Review Article

Corneal blindness and eye banking: Current strategies and best practices

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Corneal blindness (CB) is one of the leading causes of blindness in India and globally, affecting around 8 million population worldwide. Many of these corneal blind patients may be visually rehabilitated by corneal transplantation (CT). Eye banking plays a crucial role in facilitating CT and ocular research. Many countries have adopted regulatory frameworks, quality assurance programs, and technological advancements to enhance the efficacy and safety of CT. Various infrastructural and organizational frameworks of eye banks (EBs) in India, according to the Eye Bank Association of India (EBAI), aid in establishing guidelines and standards for EB practices. Initiatives such as the National Programme for Control of Blindness (NPCB) have significantly contributed to eye donation rates and improved access to donor corneas. This review article discusses the established eye banking networks in countries such as India, the United States (USA), and Europe, where dedicated EB organizations work collaboratively to ensure efficient procurement, processing, and distribution of corneal tissue. It also highlights specific strategies employed in India and global countries to address EBs' challenges. These challenges include the shortage of donor corneas, improving donor screening and tissue processing techniques, ensuring timely distribution of corneal tissue, and maintaining high-quality standards. Interestingly, the comparative analysis between India and other developed countries highlights the similarities and differences in eye banking strategies. By understanding the strategies employed by different regions, EBs can learn from each other's experiences and work toward achieving optimal outcomes in CT and ocular research worldwide. It underscores the importance of knowledge sharing and collaborative efforts in addressing common challenges and implementing best practices in eye banking.

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Corneal transplantation (CT) is the only option for restoring vision in patients with corneal opacities for various reasons, such as trauma, degenerations, dystrophies, infections, and inflammations.[1] The success of CT depends upon the quality of the donor, the nature of the recipient's pathology, and the postoperative care. Eye banks (EBs) play an essential role in providing high-quality tissues to cornea surgeons through appropriate procurement, storage, and distribution of tissues. The world's oldest transplant association is the Eye Bank Association of America (EBAA), founded in 1961; it provides tissues for performing > 85,000 CT annually.[2] The European Eye Bank Association (EEBA) was started in 1989 and includes donor tissues to 22 European countries through 80 EBs.[3] The responsibilities of eye banking have reached greater heights from procuring, storage, tissue processing, and distribution to donor screening and tissue evaluation process, development of reporting systems for adverse events, screening for infectious diseases through serological testing of the donor, preparation of precut tissues, providing preloaded tissues, keratolimbal grafts, and recently being involved in preparing bioengineered corneas. The Eye Bank Association of India (EBAI) has also joined hands with global EBs to standardize the EB guidelines throughout the country. There are many barriers for developing countries to achieve a high level of improvement in eye banking. They include trained staff, affordability of equipment, storage media cost, and inadequate public awareness.[2] Hence, we must understand the importance of current perspectives of the eye banking system in developing and developed countries and the future scopes for development. This review article describes the current spectrum of corneal blindness (CB), its statistics in India and global countries such as the United States of America, and European countries, the existing eye banking

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models in both developed and developing countries, hospital corneal retrieval programs (HCRPs), and the roads ahead of eye banking in the future.

