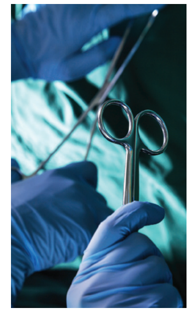
Chapter 11

Cataract Surgery



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THE GLOBAL CHALLENGE OF BLINDNESS

Prevalence

The worldwide estimate of blindness (defined as best corrected visual acuity [BCVA] of 3/60 [recognizing at 3 meters what a person with normal acuity can recognize at 60 meters] and less in the better eye) is 39 million people (Pascolini and Mariotti 2012). This figure is just the tip of the iceberg; a significantly larger proportion of people suffer from low vision (defined as BCVA in the range of 6/18 to 3/60), which reduces their levels of independence, safety, and productivity (Thylefors and others 1995). The World Health Organization (WHO) has expanded the scope of the definition of blindness by using presenting visual acuity instead of BCVA. Table 11.1 provides a classification of severity of visual impairment as recommended by the International Council of Ophthalmology (2002) and the recommendations of the WHO (2003).

Risk Factors

The distribution of the burden of disease is disparate; 90 percent of all blind and visually impaired people live in low- and middle-income countries (LMICs) (Cunningham 2001; Thylefors 1998). A study performed in 2010 indicates that visual impairment is unequally distributed among the WHO regions (Stevens and others 2013). The bulk of the blind population resides in Asia and Sub-Saharan Africa (Pascolini and Mariotti 2012). Even in high-income countries (HICs), the prevalence is more common among the economically poorer segments of the population.

Other major risk factors for blindness include advancing age, illiteracy, and rural residence (Abdull and others 2009; Huang and others 2009; Li and others 2008; Li and others 2009; Murthy and others 2010; Salomão and others 2008; Woldeyes and Adamu 2008). Conflicting data have been reported with respect to potential gender-based risks. Although some studies conducted in Sub-Saharan Africa (Komolafe and others 2010; Lewallen and others 2009; Rabiu and Muhammed 2008), China (Li and others 2008; Li and others 2009), and India (Neena and others 2008) report that the prevalence of blindness is more common in women, other studies conducted in Brazil (Salomão and others 2008), China (Huang and others 2009), India (Murthy and others 2010), and Nepal (Sherchan and others 2010) have not established an association.

Costs

The estimation of the cost of blindness has been a subject of considerable interest. One 1996 study estimates the annual worldwide productivity cost of blindness to be US$168 billion, using the data on prevalence rates, GDP, and populations (Smith and Smith 1996). This estimate is based on an assumption that all blind

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Table 11.1 Visual Acuity Scale

Presenting visual acuity Category	Worse than	Equal to or better than
Mild or no visual impairment	n.a.	6/18
0		3/10 (0.3)
		20/70
Moderate visual impairment	6/18	6/60
1	3/10 (0.3)	1/10 (0.1)
	20/70	20/200
Severe visual impairment	6/60	3/60
2	1/10 (0.1)	1/20 (0.05)
	20/200	20/400
Blindness	3/60	1/60[a]
3	1/20 (0.05)	1/50 (0.02)
	20/400	5/300 (20/1200)
Blindness	1/60[a]	Light perception
4	1/50 (0.02)	
	5/300 (20/1200)	
Blindness	No light perception	
5		
9	Undetermined or unspecified	

Source: WHO 2008.
Note: Three visual acuity measurements are included for each category because countries express visual acuity in different ways. The first notation is given in metric form and is expressed as meters. The second notation is expressed in decimal form. The third notation is given in imperial form and expressed as feet.
Note: n.a. = not applicable.
a. Or counts fingers at 1 meter.

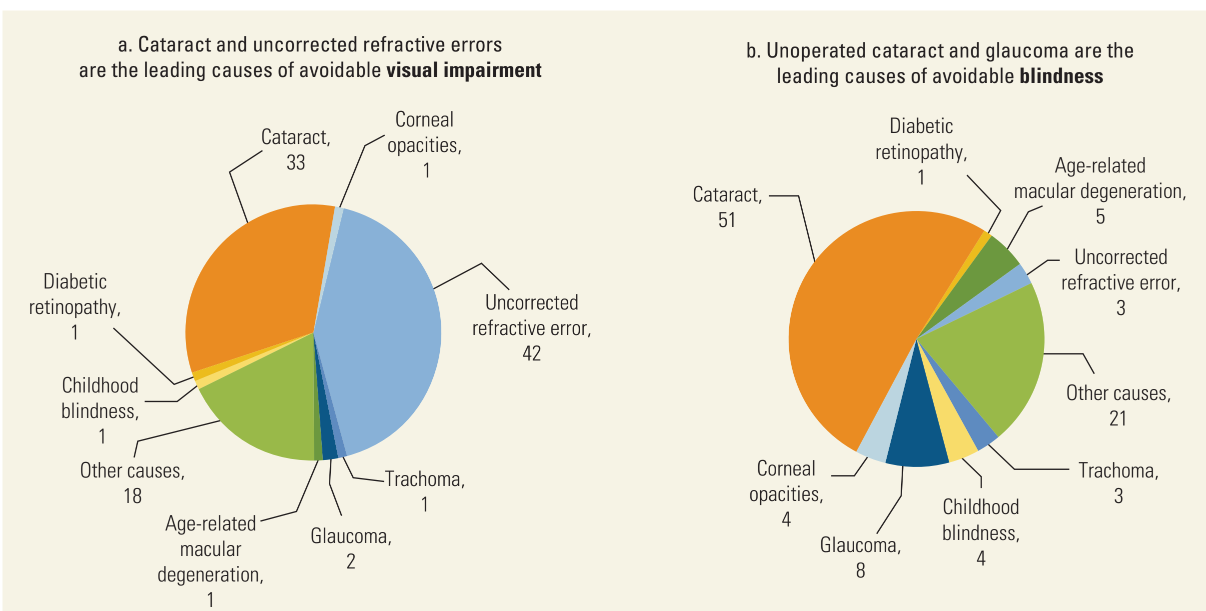
individuals are completely unproductive, while all other adults and children are assumed to be productive. A subsequent study, using data from 2000 and based on a more conservative estimate of personal productivity losses associated with blindness, estimates the economic productivity loss to be US$19 billion (Frick and Foster 2003). Another study estimates the direct investment required to treat the backlog of avoidable blindness and visual impairment over 10 years, to 2020, to be US$23.1 billion (PwC 2012).

