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Chapter

Surgical Interventions in Ocular Diseases

Hariprasad Vokuda, Srinivasa, Roopashree Rao and Kinjal H. Porwal

Abstract

THE COLORFUL WORLD WE SEE IS THE RESULT OF THE BEAUTIFUL CREATION OF THE HUMAN BODY – THE HUMAN EYE. Eye surgery has advanced swiftly over the last 25 years. The development of new technology, tools, and techniques has turned corrective eye surgery into a common procedure.

Keywords: eye diseases, blindness, eye surgery, vision correction

1. Introduction

There are various eye diseases causing blindness which can be corrected by various types of eye surgeries. This article focuses on procedures which can correct the visual acuity to near normal and treat the eye diseases.

1.1 Pediatric age group

The most common causes of blindness are:

• Refractive errors, uncorrected
• Cataract
• Glaucoma
• Corneal opacity
• Trachoma
• Vitamin A deficiency

Cataract is one of the common cause of blindness in childhood, which can be treated by surgery. Children with cataract have delayed development and poor quality of life. Nearly 200,000 or more children are affected by blindness due to untreated cataracts, from cataract surgery complications, or from cataract associated ocular anomalies [1]. Lot more children are affected by the visual difficulties, that increase as the child grows, caused by gradually progressive partial cataracts. Overall risk of cataract during the growing years is as high as 1 per 1000 [2].
1.2 In young age

1.2.1 Refractive errors

Refractive errors happen when the shape of the eye keeps light from focusing correctly on the retina (a light-sensitive layer of tissue at the back of the eye). There are various types of refractive errors and each type of refractive error is significant enough to cause reduced visual acuity.

1.2.1.1 Myopia (near-sightedness)

Myopia or near-sightedness is a condition wherein the patient has difficulty in seeing far objects. It is the condition in which parallel light rays from infinity, as they refract on cornea and lens, converge at a focus in front of the retina [3].

It can be due to increased axial length in an enlarged eyeball (axial myopia), steep cornea with regular curvature (refractive myopia), anteriorly displaced lens, or increased refractive index of aqueous humor or decreased refractive index of vitreous (index myopia) [3].

Myopia usually begins in the age span of 6 to 14 years. High myopia or pathological myopia maybe associated with degenerative changes in retina and choroid which can cause retinal detachment.

1.2.1.2 Hyperopia (far-sightedness)

Hyperopia or far-sightedness is a condition wherein the patient has difficulty in seeing near objects. It is the condition in which parallel light rays from infinity converge on a focus behind the retina after refracting on the cornea and lens [3].

It can be due to decreased axial length of eyeball (axial hyperopia), posteriorly displaced lens, absence of lens or aphakia (leading to high hyperopia), flat cornea with regular curvature (refractive hyperopia), or decreased refractive index of aqueous humor (index hyperopia) [3].

At birth the human eye usually has a hyperopia of +2.25D that increases and peaks at about 8 years [3].

1.2.1.3 Astigmatism

Astigmatism is a condition in which the light rays, after refracting, do not converge to a single point. Due to variations in the curvatures of the cornea or the lens in different axes, instead of focusing the light from a point source to a single point, the image consists of two lines, separated from each other. It is necessary to correct astigmatic refractive errors only when patients experience symptoms such as decreased visual acuity or eye fatigue from constantly adjusting accommodation to optimize the seeing between the two focal lines [3].

1.2.2 Surgical management of refractive error

Surgery has a limited role in correcting refractive error in pediatric patients. Uncorrected high refractive errors have significant negative role on a child’s intellectual and social development. When conservative methods like glasses and contact lens fail, surgery has to be considered to prevent amblyopia and blindness in the child. The main indications for surgery in the children are anisometropic amblyopia and bilateral high errors. The goal of pediatric refractive surgery is different from those of adult refractive surgery. Full correction of a refractive error is not critical
here. Allowing for adequate visual development and preventing visual suppression of one or both eyes is the key.

