [72, 73]. This screening modality may improve the physicians' ability to diagnose and manage diabetic eye disease given that 10–15% of standard fundus images captured in multiple retinal locations are incorrect [73]. UWF had been shown to reveal more pathology than standard fields including peripheral microaneurysms, neovascularization, vascular non-perfusion and vascular leakage, providing early signs that might otherwise be missed and that may suggest a greater degree of disease severity [73, 74]. In fact, the combination of both OCT and UWF had been shown to improve the DR assessment in a DR screening clinic [75].

Other Imaging Modalities

In addition, several other imaging modalities such as the portable eye examination kit (PEEK) – a smartphone-based ophthalmic tool [76, 77], retinal video recording [33], adaptive optics [78, 79], retinal function imager [80, 81] and metabolic

imaging [82] of the retina have claimed to help with DR diagnosis and prognostication. Nevertheless, more research is required to further evaluate the clinical and cost-effectiveness of these devices in the setting of DR screening.

Diabetic Retinopathy Screening Models in Resource-Poor Countries

To establish a DR screening program in resource-poor countries, the WHO Health Systems Framework recommends sound leadership and governance in six areas, (1) service delivery, (2) health workforce, (3) healthcare financing, (4) medical products and technologies, (5) leadership and governance, and (6) information and research [83]. A stepwise approach to implementing and developing a DR screening service has also been described by Scanlon et al. Key steps include [83]: (1) diagnose and treat cases in the eye clinic; (2) screen all patients with diabetes at a hospital diabetes clinic; (3) create a diabetes register and call for eye screening; (4) identify undiagnosed diabetes/DR in the community; and (5) set up a national DR screening program with education. The focus of research should be on raising public awareness, improving access in rural areas, and training the primary eye care workers to meet the demand for DR screening (Table 9.2).

In Africa, Poore and co-workers have described various forms of DR screening services, e.g. regional screening programs, hospital-based screening services, and nationwide DR screening service [83]. The development of a sustainable and integrated DR screening services requires a health systems approach, including collaboration with representatives from a variety of ministerial departments and professional bodies. The screening service can be expanded via increasing geographical coverage, integration into the general healthcare system, and stepwise progression from a passive, opportunistic service to one that systemically and proactively seeks to prevent DR. In order to maximize the finite resources that are available in the resource-poor countries, it is wise to implement the WHO Health Systems Framework as a systematic approach for planning. DR services can be delivered using static or mobile/outreach methods in a vertical or integrated fashion.

Static Diabetic Retinopathy Screening Service

Static service is one of the most common methods to screen for DR [83]. It offers the benefit of service provision at an established facility that consists of ophthalmic equipment and trained eye care providers. It can be conducted in the eye department or in the diabetes clinic. The integration of DR screening within a diabetes-focused primary care setting allows immediate referrals from the diabetes clinic to the eye clinic to see ophthalmologists if the retinal image is ungradable or there is presence of vision-threatening DR. This is a holistic model where the patients with diabetes are able to undergo a full clinical examination including eye screening, cardiac examination, blood pressure check, urine testing, foot check as well as the routine blood tests. However, one of the major obstacles facing this model of service delivery is that the patients are deterred by the long queues for DR screening after

waiting in lengthy queues in the diabetes clinic. Additionally, the static DR service will not be an ideal model for patients who have transportation or mobility issues as they may need to travel to the screening site that can be located a few hours away from their houses. As a consequence, some patients may only turn up to the screening services only when their vision has deteriorated significantly, and these patients could benefit from the mobile/outreach DR screening service.

Mobile/Outreach Diabetic Retinopathy Screening Service

Mobile/outreach eye screening has been shown not only to be cost-effective for DR screening but also able to raise awareness of DR among the community [84, 85]. In low-to-middle income countries, there is a mismatch between the supply (people performing DR screening) and demand (people with diabetes) in DR screening [84]. In Kilimanjaro and Copperbelt programs, the DR screening services provided at the local clinic with fundus photography achieved very high screening rates [83]. In India, several tele-ophthalmology DR screening models were developed by different eye hospitals to improve accessibility to tertiary eye care services among the rural population. In the Sankara Nethralaya Tele-ophthalmology Project and the Aravind Tele-ophthalmology Network, a social worker and an optometrist travel in a mobile van with an in-built ophthalmic examination facility connected to the base hospital via satellite connectivity [84]. The retinal still images are captured, transmitted and graded by the ophthalmologist. In cases where the ophthalmologist requires more information about the patients, he/she will interact with the optometrist via videoconferencing. Despite achieving a high screening rate for DR in the local community, the mobile/outreach screening service may face several challenges including the need for excellent telecommunication network to support image transmission, regular maintenance of the ophthalmic imaging devices that may not be kept in a sound environment (e.g. in a van) and also the subsequent transportation and follow-up of those patients who need to be seen in the tertiary eye care services for further intervention.

Low-Cost Measures for Diabetic Retinopathy Screening

Public Education

Wang and associates reported a surprising low number of patients with diabetes (less than 50% of the survey respondents) who were aware of HbA1c [86], with merely 17% who understood its ideal level (<7%), significance and the physiology. Younger age and post-secondary education were shown to be significantly associated with people who understood HbA1c [86]. A meta-analysis also showed that the self-management education improved glycemic control levels at immediate follow-up with a decrease of 1% noted for every additional 24 hours of contact [87]. To prevent diabetes and DR, it is critical to educate the public on the diet and lifestyle factors, optimize vascular risk factors (i.e. high blood pressure, lipid, smoking), and improve their awareness about diabetes and the associated complications. Lifestyle counseling in the primary care setting plays a crucial role in helping the patients with diabetes in optimizing their glycemic and other vascular risk factor control. For

those with diabetes, community education schemes were found to be highly effective in attracting patients to screening [83]. The local patients can be invited to screening through provision of information and education to the diabetes clinics and community.

Improving the Access for Early Detection and Treatment

Given the poor access to tertiary healthcare facilities, the prevalence of undiagnosed diabetes and DR is high in the resource-poor countries (Table 9.2) [88]. In Africa, the screening studies identified high proportions (>40%) with previously undiagnosed diabetes and sub-optimal glycemic control among those with diabetes [88]. In China, the prevalence of DR in T2DM ranged from 28% to 43% [89, 90]. Due to poorer access to screening services, the prevalence of DR was higher in the rural than the urban areas in China [89]. On the contrary, the Indians who lived in urban areas had a higher prevalence of diabetes (28.2% vs 10.4%) and DR (18% vs 10.3%) as compared to the rural Indians [91, 92].

More resources should be invested to train primary nonmedical personnel, e.g. technicians, ophthalmic nurses and optometrists to participate in DR screening in resource-poor countries. These allied health professionals should be trained to perform retinal still photography and grade the retinal still images. Early detection is crucial to prevent diabetes-related vision impairment. Primary prevention could be undertaken to prevent the occurrence of diabetes by raising the public awareness to avoid obesity, increase physical activity and consume low-fat/high-complex carbohydrate diet (Fig. 9.1) [93]. All of these strategies have been shown to increase insulin sensitivity and reduce the prevalence of diabetes in the general population. Once patients develop diabetes, secondary prevention should then focus on maintaining good glycemic control, optimizing vascular risk factors (e.g. hypertension, hyperlipidemia, cessation of smoking), and ensuring early eye screening including a retinal examination [93]. Failure to achieve a good glycemic will result in the development of vision-threatening DR (severe NPDR and PDR) that needs to be treated promptly using scattered retinal laser to prevent blinding complications [94, 95]. At present, research and clinical resources are heavily invested on the VTDR area. More focus and resources should be redirected to the research related to primary and secondary prevention in order to reduce the permanent visual loss secondary to diabetes.

Primary Eye Care Clinic in Singapore: A Secondary Eye Care Service

Treating patients in a primary care setting has been shown not only to be more cost-effective but also to be more efficient in increasing health outcomes by promoting positive patient behaviors such as adherence to medication and appointments [96]. It is estimated that at least 20% of the eye patients who were seen in the tertiary hospitals could have been monitored in the primary eye care setting [97]. In Singapore we have set up the primary eye care (PEC) clinic mainly to follow up and monitor stable DR patients [e.g., mild or moderate nonproliferative DR (NPDR) with sub-optimal media clarity, patients with previous retinal lasers and burnt out DR]. Nevertheless, this clinic may be able to serve as an additional triage platform to be the secondary eye care service for the patients who had been identified as

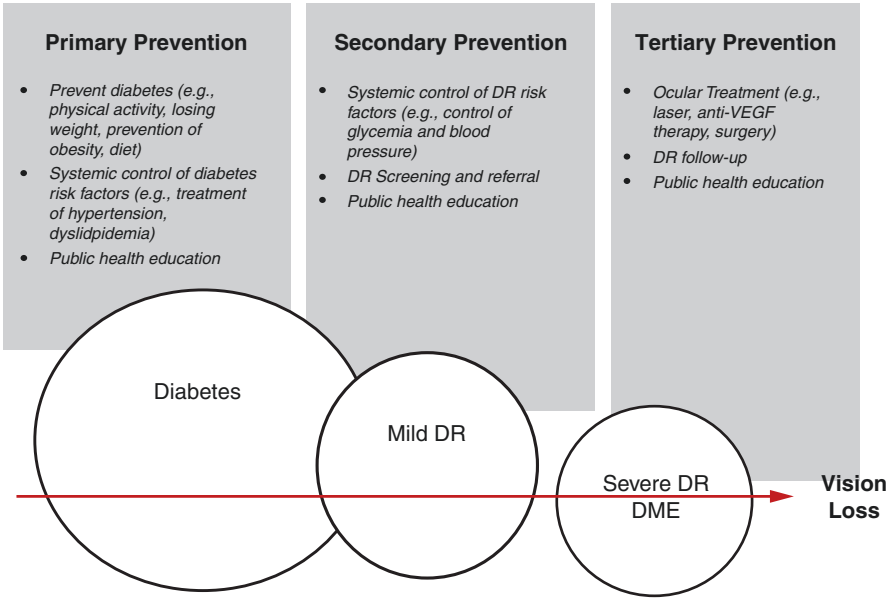

Fig. 9.1 Prevention strategies to minimize diabetes-related vision impairment. DR diabetic retinopathy, DME diabetic macular edema

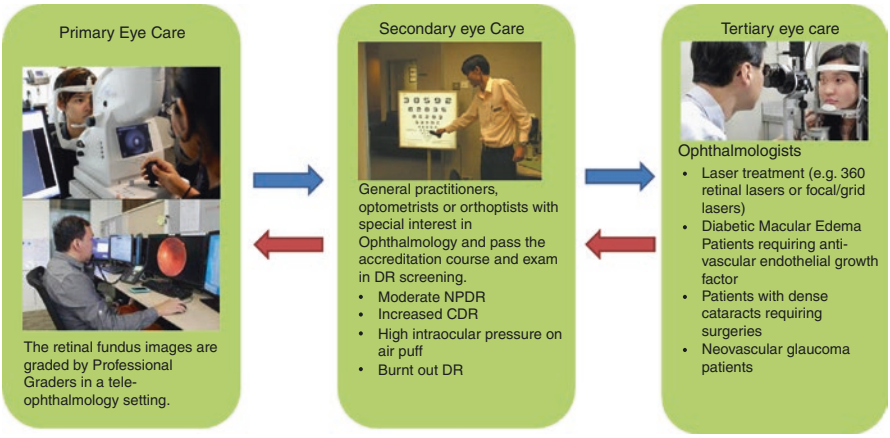

Fig. 9.2 Innovative model for primary, secondary and tertiary eye care delivery for diabetic retinopathy (DR). The trained graders can be the primary eye care providers to screen for DR via a tele-ophthalmology platform. The referable cases should then be seen at the secondary level by general practitioners, optometrists or orthoptists with special interest in DR screening. At the tertiary eye care level the ophthalmologists should assess the patients who require interventions such as retinal lasers, anti-vascular endothelial growth factor or cataract surgery

"referable" from the SiDRP (Fig. 9.2). The referable DR patients consist of patients with moderate non-proliferative DR and above, diabetic maculopathy, increased cup to disc ratio and ungradable images due to media opacities. At present, these cases are sent directly to the Singapore National Eye Centre for assessment by ophthalmologists.

Conclusions

Diabetic eye diseases impose substantial direct and indirect costs on the public healthcare system and on patients and their caregivers. Early detection and prompt treatment of DR allow the prevention of diabetes-related VI and blindness. While much of the advances and research in the past few decades have largely been focused on tertiary level care of patients with DR (e.g. laser, intraocular application of anti-vascular endothelial growth factor (anti-VEGF), and vitreoretinal surgery), solutions to sustainable prevention of VI and blindness involves developing innovative ways to optimize clinically and economically effective DR care in primary and secondary settings, both in resource-rich and resource-poor countries worldwide. Retinal photography, with additional use of ophthalmoscopy for selected cases, remains the most effective DR screening strategy in both resource-rich and resource-poor settings. The mobile eye clinic and tele-ophthalmology screening methods are cost-effective models to be implemented in both settings. Several novel DR imaging modalities have been proposed to aid with DR screening particularly in resource-rich settings, but their cost-effectiveness remains uncertain and needs to be further investigated before wide adoption, particularly in resource-poor settings. In all settings, there continues to be fragmented healthcare and eye care delivery systems which should be transformed into a comprehensive DR network to enable the capitalization of the resources, tools and training facilities. Lastly, it is crucial to evaluate not just the clinical effectiveness but also the cost-effectiveness of various different DR screening models with the aim to find the most appropriate screening model that suits a particular healthcare system, based on its existing infrastructure and the availability of clinical services, in both resource-rich and resource settings.