CATARACT DISEASE

Description and Prevalence

Cataract is defined as a significant opacity in the crystalline lens that obstructs or distorts light entering the eye. The WHO in 2004 estimated that cataract was responsible for blindness in 17.7 million people, or 47.8 percent of all blindness (Resnikoff and others 2004). A more recent estimate from Pascolini and Mariotti (2012) finds cataract the leading cause of avoidable blindness, responsible for 51 percent of cases (figure 11.1). The prevalence of cataract as a proportion of the blind population shows large variations across countries. The figure is as low as 5 percent in developed countries such as Australia, the United Kingdom, and the United States; it is more than 55 percent in countries such as Peru and some parts of Sub-Saharan Africa (Resnikoff and others 2004). An estimate based on the number of cataract surgery procedures

Figure 11.1 Global Burden of Cataract
Percent



Source: Pascolini and Mariotti 2012.

per million population shows interesting variations. Even among high-income countries (HICs), annual cataract surgical rates per million population vary dramatically; for example, there are 1,200 in the United Arab Emirates versus 8,000 in Australia (WHO 2010).

The burden of visual loss due to cataract can markedly reduce the quality of life (QOL) of the affected elderly population because routine activities like reading, driving, walking, and remaining independent are severely affected (Salive and others 1994; Stuck and others 1999; West and others 1997). Impaired vision may be associated with an increased risk of falls, which can cause broken hips and associated increased morbidity (Patino and others 2010). Studies have suggested that this visual disability may pose an increased risk for mental depression and suicide (Lam and others 2008; Zheng and others 2012).

Cataract has no proven preventive or medical therapy. Surgery, the only option, consists of removing the cloudy natural lens and replacing it with an artificial, transparent intraocular lens (IOL). Studies have clearly established that this surgery with the implantation of IOL significantly improves vision-related QOL (Fletcher and others 1998). Although economic conditions play a significant role, the availability of adequate and appropriate surgical resources and patients' perceptions of the benefits could be significant factors in increasing the utility of cataract surgery.

A visual acuity measurement can serve as a guiding factor, but the timing of surgery should be based on the visual needs of individual patients. In general, patients in developed countries are more likely to seek and obtain cataract surgery early in the course of the disease because of the widespread availability and easy accessibility of quality eye care services and probably because of government-provided or -subsidized health care, to an extent. Anecdotal experiences in India suggest that this phenomenon of early cataract surgery intervention has increased in recent years, probably due to the country's improving economy and access to affordable quality interventions. Early surgery also helps the individual make informed decisions before loss of social independence.

Preoperative Evaluation

A comprehensive ocular examination evaluates the cornea, anterior chamber, pupil, lens status, retina, and optic nerve; this examination is the first step in determining the need for a surgical procedure. This examination is useful for identifying associated comorbidities, such as glaucoma or retinal and optic nerve disorders, given that their presence may contribute to a poor final visual outcome. Räsänen and others (2006) highlight the importance of this examination; 33 percent of patients surveyed had a secondary ophthalmic diagnosis, indicating that they may receive a reduced benefit from the surgery. Systemic conditions such as diabetes mellitus, hypertension, and compromised cardiac status should be evaluated before the decision is made to subject patients to surgery.

The power of the IOL to be placed inside the eye should be customized for each individual. Ultrasonography is performed to estimate the axial length of the eye; this estimate is used to determine the power of the IOL. It might be argued that the vast majority of patients may benefit from receiving a standard 20-diopter IOL, which would eliminate the high cost of obtaining an ultrasound, but the advantage of having a customized power IOL is far greater.

The amount of preoperative testing performed for healthy patients undergoing cataract surgery may vary significantly, which might influence the ultimate cost of the intervention. A national survey in the United States assessed variations in preoperative medical tests ordered by physicians (Bass and others 1995). Results indicate that 50 percent of ophthalmologists, 40 percent of internists, and 33 percent of anesthesiologists frequently or always obtained chest x-rays; in contrast, 20 percent of ophthalmologists, 27 percent of internists, and 37 percent of anesthesiologists never obtained x-rays. Similar significant differences were also seen with respect to the ordering of routine blood tests. Many respondents (32 percent to 80 percent) believed that these tests may be unnecessary, but they cited medico-legal reasons or institutional requirements for ordering them (Bass and others 1995).