Laser vision procedures for children include PRK (photorefractive keratectomy), LASEK (laser-assisted subepithelial keratectomy) and LASIK (laser in-situ keratomileusis). PRK and LASEK are preferred over LASIK to avoid the risk of flap complications like dislocation and striae, and also because of the difficulty of examining the LASIK flap after the procedure. Performing laser vision procedures in children requires extensive logistical planning. Most laser centres do not have the necessary arrangements to provide anesthesia to children. In most cases, the laser apparatus has to be taken to a surgical centre where general anesthesia can be performed, which is expensive and involves lots of labour. Main risk after surface ablation is the development of corneal haze and ectasia. Despite drawbacks in laser refractive procedures in children, surface ablation is a good option for correcting refractive error in this children.

1.2.2.1 Phakic IOL (intraocular lens) implantation

Iris-fixated and posterior chamber IOLs have been used in correcting refractive error, thereby improving binocular fusion and preventing amblyopia.

They can correct a wider range of refractive error as compared to laser surgery and it can be reversible. But they carry the risks of endothelial cell loss, IOL rotation, pigment dispersion, anterior subcapsular cataract formation and secondary glaucoma.

Pediatric refractive surgery is still a relatively less performed procedure to treat refractive error in children, due to less data on long term outcomes on efficacy and safety.

1.3 Pediatric glaucoma

It is one of the most challenging and sight threatening condition, for an ophthalmologist to treat.

It can be classified into:

a. Primary congenital glaucoma

b. Juvenile glaucoma

c. Secondary glaucoma: post cataract surgery, trauma, associated with conditions like sturge weber syndrome, aniridia and peter’s anomaly.

Raised intraocular pressure (IOP), increased axial length, corneal edema and haab’s striae are the characteristic features of pediatric glaucoma.

Management is by step by step approach, beginning with medications and finally ending up with the surgery.

Angle surgeries are the first choice in case of congenital glaucoma, progressive and refractory glaucoma.

The basic principle of the surgery here is to address the issue of deceased aqueous outflow due to trabecular dysgenesis. Angle surgery includes goniotomy and trabeculotomy. Goniotomy is an ab interno procedure, which tries to open up the blocked trabecular meshwork, while trabeculotomy is an ab externo procedure, where the angle structures are opened up through the Schlemm canal.

If the above procedures are not successful, then trabeculectomy or glaucoma drainage devices (GDD) can be used as a final approach.
Glaucoma surgeries can also lead to complications like, hypotony, choroidal detachment, retinal detachment, endophthalmitis, cataract, tube extrusion, corneal decompensation in cases of GDD.

1.4 Middle age and old age

1.4.1 Cataract

Cataract is clouding of normal clear lens. It is associated with the breakdown of the lens architecture or clumping of the highly concentrated soluble proteins of the lens or both [4, 5]. Cataracts usually progress slowly and are painless, so vision and lifestyle of person can be affected without them realizing it. Cataracts usually cause gradually progressive diminution of vision which usually do not show pinhole improvement. Common symptoms include reduction in visual acuity, glare, colored halos and occasionally monocular diplopia [6].

Worldwide, cataract is the number one cause of preventable blindness. The only definite treatment is cataract surgery, which includes removal of the cataractous lens and implantation of an intraocular lens.

Age related cataract is the most common type of cataract and occurs due to cumulative effect of various environmental factors like UV light, X-irradiation, toxins, metals, corticosteroids, drugs, and diseases including diabetes mellitus. Traumatic cataract may occur following blunt trauma leading to a cataract with characteristic flower shaped pattern, or penetrating trauma (accidental or surgical) leading to complete lens opacification [7]. It can also occur following electric shocks, chemical injuries and irradiation. Systemic disorders like diabetes mellitus, galactosemia, Fabry’s disease, Alport’s syndrome, myotonic dystrophy can cause metabolic cataracts.

1.4.1.1 Management of pediatric cataract

The management of cataracts in childhood is tedious and often difficult, requiring many visits over many years. Success requires a dedicated team effort that often involves parents, primary care pediatricians, surgeons, anaesthesiologists, technicians, orthoptists, low vision rehabilitation specialities, and community health workers. Pediatric cataract surgery should only be performed by ophthalmic surgeons who perform them on a weekly or biweekly basis so that they can perform them with a high level of competency [8]. Due to this reason, in many places only one surgeon performs these surgeries. Whenever possible, pediatric cataracts should be referred to higher centers where large number of pediatric surgeries are performed and there is availability of multispeciality team. After the postoperative period, these patients can be followed up with the regional doctors and maybe referred to higher center only when necessary. Ophthalmologists interested in performing pediatric cataract surgery should pursue fellowship training at a higher center, to attain specific skills to perform such surgeries. After completing such fellowship, these surgeons should also take instructional courses to learn new techniques as they arise.

