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Turning the tide of corneal blindness

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Corneal diseases represent the second leading cause of blindness in most developing world countries. Worldwide, major investments in public health infrastructure and primary eye care services have built a strong foundation for preventing future corneal blindness. However, there are an estimated 4.9 million bilaterally corneal blind persons worldwide who could potentially have their sight restored through corneal transplantation. Traditionally, barriers to increased corneal transplantation have been daunting, with limited tissue availability and lack of trained corneal surgeons making widespread keratoplasty services cost prohibitive and logistically unfeasible. The ascendancy of cataract surgical rates and more robust eye care infrastructure of several Asian and African countries now provide a solid base from which to dramatically expand corneal transplantation rates. India emerges as a clear global priority as it has the world's largest corneal blind population and strong infrastructural readiness to rapidly scale its keratoplasty numbers. Technological modernization of the eye bank infrastructure must follow suit. Two key factors are the development of professional eye bank managers and the establishment of Hospital Cornea Recovery Programs. Recent adaptation of these modern eye banking models in India have led to corresponding high growth rates in the procurement of transplantable tissues, improved utilization rates, operating efficiency realization, and increased financial sustainability. The widespread adaptation of lamellar keratoplasty techniques also holds promise to improve corneal transplant success rates. The global ophthalmic community is now poised to scale up widespread access to corneal transplantation to meet the needs of the millions who are currently blind.

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Eliminating treatable corneal blindness presents a daunting but surmountable challenge for the upcoming decades. Over the past 30 years, large strides have been made toward addressing the root causes of corneal blindness from a public health standpoint. Across the globe, major investments have been made in trachoma control, vitamin A supplementation to prevent keratomalacia, onchocerciasis elimination, and investment in a primary eye care health infrastructure to prevent and treat infectious keratitis. As noted by the World Health Organization (WHO) in their 2009 Action Plan, the global health communities' ongoing challenge is to rapidly grow worldwide eye care services at a time when life expectancy and demand for eye services is simultaneously increasing.[1] It has been well documented that the vast burden of eye disease falls on those living in the developing world and that the majority of these diseases are either treatable or preventable. This is particularly true for diseases of the cornea. The phenomenal ascendancy of cataract surgical rates witnessed in Asian countries such as India and Nepal over the past two decades has laid a strong eye care foundation to begin to address the burden of existing treatable corneal blindness on a grander scale.

Epidemiology

Corneal blindness is estimated to be the second most prevalent cause of blindness in many less developed countries, but epidemiological data is limited and complicated, encompassing a wide variety of infectious and inflammatory diseases. Globally, bilateral corneal blindness is estimated to be 4.9 million persons [Table 1] or 12% of 39 million blind, utilizing WHO 2010 global blindness data and WHO 2002 sub-region causes (updated by 2010 data) to define regional prevalence.[2,3] Studies in India and Africa indicate a much greater corneal causation of blindness, 14.6–15.4% and 11–30% of total blindness, than is captured in the WHO categories of "corneal opacities" and "trachoma".[4-6] To reconcile WHO data with country level population studies, an estimated 20% of the WHO "undetermined" causes category was assigned to corneal blindness, with regional factoring from 2% to 40%. Additionally, 20% of childhood blindness is estimated to be caused by corneal blindness, with high regional variances from 2% to 50%.[7] The global breakdown illustrates the particularly heavy burden of corneal blindness on emerging and developing countries, with 98% of bilateral corneal blindness existing outside of developed countries.

Unilateral corneal blindness is not captured in WHO data, but is estimated to occur in 23 million globally, based on India's bilateral-unilateral ratios of 0.1% to 0.56% prevalence.[4] More startling is the rate of new unilateral corneal blindness cases, with one prospective study in Nepal indicating an annual incidence of corneal ulceration to be 799 per 100,000 people, primarily unilateral ulcerations.[8] In a southern India-based study, corneal blindness has been projected to grow from 0.66% (2001) to 0.84% (2020) prevalence, largely from unilateral cases.[4]

Corneal blindness trending, overall and by cause, is difficult to determine based on the WHO 2002 and 2010 reports, cited above. Trachoma, corneal opacities, and onchocerciasis have decreased from 9.5% to 7%, but "undetermined" causes of

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Table 1: Global regional estimates of total blindness and corneal blindness