SURGICAL INTERVENTIONS

Surgery is the only treatment choice for visually disabling cataract. If surgery is delayed, the following sequelae may occur:

1. Cataract may become denser (hard or brunescent, which implies a browner color) or whiter (mature cataract).
2. If still untreated, it may proceed to the following stages:
   - Phacolytic glaucoma: A hypermature cataract can leak, causing increased intraocular pressure.
   - Phacomorphic glaucoma: A mature cataract can sometimes cause crowding of the anterior chamber, leading to increased intraocular pressure. Surgery at these stages has to be undertaken as an emergency to prevent irreversible blindness.

Surgical Types and Procedures

There are three basic types of cataract surgery:

Phacoemulsification (PE)
Manual small-incision cataract surgery (MSICS)
Extracapsular cataract extraction (ECCE)

The basic steps in all three surgical procedures are the following: making an entry wound into the eye, removing the cloudy natural lens, and replacing the lens with an artificial IOL.

Incision. In PE, a small incision of approximately 2.5 millimeters (mm) is made, either in the sclera or the cornea. This wound is triplanar, which provides a self-sealing trapdoor incision. The configuration of the incision is more important than the size, with respect to the maintenance of the self-sealing property. In most cases, no sutures are used that could distort the corneal edge, any resultant induced astigmatism is negligible, and the visual rehabilitation is very quick.

In MSICS, a triplanar incision, similar in configuration to that in PE but considerably wider (8 to 9 mm), is made in the sclera. This incision is large enough to let the lens be delivered through it, but it is self-sealing because of the triplanar configuration. Hence, the entry wounds for PE and MSICS are superior to those of ECCE in ensuring quick visual rehabilitation.

In ECCE, the entry wound is biplanar, placed at the limbus, and is 10 to 12 mm in length. Because this incision is biplanar, it requires meticulous suturing. These sutures may have many inherent problems, the most important of which is suture-induced astigmatism, which prolongs visual rehabilitation. Occasionally, the sutures may cause significant irritation and may serve as a locus for potential intraocular infection.

Removal of the Cloudy Natural Lens. In PE, the nucleus is fragmented and emulsified using ultrasound within the eye. Hence, this surgery requires a smaller incision, only wide enough to allow the ultrasound probe to enter the eye and access the lens. In ECCE and MSICS, the nuclear and corneal material is manually delivered, which requires a wide incision to allow the lens to be retrieved.

Replacement with an Artificial Lens. Following the cataract extraction, an IOL of a customized dioptric power is placed in the posterior chamber of the eye. The power is determined preoperatively using a formula based on keratometry and the axial length measurement. These posterior chamber IOLs are manufactured from one of two types of material: PE uses an acrylic lens (which is foldable), and MSICS and ECCE use a rigid lens of polymethylmethacrylate (PMMA) (which is rigid).

PE is the most commonly performed cataract surgery in HICs. However, in LMICs, most surgeries are done using the MSICS and ECCE techniques. There are valid reasons for these different approaches. Patients seek cataract surgery much later than in developed countries. The surgery is often postponed until the disease progresses, by which time the cataract may have become advanced and mature. It is not uncommon to see phacolytic and phacomorphic glaucoma, the sequelae of long-standing cataract. Even though PE can be performed for hard cataract, MSICS is easier and more cost-effective in this situation. MSICS has been reported to be safer in situations such as brunescent cataract (Gogate and others 2003; Venkatesh and others 2009), white mature cataract (Venkatesh, Das, and others 2005; Venkatesh and others 2010), and cataract causing phacolytic and phacomorphic glaucomas (Ramakrishanan and others 2010; Venkatesh and others 2007), which are more prevalent in LMICs.

Another deterrent for large-scale adoption of the PE procedure in LMICs is the high cost of the instruments and the consumables, which include tubings, cassettes, and the surgical tips of the machine, and the need for trained technical personnel to maintain these sophisticated instruments. In contrast, MSICS does not require sophisticated equipment, except for an operating microscope, which is an essential requirement for all intraocular procedures.

The scarcest resource for an effective intervention is the availability of a trained ophthalmic surgeon; this can be an important rate-limiting step in eye care service delivery in LMICs. Effective use of surgeons' time by using well-organized and efficient supporting teams is a prerequisite to improving cost-effectiveness. Surgeries that take less time mean that more surgeries can be performed in a given period. In general, PE takes significantly more time than MSICS; Ruit and others (2007) and Gogate and others (2005) report mean surgical time of 15.5 minutes for PE and 9 minutes for MSICS. In high-volume settings, the mean surgical time can be reduced to as low as 4.5 minutes for MSICS, making it an extremely fast procedure (Balent and others 2001; Venkatesh and others 2005).

COMPARATIVE SAFETY OF SURGICAL INTERVENTIONS

Many studies have compared the incidence of intraoperative and postoperative complications of these procedures (Ruit and others 2007; Venkatesh and others 2010).

Posterior Capsular Rupture

During cataract surgery, the anterior capsule, the nucleus, and the cortex of the cataractous lens are removed, while the posterior capsule is retained. The integrity of the posterior capsule acts as a scaffold for keeping the artificial IOL in place. Posterior capsular rupture (PCR) with or without vitreous loss is one of the important intraoperative complications during cataract surgery and may lead to suboptimal visual outcomes.