Current status of CB in India and global countries

CB was the fifth leading cause of blindness in the world, following cataracts, glaucoma, refractive error, and age-related macular degeneration. Still, according to the National Blindness and Visual Impairment Survey India 2015–2019, CB has become the third leading cause of blindness.[4,5] Among 45 million blind people worldwide, 6–8 million are blind due to corneal diseases. About 5.5 million people worldwide are bilaterally blind, and 6.2 million are unilaterally blind due to corneal diseases. The most common causes include infective keratitis, corneal trauma, pseudophakic bullous keratopathy, chemical injuries, keratoconus, and dystrophies.[4] The burden of CB is more in developing countries, in children and young adults. When corneal diseases affect the younger population, the disability-adjusted life years are more significant compared with other causes of blindness such as cataract. Trachoma is still the most common CB in Africa and Australia.[4] The prevalence of CB in central Australia is 3.3%; trachoma is the leading cause of CB, constituting 13.2%. Similarly, in regions of sub-Saharan Africa, such as Ethiopia, CB represents 20.8% among 1.5% of total blindness. Trachoma is still endemic in Cambodia, Tanzania, and the Jimma Zone of Ethiopia, according to the African study by Lewallan and Courtright *et al*. Around 54% of the world's population lives in East, South, and Southeast Asia; subsequently, the global burden of CB is in Asia.[6,7] A high prevalence of CB is noted in India (0.88%) and the lowest in Sri Lanka (0.05%).[1] The percentage of people affected with corneal diseases in Thailand is high at 19.9%, India represents the second highest at 15.8%, China at 10.4%, and the lowest is Sri Lanka at 1.5%.[8] According to the WHO, around 2 million people in China and 7 million people in India await keratoplasty. India accounts for 20% of the 39 million blind population across the globe.[8,9] Currently, CB in India is 1.2 million, which is 0.36% of total blindness; about 25,000 to 30,000 people are added every year. Three population-based studies were conducted in India on the burden of CB. In the Andhra Pradesh study, 0.1% suffer from CB; the prevalence is 3.9%; among them, 2.9% are unilaterally blind, 3.7% of CB is prevalent in Northern India, and 13.3% is prevalent in CB in Kurnool. There exists a regional difference in the etiology of CB; ocular trauma is the leading cause of CB in North Telangana and Kurnool (59.3% and 45%, respectively) compared with pseudophakic bullous keratopathy as the leading cause of CB in North India (46.2%). These data help us understand the region that needs more eye care delivery through human resources, institutional capacity, or public awareness.[9,10] The National Programme for Control of Blindness (NPCB) (2015–19) data were retrieved through a Rapid Assessment of Avoidable Blindness (RAAB) survey conducted randomly in 31 districts of India over a population of >50 years of age. The highest prevalence of blindness was seen in Bijnor, Uttar Pradesh (UP) (3.7%), and lowest in Thrissur, Kerala (1.1%), and the second most common cause of total blindness was corneal diseases due to infections and trauma.[5] According to the meta-analysis on global trends in blindness and visual impairment during 1984–2020, 5.5 million people worldwide are bilaterally blind due to corneal opacities, and 6.2 million are unilaterally blind.[11] In China, infectious keratitis (61.7%) accounts for the leading cause of CB.[12] The prevalence of CB in Western provinces is high compared with central and eastern provinces and ranges from 0.949% to 0.106%.[12] Infectious keratitis is a silent epidemic responsible for the primary cause of preventable blindness in developing countries and mainly affects low- and middle-income countries.[8] Worldwide prevention of infectious keratitis would reduce the significant impact of CB. According to World Health Organization (WHO) estimates, in 2010, there was a 47% significant reduction in blindness in India through effective measures taken through ongoing NPCB to control blindness and visual impairment.[5]

Existing Eye Banking Model in India and Global Countries

"Eye Bank," as described by Rao GN,[13] is a not-for-profit community organization created and managed by members of the community. Its primary function includes harvesting donor corneas, detailed donor tissue and donor blood sample processing, tissue storage, and subsequent distribution to the corneal surgeons. Late Dr. R S Muthiah is credited with starting the first EB in India at the Regional Institute of Ophthalmology, Chennai, in 1945.[14] The first CT in India was also successfully performed by him in 1948.[14] The Indian government set up legislation on eye banking and eye donation in 1957. The EBAI, a not-for-profit society, was formed in 1989 to promote eye banking in India. The Transplantation of Human Organ Act, 1994, which allowed only registered medical practitioners to harvest corneal tissue, was modified in 2011 and classified cornea as a tissue and not an organ and allowed relatives to provide consent for eye donation and trained technicians to retrieve cornea from the deceased.[15]