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Innovative Approaches in Delivery of Eye Care: Age-Related Macular Degeneration

10

Ryo Kawasaki and Yumiko Kawasaki

Burden of Age-Related Macular Degeneration

Age-related macular degeneration (AMD) is one of the leading causes of severe central vision loss and blindness in an elderly population. Global prevalence of early, late and any AMD in people 45–85 years are estimated to be 8.01%, 0.37%, and 8.69%, respectively [1]. Based on this prevalence, with aging of the global population, the projected number of people with AMD in 2020 is estimated to be up to 196 million, reaching up to 288 million in 2040 [1].

The early stage of AMD includes drusen and pigmentary abnormalities. The advanced stage of AMD is categorized as neovascular AMD or geographic atrophy. Neovascular AMD is defined as having a choroidal neovascularization (CNV) which is pathologic angiogenesis originating from the choroidal vasculature extending to the subretinal space through Bruch's membrane. CNV usually coexists with serous or hemorrhagic detachment of the neurosensory retina or retinal pigmentary epithelial (RPE) cell layer. Other exudative changes such as hard exudates may develop as well. It also develops subretinal or sub-RPE fibrovascular fibrosis, known as a disciform scar formation. Geographic atrophy is defined as a round- or oval-shaped area of depigmentation of the RPE with sharp margins. Visibility of underlying large choroidal vessels through the depigmented area is typical.

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The prognosis of neovascular AMD, an aggressive form of late AMD is poor without treatment [2]. If untreated, one in four patients with neovascular AMD lose visual acuity more than three lines at 3 months and one in two patients with neovascular AMD lose visual acuity more than three lines at 12 months [2]. AMD is associated with significant functional limitations in daily living due to its devastating central visual disturbance caused by the disease [3, 4]. Patients with AMD need more assistance in daily living, and they also experience a decline in the quality of life [4, 5].

Advancement in the treatment for neovascular AMD with anti-vascular endothelial growth factor (VEGF) injections has changed the treatment of AMD. Before anti-VEGF treatment was available, photodynamic therapy with photosensitizer and thermal direct macular photocoagulation were the only treatment modalities. With anti-VEGF available for the current management of neovascular AMD, it is not just stabilizing the vision, but improvement in visual acuity can be expected. It is still challenging to improve vision in patients with geographic atrophy; however, multiple trials are underway to slow down and prevent the incidence of vision loss from geographic atrophy.

Epidemiology and Risk Factors of Age-Related Macular Degeneration

The prevalence of age-related macular degeneration in the United States was estimated to be 1.47% (95% confidence intervals [CI] 1.38–1.55%) in persons 40 years or older by Friedman et al. in 2004 [6]. Rudnicka et al. [7] performed a meta-analysis on the incidence of AMD in white European ancestry. They estimated that the annual incidence of late AMD was 3.5 per 1000 persons aged 50 years or more (95% CI 2.5–4.7 per 1000). When divided by the subgroups of late AMD, annual incidence of geographic atrophy (GA) was 1.9 per 1000 persons and neovascular AMD was 1.8 per 1000 persons aged 50 years or more.

Both genetic and environmental factors have been identified as playing major roles in the etiology of AMD. Among those factors, older age and smoking are the two major non-genetic risk factors of AMD. Less consistent risk factors include nutritional factors and cardiovascular risks. Genetic predispositions such as complement factor H gene variants have been reported to be associated with AMD, and this was one of the successful examples of genome-wide association studies [8–10].

Older Age

The 15-year follow-up study of the Blue Mountains Eye Study (BMES) revealed that age-standardized cumulative incidence of early and late AMD were 13.1% (95% CI 11.7–14.6%) and 3.3% (95% CI 2.6–4.0%) adjusted for the competing risk of deaths [11]. Incidence of early and late AMD is higher as age increased (Fig. 10.1). Each increase in the age by 10 years was associated with 11% and 20% increased risk of early AMD and late AMD respectively, after adjusting for other risk factors.

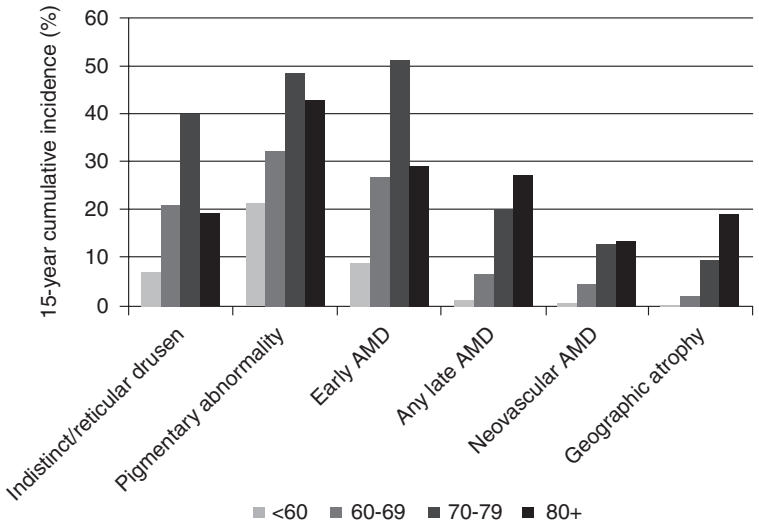

Fig. 10.1 Incidence of AMD by baseline age groups in the Blue Mountains Eye Study. (Modified and cited from the original article by Joachim et al. [11])

Smoking

Smoking is one of the most important risk factors because it is a strong and modifiable risk factor of AMD confirmed in multiple epidemiological and clinical studies. In the 15-year follow-up study of the BMES [11], current smoking was associated with more than a threefold increased risk of developing late AMD (OR 3.63, 95% CI 1.86–7.06). While the association between current smoking and early AMD was not significant in the BMES 15-year follow-up study (adjusted OR 1.45; 95% 0.90–2.36), there are other studies that observed a significant association between smoking and early AMD [12].

Thornton et al. [13] reported a review on the association between smoking and AMD based on 17 epidemiological studies as a causal relationship. Thirteen out of 17 studies found a statistically significant association between smoking and AMD; current smokers or ever smokers had up to fivefold increased risk of AMD compared to nonsmokers or never smokers (RR/OR 1.06–4.96). This supports a strong and consistent association between smoking and AMD. Smoking is associated with 5-year or 10-year incidence of AMD supporting a temporal relationship between exposure to smoking and future development of AMD. Studies examining the number of cigarettes smoked or pack-years estimation reported a dose-response association between smoking and AMD. Ex-smokers were at relatively lower risk of AMD compared to current smokers, suggesting a reversibility of the association. The evidence is altogether supportive of not just considering smoking as a risk of AMD, but smoking cessation may be the most influential point of intervention to prevent AMD.

Nutrition

Considering the fact that the global population is aging rapidly, affordable preventive interventions through modifying dietary nutrition might be a strategy that contributes to prevention of the disease and mitigation of the burden of disease. Schleicher et al. [14] and Zampatti et al. [15] have listed nutritional factors potentially associated with a decreased risk of AMD (Table 10.1). Overall, it is likely that there are associations between nutritional factors and AMD or its earlier signs.

However, it is also important to understand that not all nutritional risk factors are translated into preventive strategies easily. There is a case that intervention to the nutritional risk factors identified in the epidemiological studies did not demonstrate a beneficial effect in clinical studies. Although there is a successful example of secondary prevention of AMD such as the Age-Related Eye Disease Study (AREDS) and AREDS2, primary prevention of neovascular AMD by nutritional supplementation has not been established. AREDS and AREDS2 successfully demonstrated that the supplementation of the combination of multiple nutritional factors can reduce the risk of developing neovascular AMD from eyes with high-risk characteristics such as large drusen. Whether nutritional supplementation or modification of dietary patterns can provide primary or secondary prevention to early AMD and geographic atrophy is not confirmed yet.

Chong et al. [16] provided a systematic review and meta-analysis on dietary antioxidants (vitamin A, vitamin C, vitamin E, zinc, lutein, zeaxanthin, α carotene, β carotene, β cryptoxanthin, and lycopene) and primary prevention of early AMD (i.e. no AMD to early AMD). As a result, they found no or little benefit of these dietary antioxidants intake in the primary prevention of early AMD.

In the AREDS2 [17], intervention with supplements containing antioxidants (vitamin C 500 mg, vitamin E 400 IU, zinc/copper 80 mg/2 mg, and lutein/zeaxanthin 10 mg/2 mg) showed preventive effects in those with the Category 3 in the AREDS defined as having "many medium-sized drusen or one or more large drusen in one or both eyes" and the Category 4 as having "either a breakdown of light-sensitive cells and supporting tissue in the central retinal area (advanced dry form) or abnormal and fragile blood vessels under the retina (wet form)" in one eye only. Thus, the earliest sign to consider the AREDS2 formulated supplements to be beneficial to prevent the progression to advanced stage of AMD is the presence of at least one large drusen (≥125 μm in diameter). The beneficial effect to reduce the risk of progression was observed more in those who are taking enough dietary lutein/zeaxanthin; this subgroup might be the best target of these supplements.

Wang et al. [18] found that two risk alleles of either or both the complement factor H (CFH) rs1061170 or age-related maculopathy susceptibility 2 (ARMS2) rs10490924 polymorphisms had a significantly lower risk of early or any AMD if they frequently consumed lutein-/zeaxanthin-rich food items in the BMES and the Rotterdam Study samples.

Table 10.1 List of nutritional factors associated with early and late AMD in prospective studies [14, 15]

	Early AMD	Late AMD
1. Dietary carbohydrate		
Higher glycemic index		
2. Dietary Fats and Fish		
Higher intake of Omega-3		
Higher intake of Omega-6		
Fish intake		
Polyunsaturated fat and nut intake		
Polyunsaturated fat		
Monounsaturated fatty acids		
Vegetable fat		
Animal fat		
High fat		
Saturated fat		
Trans-fatty acids		
3. Cholesterol		
4. Carotenoids		
Total carotenoids		
Beta-carotene, Alpha-carotene, Lycopene, Cryptoxanthin, Total carotenoids		
5. Vitamin A		
6. Vitamin E		
7. Vitamin C		
8. Antioxidant combination or multivitamin		
9. Zinc		

No studies identified
Not statistically significant
Odds ratios or relative risks equal to “1 to <1.5”or “1 to >0.67”
Odds ratios or relative risks equal to “1.5 to <2”or “0.67->0.5”
Odds ratios or relative risks equal to “2 or more”or “0.5 or less”
Inconsistent associations

Nested case-control studies from the Rotterdam Study [19] reported that those with risk CFH Y402H genotype and LOC387715 A69S genotype benefitted most from higher dietary intake of zinc, ω-3 fatty acids, β-carotene, and lutein/zeaxanthin with a lower incidence of early AMD.

Genetic Variants

AMD is considered as one of the early successful outcomes of the genome-wide association study in identifying unknown genetic polymorphisms associated with common diseases in addition to linkage analysis and candidate gene analysis. A list of genetic loci associated with AMD [20] is shown in Table 10.2.

Initial genome-wide association studies were done using case-control study design. Recent cohort studies confirmed that identified genetic variants in the CFH gene and ARMS2 gene were associated with higher risk of developing early and late AMD in a longitudinal cohort study design. C/C genotype of the CFH rs1061170 was associated with 2.56 times higher risk of developing early AMD; C/T and C/C genotypes were associated with 2.25 (95% CI 1.22–4.15) times, and 4.45 (95% CI 2.19–9.03) times higher risk of developing late AMD in the 15-year follow-up study of the BMES. G/T genotype in the ARMS2 rs10490924 was associated with 1.53 (95% CI 1.12–2.08) and 2.16 (95% CI 1.07–4.37) times higher risk of early AMD; T/T genotype was associated with 2.59 (95% CI 1.56–4.31) and 5.81 (95% CI 2.09–16.12) times higher risk of late AMD.