The occurrence of PCR is often used as a surrogate for estimation of safety in cataract surgeries. Ruit and others (2007) report a 1.85 percent PCR rate in the PE group, versus none in the MSICS group. Venkatesh and others (2010) report that PCR occurred in 2.2 percent of PE cases, compared with 1.4 percent in MSICS cases. Gogate and others (2005) report a higher incidence of PCR in both groups: 6 percent in the MSICS group versus 3.5 percent in the PE group. These studies show that the incidence of PCR is comparable between the groups; anecdotal experience among high-volume surgeons suggests that the incidence of PCR declines with increasing surgical experience.

Endophthalmitis

Endophthalmitis is a serious postoperative complication that can cause significant ocular morbidity. Infection within the eye is more difficult to treat because antibiotics are not able to cross the blood-ocular barrier with ease. Hence, the results are very often devastating and all efforts should be made to prevent this complication. A retrospective observational study reported the comparative incidence for PE and MSICS (Ravindran and others 2009). This study was performed at Aravind Eye Hospital, a large eye care facility in India that offers services to two distinct subsets of patients: private patients who come from comparatively good economic backgrounds; and poor patients who come from distant areas, where outreach screening eye examinations are conducted. This study reports lower incidence of endophthalmitis in private patients, who had a better standard of living, than in patients from eye camps.

Posterior Capsule Opacification

Posterior capsule opacification (PCO) is one of the significant postoperative occurrences following cataract surgery, and the incidence increases over longer follow-up periods. Although a minimal PCO does not warrant any treatment, a significant PCO may cause a substantial reduction in visual acuity and requires an additional surgical intervention called yttrium-aluminum garnet laser capsulotomy. Ruit and others (2007) report an incidence of grade-one PCO (defined as a non-vision-threatening, mild peripheral PCO) of 26.1 percent of MSICS patients, compared with 14.6 percent in PE patients. The incidence of grade-two PCO was 17.4 percent in the MSICS group, and none in the PE group. However, in this study, IOLs made of different materials were used for these two interventions. The design of the IOL also matters. Square-edged IOLs are known to cause less PCO than round-edged IOLs.

COMPARATIVE EFFICACY OF SURGICAL INTERVENTIONS

Visual Acuity

The visual outcomes following cataract surgery are often reported either as uncorrected visual acuity (UCVA) or BCVA. UCVA, which is the visual acuity of the operated eye without the aid of additional refractive tools like spectacles, often reflects the real-life situation in LMICs, in which patients often do not have easy access to spectacles. BCVA represents the best possible visual potential of the operated eye, usually with the aid of spectacles. The WHO recommends that 88 percent of surgically operated patients should have a UCVA of 6/18 and better (WHO 1998).

The three randomized trials mentioned compare the visual outcomes between PE and MSICS. Venkatesh and others (2010) randomize 270 consecutive patients, who presented with white mature cataract (a common occurrence in many LMICs), to receive either PE or MSICS. At six weeks' follow-up, 87.6 percent of the eyes in the PE group and 82.0 percent in the MSICS group had a UCVA of 6/18 and better. The BCVA comparison revealed that 99.0 percent of the eyes in the PE group and 98.2 percent of the eyes in the MSICS group had vision of 6/18 and better. Gogate and others (2005), who compare PE with MSICS in a prospective randomized trial of 400 eyes, report that UCVA of 6/18 or better was achieved by 81.1 percent of the PE eyes, versus 71.1 percent of the MSICS eyes, at six weeks. The BCVA was 6/18 or better in 98.4 percent of the PE group and 98.4 percent of the MSICS group at six weeks. Ruit and others (2007) report longer-term visual outcomes in a prospective trial of 108 eyes in Nepal. The patients were randomized to PE or MSICS, with each type of surgery performed by an acknowledged expert in that technique. They report comparable rates of 98 percent achieving BCVA of 6/18 or better at six months.

Surgically Induced Astigmatism

The main determinant in the difference between UCVA and BCVA is the amount of surgically induced astigmatism (SIA). SIA is the most important reason for patients to have a suboptimal UCVA, while their BCVA may be normal. The lower the SIA created, the closer UCVA and BCVA will be to each other, an ideal situation. Hence, one of the main strategies for optimizing the visual acuity of the patient is to keep the incidence of SIA as low as possible.

The size and location of the incision play key roles in the occurrence of SIA; larger incisions cause more SIA. A prospective Japanese study compares the SIA between two sizes of surgical incision in MSICS, 3.2 mm and 5.5 mm, and finds a reduction of SIA by 0.3 diopter when the smaller incision size is used (Kimura and others 1999). Surgical incisions created in the temporal side of the corneo-scleral junction are known to cause less SIA than the traditional superior incisions (Gokhale and Sawhney 2005; Reddy, Raj, and Singh 2007).

Studies have also looked at the SIA created by PE and MSICS. At six months' follow-up, Ruit and others (2007) report a mean astigmatism of 0.7 diopter for the PE group and 0.88 for the MSICS group. This difference of astigmatism was not statistically significant. At six weeks postoperatively, Gogate and others (2005) report mean astigmatism of 1.1 diopters for PE and 1.2 diopters for MSICS, which were also comparable. Other authors, however, report that PE causes significantly less SIA than MSICS at six weeks postoperatively (George and others 2005; Venkatesh and others 2010). Astigmatism caused by MSICS is greater when a superior incision is used; accordingly, it can be lessened to a great extent by using a temporal incision, thereby improving the UCVA of MSICS (Gokhale and Sawhney 2005; Kimura and others 1999).