	Total Pop (MM)	Total Blindness (MM)	Total Prevalence (%)	Bilateral Corneal Blindness - Est. (MM)	% of Total Blind - Est	Total Prevalence -Est (%)	Corneal Causes (Est. % of Total Blindness)			
							Corneal Opacities %	Corneal - Childhood Blindness %	Trachoma %	Corneal % in "Undetermined Category"
Africa	804.9	5.9	0.73	1.12	19	0.14	8.0	1.6	5.7	3.5
Americas	915.4	3.2	0.35	0.17	5	0.02	3.2	0.3	0.4	1.4
Eastern Med	580.2	4.9	0.85	0.81	17	0.14	4.2	0.9	3.3	8.1
European	889.2	2.7	0.31	0.14	5	0.02	3.6	0.2	0.0	1.5
SE Asian	579.1	4.0	0.69	0.41	10	0.07	3.3	0.8	0.5	5.6
W Pacific	442.3	2.3	0.53	0.20	8	0.04	3.7	0.3	2.3	2.1
India	1181.4	8.1	0.68	1.14	14	0.10	3.9	1.5	1.4	7.3
China	1344.9	8.2	0.61	0.83	10	0.06	2.4	0.2	5.3	2.2
Total	6737.4	39.4	0.58	4.81	12	0.07	4.0	0.8	3.0	4.4

blindness have increased from 13% to 21%. Keratitis, a leading cause of ocular morbidity, is correlated to socio-economic conditions with economic improvements and active Vitamin A deficiency programs occurring in many regions. In contrast, trauma is estimated in southern India to be 26% of the source of corneal blindness, with 71.4% occurring before the age of 15 years in urban areas and no sign of the annual rate of occurrences declining. Traditional medicines are still cited as a key cause of corneal ulceration, with no trends identified. Corneal dystrophies and bullous keratopathy are additional key causes of corneal blindness, with greater significance in the developed world.

The burden of corneal blindness on the community is not just reflected by the prevalence, but also by the younger age of those with corneal blindness, with very high disability adjusted life years (DALYs), relative to cataract blindness. A Hyderabad population-based study identified the average age for blindness caused by cataract to be 68.5 (n = 21) and the average age for blindness caused by corneal opacities to be 5.0 (n = 4).[5] While the sample size is too small to project a specific age delta, it illustrates that corneal blindness impacts many in their most productive years and indicates that the corneal blindness population could have a greater total DALYs than the cataract blindness population.

Preventing Corneal Blindness – Public Health Progress

Nearly 80% of all corneal blindness is avoidable.[1]At a rudimentary level, corneal diseases are highly associated with poverty and lead to a marked reduction in life expectancy, especially among corneal blind children. As nutritional health and public sanitation improves in the world's poorest communities, an expected reduction in the incidence of corneal blindness should follow. There are several broad initiatives aimed at reducing corneal blindness worldwide being managed through primary health interventions:

Trachoma

In 1998 the WHO Alliance for the Global Elimination of Blinding Trachoma (GET 2020) was created with the goal of eliminating trachoma by the year 2020. The promotion of the SAFE strategy (S – eyelid surgery, A – antibiotics, F – facial cleanliness, and E – environmental improvements to reduce transmission) is the favored approach. This continues to be a collaborative success story with trachoma elimination confirmation over the past 5 years occurring in several Middle Eastern countries (Saudi Arabia, Oman), North America (Mexico), and, most recently in 2009, a Sub-Saharan African country (Ghana). However, the news is not all positive as the most recently available worldwide data shows that 14 countries continue to shoulder 80% of the trachoma burden with 110 million persons living in confirmed hyper endemic trachoma areas.[9] An estimated 4.6 million persons are estimated to have trichiasis and to be at high risk of developing corneal blindness. The international trachoma initiative (ITI) continues to facilitate mass treatment of hyperendemic area with oral Azithromycin. Encouragingly, the reported numbers of people affected by trachoma appears to be steadily declining although epidemiological reliability remains a major challenge.[10] Elimination of the scourge of trachoma is plausible and the total cost of implementing the SAFE strategy in all remaining known endemic countries is estimated at $430–$748 million.[9]

Onchocerciasis

Through collaborative global health efforts, new cases of river blindness-related corneal opacity have decreased to the point of being eliminated in the Americas and in some areas of Africa. While onchocerciasis is not "eradicable", continued vigilance and distribution of Ivermectin on a large scale in endemic countries has diminished what once was a leading infectious cause of blindness.