Table 10.2 List of genes/loci associated with AMD, confirmed by multiple genome-wide association studies

DNA marker	Nearby gene(s)	Pathway
rs429358, rs7412	APOE	Transport and metabolism of lipoproteins
rs10490924/rs11200638	ARMS2/HTRA1	Unknown
rs9332739/rs415667	C2/CFB	Complement pathway
rs2230199	C3	Complement pathway
rs3764261, rs2303790	CETP	Transport and metabolism of lipoproteins
rs1061170, rs10737680, rs800292	CFH	Complement pathway
rs2285714, rs2295334	CFI	Complement pathway
rs13095226, rs13081855	COL8A1/ FILIP1L	Extracellular/collagen matrix pathway
rs1999930, rs3812111	FRK/COL10A1	Extracellular/collagen matrix pathway
rs493258, rs10468017, rs920915	LIPC	Transport and metabolism of lipoproteins
rs9621532, rs5749482	TIMP3	Degradation of the extracellular matrix
rs13278062	TNFRSF10A	Unknown
rs4711751, rs943080	VEGFA	Angiogenesis

Modified and updated based on the table in Ratnapriya and Chew [20]

Other Potential Risk Factors

Sunlight Exposure

Although sunlight exposure has been reported to be associated with a risk of AMD, it is still controversial as an established risk factor. Sui et al. [21] performed a systematic review and meta-analysis examining an association between sunlight exposure and risk of AMD based on 14 studies. It is challenging how to assess sunlight exposures in a study setting; time spent outdoors and outdoor jobs were common exposures used in the study. One study was based on a quantitative evaluation of facial wrinkles as a surrogate of sunlight exposure. Although the heterogeneity was suggested, pooled odds ratio in people with the highest exposure was 1.379 (95% CI 1.091–1.745) compared to the people with the lowest sunlight exposure [21]. The sub-analysis of meta-regression examining the association between the gross domestic product per capita and the association of sunlight exposure suggested that the association is stronger in lower-income countries. While the explanation of this trend is not clear, authors discussed a potential attribution of better eye protection against sunlight exposure, such as wearing a hat or sunglasses.

Cardiovascular Risk Factors

Although it is still controversial, multiple studies have shown a potential link between cardiovascular risk factors and AMD, e.g. hypertension, serum lipids, body mass index, and obesity [22]. Persons with the metabolic syndrome were at higher risk of late AMD in the 10-year follow-up of the BMES [23]. The potential link commonly contributed to the etiology of cardiovascular diseases and AMD is supported by the fact that drusen have similar molecular compositions of atherosclerosis in the arteriolar walls [24]. There are studies suggesting similar pathological changes in the Bruch's membrane and the vascular intima in atherosclerosis, supporting a common pathophysiology of AMD and atherosclerosis involving genetic variations, oxidative stress, or inflammatory etiology in ocular and systemic vascular system [25].

Chronic Infection

Studies have shown that patients with AMD have higher antibody titer of *Chlamydia pneumoniae* [26]. This is hypothesized as there has been a link between the history of *C. pneumoniae* infection and cardiovascular disease. Further studies have identified *C. pneumoniae* within choroidal neovascular membranes surgically removed from patients with neovascular AMD [27]; however, another study did not find the deoxyribonucleic acids of *C. pneumoniae* in specimens [28]. Multiple population-based epidemiological studies have tried to confirm the association [29, 30] but are not fully supportive to this association. Similar to *C. pneumoniae*, chronic infection with cytomegalovirus infection confirmed by cytomegalovirus IgG titers was reported to be associated with neovascular AMD [31].

Male Gender in Asian Populations

Meta-analysis of the prevalence of AMD in Asian population-based studies has revealed that Asian men are more likely to have AMD than women [32]. Yasuda

et al. [33] determined the 9-year incidence of AMD in a Japanese population-based sample of the Hisayama study, and they found that men have threefold higher risk of developing AMD than women. It is also reported that a large part of this association can be explained by smoking because there are more smokers in Asian men than Asian women [33].

Heavy Alcohol Consumption

Chong et al. [34] performed a systematic review and meta-analysis examining the association between alcohol consumption and the risk of AMD. They found that heavy alcohol consumption defined as having "more than three standard drinks per day" is associated with an increased risk of early AMD (OR 1.47, 95% CI 1.10–1.95). The association was not consistent for late AMD. There was no protective effect of mild to moderate alcohol consumption and the risk of AMD.

Risk Prediction Algorithm and Models

Seddon et al. [35] have reported a prediction algorithm for progression to advanced AMD based on six common single-nucleotide polymorphisms (SNPs) associated with AMD and non-genetic risk factors (age, sex, education, smoking, body mass index, and baseline grading for the AMD category [no AMD, early AMD, intermediate AMD]). The fully adjusted for confounders prediction model for 10-year incidence of AMD with both genetic and non-genetic risk factors provided a good predictive value (area under the receiver operating curve [ROC] of 0.884 and 0.809 in the derivation and validation samples, respectively) [35].

Buitendijk et al. [36] have reported a prediction model for AMD using three population-based epidemiological studies, the Rotterdam Study, the Beaver Dam Eye Study (BDES), and the BMES. They incorporated age, sex, body mass index, smoking, and baseline AMD scale with 26 SNPs associated with AMD; the highest area under the ROC was obtained with a fully adjusted model with all the information (0.88 and 0.85 in the Rotterdam Study as a derivation sample set and the BDES plus BMES as a validation sample set) [36].

Chiu et al. [37] further developed a risk prediction model for 10-year risk of developing AMD based on non-genetic risk factors of age, sex, education level, race, smoking status, and presence of pigment abnormality, soft drusen, and maximum drusen size as "the Macular Risk Scoring System (MRSS)" based on the AREDS and the BMES data. They have expanded the use of risk prediction model into the population by deploying the risk prediction model as a free mobile app [38].

Although it has been shown that the prediction model based on environmental and genetic polymorphisms perform well in identifying persons at higher risk of AMD, its benefit in improving clinical outcomes is not validated. Risk prediction algorithms might be fully utilized to improve patient care only if they are combined with adequate screening programs to segment high-risk individuals at preclinical or early stage of AMD. It is also essential to consider what can be provided when those high-risk individuals are identified. At this moment, however, evidence of

preventive measures for incidence of AMD is scarce, and strong evidence of delaying progression from early AMD to late AMD is limited. Therefore, it is still controversial whether genetic testing should be adopted as a part of standard care for AMD because there has been no solid evidence that supports significant benefit of the genetic information in prevention, management, and decision-making for treatment. Further studies are warranted if the genetic information is clinically useful in this context.

Screening for Early Signs of Age-Related Macular Degeneration

Given that modifiable risk factors of AMD have been recognized as shown in the section "Epidemiology and Risk Factors of Age-Related Macular Degeneration", screening for AMD might be of benefit to identify early preclinical signs of AMD (drusen and pigmentary abnormalities) to consider preventative interventions and modification of lifestyle-related risk factors to delay or prevent development of AMD.

Screening for early signs of AMD is performed by standard fundus photography. Recently, reticular drusen was also considered as a high-risk characteristic associated with the risk of advanced AMD [39]. Advanced retinal imaging with optical coherence tomography (OCT) has expanded the concept of early signs of neovascular AMD, especially of polypoidal choroidal vasculopathy (PCV) with noninvasive assessment of the choroidal layer.

Salti et al. [40] evaluated two screening methods to detect AMD. Non-mydriatic fundus photography had 64% sensitivity and 97% specificity; spectral-domain optical coherence tomography (OCT) increased the sensitivity to 91.5% and specificity to 98.6%. They concluded that using OCT in screening in addition to non-mydriatic fundus photography enhances the screening capacity, while the additional cost of implementing OCT in a screening setting should be supported by cost-effectiveness assessment.

Drusen and Pigmentary Abnormalities

Drusen and pigmentary abnormalities have been considered as two pre-clinical signs of AMD. In the international classification and grading system for age-related maculopathy and AMD proposed by the International Age-Related Maculopathy Epidemiological Study Group [41], drusen was described as "discrete whitish-yellow spots," and "they may be soft and confluent, most often with indistinct borders. Small, hard drusen are usually present in eyes with as well as those without ARM, so do not of themselves characterize the disorder." Pigmentary abnormalities are classified into areas of increased pigment or hyperpigmentation and areas of depigmentation or hypopigmentation of the RPE, most often more sharply demarcated than drusen.

The clinical classification for AMD has been updated following detailed observations of longitudinal epidemiological studies and clinical trials (Table 10.3). It adopted a simplified severity scale with semi-quantifiable signs defined based on the risk of development of advanced stages of AMD; it now provides clinical severity in addition to classification of the early signs. The updated classification is useful especially when accompanied by the updated evidence of recommendations, and it is simple enough to be used in a screening setting aiming at early detection and risk assessment for AMD (Table 10.3).

Reticular Drusen

Recently, the concept of earlier signs of AMD has been expanded in at least two aspects. Firstly, reticular (pseudo-) drusen is now considered as a sign indicating a higher risk of AMD. In the BMES, SNPs of rs1061170 (CFH) and rs10490924 (ARMS2) were associated with higher incidence of reticular drusen over the 15-year follow-up, along with older age, current smoking and female gender [43]. One in three eyes with reticular drusen developed late AMD in 5 years, a fourfold higher risk compared to eyes with early AMD but without reticular drusen. More than half of the eyes with reticular drusen developed geographic atrophy, which is a higher rate than late AMD progressed from early AMD without reticular drusen [43]. Reticular drusen is also reported to be associated with the retinal angiomatous proliferation (RAP) compared to typical AMD or PCV. Yoneyama et al. [44] examined 408 cases of exudative AMD and found that the prevalence of reticular drusen in

Table 10.3 Proposed AMD clinical classification

Classification of AMD	Definition (lesions assessed within 2 disc diameters of fovea in either eye)	Recommendation
No apparent aging changes	No drusen and no AMD pigmentary abnormalities[a]	Avoid: smoking, heavy alcohol consumption, sunlight exposure
		Encourage: balanced healthy diet
Normal aging changes	Only droplets (small drusen ≤63 μm) and no AMD pigmentary abnormalities[a]	(Same as above)
Early AMD	Medium drusen >63 μm and ≤125 μm and no AMD pigmentary abnormalities[a]	(Same as above)
Intermediate AMD	Large drusen >125 μm and/or any AMD pigmentary abnormalities[a]	(Same as above)
		+Consider AREDS2 supplementation
Late AMD	Neovascular AMD and/or any geographic atrophy	(Same as intermediate AMD)
		+Anti-VEGF treatment, PDT for PCV cases

Modified based on Ferris et al. [42]
AMD age-related macular degeneration, *VEGF* vascular endothelial growth factor, *PDT* photodynamic therapy, *PCV* polypoidal choroidal vasculopathy
[a]AMD pigmentary abnormalities = any definite hyper- or hypo-pigmentary abnormalities associated with medium or large drusen but not associated with known disease entities

typical AMD, PCV and RAP was 13.6%, 0% and 38.2%, respectively [44]. Ueda-Arakawa et al. reported that the prevalence of reticular drusen in RAP, geographic atrophy, typical AMD and PCV was 83%, 50%, 9% and 2%, respectively [45].

Pachychoroid

Advanced retinal imaging with the OCT with enhanced depth imaging or swept source OCT has enabled us to quantify the thickness of the choroid non-invasively in vivo. There has been accumulated evidence supporting an overlapped disease entity of AMD and the pachychoroid spectrum diseases [46–49]. Pachychoroid is defined as "an abnormal and permanent increase in choroidal thickness often showing dilated choroidal vessels and other structural alterations of the normal choroidal architecture [46, 49]." There is a spectrum of the disease related to the pachychoroid, e.g. central serous chorioretinopathy (CSC), pachychoroid pigment epitheliopathy and pachychoroid neovasculopathy. Pachychoroid neovasculopathy is considered as a late complication of CSC, and it can develop type 1 choroidal neovascularization similar to typical AMD and/or PCV. Multiple studies have consistently shown that eyes with PCV have thicker choroidal thickness compared to those with typical AMD [50, 51]. Eyes with PCV have higher permeability in the choroid [51], the thick choroid observed as pachychoroid might reflect these pathologic changes. Studies have also shown that history of CSC is associated with increased risk of PCV [52, 53].

Figure 10.2 illustrates a continuum of age-related macular degeneration including preclinical signs and subtypes of AMD.