FACTORS AFFECTING THE EFFICACY OF SURGICAL INTERVENTIONS

Advantages of Interventions

Cataract surgery has several advantages over other ophthalmic conditions, including the following:

- Because cataract causes visual disability early in the disease course, patients become symptomatic and seek medical care, which is in contrast to other ocular morbidities, such as diabetic retinopathy and glaucoma, in which patients may be asymptomatic and may not seek care until the disease is more advanced.
- The treatment is often a one-time surgical intervention with excellent visual rehabilitation. This is one of the few age-related conditions for which surgical intervention will result in near-normal functional levels. Because there is no need for routine systemic antibiotics, the cost of postoperative medications is lower.
- Visual acuity becomes normal after the initial convalescent period of one month, and patients are able to resume their occupations with near-normal productivity.

Despite these factors and the availability of time-tested surgical options, cataract continues to constitute a major global health care burden, not because of the lack of a clinical solution, but because of the challenging issues in effective program implementation. These challenges include identifying patients in need, making services available, creating supportive infrastructures, ensuring quality, and developing sustainable service delivery systems.

Identifying Patients in Need

The first strategy for a successful cataract surgery program is to ensure a high throughput of patients into an efficient, quality-conscious, and cost-effective service delivery system. Emerging evidence indicates that the incidence of blinding cataract varies among regions. Studies have suggested that the burden of cataract disease may be lower in Sub-Saharan Africa than in India (Mathenge and others 2007; Neena and others 2008; Oye and Kuper 2007; Oye and others 2006). The proportion of people in India who are older than age 50 years is about 16 percent of the total population, which is twice that of some Sub-Saharan African countries (Lewallen and Thulasiraj 2010). Given that advancing age is a significant risk factor for the development of cataract, it may be prudent to assume that the incidence in these Sub-Saharan African countries may be lower than that in India. In addition, physical access to patients in remote locations such as the mountainous regions of Nepal and in some Sub-Saharan African countries with low population density may be considerably more difficult than in a country such as India, which has high population density.

Increasing Access to Care

It is often difficult to provide continuous ophthalmic services to sparsely populated areas. However, evidence exists that even when such services are provided, they are underutilized (Brilliant and Brilliant 1985;

Brilliant and others 1991; Courtright, Kanjaloti, and Lewallen 1995; Gupta and Murthy 1995; Venkataswamy and Brilliant 1981). In India, screening eye camps have been available for decades to identify and advise surgery to people affected by cataract. A study conducted by the Aravind Eye Hospital investigated service uptake in rural Indian populations served by regular outreach camps and tried to identify the barriers (Fletcher and others 1999). The authors found that, of the people with eye problems, only 7 percent attended the eye camps. The major barriers were lack of resources such as money, transportation, and attendants.

The cost of getting cataract patients to hospitals can also vary significantly between geographic settings. Whereas it costs about US$4.50 to transport one patient for cataract surgery to Aravind Eye Hospital in southern India, the same effort is estimated to cost US$40 to US$60 in the much less densely populated areas of eastern Africa (Lewallen, Eliah, and Gilbert 2006). Innovative programs, such as the creation of low-cost permanent facilities staffed by ophthalmic assistants connected with an ophthalmologist in a central location through telemedicine connectivity, may positively influence eye care–seeking behavior.

Optimizing Productivity

The lack of availability of ophthalmologists and their disproportional distribution is a major issue. There are approximately 200,000 ophthalmologists worldwide. Although this number is growing annually by 1.2 percent, the population older than age 60 years, which is more at risk of developing cataract, is growing by 2.9 percent. Sub-Saharan Africa has three ophthalmologists per 1 million population in contrast to 79 ophthalmologists per 1 million population in HICs (Resnikoff and others 2012).

Although the presence of skilled ophthalmologists is a key factor, this alone may not solve the issue of optimal productivity. Good infrastructure with optimal paramedical support is crucial for the productivity of ophthalmologists. In a study in Sub-Saharan Africa, Courtright and others (2007) show that the creation of an enabling environment improves the productivity of a cataract surgeon by four- to five-fold, from a low of 100 to a high of nearly 500 surgeries per year.

The establishment of such a system has produced a successful high-volume, high-quality eye care service model in India (Natchiar and others 1994). Maximizing operating room efficiency is extremely important in achieving high-volume productivity. Venkatesh, Muralikrishnan, and others (2005) describe how the Aravind Eye Hospital operating room staff supports a single surgeon; the staff includes three scrub nurses, one orderly, one circulating nurse, and one nurse to clean and sterilize instruments. To minimize the surgical turnaround time, the ophthalmologist alternates between two adjacent operating tables. A centrally placed operating microscope can rotate between the two tables. While the surgeon is operating on one patient, the paramedical team positions and prepares the next patient on an adjacent table. The average surgical time is about 3.5 minutes, with 16 to 18 surgeries performed by a single surgeon per hour. The complication rate and the visual results are comparable to the best global standards (Venkatesh, Muralikrishnan, and others 2005).

Ensuring Quality

The WHO recommends that 80 percent of eyes should have presenting visual acuity better than 6/18 after surgery, and fewer than 5 percent should be worse than 6/60 (Lewallen and Thulasiraj 2010). However, several population-based studies have reported poor visual outcome of less than 6/60, which would be defined as blind in most countries (Courtright and others 2004; Habiyakire and others 2010; Kimani and others 2008; Oye and Kuper 2007; Oye and others 2006). These population-based studies may have encompassed patients operated over a large time span; hence, the results may reflect services offered both in the past and in the present. Nevertheless, these data clearly indicate significant room for improvement. Poor outcomes start a vicious cycle that will result in lower demand and lower patient volumes.