Vitamin A deficiency

Keratomalacia still remains the leading cause of new blindness in children and significantly increases the risk of infant mortality. Estimates range from 250,00 to 500,000 new cases of corneal blindness a year.[11] Vitamin A deficiency is being managed through primary health interventions including widespread vitamin A distribution, promotion of breast-feeding, fortification of food, and counseling regarding dietary changes. National programs aimed at linking eye health to

maternal and child health programs with a strong focus on prevention of ophthalmic neonatorum and vitamin A deficiency are especially important for continued success.

Primary eye care health

Community-based eye care workers are the workhorses for the prevention of worldwide corneal blindness. Primary prevention is particularly relevant for vitamin A deficiency, ophthalmia neonatorum, trachoma, prevention of eye injuries, the early diagnosis and treatment of corneal ulcers, and discouragement of the use of harmful traditional eye remedies.[12] Primary eye health workers are likely the most cost effective current means of addressing corneal blindness in countries with minimal health care infrastructure and low cataract surgical rates. The continued strengthening of primary eye health in the world's poorest places is paramount to reduce incident rates of corneal blindness.

Corneal Transplantation

Corneal transplantation remains the primary sight restoring procedure for corneal blindness. While 82% of overall blindness worldwide is found in those aged 50 years or older, corneal blindness in developing countries effects a significantly younger population than other forms of blindness.[3] Corneal transplants therefore have the potential to provide a higher social return than cataract surgery. This helps to justify the increased costs and risks of the procedure.

Barriers to corneal transplantation

Not all cornea blindness is amenable to sight restoration with keratoplasty. Ocular comorbidities including corneal vascularization, adherent leukoma, glaucoma, retinal disease, and ocular surface disease all dramatically reduce graft long-term success rates. Bilaterally blind children and pediatric keratoplasty generally fare worse than adult keratoplasty. Only 40% of bilateral corneal blindness is estimated to be treatable with keratoplasty in one Indian study.[13] Operating in high-risk eyes in developing world settings often leads to a high rate of repeat keratoplasty.[7]

There are also significant social and logistical barriers to achieving success in keratoplasty. Many corneal patients are economically disadvantaged and can pay little for services. Access to high quality steroid and antibiotic medicines does not exist in many parts of the world. Finally, the intensive follow-up required for keratoplasty increases the risk of graft failure. In one large study of keratoplasty outcomes in Nepal, the biggest predictor of success was the distance the patient lived from the tertiary hospital, highlighting the challenges of effective postoperative management in many locations.[14]

Finally, a lack of trained corneal surgeons remains a major obstacle to increasing keratoplasty rates in most parts of the world. While more doctors are needed for corneal fellowship training a lack of access to corneal training is only part of the issue. There are many well trained corneal surgeons in the world who are doing low numbers of transplants due to a variety of factors, including: a lack of access to tissue, the high cost of tissue, poor institutional support for a keratoplasty program, lack of access to trephines, inadequate surgical instrumentation, and low quality sutures. Many doctors in the developing world assume simultaneous clinical, teaching, and administrative roles that may leave little time to "scale up" keratoplasty volume despite a huge patient demand for this service. To further complicate successful large-scale keratoplasty, there are often few adequately trained comprehensive ophthalmologists or ophthalmic ancillary personnel to share in the pre and postoperative management of keratoplasty patients, which is a prerequisite for long-term successful graft outcomes.

Underdeveloped eye banking infrastructure

However, by and far the largest barrier to reducing blindness through increased keratoplasty rates is the widespread lack of availability of donor tissue at a reasonable cost. Simply put, the current worldwide eye banking system is insufficient to meet the worldwide demand for tissue. On a global level, there were approximately 150,000 keratoplasties performed in 2011 with the vast majority being performed in the USA and Europe. India, the country with the largest amount of treatable blindness, performed approximately 17,000 keratoplasties (Eye Bank Association of India estimate). This is a Transplant Surgery Rate (TSR) per million population of 15 in a country with a Cataract Surgical Rate (CSR) of over 4000. Traditionally much of the corneal supply for developing world countries has been through subsidized or gratis tissues from North American eye banks flowing to developing countries.