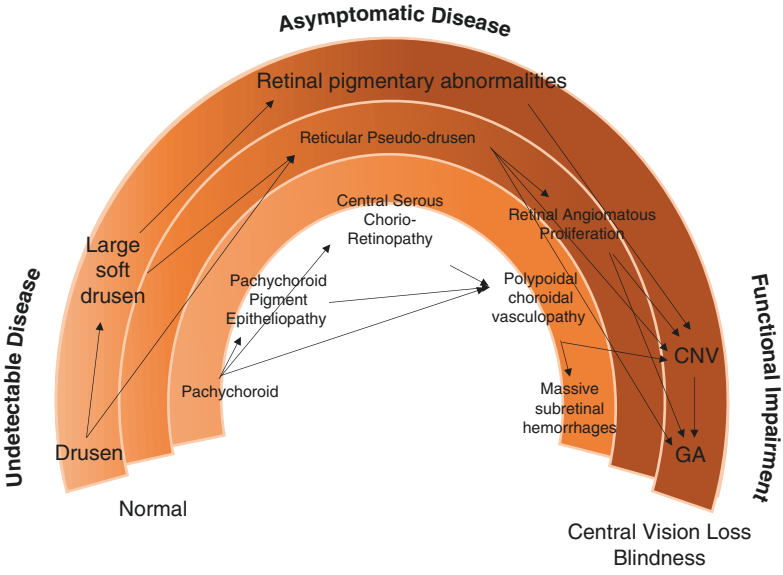

Fig. 10.2 Age-related macular degeneration continuum (*CNV* choroidal neovascularization, *GA* geographic atrophy)

Treatment of Age-Related Macular Degeneration

Therapeutic developments for AMD have evolved from thermal laser photocoagulation then to photodynamic therapy (PDT) stabilizing vision. The current standard therapy is intravitreal anti-vascular endothelial growth factor (VEGF) injection [54, 55] providing the first ever treatment potentially improving visual acuity. At this moment, three anti-VEGF agents of bevacizumab, ranibizumab, and aflibercept are available in the market (Table 10.4). In the Cochrane review for anti-VEGF for neovascular AMD, anti-VEGF of ranibizumab achieved 17.8 letters or more visual acuity gain [55]. There was no significant difference in gains in visual acuity between ranibizumab and aflibercept [54]. The challenge we face is how we maximize the treatment effect with the least numbers of injections minimizing patients' burden of risk of ocular and systemic side effects and cost of the treatment.

Table 10.4 Comparison of anti-VEGF agents and supporting clinical trial outcomes over 2 years

	Bevacizumab 1.25 mg	Ranibizumab 0.5 mg	Aflibercept 2 mg
Mean change in visual acuity (letters)	CATT-PRN: +5	ANCHOR-1M: +10.7	VIEW-1M: +7.6
	CATT-1M: +7.8	CATT-PRN: +6.4	VIEW-Q8: +7.6
		CATT-1M: +8.8	
		VIEW-1M: +7.9	
%Gained 15 letters or more	CATT-PRN: 28.3%	ANCHOR-1M: 41%	VIEW-1M: 31%
	CATT-1M: 31.8%	CATT-PRN: 30.7%	VIEW-Q8: 33%
		CATT-1M: 32.8%	
		VIEW-1M: 32%	
%Lost 15 letters or more	CATT-PRN: 11.6%	ANCHOR-1M: 11%	VIEW-1M: 8%
	CATT-1M: 7.8%	CATT-PRN: 7.2%	VIEW-Q8: 8%
		CATT-1M: 6.7%	
		VIEW-1M: 8%	
Number of injections	CATT-PRN: 14.1	ANCHOR-1M: 21.3	VIEW-1M: 16
	CATT-1M: 23.4	CATT-PRN: 12.6	VIEW-Q8: 11.2
		CATT-1M: 22.4	
		VIEW-1M: 16.5	
Approximate cost of drug	$23.48	$1991.55	$1961

Modified based on the article by Kent [56]
CATT Comparison of AMD Treatment Trials, *ANCHOR* The Anti-VEGF Antibody for the Treatment of Predominantly Classic Choroidal Neovascularization in Age-Related Macular Degeneration trial, *VEGF Trap-Eye* Investigation of Efficacy and Safety in Wet AMD trial, *PRN* pro re nata regimen, *1M* monthly injections, *Q8* injections every 8 weeks, *VIEW* VEGF Trap-Eye: Investigation of Efficacy and Safety in Wet AMD

Rehabilitation of Vision Impairment due to Age-Related Macular Degeneration

Patients with AMD suffer from loss of central vision at later stages of their life and it has been known that those patients have higher prevalence of comorbidity of depression. There are four potential mechanisms linking AMD and the development of depression classified by Cimarolli et al. [57], namely, (1) loss of functional capacity and depression symptoms, (2) deficit in problem-solving skills in new vision problem in later life, (3) difficulty in enacting different control strategies at different stages of AMD, and (4) poor future outlook with sudden unpredictable losses in vision. Surprisingly, one in ten patients with AMD had symptoms of depression and anxiety in the study by Eramudugolla et al. [58]; the prevalence was much higher than those in patients with cataract (6.7%) and glaucoma (4.3%) [58]. Patients with AMD develop depression more than persons without AMD in similar age groups; having depression is also associated with a worse visual functioning score. Patients with AMD who live alone were more likely to develop depression [59]. Dawson et al. [60] have performed a systematic review and meta-analysis, showing that 15.7–44% of patients with AMD had depressive symptoms and 9.6–30.1% for symptoms of anxiety [60].

Low vision rehabilitation in general is important to mitigate the risk of depression and increase participation in activities for patients with AMD [57]. Behavioral and self-management programs have been shown to be successful in reducing the risk of depression in patients with AMD and expected to be promising in reducing the risk of depression [57]. Rovner et al. [61] conducted a clinical trial and found that low vision rehabilitation combined with behavior activation (8-week sessions with occupational therapists) has halved the incidence of depression compared to low vision rehabilitation with supportive therapy with discussion of illness, disability, and vision loss. Severe vision loss from AMD at later stages of life course can lower the quality of life of the patients, and it is important to secure access to adequate treatment coupled with rehabilitation for low vision.

Compliance with Ethical Requirements Ryo Kawasaki and Yumiko Kawasaki declare that they have no conflict of interest.

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

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11 Innovative Approaches in the Delivery of Eye Care: Refractive Errors (Including Presbyopia)

Kovin S. Naidoo, Pirindhavellie Govender, and Jyoti Naidoo

The Challenge of Refractive Errors

Vision impairment is a significant public health menace globally, with more than 32.4 million people estimated as blind and 191 million with impaired vision [54]. The leading cause of vision impairment is uncorrected refractive error (URE), which accounts for 21% of worldwide blindness and 53% of vision impairment [54]. The change in the number of people blind due to URE from 1990 to 2010 was reported by Naidoo et al. [37] as 6.3 to 6.8 million, whereas moderate and severe vision impairment due to URE changed from 87.9 to 101.2 million from 1990 to 2010. Refractive error is also the leading cause of vision impairment (visual acuity <6/18) among children, with more than 12 million children between 5 and 15 years old being affected with the condition worldwide – half of whom live in China [46]. Refractive error stems from disorders of the eye's ability to focus light on the retina, leading to an unfocussed view of the world. The different types of refractive error that can cause poor vision are myopia or short-sightedness (when distance vision is out of focus), hyperopia or long-sightedness (when clear near vision can be difficult) and/or astigmatism (when distance and near vision are distorted) [55].

Presbyopia (age-related far-sightedness) has more recently been recognised as a type of refractive error. The condition is the result of a gradual deterioration of the ability of the lens to focus on near objects, particularly affecting individuals over 40 years [13] and is the most common physiological change occurring in the adult

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eye which is projected to cause universal near vision impairment with advancing age [42]. The simplest and most cost-effective method of correcting presbyopia is through spectacle correction [19]; however spectacles have their disadvantages including, practical, optical and aesthetic appeal – thus those who have the luxury of access often opt for contact lenses as an alternative.

Myopia or short-sightedness is the most common cause of distance vision impairment globally, which affects nearly 1.5 billion people worldwide and is associated with significant health and socio-economic burdens [18]. The condition, despite being referred to as a "simple" refractive error may increase the risk of other serious eye disorders such as cataract, glaucoma and retinal detachment [18]. In the last few decades, the prevalence of myopia has been increasing at an alarming rate, more specifically in adolescents in China and East Asian countries – reaching between 70% and 80% [16, 18]. However the process that causes refractive error still remains unknown, despite research studies contributing to a better understanding on the onset and progression of myopia [47]. More recently Holden et al. [21] provided alarming data that indicates by the year 2050 five billion people will be myopic, representing 50% of the population at that time. Even more alarming is the fact that one billion people will have high myopia thus exposing them to the risk of vision impairment and blindness.

Refractive error development is influenced by both environmental and behavioural risk factors such as education [52], socio-economic status [58], reading/near work/studying habits [34], intelligence [49], urbanisation [61], outdoor activity [9] and occupation [32]. Genetic factors also play a key role in refractive development and include syndromic refractive errors [56], effect of parental refractive status [24], heritability and familial aggregation [43], genetic linkage [57], segregation [25] and genetic association [33].

Refractive errors are correctable [2]. In recent times, there has been an increasing popularity of the use of contact lenses (CL) and refractive surgery as corrective methods; however the use of spectacles remains the most popular method of refractive error correction [48]. Despite this, assessments show that 625 million people have impaired vision because they do not have access to adequate services for refraction and correction [38], and refractive error studies conducted in children at eight locations in Asia, Africa and South America suggest that 10% of children in the developing world, a proportion significantly more than this in some regions of Asia, could benefit from refractive correction [7, 15, 17, 31, 35, 39, 40, 44].

Uncorrected refractive errors threaten the quality of life of those impacted upon, their family and society [20] and are suggested to have negative implications towards employment opportunities [19] and productivity [12]. The condition impacts negatively on children's quality of life [26] and wellbeing [50]. Additional implications for children include impaired literacy [51], reading difficulties [10], poor school performance [28] and a lack of self-esteem [8].

The delivery of refractive services is key to resolving the many challenges that are posed by refractive errors and uncorrected refractive errors.

Recent and Emerging Practices for the Provision of Refractive Error Services

The prioritisation of refractive error among the causes of avoidable blindness by VISION 2020, a joint initiative by the World Health Organization (WHO) and the International Agency for the Prevention of Blindness (IAPB) since 2006 has seen refractive service delivery receive much attention across all regions of the world [20]. Governments, civil society partners and philanthropists are constantly looking at models in which refractive care can be delivered to the masses in an equitable and efficient manner without compromising the quality of eye care. This chapter will review these models according to those outlined by the WHO position paper on uncorrected refractive errors, including presbyopia [59]. It will explore the strengths and weaknesses of existing models and will in addition provide updates on more recent approaches adopted.

Preparing for Refractive Service Delivery

Very often the success of the model implemented is dependent on community needs, existing systems and stakeholders present. A situational analysis is often a good exercise to determine which model would be favourable within the context. The situational analysis should consider the following:

- Burden of RE in the area (determined through a rapid assessment of refractive error (RARE) study) [29] or other population-based prevalence studies that included refractive error and in addition also take note of the prevalence of other eye health issues that are prevalent in the area under investigation)
- The local existing resources (range of eye care cadres, local training institutions, systems of healthcare delivery, local public and private eye care facilities and optical suppliers, uptake of services at existing facilities, local cultural and societal factors)
- Refractive care
- The stakeholders (government, NGOs, private practitioners, professional bodies, end users of the intended services), enabling and restricting policies or the absence of needed policies (Fig. 11.1)

Refractive Error Service Delivery Models

Public Sector Approaches

District Health System

The district health system has been identified as the vehicle for the delivery of healthcare at various levels within the national health system in societies where

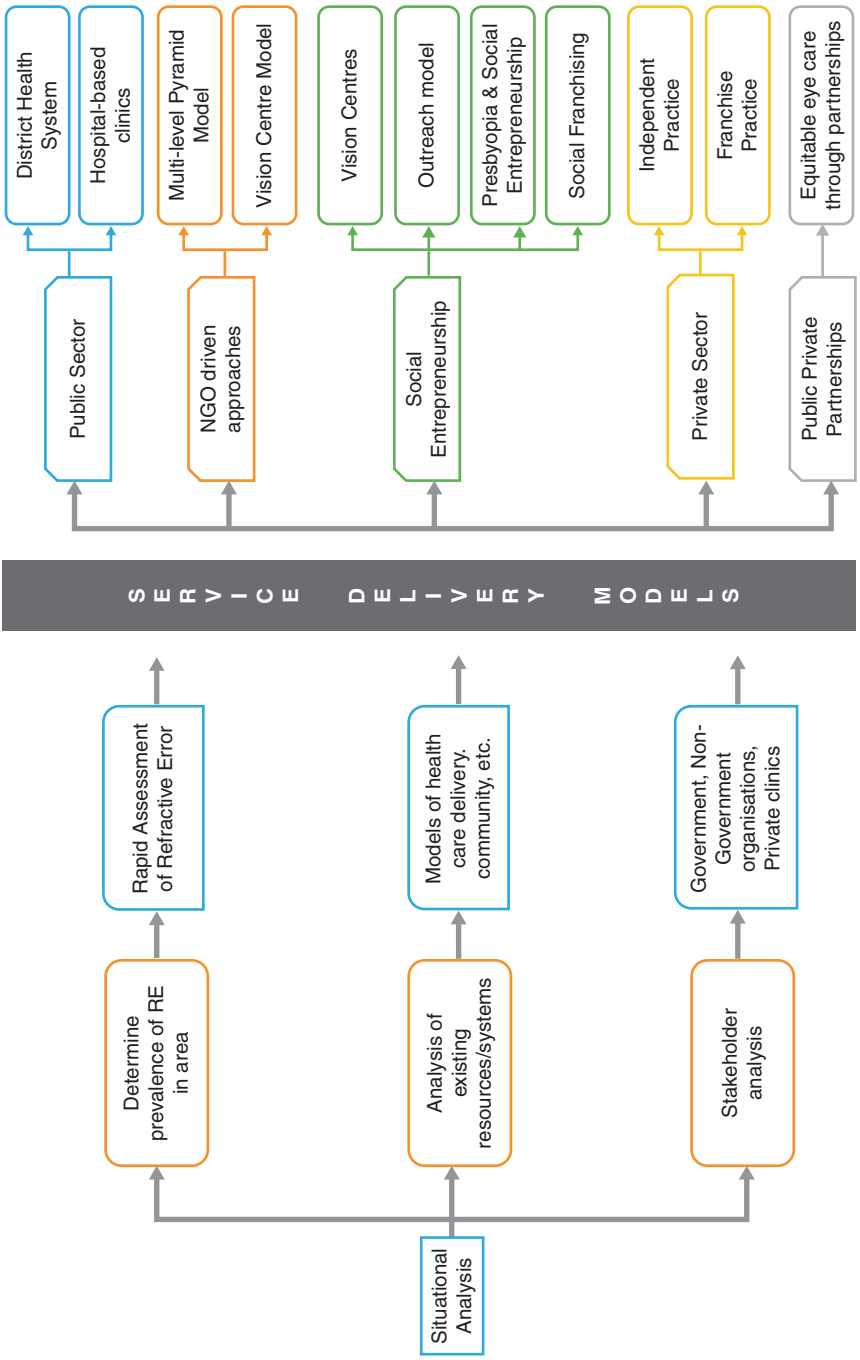

Fig. 11.1 Factors to consider in setting up refractive service delivery

government-coordinated healthcare dominates. It enables eye care services to reach communities at primary level and limits the unnecessary cases from burdening the secondary and tertiary levels of care.