Building Sustainable Service Delivery Systems

Excellent programs are not able to continue without sustainable strategies. Although philanthropy can be an initial source of support, programs need to devise ways to become self-sustaining to continue to be efficient. Eye care service providers can allow patients to choose the type of surgical procedure and the IOL from a menu of options. For example, Aravind Eye Hospitals have developed a tiered service system. Using this system, it offers free surgery to patients from eye camps, subsidized by fees paid by wealthier patients who choose to pay for special services such as PE procedures with costlier IOLs or for private rooms. Paying customers also have high standards for quality care, and these standards are used as the benchmark for nonpaying customers as well (Rangan and Thulasiraj 2007).

MEASURING COSTS OF SURGICAL PROGRAMS

There are different ways of analyzing the economic implications of cataract surgical procedures.

Cost-Minimization Analysis

Cost-minimization analysis compares events that have similar outcomes and determines which procedures are less costly (Brown and others 2003). The results are expressed in units of currency expended for each outcome. Various studies report the cost of providing PE and MSICS services (table 11.2).

The data in table 11.2 show, in the three studies, that provider costs for MSICS are consistently less than those for PE. Provider costs for PE show a wide variation, ranging from US$25.50 to US$70 even though these studies were in similar geographic locations with comparable socioeconomic dynamics. The cost difference was mainly attributable to the different types of IOLs used. For example, in the Nepal study (Ruit and others 2007), the provider cost was US$70, of which US$52 was due to the more expensive, imported, foldable acrylic IOL. In comparison, the cost of an indigenous IOL made of PMMA would be US$3. If a PMMA lens had been used instead of a foldable acrylic IOL, the provider cost would have been reduced dramatically and would have been similar to the costs reported in the other studies (Gogate and others 2005; Muralikrishnan and others 2004). Muralikrishnan and others (2004) study the societal costs (obtained by summing the provider costs and the patient costs) of the two procedures and arrive at US$29.40 for MSICS and US$37.92 for PE. Even though rigid PMMA IOLs were used in both arms of this study, PE procedures were more expensive because of the capital costs of the machine and the costs of the consumables. Compared with PE, MSICS clearly reduces the costs for the health care delivery system (Gogate, Deshpande, and Nirmalan 2007).

Table 11.2 Providers' Cost of PE and MSICS

US$ per procedure

Study	PE	MSICS
Muralikrishnan and others 2004	25.55	17.03
Gogate and others 2005	42.10	15.34
Ruit and others 2007	70	15

Source: Venkatesh and others 2012.
Note: MSICS = manual small-incision cataract surgery; PE = phacoemulsification.

Cost-Effectiveness Analysis

Cost-effectiveness analysis looks beyond the concepts of cost minimization and cost-benefit analysis to measure the costs expended upon an intervention and compares them for a single outcome (Brown and others 2003). These outcomes can be analyzed as measured by life-years gained, vision-years gained, or disability-adjusted life years (DALYs) averted, and expressed in cost per output unit (Lansingh, Carter, and Martens 2007). The first Global Burden of Disease study quantified health effects by employing DALYs (Murray and Lopez 1996). This metric integrates parameters such as morbidity, mortality, and disability information, and arrives at a single unit. In essence, this unit aims to measure the difference between the current health status of individuals and ideal situations in which people would live to old age without disease or disability.

Data from the WHO's Global Health Estimates study indicate that the global burden of eye disease was an estimated 25 million DALYs, accounting for 1 percent of total DALYs (WHO 2013). The highest number of DALYs was found in South Asia (including India), and East Asia and the Pacific (including China), followed by Sub-Saharan Africa and the other LMICs. Among the ocular noncommunicable diseases, cataract was most unevenly distributed across the globe, with increased presence in LMICs, and contributed to 7 million DALYs. In HICs such as Australia and the United States, cataract surgery is offered to people with early lens changes and not delayed until cases are severe, probably because of market demand (Ono, Hiratsuka, and Murakami 2010).

Cost-effectiveness can vary among countries and also among providers in the same country. Singh, Garner, and Floyd (2000) compare the cost-effectiveness of cataract surgery in southern India in three types of facilities: government camps, a nongovernment hospital, and a state medical college functioning as a first-level hospital. This study reports that even though camps were a low-cost option, the poor outcomes experienced there reduced their cost-effectiveness to US$97 per patient. The state medical college hospital was least cost-effective at US$176 per patient; the nongovernmental hospital was the most cost-effective at US$54 per patient. A study from Nepal reports that under a best-estimate scenario, cataract surgery had a cost of US$5.06 per DALY, which places it among the most cost-effective public health interventions (Marseille 1996).

Cost Utility Analysis

Cost utility analysis is more exhaustive than simple cost-effectiveness in that it includes evaluation of both QOL as perceived by the patient and longevity (Brown and Brown 2005; Brown, Brown, and Sharma 2004; Lansingh, Carter, and Martens 2007). Improvement in visual outcome following an intervention is often used as the indicator of success after the procedure. However, this result does not effectively illuminate the intrinsic value of the intervention from patients' perspectives.