The eye banking services have remained underdeveloped for myriad reasons including the lack of trained human resources, inefficient operations, restrictive laws, poor distribution infrastructure, high cost of long-term storage media, poorly followed medical standards, and sociocultural factors associated with organ donation. Over 700 eye banks are currently registered in India, each providing only an average of 25 transplantable corneas annually. The lack of tissue is not due to a lack of eye banks, but the lack of large professional eye banks that can effectively perform the four key eye bank functions: approach and consent, recovery, processing, and distribution.

Expanding keratoplasty surgery via increased eye banking

Worldwide, we have seen the eye health care infrastructure rapidly expand in many large countries, most notably, India. This is evidenced by the dramatic increase in the numbers of ophthalmologists and the rise in the CSR to greater than 4000 cataract surgeries per million persons. As cataract blindness is addressed there is a natural gravitation of surgeons toward subspecialty ophthalmologic care and more human and institutional resources become available to expand corneal care and increase the numbers of keratoplasties. In essence, subspecialty focus on the treatment of corneal blindness should be based on a foundational infrastructure of primary care and sufficient cataract surgeries [Fig. 1].

Based on the pre-requisite of a healthcare infrastructure to justify the development of eye banks and the training of corneal surgeons, an analysis was performed to assess each country's need and "readiness" for corneal transplantation. The map [Fig. 2] provides a visual representation of the analysis. Corneal blind estimates were developed for each country and each country was sized proportional to their corneal blind population. The country's "readiness" is stratified by color and is defined primarily by using CSR as a proxy for existing eye care infrastructure. "Readiness" adjustments were made,

based on country specific factors available: number of corneal surgeons, organ/tissue laws, existing eye banks' performance, and socio-cultural data. India emerges as a clear global priority, with the largest corneal blind population and strong infrastructural "readiness".

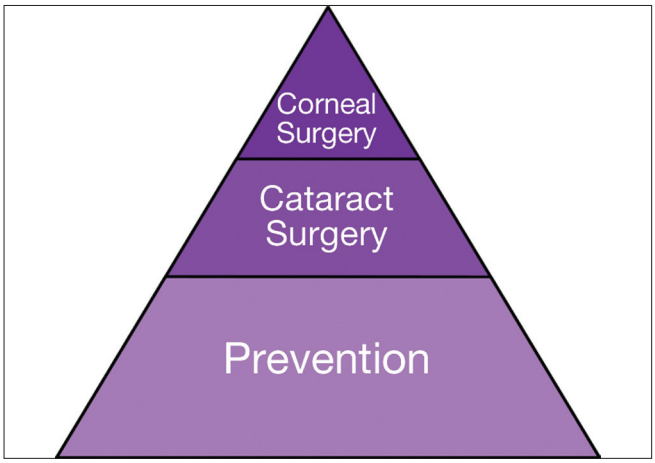

Figure 1: Foundational infrastructure for corneal transplantation

Successful eye bank model in India

The potential of eye banking to meet the need for transplantable corneas is evident in India, based on the success of 8 large eye banks since 2009. The new operating model supported annual internal growth rates of 34% (2010—5 eye banks) and 20% (2011—8 eye banks) supporting 5,600 transplants, 31% of all transplants in India (SightLife, internal data). A number of factors contributed to the successful growth, but two key factors are the establishment and development of professional eye bank managers and the development of Hospital Cornea Recovery Programs (HCRP), where trained eye donation counselors are stationed in large hospitals to approach potential donor families to gain consent. This contrasts to the typical Indian eye bank operation, which uses a "voluntary" program with a focus on general public awareness and responding to family requests to do recoveries. The voluntary program is currently operationally inefficient, with low tissue utilization. According to the Eye Bank Association of India, the overall Indian eye bank utilization of tissue, through primarily voluntary collection, is 38%. Tissue utilization of donors within a HCRP model (8 sample eye banks) is 72%, based primarily on improved donor selection (Ganesh, G, personal communication).