Examples of programmes that use this approach include:

- *Pakistan's District Comprehensive Eye Care*: This programme was initiated to provide a cost-effective and sustainable solution to reach rural communities where 70% of Pakistan's communities reside [14]. This programme is a collaboration of the Government of Pakistan, eye care NGOs and professionals.
- *Giving Sight to KwaZulu-Natal* (GSKZN): South Africa has endured the inequity of apartheid. Post-apartheid, the South African government adopted the district health system to ensure equitable distribution of healthcare services. Eye care services, however, were not integrated into the district health system and therefore formed the motivation for the GSKZN project [36]. This approach integrated optometrists into a comprehensive eye health system.
- *National Intervention on Uncorrected Refractive Errors (NIURE) in Uganda* sees the integration of uncorrected refractive error into the national health system and the roll-out of services at district level, including outreach and school eye health. This project has been planned on a phased approach which involved the training of ophthalmic clinical officers (OCOs) in refraction, the opening of a local laboratory to cut and fit lenses and training of spectacle technicians to service the laboratories and the introduction of an optometry training programme at Makerere University [27] (Table 11.1).

Table 11.1 Strengths and weaknesses of the district health system

Strengths	Weaknesses
The approach facilitates the equitable delivery of eye care at all levels	Ill-defined role of eye care personnel at various levels within the healthcare system
Accessibility to eye care services at community level	Inadequate integration of the various cadres of eye health workers in the chain of delivery of refractive services can lead to inefficient referral systems
This model facilitates a streamline of refractive services where basic cases are dealt with at the primary level and more advanced care is provided at the secondary and tertiary levels	Inadequate infrastructure and equipment at the various levels of care can be a hindrance in adhering to the scope of practice at each level
	Poor adherence to referral mechanisms can result in patients not receiving the care that they require
	Ill-defined clinical protocols can result in unnecessary referrals
	Burdened by bureaucracy and lack of entrepreneurial or income generating activities

Hospital-Based Refraction Clinics

Hospital-based refraction clinics are clinics with no interaction with other levels of the district health system. They can exist at district, regional or national levels. In some cases these clinics function merely as refraction clinics without the provision of spectacles due to limited resources and limited capacity to source affordable spectacles or cut and fit spectacles in lens labs.

In many developing contexts, the hospital-based clinics are serviced by refractionists or ophthalmic technicians who receive refraction training through 1–2 year programmes, ophthalmic clinical officers and various other mid-level personnel.

In some scenarios, the high number of ophthalmologists and absent optometry cadre has resulted in ophthalmologists adding refraction to their repertoire, e.g. Orbis project, MEMO (Model of Excellence in Modern Ophthalmology in Mongolia), Pediatric Vision Network (Table 11.2).

NGO/Civil Society Approaches

Vision Centre Models

Vision centres are 'permanent eye care' facilities that can be found both in remote areas and villages. They are established in areas where there are no permanent eye care services [45]. They enable the provision of affordable, culturally appropriate services in the community. The focus of care is at the primary level. They can be serviced by optometrists or optometric technicians/refractionists. Refractions, dispensing of spectacles and screening for potentially blinding pathologies can be performed here. Patients requiring further care are referred from this facility.

The versatile nature of vision centres allows them to exist as stand-alone clinics or integrated within a primary care clinic or district hospital. They can be profit generating or not-for-profit initiatives. Staff trained in all aspects of vision centre management (ranging from clinical care to business and human resource management) are critical to the success of the model.

Table 11.2 Strengths and weaknesses of hospital-based refraction clinics

Strengths	Weaknesses
High patient volumes can be accommodated here	Limited capacity to address advanced refractive needs
Specialisation of HR in refraction	The provision of refractive services without the provision of spectacles presents an ethical issue
Short duration of training cadres which function at this level	The lack of a career path in some cases for cadres involved
This approach facilitates the good clinical exposure to trainees and personnel. Task sharing or shifting can be a strength when you have adequate human resources to address the needs	Task sharing and shifting can be a weakness when you do not have adequate human resources to distribute between competing health priorities

Vision centres can also be linked to an academic institution (*academic vision centres*). These centres serve as a site for supervised clinical rotations of students involved in eye health and serve the community at the same time. In many cases, the level of care can exceed that provided in the private sector as the focus is on provision of comprehensive eye care, including several diagnostic or specialty skills which may not be available at private practices. The financial success of such a centre is based on cost recovery or profit-generating.

Examples of such models include:

(i) *Brien Holden Vision Institute's Vision Centre Model:* This model is implemented in Sri Lanka (Colombo Comprehensive Urban Eye care project) and Papua New Guinea (PNG Eye Care Vision Centres). The Institute places significant emphasis on local community control so that the service can be sustained even after the Institute moves on to another community/country in need [4].

(ii) *Optical Centre Model in West Africa:* In some cases, vision centres can offer a mix of services beyond just simple refractive error case finding and refraction services. An example is the *Optical Centre Model in West Africa* which expanded to include low vision services [22].

(iii) *Malawi Academic Vision Centre:* This is an example of a vision centre introduced to alleviate the problem of limited refractive care in the country and is linked to the optometry and optometric technician programmes developed for the country [3].

(iv) *L V Prasad Eye Institute and Aravind Eye Care System:* Both have vision centres as part of a comprehensive eye care model. This is discussed later in the chapter (Table 11.3).

Table 11.3 Strengths and weaknesses of vision centre model

Strengths	Weaknesses
The engagement of local leadership garners support	The model is not a one-size-fits-all solution since it is not always successful when implemented
Knowledgeable staff trained in all areas of vision centre management	Lack of links to affordable spectacle supply can reduce the initiatives sustainability
The community base makes the vision centre ideal to serve other primary eye care roles in the community, like home-based care, outreach, school eye health	Poor integration or links with other healthcare facilities can result in ineffective service delivery
Access to affordable specialty or diagnostic skills at academic vision centres	The model is more successful in densely populated areas and has limited viability in sparsely populated areas
	The inclusion of additional services of a vision centre can be at the expense of the financial sustainability or viability of the model

Table 11.4 Strengths and weaknesses of the outreach model

Strengths	Weaknesses
It is sometimes the only service provided in a particular area	The temporary nature of the service does not allow for the equitable distribution of services
Mobility of services allows a larger reach	Sometimes there is a limited scope of services that can be provided through outreach thus compromising quality
Is a means of providing targeted service delivery	Sustainability of services is sometimes difficult to maintain
	There is usually little to no follow-up of care on surgical procedures and no supply of spectacles if they break or patients experience difficulty with adapting to spectacle wear

Outreach Model

Outreach is taking eye care to where the people are. Activities can be executed as part of other refractive error service delivery models or as stand-alone services and can be located locally or internationally. Some activities include a full-service (refraction and spectacles) and others just involve refractions without correction. Some are done on a regular basis, while others can be done intermittently, like those conducted to commemorate special days in the year, e.g. World Sight Day. Outreach can sometimes be accomplished through mobile units like those sponsored by Essilor's 2.5 New Vision Generation (NVG) India project. The mobile units are equipped to provide refraction services and spectacle dispensing to people in 'hard to reach' places [11].

(i) *Local Outreach:* Local outreach services are often provided as health or eye camps coordinated by religious or community organisations, academic institutions, etc. They utilise the skills of locally trained eye care providers.
(ii) *International Outreach:* International outreach involves the use of human resources and skills from developed countries to provide services in developing countries. There are several organisations around the world who conduct international outreach activities, e.g. Visiting Optometry Services to Humanity (VOSH), Vision Aid Overseas (VAO), etc. These activities are very often temporary and intermittent (Table 11.4).

Multilevel Pyramid Models

(i) *L V Prasad Eye Institute Pyramidal Eye Care Service Delivery Model:* The pyramidal model evolved from the rural eye care model adopted by the Institute in 1994. The pyramidal model comprises five interlinked tiers (Fig. 11.2) which answers the 'universal eye health coverage' call [45]. The model addresses 'disease control, geographic and population coverage, services provided, delivery structures, linkages and referrals' [45]. At the community

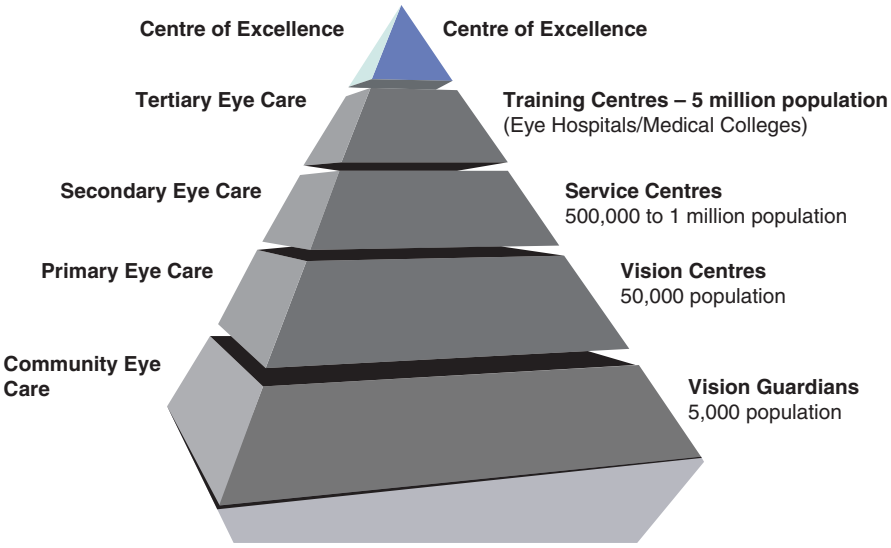

Fig. 11.2 The LVPEI model for eye care service delivery [45]

eye care level, *vision guardians* provide screening and health promotion activities. In addition to this, school teachers are also taught to perform vision screening of learners in school. Anyone identified with an eye problem is referred to primary eye care centres or *vision centres* or secondary eye care facilities or *service centres*. The tertiary centres are serviced by ophthalmologists with subspecialties, optometrists with special training, operating and administrative staff. Tertiary centres provide specialist care since the primary and secondary levels of care are delivered in communities. Research and education of all cadres of eye care workers are conducted in a tertiary centre. The apex of the pyramidal model is occupied by a centre of excellence. Training of trainers and postgraduate programmes and advanced research takes place in this centre that is framed on other major eye centres around the world.

(ii) *Aravind Eye Care System:* The Aravind Eye Care System (Fig. 11.3) was the brain child of Dr Govindappa Venkataswamy. It was initiated to provide care to patients requiring cataract surgical intervention. The Aravind system uses the profits generated from services rendered to those who can afford market-related pricing to subsidise care for those who cannot afford care [53]. The standard of care is the same for all patients. Their operational research has motivated them to develop and manufacture their own lenses to reduce variable costs and create innovative clinical approaches to reduce fixed costs (Table 11.5).