Utility value is a quantifiable measure of data derived from patient-preference-based value, clinician, and community (Groot 2000). The time tradeoff (TTO) method is a major tool for measuring utility value; subjects are asked what proportion of their lives they would be willing to trade in return for guaranteed perfect vision in each eye (Brown, Brown, Sharma, Busbee, and Brown 2001; Brown, Brown, Sharma, and Garrett 1999; Brown, Brown, Sharma, and Shah 1999; Brown, Sharma, Brown, and Garrett 1999; Wakker and Stiggelbout 1995). TTO utility values were significantly higher in patients with ocular disease and good bilateral visual acuity than in those with good unilateral visual acuity (Brown, Brown, Sharma, Busbee, and Brown 2001). Patients who had undergone cataract surgery in both eyes had a better QOL than those who had surgery in only one eye (Castells and others 1999; Desai and others 1996; Javitt, Brenner, and others 1993; Javitt, Steinberg, and others 1995). A 2012 cataract surgery cost utility study finds that cataract surgery yielded a remarkable 36.2 percent gain in QOL for surgery in both eyes. Additionally, it was highly cost-effective, being 34.4 percent less expensive than in 2000 and 85 percent less expensive than in 1985. Initial cataract surgery was estimated to yield an extraordinary 4.57 percent financial return on investment to society over 13 years (Brown and others 2013).

Surgery on the First Eye. The results of the cost utility analysis are expressed using cost per quality-adjusted life year ($/QALY) gained. Vision improvement after cataract surgery has been shown to positively affect utility values and, in most instances, to correlate positively with health-related QOL instruments or utility measuring methods (Brown, Brown, Sharma, Busbee, and Brown 2001; Gafni 1994; Lee and others 2000; Rosen, Kaplan, and David 2005). Studies have been performed on cost utility following cataract surgery; the results have been depicted in the form of QALY per unit of currency (table 11.3).

A Swedish study that analyzes the cost utility of cataract surgery based on cost data and vision and disability scores estimates the cost utility in 2006 to be US$4,800 per QALY, using the common benefit discount of 3 percent (Kobelt, Lundström, and Stenevi 2002). In HICs such as the United States, interventions costing less than US$100,000 per QALY gained have been considered cost-effective (Laupacis and others 1992). Cost-effectiveness is accentuated when the cost is less than US$20,000.

The benefit of any surgery is increased if the duration of the benefit is extended. One study tries to determine the duration of the visual improvement following cataract surgery (Lundstrom and Wendel 2005). This study, performed in Sweden on 615 patients, assesses the patients preoperatively, at one year, and at eight years after the surgery, using clinical data and the Catquest questionnaire. The results indicate that 80 percent of patients reported improved visual function at the

Table 11.3 Studies Reporting Cost Utility of Cataract Surgery Using Intraocular Implants for the First Eye, Unless Otherwise Stated

Study	Year published	Country	Cost utility (US$/QALY)	Method used to measure utility	Remarks
Aribaba	2004	Nigeria	1,928–2,875	TTO	Cost utility for four scenarios
Busbee and others	2002	United States	2,020	TTO	Cost/QALYs discounted 3 percent over 12 years (life expectancy)
Busbee and others	2003	United States	2,727	TTO	Cost utility of surgery for second eye
Kobelt, Lundström, and Stenevi	2002	Sweden	4,900	EQ-5D and Catquest*	Undiscounted costs; QALYs discounted 3 percent over 5 years (life expectancy); correlation of Catquest and EQ-5D
Räsänen and others	2006	Finland	13,018	15D	QALYs discounted 3 percent; costs not discounted; life expectancy unknown

Source: Lansingh, Carter, and Martens 2007.
Note: EQ-5D = Euro quality of life measure on five dimensions; QALY = quality-adjusted life year; TTO = time tradeoff; 15D = 15 dimensions of the health-related quality of life.
*Catquest = a disease-specific, health-related quality-of-life instrument measuring the benefit of surgery as a function of a patient's specifics at baseline.

latest follow-up, implying that the cost utility benefit of cataract surgery may continue throughout individuals' life spans. As life expectancy increases, higher numbers of QALYs can be expected. The costs will also be discounted over the longer period. Brown and others (2013) find that cataract surgery is very effective at $2,222 per QALY, from the third-party insurer cost perspective.

Surgery on the Second Eye. Cost utility studies have demonstrated the benefit of surgery on the second eye in cases of bilateral cataract. Busbee and others (2003) analyze the cost utility of cataract surgery in the second eye of the same patient in the outcomes research team study cohort; they find that patients gained 0.92 QALYs. This figure is similar to the cost utility for the first eye reported by the same authors (Busbee and others 2002). These studies indicate that the cost utilities for surgeries on both eyes are similar when calculated using the same methodology.

Utility values can also be used to compare the cost-effectiveness analyses of medical interventions across different specialties. One study compares the cost-effectiveness of cataract surgery and other surgical options; results indicate that cataract surgery is more cost-effective than knee arthroplasty, epileptic surgery, or implantation of a defibrillator, but it may be less cost-effective than hip arthroplasty (Lansingh, Carter, and Martens 2007). Another study states that when total benefits are compared with total costs (estimated to eliminate avoidable blindness and visual impairment), the result shows a 2:1 benefit-to-cost ratio (PwC 2012).