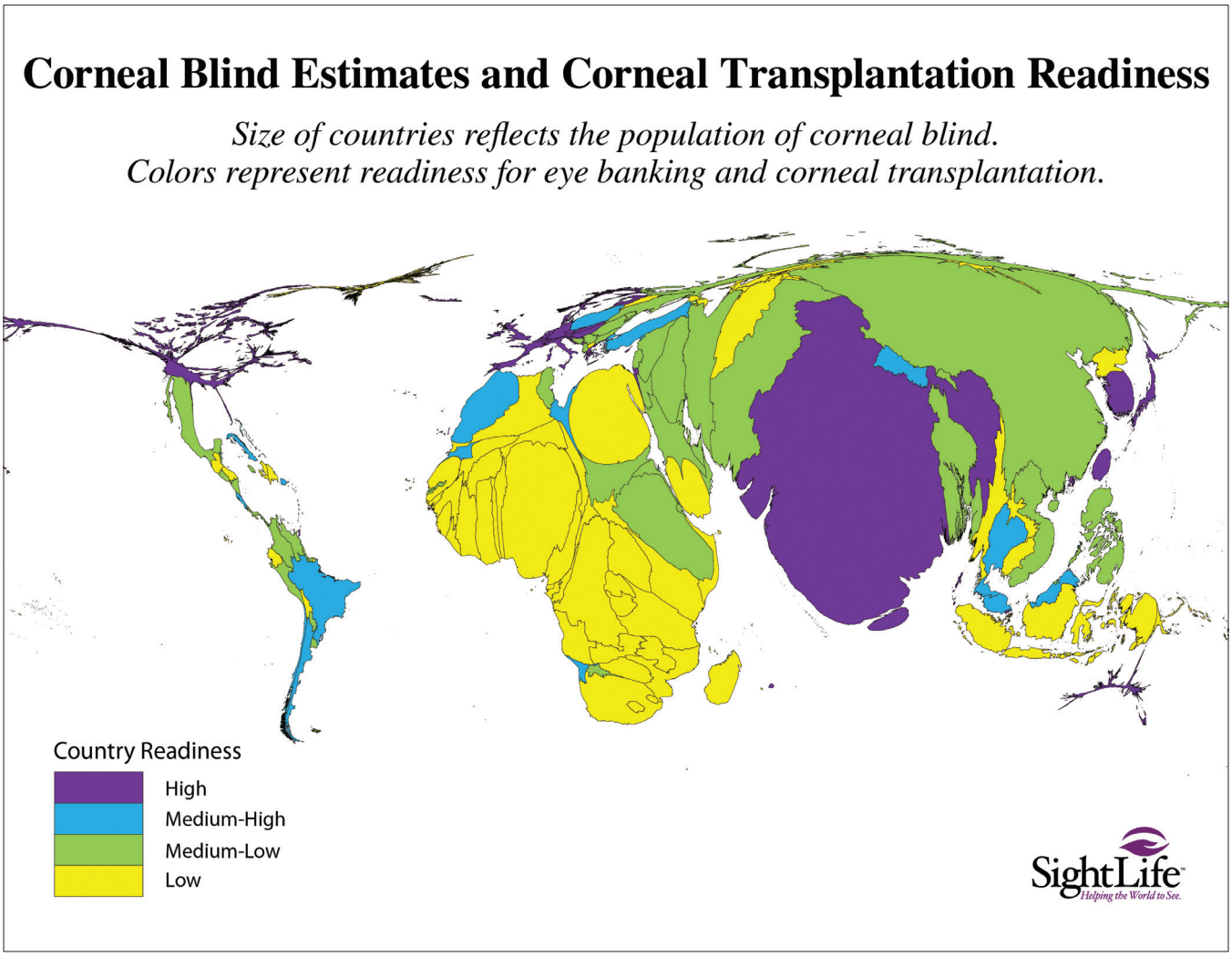

Figure 2: World corneal blindness and readiness for corneal transplantation surgery

In India, a 2004 national plan was developed by the Indian government (National Program for Control of Blindness) and Non Government Organizations (NGOs) to treat corneal blindness, with a target of 1 lakh (100,000) transplants annually by 2020. More than 1 lakh of transplantable tissue can be achieved by a model of large professional eye banks utilizing HCRP and focusing on the country's 100 largest hospitals. This highly focused and efficient approach minimizes the resources and donors required; at 70% utilization approximately 75,000 consenting and qualified donors are required to meet India's 1 lakh need. This is less than 1% of all annual deaths. A close partnership between the eye banks and the participating hospitals is a critical element to the success of this approach.