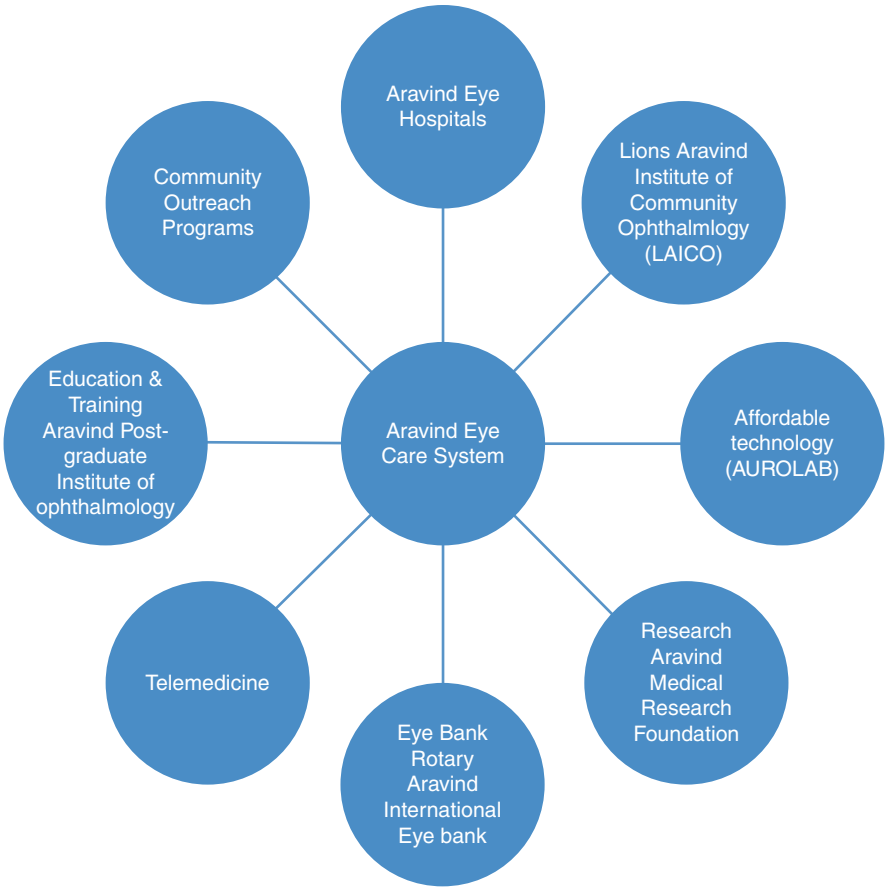

Fig. 11.3 Components of the Aravind Eye Care System

Table 11.5 Strengths and weaknesses of multilevel pyramid models

Strengths	Weaknesses
Addresses the limited services provided at community level	The model is more viable in areas where population density is great
Provides services in rural communities where financial resources for eye care are limited	The model requires a cash injection from donors to establish itself
The integrated continuum of care allows for comprehensive eye care for all	Poor adherence to referral mechanisms or inadequate linkages can make the model unsuccessful in addressing the eye health concerns of the population

Social Entrepreneur Model

Presbyopia and Social Entrepreneurship

A social enterprise is 'a type of non-profit business that employs people and earns income in order to help address perceived social or environmental issues' [5]. An integrated social enterprise is one in which the funds raised support the non-profit activities of the organisation.

The *Scojo Foundation* which was later named VisionSpring uses a franchise and micro-consignment system. It is an example of an integrated social enterprise that fulfils its social mission through its business activities [60]. The Foundation has an urban commercial arm which funds the rural social programme. Based on the premise that 80% of people over 35 years have presbyopia which consequently affects their productivity, the Foundation implemented a programme in which simple ready-made spectacles were sold to urban non-optical shops such as pharmacies, general stores and book stores (Table 11.6).

Vision Centres and Social Entrepreneurship

Vision centres as described earlier are established in the community. This approach allows easy access for people in the community. Very often these centres are established with the support of corporate sponsors or development organisations. An example of such a program is the *Eye Mitra Optician* programme which involves the training of local unemployed women in basic screening and spectacle dispensing and entrepreneurial skills [11] (Table 11.7).

Social Franchise

Social franchise is a franchise model with a social mission. This model provides local practitioners an opportunity to run their own practices under a social franchise brand. Very often optometrists have adequate clinical skill, but lack the business acumen to start up and sustain profitable practices [1]. The social franchise model provides practitioners from marginalised communities in developing countries with start-up funds and the management and business guidelines to run a successful practice while serving the needs of the working poor and lower middle class. The social franchise does not have profit as its major focus but rather supporting local eye care practitioners to be successful entrepreneurs.

Table 11.6 Strengths and weaknesses of presbyopia and entrepreneurship model

Strengths	Weaknesses
The model encourages greater accessibility for patients requiring correction for near vision	While the model does allow for the reach of the intervention to be expanded into communities, it is important the quantity of spectacles sold or provided to recipients does not outweigh the quality of eye care needed
This project has the potential to alleviate the burden of $25,367 billion in lost productivity due to uncorrected or under-corrected presbyopia if considering people up to the age of 65 years being productive [12]	Even though the provision of spectacles rectifies the burden imposed by presbyopia, the provision of a 'part' eye exam as opposed to a comprehensive eye exam and giving individuals a false sense of security in terms of their eye health raise ethical and quality issues

Table 11.7 Strengths and weaknesses of vision centres in a social entrepreneur model

Strengths	Weaknesses
Services are delivered in the community	Profit margins are lower and therefore the model is more successful in densely populated areas
People are empowered to take responsibility for their community's vision needs	The scope and quality of training is a challenge
Poverty alleviation	

Eye Mitra is a public-private partnership between Essilor India Pvt Ltd and DEG (Deutsche Investitions- und Entwicklungsgesellschaft mbH – a German development institution). It is a programme designed to take high-quality eye care to remote areas in India where availability of eye care services is scarce. It uses a franchising model to support entrepreneurs in underserved communities to own and run a refractive service (Table 11.8).

Private Sector Approaches

Independent Practice

Independent/private practice provides for patients' needs in an age of consumerism and competition. Private practices as in most countries are unevenly distributed with the majority located in urban areas [30].

Practitioners enjoy significant autonomy in the operations and are usually only legally bound by the rules of the profession. From a business perspective, they can operate as a sole proprietorship or a partnership (Table 11.9).

Table 11.8 Strengths and weaknesses of a social franchise model

Strengths	Weaknesses
Management and business guidelines provided	This type of practice needs high volumes to generate profits comparable to independent or standard franchise practice models
Buying power of the franchise enables practitioners access to lower-cost prices	Franchising fees
Practitioner benefits from single and uniform marketing campaigns	Limited freedom with running business due to franchise specifications
The practitioner benefits from the reputation of the brand	Restricted profit margins
	Limited product range to what is offered by the franchise
	Generally restricted to particular areas of operation)
	Start-up costs can be significant

Table 11.9 Strengths and weaknesses of an independent practice model

Strengths	Weaknesses
Practitioner autonomy in marketing and scope of practice	The practitioner bears a greater burden of debt
No fear of job loss for the practitioner	Limited negotiating power
Freedom of strategic direction (including partnerships)	The quality and level of service provided are dependent on the financial resources of the practitioner and therefore not uniform
Freedom to create own profit margins	Marketing is limited in terms of reach and scale
Direct access to suppliers	Longevity is limited to lifespan of the practitioner
Greater control of the supply chain	The cost to patients is far greater than that incurred in the public sector
The practitioner can enjoy freedom of association	Consumer confidence may not be as great as with recognised brands
Patients do not have to suffer long waits for appointments or services	Patients have limited recourse for problems encountered
	Negative impact related to costs to patient due to variations in economies of scale of smaller businesses

Table 11.10 Strengths and weaknesses of public-private partnership model

Strengths	Weaknesses
Model enables eye care providers to meet the challenges of reduced funding and increased demand for care	A breakdown in the partnership

Public-Private Partnerships

Public-private partnerships (PPP) involve the collaboration of government health departments, public service organisations, development organisations and the private sector. According to the International Finance Corporation [23], "PPPs allow governments to leverage the expertise of the private sector to improve the quality, accessibility and efficiency of public healthcare systems without burdening public finances". The examples provided below are just two of many.

Northern Territory (NT) Aboriginal Vision Programme

The NT Aboriginal Vision programme in Australia is an example of collaboration between a development organisation and the private sector. The programme was started by an NGDO, the Brien Holden Vision Institute on request from the government sector in the Barkly region of the Northern Territory in Australia. This project is a collaboration between various state, federal, community and professional organisations and individuals. The programme provides a range of services including education, advocacy, health promotion, research and service delivery. Optometrists from the Australian College of Optometrists (an organisation providing low-cost eye care to disadvantaged communities in Victoria) give their time and expertise to conduct the outreach visits (Table 11.10).

Setting up models of refractive error services should be underpinned by the needs for the service, awareness of services, partnerships, human resources, synergy, level of awareness of the target population and feasibility. Failure to take cognisance of these characteristics will impact on the success of the chosen model of refractive error service delivery.

The Use of Technology in Eye Care Service Delivery

There has been an explosion of technological advances in the last decade, especially with the invention of the smartphone and tablets. Smartphone technology has enabled eye care practitioners a great reach beyond the standard clinical setting to where it is required in the community. There are more than 340 eye care-related apps, with most of them free or at a minimal cost [6]. These apps combine 'clinical assessment, educational and reference tools'. There are applications to screen the vision of people of all ages, take pictures of the retina and simulate poor vision to educate people on the impact certain conditions have on vision, screen contrast and colour vision. For example, the LUMA Vision Simulator app by Eyemaginations allows the practitioner to educate patients using simulations. The use of these applications cannot replace face-to-face consultations in providing services, but it is especially useful in primary eye care where case finding is critical. An example of

smartphone technology used for refractive screening is the Near Eye Tool for Refractive Assessment, or NETRA (Sanskrit for 'eye').

Information transfer can facilitate the proper diagnosis and management of eye conditions – *telemedicine*. The smartphone can take the professionals into the most remote areas without them having to be present. Images and patient records can be sent to health professionals. In addition, smartphones or tablets can serve as an on-hand reference guide for better patient management. Professional education can be more affordable with little or no costs attached to accessing professional education platforms in the most remote areas with access, for example, the Eye Education App from Johnson & Johnson Vision Care which allows easier access to obtaining continuing education credits. Health promotion and patient education can be at the fingertips of patients. Practitioners can spend less time elaborating issues which the patient can access at their own pace. While the information transfer is facilitated by the smartphone and tablets, practitioners must not lose the quality of healthcare provided and rely too heavily on the technology to serve as the surrogate practitioner. Guidance must be provided to patients on how they can access information and what they should specifically be looking at. Importantly the balance between access and quality needs to be considered so that self-diagnosis does not lead to the growth of undetected eye health problems.

Summative Statement

The recent data on uncorrected refractive error [37] and on myopia [21] have once again focussed our attention on a burgeoning public health challenge. Projections of 50% of the global population being myopic by the year 2050 point to a looming public health challenge with an extremely high prevalence and widespread impact, encompassing both developing and developed countries. This chapter has shown that there are multifaceted approaches to addressing refractive errors. In order to reach the 7.5 billion people in our world, we have to acknowledge that a combination of efforts is needed both between and within countries. This means that the private sector, public sector, NGDO programmes and social enterprise approaches have to all be deployed when it makes sense and sometimes can co-exist for different sections of the population. Arguing against the private sector in a country, for example, fails to recognise that if more people can access affordable services in the private sector, then less poor people will present at government hospitals where limited services and personnel are available. The focus rather should be on how we can transform all avenues of service delivery to provide services with multiple cost points making them accessible to more. We should not be debating what the most appropriate model is but rather set a list of deliverables that define any refractive error service. The list below is by no means an exhaustive one but points to the direction that this discourse should go in:

- Quality
- Accessibility

- Comprehensiveness
- Affordability
- Integration with health systems
- Appropriate follow-up
- Sustainability
- Consistency of services

The need for the above has taken on a new urgency with recent data indicating that conventional correction of myopia causes further myopia development and that there is a need for myopia control and other strategies. Quick fix solutions cannot ignore this reality and need to adapt to this new paradigm.

Compliance with Ethical Requirements Compliance with ethical requirements: Kovin Naidoo, Prindha Govender and Jyothi Jaggernath declare that they have no conflict of interest.

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

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Assessment of Eye Health Services: A Health Systems Approach

12

Haroon Awan

Preamble

Typically, it is assumed that access to comprehensive eye care services is determined by the availability and skills of eye doctors and other eye health professionals, establishment of eye care units in hospitals and health centres, their equipment and availability of appropriate medicines and treatment options. While most of this may hold true for the actual provision of eye care in a hospital, the assessment of eye health services from a policy and planning perspective requires a broader perspective using a systems approach [1].

The World Health Organization (WHO) developed an approach called the '*Health Systems*' [2], in which health systems are essentially divided into building blocks, each interconnected with the other and working as multiple components to achieve improved health outcomes. These building blocks are categorised as follows:

- Service delivery
- Health workforce
- Health information
- Medical products, vaccines and technology
- Health financing
- Leadership and governance

Most national health policies and health sector strategies developed by ministries of health now conform to using a health systems approach. This implies that health programmes are increasingly contextualised within an overarching health systems framework.