The eye banking model proposed for India under the NPCB involves a three-tier system consisting of an EB training center (EBTC) at the top, followed by an EB in the middle and eye retrieval centers (ERCs) at the bottom of the pyramid. Five eye donation training centers and 50 EBs with 40 ERCs connected to each EB were the plans envisaged in 2004.[16] ERCs should be affiliated with an EB and perform the function of increasing public awareness about eye donations, coordinating with the community and hospitals, and harvesting, storing, and transporting corneal tissue and blood from donors to the EB. EBs were assigned the pivotal role of increasing public awareness, harvesting, evaluation, storage, and distribution of corneal tissue in an equitable fashion. The EBs were also assigned to run the Hospital Cornea Retrieval Program (HCRP), which involves retrieving donor corneal tissue from the deceased in major hospitals and medical colleges. EBTCs are specialized EBs meant to serve additionally as training centers for EB personnel.

The functioning of EBTC and EB is governed by a board of directors, a medical director, who should be an ophthalmologist with fellowship training in cornea, and an eye bank manager. The ERC is headed by a director or in charge. Trained and certified EB technicians and eye donation counselors also undergo eye banking and grief counseling training from the rest of the team at all EBTC, EB, and ERC. The EBTC and EB should be equipped with equipment such as slit lamp, specular microscope, and laminar airflow hood and have a functional serology and tissue processing laboratory. EBTC, EB, and ERC

must have a refrigerator, instruments for tissue retrieval, an autoclave for sterilization, and an instrument cleaning and storage area.[13]

Although 435 EBs and ERCs were functional under NPCB in 2018,[17] the number of functional EBs and ERCs was found to be 380 in 2020, as per records of the Ministry of Health and Family Welfare, Government of India. "Vision 2020 – Right to Sight" set the target to establish 20 EBTCs, 200 EBs, and 2000 ERCs. Furthermore, the integration of community health workers, optometrists working in vision centers, and all grassroot-level volunteers with EBs or Eye donation collection centers (EDCs) is being promoted to increase public awareness and voluntary eye donations (VEDs) at the community level.[18]

For harvesting of donor cornea, informed consent from relatives is mandatory. It is mandatory to collect a blood sample from the deceased and subject it to serological testing for non-reactivity against the following[17]

1. Human Immune deficiency virus (HIV) 1 and 2
2. Hepatitis B virus
3. Hepatitis C virus
4. Coronavirus disease (COVID-19)
5. Syphilis.

Harvesting tissue from donors with the following diseases is contra-indicated due to the risk of transmitting the disease to EB personnel and recipient. These include patients with active viral hepatitis, HIV infection, viral encephalitis, Creutzfeldt–Jakob disease, and Rabies—the eye banking standards provided by the NPCB detail the various other relative contraindications. Death to enucleation time should be within 6 hours during the summer and 8 hours during the winter.[17]

Enucleation of the whole eyeball or *in situ* excision of the corneoscleral disk is permissible. In case of whole globe enucleation, the corneal–scleral disk should be prepared under a laminar air flow hood with International Organization for standardization (ISO) class 5 standards within an appropriate environment in the EB or EBTC and transferred to a suitable corneal storage medium such as McCarey–Kaufman (MK) medium, Optisol corneal storage media (Optisol-GS), Cornisol, and Eusol.[19] The corneal tissue undergoes detailed evaluation by slit-lamp biomicroscopy and specular microscopy and is then graded to determine its further application. It is also permissible to subject the corneal tissue to lamellar dissection using manual or automated techniques and transport to surgeons. Other components, such as the whole globe and sclera, can also be preserved. Preservation of corneoscleral disk in glycerol and organ culture medium for long-term preservation is also permissible. Adequate numbering and tissue labeling are mandatory before storage and transport to corneal surgeons. Equitable distribution of corneal tissue is also mandated as per the NPCB guidelines.[17]