CONCLUSIONS

Rising Costs

Health care expenditures are rising throughout the world and hence must be considered in any health care delivery intervention. In 1970, total health care expenditure in the United States was US$73.1 billion, which was 7 percent of GDP. By 2001, this figure had risen to US$1,425 billion or 14.1 percent of GDP (Brown and others 2003).

In 2000, the WHO published a health system performance assessment of its 191 member states that measured how efficiently health systems translate expenditures into health care (Brown and others 2003; WHO 2000). The United States, which incurred the highest health care expenditures per capita, adjusted for cost of living differences in 1997, achieved a ranking of 72, between Argentina and Bhutan. Clearly, increasing the amount of per capita spending on health alone does not translate into an efficient health system. It is imperative to find more effective, sustainable, and equitable solutions to meet the needs of the world's population.

Changing Demographics

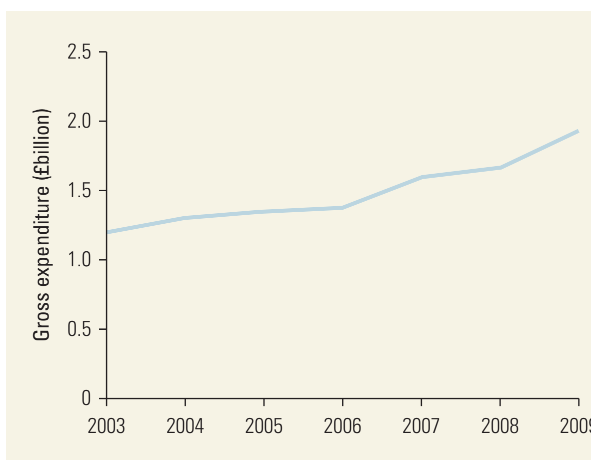
Demographic projections suggest that there will be a significant increase in the general population and in the proportion of the population that is older (Lutz, Sanderson, and Scherbov 1997). Without new interventions, the global number of blind individuals is likely to increase from 44 million in 2000 to 76 million in 2020 (Frick and Foster 2003). Providing quality eye care, with its projected increase in costs, is going to be an increasing challenge for both LMICs and HICs. The government of the United Kingdom had to increase its eye care budget by £730 million between 2003 and 2009, a 60 percent increase (figure 11.2) (Malik and others 2013). In this era of financial austerity, such increased expenditures cannot be sustained.

Current Scenario

Realizing the need for an increasing thrust to combat avoidable blindness, the WHO, in partnership with the International Agency for the Prevention of Blindness, launched the VISION 2020 Right to Sight initiative in 1999. At that time, it was envisaged that if successfully implemented, this initiative would lower the projected number of people who are blind to 24 million in 2020 and lead to 429 million blind person-years avoided.

Recent studies done across the world have shown encouraging trends in the reduction of vision loss. In Southeast Asia, blindness decreased significantly from

Figure 11.2 Gross Expenditure on Vision Program, 2003–09



Source: Malik and others 2013.

1.4 percent in 1990 to 0.8 percent in 2010, a 43 percent decrease (Keeffe and others 2014). Similarly, in Central Asia, the estimated age-standardized prevalence of blindness decreased from 0.4 percent in 1990 to 0.2 percent in 2010, while in South Asia, blindness has decreased from 1.7 percent to 1.1 percent in the same period (Jonas and others 2014). East Asia was no different, and the blindness prevalence dropped from 0.7 percent in 1990 to 0.4 percent in 2010 (Wong and others 2014). The change in these figures can be linked to major cataract programs that have been conducted in the most populous countries, such as India, which now has a cataract surgery rate of 4,000 per 1 million population (Keeffe and others 2014). However, in absolute numbers, the number of blind people remains constant because of the rapid increase in the older adult population (Stevens and others 2013).

Demand and Supply Strategies

In an early study, cataract surgery was identified by the World Bank as one of the most cost-effective interventions that can be offered in LMICs (Javitt, Venkataswamy, and Somme 1983). Programs need to put effective teams and processes in place to create an environment that can address both the demand and the supply sides of the equation. Strategies on demand creation would ensure that all those who can benefit from cataract surgery will actively seek it; such strategies also need to facilitate the efficient delivery of cataract services with good visual outcomes. The scenario of increasing backlogs of patients, low surgical productivity, and poor visual outcomes indicates that this demand-supply equation needs to be refined, evaluated, and monitored. Although the resource bases such as infrastructure, equipment, ophthalmologists, and paramedical staff should be strengthened, an equal emphasis is needed on management aspects and competencies (Lewallen and Thulasiraj 2010) to build the effective processes and organizational capabilities to use resources optimally.

LMICs have to use their economic resources even more judiciously in light of competing and compelling health care needs, such as maternal and child health programs and immunizations. Resources are neither infinite nor indefinite. The law of diminishing returns states that for a certain period, the benefits to patients increase when health care resources are increased. After a certain point, however, additional resources may lead to a reduction in net benefits to patients (Malik and others 2013). Supporting literature indicates that PE and MSICS procedures are comparable with respect to safety and efficacy, and MSICS is more cost-effective and more appropriate in these settings.

NOTE

The World Bank classifies countries according to four income groupings. Income is measured using gross national income (GNI) per capita, in U.S. dollars, converted from local currency using the *World Bank Atlas* method. Classifications as of July 2014 are as follows:

- Low-income countries (LICs) = US$1,045 or less in 2013
- Middle-income countries (MICs) are subdivided:
  - Lower-middle-income = US$1,046 to US$4,125
  - Upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more

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