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This chapter aims to introduce the reader to the implications that various health systems building blocks have for eye health, and how a health systems approach can be used to assess eye health services for planning and development in the context of a broader system. In this chapter, the term 'eye health' is used to denote the broader systems perspective, while 'eye care' is generally used when referring to a service within a health facility or by an eye health professional.

Health System

The WHO states that a health system consists of all organisations, people and actions whose primary intent is to promote, restore or maintain health [1]. If we apply this for eye health, one may conclude that to have high-quality comprehensive eye health services integrated in the country's health system, there needs to be *trained and skilled eye health professionals, a well-maintained infrastructure of eye health services providing a continuum of care and a reliable supply of essential medicines, consumables and technologies appropriate to the level of eye health, backed by adequate funding, strong and well-coordinated eye health plans and evidence-based policies and strategies for eye health.*

Figure 12.1 shows the six building blocks of a health system [2].

Good *health services* are those which deliver effective, safe, quality personal and non-personal health interventions to those that need them, when and where needed, with minimum waste of resources.

A well-functioning *health workforce* is one that works in ways that are responsive, fair and efficient to achieve the best health outcomes possible, given available resources and circumstances (i.e. there are sufficient staff, fairly distributed; they are competent, responsive and productive).

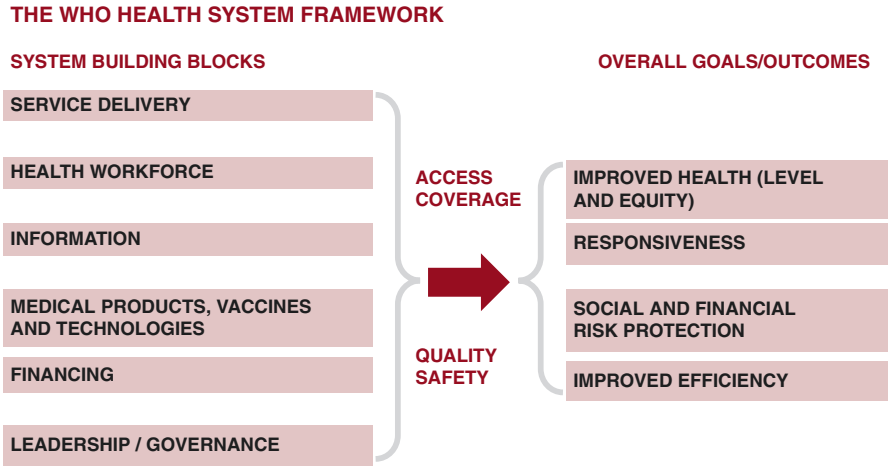

Fig. 12.1 The six building blocks of a health system. (*Source*: Everybody's business – strengthening health systems to improve health outcomes. WHO's Framework for Action, 2007)

A well-functioning *health information* system is one that ensures the production, analysis, dissemination and use of reliable and timely information on health determinants, health system performance and health status.

A well-functioning health system ensures equitable access to essential *medical products, vaccines and technologies* of assured quality, safety, efficacy and cost-effectiveness, and their scientifically sound and cost-effective use.

A good *health financing* system raises adequate funds for health, in ways that ensure people can use needed services and are protected from financial catastrophe or impoverishment associated with having to pay for them. It provides incentives for providers and users to be efficient.

Leadership and governance involves ensuring strategic policy frameworks exist and are combined with effective oversight, coalition building, regulation, attention to system design and accountability.

Two terms that are used commonly in health systems are 'universal coverage' and 'equity'. Universal coverage is defined as ensuring that the population has access to needed services without the risk of financial catastrophe [3], while 'equity' is defined as the absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically or geographically [4]. Health inequities therefore involve more than inequality with respect to health determinants, access to the resources needed to improve and maintain health or health outcomes.

A health system assessment can be carried out at various levels of health care. Most countries follow a standard structure of health care for a defined unit of population, which comprises of (i) a *primary* or first contact level and which usually includes community health workers, health posts and health centres; (ii) a *secondary* level which usually comprises a general hospital, e.g. a district hospital; and (iii) a *tertiary* level where more specialised care is available [5].

Eye Health Services

Eye health services are generally structured within the health service structure [5] although there may be some variation among countries in settings depending on their level of development.

- *Primary level.* In lower-income settings, usually a community health worker or integrated eye health worker trained in primary eye care provides eye care. The primary task of the health worker is health promotion and disease prevention, and primary eye care may be added to their scope of work. Further, in settings where the level of development permits, other eye health professionals may also be found at health centres like physician or non-physician eye health workers, ophthalmic nurses and optometrists. Primary eye care comprises prevention and treatment of the most common eye conditions and referral for most surgical and advanced treatments.

- *Secondary level*. Depending on the level of development of the country, the district hospital can have a dedicated eye unit that is staffed by ophthalmologists and other ophthalmic professionals. Secondary eye care comprises primary eye care services plus clinical and surgical services for the most common eye conditions such as refractive errors, cataract and glaucoma. In some countries, it also provides comprehensive eye care.[1]
- *Tertiary level*. There is a dedicated eye department staffed by ophthalmologists and other eye health professionals that provide comprehensive eye care services. If it is a teaching eye department, there will also be postgraduate residents undergoing training. Tertiary eye services should comprise all sub-speciality eye care services, including advanced diagnostic, medical and surgical treatment for both children and adults. Facilities for such sophisticated eye care are often available in university hospitals or similar institutions which may be in the government, non-government or private sectors.

One can apply the six building blocks of health systems to assess either a particular level of care, e.g. secondary level or one can apply it to all the three levels to obtain a fuller picture of the eye health services at national or sub-national level, e.g. a state or a province. Table 12.1 provides some suggestions on how assessment of eye health services may be contextualised in a health systems framework.

The framework provides a guide for identifying gaps in service provision and areas requiring further improvement so that appropriate interventions can be identified and implemented. A more comprehensive WHO tool for eye health assessment is discussed later in the chapter.

To increase access to high-quality integrated comprehensive eye health services, the Universal Eye Health: a Global Action Plan 2014–2019 was adopted by Member States at the Sixty-sixth World Health Assembly in the resolution WHA66.4. Its proposed actions are structured around the following objectives:

- *Objective 1* addresses the need for generating evidence on the magnitude and causes of vision impairment and eye health services and using it to monitor progress, identify priorities and advocate for greater political and financial commitment by Member States to eye health.
- *Objective 2* encourages the development and implementation of integrated national eye health policies, plans and programmes to enhance universal eye health with activities in line with WHO's framework for action for strengthening health systems to improve health outcomes.
- *Objective 3* addresses multisectoral engagement and effective partnerships to strengthen eye health.

[1] The International Agency for the Prevention of Blindness defines 'Comprehensive Eye Care Services as those offering a breadth of services covering the range of causes of vision impairment, from promotion, prevention to rehabilitation and care'. http://www.iapb.org/advocacy/who-action-plan/UEH accessed 23 February 2017.

Table 12.1 Contextualising assessment of eye health services in a health system framework

Health system	Health care
Service delivery	Is there any service for eye health at the primary, secondary and tertiary levels of health care – if so, is it provided at a health facility or in the community
	Is there any referral system for eye patients to the next level of care
Health workforce	What type of health workforce is available at the primary, secondary and tertiary levels of health care
	Is any cadre trained in primary health care; is primary eye care included in their training curriculum; can they be trained in primary eye care
	What type of eye health personnel cadres are available at the secondary and tertiary levels – have these staff been trained through accredited training programmes; do they have necessary skills to perform their roles; are they in sufficient number
Health information	Is any eye health data collected and reported at the primary, secondary and tertiary levels of health care – if so, what is it and what is the reporting pathway
	How have the health staff been trained to collect and report this data
Medical products and technologies	Are there any eye health medicines and consumables available at the health facilities and with health workers – if so, how are these provided and replenished; are they part of a nationally approved standard list
	What is the status of the technology and equipment maintenance in the eye units; is it according to a nationally approved standard list
Health financing	What is the mechanism of financing of primary, secondary and tertiary health-care services
	Do patients have to pay a fee for services and medicines
	Is there a mechanism for health insurance cover of these costs
Leadership and governance	Is there a planning and coordinating mechanism for health at the primary, secondary and tertiary levels of health care
	Is planning and coordination of primary, secondary and tertiary eye care included in this at the respective levels, or is there a separate planning and coordination mechanism for eye health

Assessing Eye Health Services

One of the prerequisites for implementation of the global eye health action plan is to update or prepare a national or district plan that is evidence-based. There are often challenges in obtaining updated information in a systematic manner for purposes of planning and monitoring of national or subnational eye health programmes. Furthermore, the analysis of information collected should result in meaningful identification of gaps and needs. In order to facilitate collection of information on the provision of and access to eye health services, and the development of evidence-based interventions for their further improvement, WHO developed the '*Eye Care Service Assessment Tool*' (*ECSAT*) [5]. ECSAT is intended to assist implementation of the selected evidence-based interventions, as periodic completion of the questionnaire can provide data and information for assessing the impact of interventions and identify trends and newly emerging needs. These findings should be included in refining and updating national plans for continuous activities.

Eye Care Service Assessment Tool

While the adoption of the global eye health action plan 2014–2019 prompted intensified work on developing the tool for data collection and eye care assessment, the health system approach and the applicability of this tool are likely to outlive the actual action plan's time frame. ECSAT is structured as follows:

Background Information and Country Socio-economic Indicators

This introductory chapter includes selected indicators such as demographic data, life expectancy and overall expenditure on health to provide a summary overview of the socioeconomic and health status of the population.

Evidence for Advocacy and Awareness Creation

Guidance is provided for compiling available data and information on the magnitude and causes of vision impairment, on identifying those communities and vulnerable groups in major need of improved eye health services and on the use of available evidence in advocacy and awareness creation to strengthen eye health in the population.

Enhancing Comprehensive Eye Health Services Through the WHO Health System Approach

In this section the health system approach is used to examine the eye health service provision and access to it, including low vision services and rehabilitation. It is structured in six sub-sections.

Leadership and Governance

Structured collection of information is encouraged about the national and/or sub-national eye health programme; eye health policies and clinical guidelines, the regulatory structures for the various eye health personnel cadres; the proportion of eye health services delivered by different service providers such as government, non-government, private and others. It also seeks information about the organisational structure for the national eye health programme, e.g. national committee for eye health, a national coordinator for eye health and existence of any professional societies or organisations of eye health professionals and those for people blind and visually impaired.

Eye Health Financing

This section provides guidance on the critical information needed to understand the practice in financing eye health and on how eye health services are obtained by those in need. It also seeks information about the service costs at the different providers of eye health services, e.g. government, non-state actors and the private sector, and whether these services are covered by health insurance. The information sought is to assist in determining what proportion of the population has access to affordable eye health services so that an assessment can be made on the extent to which universal eye health coverage is being achieved.

Eye Health Workforce

In this section the tool seeks to obtain information about the eye health professionals that constitute the eye health workforce in the country, e.g. numbers and sub-specialization of ophthalmologists, optometrists and allied ophthalmic personnel comprising opticians, ophthalmic nurses and other cadres. It uses definitions of professional groups based on the minimum education and examinations required to obtain a licence to practise the profession. Further information is requested on educational institutions for eye health professionals and the number of eye health professionals who graduate each year. The section tries to elucidate whether there are any government bodies for national accreditation of the educational institutions for ophthalmologists, optometrists, opticians and ophthalmic nurses, and whether there is any continuing medical education programme or requirement for renewal of licences or registration of professionals. The section further enquires about the distribution and retention of eye health professionals, whether there is any reporting system on human resources for eye health, and whether there are any government plans or strategies for the development of human resources for eye health.

Eye Health Service Provision

Suggestions are provided on the key areas of information needed to understand to what extent there are comprehensive high-quality eye health services accessible for the community. It includes dedicated subsections to the main causes of vision impairment such as cataract, refractive errors, diabetes mellitus and diabetic retinopathy, glaucoma, age-related macular degeneration as well as paediatric and other subspecialities in eye health including low vision and rehabilitation services.

Essential Medicines, Medical Products and Technologies for Eye Health

This section seeks information about whether there are any standard lists and policies for essential medicines, medical products and technologies for eye health. Further, the section enquires about regulatory processes for procurement prices and use of essential medicines for eye health, and whether domestic companies also produce eye medicines, medical products or technologies. It is intended that the available standard list is compared with the one developed by WHO to determine possible gaps [6].

Health Information System

Guidance is provided on finding out the key information on the national health information system or other mechanisms for collecting national health data and information, and whether there is any centrally collected data and information on eye health in the country, or if eye health information is included in disease surveillance.

Engagement of the Non-health Sector in the Preparation and Implementation of Policies and Plans on Eye Health and the Prevention of Vision Impairment

To complement the above sections providing guidance on collecting data and information pertaining almost exclusively to eye health, in this section, the tool seeks

information about broader health and development agendas, engagement of domestic and international non-state actors, development of partnerships and alliances and cross-cutting agendas for strengthening eye health in the population as part of the strategies for enhancing the socioeconomic development.