Global eye banking models

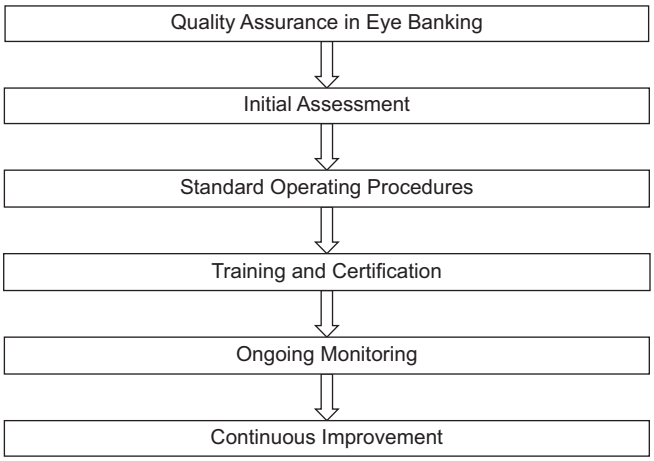
Modern eye banking was conceived by Filatov of the USSR, who started harvesting cadaveric donor corneal tissue within a few hours of death, preserving tissue at 4–6 deg Celsius, and utilizing it within 20–56 hours of death.[20] Dr. R Townley Paton established the first American EB in New York in 1944.[21] The American Academy of Ophthalmology and Otolaryngology was instrumental in creating an association that eventually led to the EBAA in 1961.[22] The EBAA not only functions as an EB but also performs the function of accrediting and standard setting for EBs. The Medical Eye Bank Inc. was established in 1962 in Baltimore. To make eye banking a financially sustainable exercise, Modern eye banking (MEB) started the practice of billing third-party health insurance companies for the cost of processing donor corneal tissue. This practice was eventually adopted by EBAA for all EBs, thus making eye banking a financially viable reality.[22] The table 1 shows the brief description Eye banking models that exist in different parts of the world. The MK medium for intermediate-term storage of donor corneal tissue was introduced in 1974.[19] In 1975, legislation was passed to enable the harvesting of corneas from deaths under the purview of the medical examiner, which needed autopsy, thus paving the way for harvesting corneal tissue from young donors. The Anatomical Gifts Act 1968, which was revised in 1987 and again in 2006, has been instrumental in increasing eye donations along with that of other organs as "anatomical gifts."[23-25]

The administrative team for any EB, as per EBAA, consists of a board of directors, a director, and a medical director, very similar to what is followed in India. The medical director is responsible for the day-to-day functioning of the EB. All other personnel working in the EBs should be trained and certified—Certified Eye Bank Technician (CEBT). EB should be adequately equipped with a separate designated laboratory area. All activities of the EB are guided by Standard Operating Procedures (SOP) prepared by the director and medical director of the EB [Flowchart 1]**.** Apart from harvesting corneoscleral disks, the technicians are also trained to perform lamellar dissection using an automated microkeratome, manual dissection for endothelial keratoplasty (DSEK or DMEK), laser-based dissection, and keratolimbal allograft (KLAL).[22,24]

All donors are screened per criteria laid down by EBAA and for FDA-defined relevant communicable disease agents and diseases. EBAA recommends that corneal preservation should be performed as soon as possible after death. Thus, all time intervals need to be recorded. All standards for cadaveric tissue will

Table 1: Eye banking models worldwide

Eye banking model	Description	Countries/regions
Centralized eye bank	A single central organization responsible for eye donation, evaluation, storage, and distribution of corneas	United States, United Kingdom, Australia, Canada Several European countries
Hospital-based eye bank	Eye banking services integrated within a hospital or eye care center	India, Brazil, Singapore, some European countries
Community-based eye bank	Eye banking services established at the community level in collaboration with Non-Government organizations (NGO's) and local organizations	Nepal, Sri Lanka, parts of Africa and South Asia