Evolving Surgical Techniques

Corneal techniques continue to advance with a steady progression of surgeons worldwide opting for more lamellar procedures, especially deep anterior lamellar keratoplasty (DALK) and endothelial keratoplasty (EK). Rapid adoption of these lamellar techniques in the developing world offers the potential for improved visual outcomes through reduced follow-up needs, decreased endothelial rejection rates, less steroid-induced glaucoma, and less suture-related complications.[15]

Lamellar techniques may also help expand the corneal supply by allowing one cornea donor to restore sight in two recipients.[16] Anterior lamellar techniques have facilitated the utilization of low endothelial cell count corneas as well as those preserved in long-term storage media such as glycerin with shelf lives of over 1 year.[17] Finally, there is an increasing body of evidence of good outcomes with the use of the Boston keratoprosthesis in the developing world as an alternative to keratoplasty, especially in vascularized corneas or those with other high-risk characteristics.[18]

Hope for the future

While the numbers of existing corneal blind worldwide is daunting there is large reason for optimism, based on overall improvement in medical care and infrastructure, successful eye bank development efforts and evolving techniques in corneal transplantation. While public health initiatives and preventative care provides the long-term solution to addressing corneal blindness, the world's ophthalmic community is poised to dramatically scale up access to corneal transplantation to meet the needs of the millions who are currently blind. Similar to the growth of cataract surgeries, countries, such as India, are well positioned to develop widespread, innovative, and sustainable models for providing transplantation.

References

1. World Health Assembly Document A62/7: Action plan for the prevention of avoidable blindness and visual impairment. 2009 – 2013. Geneva: WHO Press; 2009. p. 7-17.
2. Pascolini D, Mariotti SP. Global estimates of visual impairment 2010. Br J Ophthalmol 2012;96:614-8.
3. Resnikoff S, Pascolini D, Etya'ale D, Kocur I, Pararajasegaram R, Pokharel GP, *et al*. Global data on visual impairment in the year 2002. Bull World Health Organ 2002;82:844-51.
4. Dandona R, Dandona L. Corneal blindness in a southern Indian population: Need for health promotion strategies. Br J Ophthalmol 2003;87:133-41.
5. Dandona L, Dandona R, Naduvilath TJ, McCarty CA, Nanda A, Srinivas M, *et al*. Is current eye-care-policy focus almost exclusively on cataract adequate to deal with blindness in India? Lancet 1998;351:1312-6.
6. Lewallan S, Courtright P. Blindness in Africa: Present situation and future needs. Br J Ophthalmol 2001;85:897-903.
7. Garg P, Krishna PV, Stratis AK, Gopinathan U. The value of corneal transplantation in reducing blindness. Eye (Lond) 2005;19:1106-14.
8. Witcher J, Srinivasan M, Upadhyay MP. Corneal blindness: A global perspective. Bull World Health Organ 2001;79:214-21.
9. International coalition for trachoma control. The End in Sight. 2020 Insight. 2011. p. 1-35.
10. Burton MJ, Mabey D. The global burden of trachoma: A review. PLoS Negl Trop Dis 2009;3:e460.
11. WHO global database on vitamin A deficiency global prevalence of vitamin A deficiency in populations at risk 1995-2005. Geneva, Switzerland: World Health Organization; 2009. p. 1-55.
12. Faal H. Preventing corneal blindness, working with communities. Community Eye Health 2009;22:36-7.
13. Sinha R, Sharman, Vajpayee RB. Corneal blindness - present status. Cataract Refract Surg Today 2005:59-61.
14. Tabin GC, Gurung R, Paudyal G, Reddy HS, Hobbs CL, Wiedman MS, *et al*. Penetrating keratoplasty in Nepal. Cornea 2004;23:589-96.
15. Han DC, Mehta JS, Por YM, Htoon HM, Tan DT. Comparison of outcomes of lamellar keratoplasty and penetrating keratoplasty in keratoconus. Am J Ophthalmol 2009;148:744-51.e1.
16. Sharma N, Agarwal P, Titiyal JS, Kumar C, Sinha R, Vajpayee RB. Optimal use of donor corneal tissue: One cornea for two recipients. Cornea 2011;30:1140-4.
17. Feilmeier MR, Tabin GC, Williams L, Oliva M. The use of glycerol-preserved corneas in the developing world. Middle East Afr J Ophthalmol 2010;17:38-43.
18. Ament JD, Todani A, Pineda R 2nd, Shen TT, Aldave AJ, Dohlman CH, *et al*. Global corneal blindness and the boston keratoprosthesis type I. Am J Ophthalmol 2010;149:537-9.

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