Selected areas of service provision and access to them can be further examined by the following tools:

Tool for the Assessment of Diabetic Retinopathy and Diabetes Management Systems (TADDS) [7]

Diabetes mellitus constitutes one of the emerging threats to public health all over the world. Diabetic retinopathy is the fifth leading cause of vision impairment and the fourth leading cause of blindness in the world [8]. The onset of diabetic retinopathy is the result of long-lasting diabetes. The most critical role of health systems in managing diabetes and preventing irreversible blindness from the disease is cooperation between those responsible for diabetes management and those concerned with diabetic retinopathy.

In order to assess both management of diabetes and diabetic retinopathy in countries and to estimate the level of cooperation and synergy between these two branches of health care, WHO has designed an assessment tool, '*Tool for the Assessment of Diabetic Retinopathy and Diabetes Management Systems*' (*TADDS*). The tool will make it possible to carry out a situation analysis, define service provision levels and identify the gaps to be addressed in ensuring universal access to diabetes care and to effective prevention and treatment of diabetic retinopathy. The survey items in TADDS are organised according to the health systems building blocks.

Tool for Assessment of Rehabilitation Services and Systems (TARSS)

The *Tool for Assessment of Rehabilitation Support Services* (*TARSS*) [9] has been designed to obtain baseline data on eye health and rehabilitation services available for people with low vision and blindness. Findings from TARSS are for Member States to use in analysing and responding to a situation where low vision rehabilitation services, especially in low- and middle-income countries, are ignored or given low priority in terms of financing, human resources and provision of services. The tool exhorts programme managers to think broadly from a health systems standpoint.

Along with the detailed information on eye health service delivery and access to it, the success of eye health intervention is conditioned by the sufficient knowledge of the magnitude and causes of vision impairment in the community. Owing to the high costs involved in conducting population-based surveys, several rapid assessment tools have been developed [10]. Some of these are highlighted below.

Rapid Assessment of Avoidable Blindness (RAAB) [11]

Rapid Assessment of Avoidable Blindness (*RAAB*) is a rapid survey methodology [12]. It is a population-based survey of vision impairment including blindness and eye health services among people aged 50 years and over. RAAB can provide the prevalence of blindness and severe and moderate vision impairment, their main causes, the output and quality of eye health services, barriers, Cataract Surgical Coverage and other indicators of eye health services in a specific geographical area.

RAAB is not a detailed epidemiological survey. It provides an estimate of the prevalence of blindness and vision impairment, and the proportion that is avoidable in the studied geographic area. RAAB does not measure posterior segment disease in detail. *RAAB 5* provides data on uncorrected refractive errors, spectacle coverage and uncorrected presbyopia in people aged 50 years and over.

There is a RAAB software package for the entry and analysis of data recorded on those individuals who have been examined. There are currently two versions of the RAAB package – RAAB 5 and RAAB 6. Features in RAAB 5 include:

- Summary reports on key outputs
- Optional Diabetic Retinopathy module plus supporting materials
- Improved survey and interobserver variation forms
- Tables on functional low vision – people aged 50+ with best corrected visual acuity<6/18 to PL+ in the better eye

RAAB 6 has all the functions of RAAB 5, with an additional option to include those individuals with the visual acuity less than 6/12.

Rapid Assessment of Refractive Errors (RARE) [10]

Rapid Assessment of Refractive Errors (*RARE*) is used to assess the prevalence of uncorrected refractive errors, presbyopia, spectacle coverage and barriers to uptake of services for refractive errors and presbyopia. RARE is a methodology developed with a focus on uncorrected refractive errors and presbyopia. Typically, younger age groups, 15–49 years are selected for the survey, as refractive errors are a common cause of vision impairment in this age group.

Monitoring Health Coverage and Its Implications for Eye Health

Universal Health Coverage is defined as access of all people to the health promotion, prevention, treatment and rehabilitation services they require, which are of sufficient quality to be effective, and that they do not suffer financial hardship in paying for these services [13]. Several factors must be in place for a community or country to achieve universal health coverage including a strong, efficient and well-run health

system that meets health priorities with people-centred, integrated care, provision of affordable health services and access to essential medicines and techniques to diagnose and treat medical problems, in addition to sufficient well-trained, motivated health workers to provide the services on the basis of the best available evidence.

The same applies to universally available, comprehensive eye health integrated into national health systems. In the recent World Health Report entitled 'Research for Universal Health Coverage', WHO cited experience in its Member States and research on reaching the goal of universal health coverage [14]. Progress towards universal health coverage must be monitored both globally and in countries, including coverage with interventions and financial risk protection, both with an equity dimension [15, 16].

Universal eye health is a key objective for countries, as reflected in the 66th World Health Assembly resolution WHA 66.4, which calls for a global action plan aimed at the goal of a world in which nobody is needlessly vision impaired, where those with unavoidable vision loss can achieve their full potential and where there is universal access to comprehensive eye health and rehabilitation services.

Three key indicators were endorsed by Member States to monitor progress in the implementation of the Global Action Plan (Appendix 4 of the Plan). These are:

- Prevalence and causes of vision impairment
- Number of eye-care personnel
- Number of cataract surgeries performed as a proxy indicator for the provision of eye care services

Cataract Surgical Coverage (*CSC*) is defined as the proportion of people with bilateral cataract who have received cataract surgery in one or both eyes. It is an indicator not only of ophthalmological surgical care coverage, but of disability among older adults and access to care by the elderly which is a growing segment of the global population in all countries. Cataract Surgical Coverage can be calculated from a population-based survey that measures visual acuity, causes of vision impairment and whether respondents have previously undergone surgery for cataract.

CSC is a highly relevant indicator that can inform policy makers and service providers not only about the state of the eye health services in a country or defined community but also contribute to the measurement of universal health coverage. It is a useful proxy in determining broader health coverage and unmet need for older persons [17].

To determine impact of an eye health service, repeating a population-based survey in the same community by using the same standardised methodology after 5 or more years can inform the progress made in terms of reducing the prevalence of vision impairment including blindness and therefore indicate the impact of the intervention.

Health Information System and Implications for Eye Health

One often finds that most eye departments at tertiary and secondary levels of health care have some form of eye health reporting. This may be a standard reporting form on which there is monthly reporting of the number of outpatients and inpatients,

patients examined and treated for various eye diseases, patients operated and selected diagnostic tests or special treatments like laser performed for eye conditions. Sometimes, there is reporting of a couple of indicators for eye health at the primary level as well.

However, the limitation is that this information is mostly collected at the level of the health facility but may not be collectively collated, analysed and synthesised at national or subnational levels to ascertain the trends and overall performance of the eye health service. There may be no coordinating mechanism in place that allows for periodic analysis and interpretation of such data.

Many countries have a standardised health information process usually called 'Health Management Information System' (HMIS). One example of a health information system is the '*District Health Information System*' (*DHIS 2*) [18], which is used in several countries.

An *Eye Health Information System* (*EHIS*) is essentially meant to be integrated within a national or sub-national health information system. In this way, eye health information appears in health information reports alongside other health priorities and health planners and decision makers can make informed decisions about development and interventions in eye health. Further, it provides a useful mechanism to develop a monitoring and evaluation framework.

When planning for an EHIS, it is advisable to pilot the process in an administrative unit, e.g. a district before scaling it up more widely. Some of the essential requirements include preferred use of a web-based reporting system that can be used on smartphones as well (e.g. the open-source software by DHIS 2); an essential set of eye health indicators that can be collected and reported, are meaningful for planning and monitoring purposes and can be used for advocacy; training of eye health personnel in the use of the EHIS and monitoring quality of reporting; and a process to analyse and synthesise data collected and for reporting and dissemination.

Where Does One Start

This chapter attempted to provide an overview of the systems approach to eye health assessment and tried to clarify some of the commonly used terminology in health systems. It also sought to introduce the reader to some of the contemporary and more commonly used tools and applications for various types of eye health assessments using a health systems approach.

In addition to the desk examination of publically accessible sources and thorough web search on the subject, additional information needed for the assessments is usually derived from interviews with personnel at the Ministry of Health and other relevant government institutions (such as the ministries of finance and education). It can also be obtained from national societies of eye health professionals, organisations for people with vision impairment and, to a certain extent, proactive collection of information (Table 12.2).

Table 12.2 Information needed for assessments and possible sources

Type of information	Possible sources of information
Socioeconomic, demographic and vision impairment data	UN reports and websites such as Human Development Report from UNDP; UN Department of Economic and Social Affairs; WHO and World Bank country information, for example. Many countries conduct periodic Demographic and Health Surveys and Social and Living Standards Measurement Surveys. Information about these can usually be found from the respective Bureau of Statistics. If any recent prevalence of blindness surveys have been conducted, one should try to obtain a report informing on the findings. One may also find more information from the IAPB Global Vision Atlas [19], RAAB Repository [11] and the Global Burden of Disease vision loss papers [20]
Health policy and strategy	Ministry of Health website and web search by the key words. Most countries have agreed with the WHO their Country Cooperation Strategy (CCS) which is a medium-term vision for WHO's technical cooperation with a given Member State, to support the country's national health policy, strategy or plan [21]. The CCS document provides a lot of useful information
Health financing	WHO Health Accounts website provides health expenditure data from Member States engaged through the Health Accounts Country Platform [22]. Further data on health financing may be obtained from the websites of the Ministry of Finance and Ministry of Planning and Development or similar government structures
Health workforce	Many countries have developed their Human Resources for Health Strategies and Development Plans. Further information can be obtained from licencing and registration authorities such as medical councils or from eye health professional societies
Health information	Website of the health information section within the Ministry of Health and web search by key words
Medical products and technology	Essential medicine list and related information on equipment and technologies may be accessed on websites of the Ministry of Health, drug regulatory authorities, government procurement bodies and National Committee for Eye Health
Service delivery	Websites and publications of the Ministry of Health, other government institutions, non-state sector, resources available from the National Committee for Eye Health, possible previous health care and/or eye health service delivery assessments and through interviews
Leadership and governance	Collated from webpage and publications of the Ministry of Health and other government institutions, National Committee for Eye Health, through web search of professional societies and regulatory authorities and through interviews

Not all the information for completing a thorough assessment of eye health service may be readily available. Some may require more efforts to obtain and some may not be available at all, for instance, epidemiological data on the magnitude and causes of vision impairment or national data on selected treatment procedures such as cataract surgeries. For that reason, the use of the above introduced tools should provide an update on all the information that could be collected and compiled and advice on which information was not available.

Further consideration should be then given to the identification of:

- Which missing information is strategically important for further research in order to support evidence-based interventions
- What are the recognised gaps in eye health service provision, structured according to the six areas of the WHO framework for strengthening health systems
- What are the gaps in evidence for advocacy, awareness creation and multisectoral engagement

Figure 12.2 provides suggested preparatory processes for collecting information through the desk examination of publically accessible sources, key informant interviews and thorough web search on the subject.

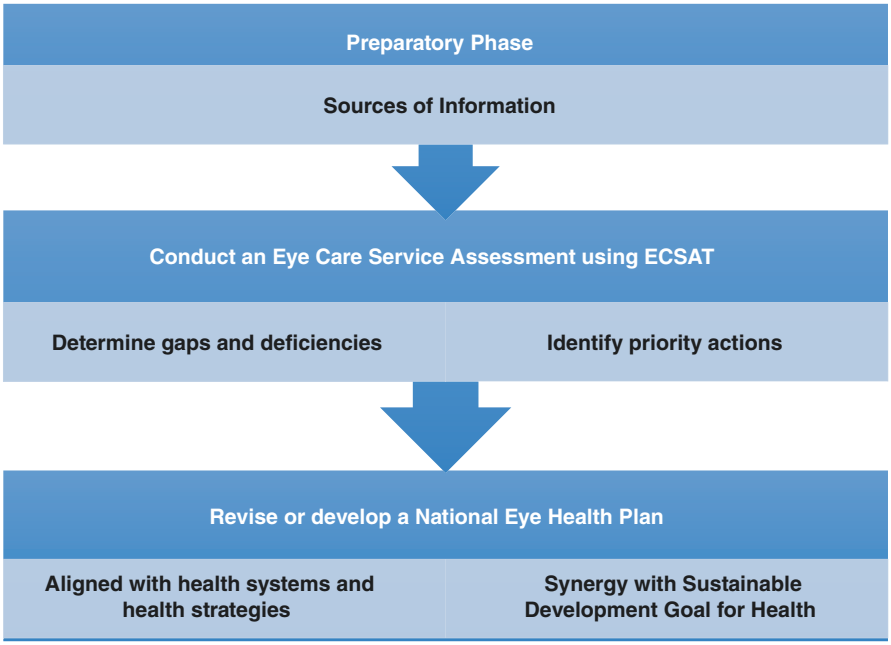

Fig. 12.2 Diagrammatic overview of an Eye Health Service Assessment

Compliance with Ethical Requirements Haroon Awan declares no conflict of interest.

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

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