Flowchart 1: Quality assurance process in eye banking

apply to eye tissue retrieved from a living donor and meant for surgical use. The globe and corneoscleral disks can be harvested using a pen light after the initial gross examination. In the case of whole globe enucleation, the corneoscleral disk is prepared in the EB under laminar air flow as per SOP. The whole globe for lamellar dissection may be stored in a moist chamber at +2-8°C. Corneoscleral disks may be stored in an intermediate-term corneal storage medium (Optisol-GS, Eusol, etc.) or a long-term corneal storage medium such as an organ culture medium, manufactured as per the Food and Drug administration (FDA) Good Manufacturing Practices. Donor tissue is evaluated in detail by slit-lamp examination and specular microscopy and graded to ascertain suitability for final usage. Donor tissue is provided for the following surgical procedure—PK, anterior lamellar keratoplasty (ALK) or Deep anterior lamellar keratoplasty (DALK), DSEK or Descemet's stripping endothelial keratoplasty (DSAEK), DMEK, KLAL, and KPro implantation. Serology on donor blood samples is also performed. Quality assurance, quality control, microbiological testing, documentation of recipient details, reporting, and documentation of adverse events are also performed. Tissue is adequately labeled, and equitable distribution is ensured.[24] Although meticulous care is taken during all steps, the final responsibility for determining tissue suitability for transplantation lies with the transplant surgeon. Currently, Sight Life, a nonprofit company established in 1969, maintains one of the largest EBs in the United States (USA). While traditional EBs work with local community members and promote VEDs, Sight Life works with hospitals and Organ Procurement Organizations (OPOs).[23] However, its daughter company Cornea Gen is a "for-profit" organization. Sight Life, India, which is operational from New Delhi, is involved in corneal tissue distribution, advocacy, and training of surgeons across India. EEBA, which convened its first meeting in 1989, is governed by a secretariat located in Veneto, Venice, with members from across Europe and beyond. EBs in countries belonging to the European Union (EU) must follow the technical guidelines laid down by the EEBA. EEBA allows only trained personnel to retrieve tissue with proper consent from next of kin with documented "no objection." It allows for 1. *In situ* excision of corneoscleral disk directly from the donor's eye.

2. Excision of corneo—scleral disk, *in vitro*, from the enucleated eyeball, at the EB.

3. Lamellar dissection of tissue at the EB using manual, automated, and laser-based techniques.[25,26]

Various storage methods that the EEBA approves include hypothermic storage of the whole eyeball up to a maximum of 72 hours, hypothermic storage of corneoscleral disks in a corneal storage medium at +2-8°C for a duration recommended for that medium, and storage in organ culture medium at +28-37°C for a maximum duration of 34 days. Microbiological evaluation of the storage medium is also mandatory. Alternative storage methods such as cryopreservation by trained personnel are permitted.

A detailed macroscopic evaluation of the eyeball and slit-lamp evaluation of all the corneal layers is mandatory. Additionally, endothelium should be evaluated by specular or transmitted light microscopy (bright field, phase contrast). EEBA also has approved guidelines for processing and storage of sclera and amnion. Sclera, after decontamination, can be stored at room temperature, dehydrated in 70% ethanol or higher, treated with aqueous solution after denaturation with ethanol, formalin-fixed, or freeze-fried. Sclera can also be stored in the refrigerator at +2-8°C in a hypothermic storage medium, in 70% ethanol, or a saline solution supplemented with antibiotics. Sclera can also be stored frozen at -30°C. Contraindications for scleral donation include malignancies, ocular pathologies such as staphyloma pterygium, and abnormal contour in donors who have undergone cryosurgery or ablation surgery. The amniotic membrane can be retrieved from donors undergoing planned lower segment cesarean section after informed consent. Prior prenatal evaluation of the donor must rule out a history of malignancies, genetic disorders, and transmissible diseases. Amniotic membrane is prepared from the placenta under approved air quality in a laminar flow hood and stored in a freezer at -80°C, in liquid nitrogen, freeze-dried, or in a carrier at -20°C. All tissues from the EB are labeled, and donor details are documented as per recommendations. The tissues are transported to various EU countries per transport protocols laid down by the EU. Under EEBA, all EBs must take up continuous education and training of all personnel involved in the functioning of the EB. In 2018 at the World Ophthalmology Congress, an agreement after that named "The Barcelona Principles" was signed by the Global Alliance of Eye Bank Association (GAEBA) along with other stakeholders.[21,24,25] This agreement laid down the guiding principles for all EBs, regarding the ethical use of donated human ocular tissue for transplantation, research, and future technologies. It enforced equitable distribution of corneal tissue and self-sufficiency of EBs without adopting a "for-profit" model.[26]

Consent systems for eye donation

Organ donations are legalised in India, under Transplantation of Human Organs and Tissues Act (THOTA), in 1994.[26] Policies for organ donations are different among countries worldwide.[25] There are two prime consents for organ donations: 1) expressed consent ("opt-in")—it refers to individuals who have consented to organ or tissue donation through the registry, health card, or driver's license; 2) presumed consent ("opt-in")—it refers to an approach in which individuals are presumed to have consented for organ donation following death unless they opt-out before death. The presumed consent policies for organ donations have been followed in Spain since 1979, Belgium since 1987, and Austria, France, Columbia, Norway, Italy, and Singapore. The number of organ donations quadrupled after the presumed consent law. A proposal for the inclusion of a consent column for eye donation in the medical cause of death

certificate required for crimination or burial has been enacted and implemented through the Human Organ Transplantation Act (HOTA) in 2011 in India. The effectiveness of following the legislature could be more credible, and it needs enormous cooperation from each state government official with a positive perspective on a larger scale.[26,27]

Statistics of donor eyes and CT in India and global countries

According to the global CT and eye banking survey, 55% of all donor corneas are retrieved from the USA and India. The EBAA has created eye banking standards for evaluating and distributing donor tissues. It represents 83 EBs across the USA and 14 international EBs. According to the EBAA statistics, in 2010, 110,600 corneas were received, and 59,271 tissues were distributed, and with 42,642 donors, CT was performed. It was interesting to note that according to the EBAA statistics for 2022, 122,472 corneas were received, and the utilization was the same as in 2010. Still, the distribution trend has been increasing since 2018, from 68,102 donors to 79,126 in 2022.[28] Tan H *et al*.[12] analyzed the CT and donor characteristic trends in China EB from 1999 to 2018. About 3,910 corneas were received in Chongqing EB, China, and 65% were utilized for CT. Preregistered donors' ages varied from 30 to 39 years from 1999 to 2003 to 60–69 years from 2014 to 2018. The author explained that the difference in trend analysis concerning age might be due to reduced public awareness and increased hospital corneal retrievals recently [Table 2]. Approximately 35,000 corneas are procured annually through the EEBA. According to EEBA statistics for 2015, 39,525 corneas were received from 68 EBs across 22 European countries, and 66% were utilized.[3] India is the world's largest country with CB. Even though there are over 700 EBs across the country, 20,000 corneas are being procured yearly; only 58 collect 100 corneas annually. The reason behind this is that the collection trend needs to be more consistent, existing religion-based myths exist, and there needs to be more public awareness.[1,5,10] Globally, 185,000 CTs are performed yearly in 116 countries, with 284,000 donor corneas from 82 countries and an estimated 12.7 million people waiting for CT. Thailand, Myanmar, Korea, Malaysia, Indonesia, and Vietnam are contributing central EBs worldwide, but they have an extensive waiting list for CT. Some of the facts on EB include the following: 1) The highest CT per capita is being performed in the USA, Lebanon, and Canada; 2) donor corneal distribution is highest from EBAA and the Eye Donation Society of Sri Lanka; 3) the largest and most active EB, worldwide, is based in Sorocaba, Brazil; and 4) in last three decades, EBAA through its member EBs has provided >1,645,013 tissues till now. Despite this fact, 53% of the world's population lacks access to CT.[28] Hence, it is necessary to standardize the EB function, increase the eye collection centers in rural villages, strengthen eye care service delivery, develop human resources for eye care, promote outreach activities and public awareness, develop infrastructure capacities, and increase and expand the research.

Table 2: Comparing eye donation rates in different regions or countries

Country/ region	Eye donation rate (per million population)	Factors influencing donation rates
India	~3-4	Cultural beliefs, awareness campaigns, healthcare infrastructure
United States	~20-25	Organ donation system, public awareness, opt-out system
United Kingdom	~9-10	Public education, healthcare infrastructure, and opt-out system
Australia	~15-20	Organ donation system, public awareness, medical practices
Nepal	~3-4	Limited healthcare facilities, awareness campaigns, and cultural factors
Canada	~18-20	Public awareness and government support for eye donation
Sri Lanka	~-10	Public education and religious beliefs

HCRPs in India and Global Countries

There are currently two ways to procure corneal tissues for transplantation in India. One is VED, and the other is HCRP. In VED, the deceased's family members inform the EB, and the EB sends technicians to harvest the tissue. In HCRP, a trained "grief counselor" is stationed at hospitals linked to the EB. When a person dies at the hospital, the counselor approaches and counsels the next of kin to get consent for donating the eyes of the deceased. HCRP, introduced in 1991, has provided a much-needed boost to cornea procurement in India.[29] The motivation provided by the counselors to the family of the deceased eases the apprehensions that they may have toward the corneal donation. This method also has the advantage of knowing the donor's medical history. As reported in a study conducted in a community EB in Eastern India, 86% of eye donations were motivated, and only 14% were voluntary.[30] The literacy status of a family, their socioeconomic status, and their knowledge about eye donation do not affect the decision to donate corneas of the deceased by the family. Counseling and encouragement from counselors prove to be effective in convincing even families with no prior knowledge of eye donation and low economic status.[30] In a study conducted in Nepal Eye Bank, the number of tissues procured by HCRP and the tissue quality, in terms of the average age of the donor and the cornea clarity, was better than VED. The study also claimed a twofold increase in tissue procurement once HCRP was introduced.[31] Globally, the regulations for corneal tissue procurement differ. The global survey of CT and eye banking[28] divided countries into those using an "opt-in" system and those using an "opt-out" system. The opt-in system requires explicit consent from the donor or their families. In the opt-out approach, anyone who has not refused to donate their eyes is considered a donor. According to the survey, of 77 countries where corneas are procured, 42 (55%) used an opt-out system. Corneal tissue procurement was significantly better in the opt-out system. HCRP is a form of an opt-in system.[27,32]

Tissue Distribution: The Current Strategy Followed in India and Global Countries

Eye donation serves as a gift of sight, an invaluable treasure, and for those afflicted by blinding corneal diseases, surgery by

CT offers hope of restoring vision. There is a wide discrepancy between the demand and supply of corneas for transplantation, with adequate numbers in a few high-income countries and marked scarcity in low-income scenarios. There is an effort to boost international collaboration and distribution practices, which can be crucial in ensuring that those in need can be helped with this life-changing procedure. Very little information is available in the scientific literature on global efforts and best practices involved in international corneal distribution. This is further compounded by differences in the legal framework pertaining to this need and a lot of variability in regulations across different geographical regions.[33]

Collaborative Networks and Organizations: Eye Bank Associations in different countries offer a platform for sharing knowledge, information, technical know-how, and skills and also collaboration and cooperation in sharing tissues to a variable extent depending on the particular region and resources. The emergence of organizational networks to facilitate such efforts across countries and continents is another positive development in recent times. The EBAI, the EBAA, the EEBA, the Asia Cornea Society (ACS), and the GAEBA are examples of organizations, which play a vital role in fostering partnerships, establishing some uniformity in protocols by establishing guidelines, and coordinating efforts among eye bankers and other healthcare professionals globally.[34]

Standardization of Processes: One of the critical aspects of international corneal distribution practices is the standardization of processes. This includes guidelines for screening and evaluating corneal donors, tissue recovery, processing, preservation, and distribution. Standardization ensures the safety and quality of corneal tissue, reducing the risk of transmission of infections or diseases.[22,35-37]

Allocation Systems: To ensure fairness and equity in corneal distribution, many regions and countries have implemented allocation systems. These systems consider waiting time, medical urgency, and compatibility between the donor and recipient. They aim to allocate corneal tissue to those who benefit the most and have the highest chance of successful transplantation. The allocation systems also consider international cooperation, allowing for the redistribution of corneas between countries when needed.[38]

International Cooperation and Redistribution: International cooperation is critical to international corneal distribution practices. Due to variations in corneal supply and demand across countries, collaboration is essential to ensure that corneas reach the recipients in need, regardless of their geographic location. When a particular region has a surplus of corneas, it can redistribute them to areas where the demand exceeds the local supply. This cooperative approach helps to optimize the utilization of available corneas and address disparities in access to transplantation.

Challenges and Future Outlook: While significant progress has been made in international corneal distribution practices, challenges persist. These include logistical hurdles, varying regulatory frameworks, cultural beliefs, and socioeconomic factors that may impact the availability and acceptance of corneal tissue. To overcome these challenges, continued efforts are needed to promote awareness, educate communities, streamline processes, and strengthen international collaborations.

Future Scope of Eye Banking in India

In a recent survey of EBs associated with EBAI, more than half of donor corneas were obtained by 2% of the 740 EBs in India. This highlights the gross geographical disparity in the availability of cornea across the country.[39] To address the growing demand for donor corneas, efficient functioning of the existing EBs is necessary, with improvement in the quantity and quality of procured donor corneas, their distribution, and effective utilization. Effective networking is essential that connects Eye banks to address the critical shortage of corneas and efficiently transport tissues from areas of tissue abundance to areas in desperate need of donor corneas.[40] More than 80% of corneas in India are stored in the MK medium, which is a short-term storage medium.[33] Studies have shown that corneas stored in intermediate storage media such as Optisol-GS and Cornisol have a better endothelial cell count than MK medium.[41] The tissue utilization in the west is higher due to the usage of intermediate and long-term storage media such as Optisol-GS and organ culture.[42] Using an intermediate storage medium such as Cornisol can prolong the survival of optical-grade donor corneas. It can help in tissue distribution from high-volume EBs to corneal surgeons in areas of poor corneal availability.

Long-term storage of corneal tissues in tissue culture can also help us tide over unexpected situations like the COVID-19 pandemic.[37] Though penetrating keratoplasty (optical and therapeutic) accounts for more than three-fourths of keratoplasty performed in India, there has been an increase in the proportion of lamellar keratoplasty being done in the last decade.[39] The availability of precut and pre-striped tissues can help surgeons reduce tissue wastage while preparing the tissues themselves. They can increase the uptake of lamellar keratoplasty among budding surgeons. The last two decades have also witnessed a leap in bioengineering and regenerative therapy for corneal repair and transplantation. These include keratoprosthesis with regenerative functions, biopolymer-based scaffolds, and cell-based regenerative therapies.[38] Novel tissue-engineered corneas made of composites of natural and synthetic biopolymers together with corneal cell lines or stem cells will be the future of CT.[43] The research into bioengineered corneas started way back in 1999 by Griffith *et al*.; the authors have attempted to construct corneal epithelial, stromal, and endothelial cell equivalents for drug testing and biomedical research.[43,44] Although successful animal studies on culturing epithelial and endothelial stem cells exist, there are many barriers to tissue cultures, such as the need for trained personnel, successful delivery of cultured endothelial stem cells to the recipient cornea, dedicated transport facilities, and other resources. It may appear as an adjunctive future scope to replace donor tissue for endothelium transplantation. The self-assembled corneal substitutes by inducing keratocytes with ascorbic acid for producing stromal-like extracellular macromolecules are being tried. The limiting factor is the long processing time, requiring a minimum of 4 weeks to produce mere 36 micrometers of tissue. Interestingly, in 2008, a Swedish group of corneal surgeons performed anterior lamellar keratoplasty (ALK) using 500 um of thick biosynthetic recombinant human collagen in 10 patients with keratoconus.

The latest research involves remodeling post-Small Incision Lenticule Extraction (SMILE) lenticules for patients with hyperopia and keratoconus. It involves decellularization to prevent graft rejection and storage to preserve tissue integrity.

The limitations embrace the need for generating large libraries to store the lenticules for distribution and the associated cost. Corneal surgery starts in the EB; collaborative efforts between surgeons and EBs can help find solutions for adequate tissue procurement and utilization.[43,44]

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Conflicts of interest

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