1.4.1.2 Preoperative measurements

To get the best possible visual outcomes, determination of power of intraocular lens implant is necessary, which requires several preoperative measurements. A dilated
refraction has to be performed necessarily, especially if planning to operate only on one eye, to avoid anisometropia postoperatively, which can be detrimental to patients later on. Measurements of axial length of the eye, the corneal refractive power and curvature, and the anterior chamber depth are necessary for calculation intraocular lens power. Corneal topography, intraocular pressure measurement and endothelial cell count are certain additional tests which can be done in some special cases.

1.4.1.3 Nonsurgical management

As of now, there is no medical treatment that is effective in treatment or prevention of cataracts. Nutritional, pharmacological, and specific medical interventions like reducing UV-B exposure and smoking maybe helpful in preventing cataract, but the most important risk factor, aging, cannot be modified [7].

1.4.1.4 Surgical management

Cataract surgery is the most common surgery performed on an outpatient basis all around the world [9]. The most common type of cataract surgery performed worldwide is phacoemulsification, wherein the cataractous lens is fragmented into smaller particles using ultrasound energy and aspirated through a handpiece. Another method, not commonly used nowadays, is ECCE (Extracapsular Cataract Extraction) wherein the lens nucleus is delivered intact through a limbal incision of about 10 mm [10]. Another technique, more commonly used in developing countries, is small incision cataract surgery. Three important steps in this technique are a well-constructed scleral tunnel with a larger internal opening than the external scleral incision, a triangular capsulotomy technique, and lens-delivery technique relies on use of fluidics and eye positioning to irrigate the nucleus through our funnel-shaped wound and out of the eye [11].

The goal of the modern cataract surgery includes implantation of intraocular lens in addition to removal of the cataractous lens. The intraocular lens is usually placed inside the capsular bag, which is known as posterior chamber IOL (PCIOL), or in the sulcus as sulcus lens, or in the anterior chamber known as anterior chamber IOL (ACIOL). There are many types of IOLs used in cataract surgery like monofocal, multifocal, trifocal and toric IOLs. The main goal in using such IOLs is vision improvement and reducing spectacles and contact lens dependency.

Recently, a new technique called Femtosecond laser assisted cataract surgery (FLACS) is becoming popular. Here, the laser is used to perform certain steps of cataract surgery like clear corneal incisions, capsulorhexis, lens fragmentation, and if required making corneal arcuate incisions for astigmatism correction [12].

1.4.1.5 Single-piece intraocular lenses

IOLs are composed of two elements: an optic and haptics. The optic is the central area responsible for refraction, and the haptics are the appendages from the center optic that hold it in place [13]. Single-piece IOLs (also referred to as one-piece) are named as such due to both elements being composed of the same material (acrylic, silicone or PMMA) [14].

1.4.1.6 Premium IOLs

They have unique features in terms of material, design and refractive designs, as compared to monofocal IOLs [15]. These premium IOLs can correct presbyopia and
astigmatism, which the regular design IOLs cannot do. Centration is the key, to have accurate visual outcomes in cases of premium IOLs. The center of the undilated pupil is used as the axial center for IOLs [16].

Patients with multifocal IOLs can comfortably see both near and distance objects, as compared to monofocal IOLs which have single point of focus for one distance, as compared to multifocal IOLs, which have multiple focal points of distance and near vision [17]. They work on the principle of neuroadaptation and neural suppression. Multifocal IOLs are classified into Refractive, Diffractive and Hybrid IOLs [15, 18]. Refractive IOLs create multiple focal points with concentric zones of different dioptric power [18]. Diffractive IOLs have multiple diffractive zones on the posterior lens surface. Hybrid IOLs have the features of both refractive and diffractive IOLs. Multifocal IOLs can also be classified as bifocal or trifocal IOLs. Bifocal IOLs have both a near and far focus, while trifocal IOLs have far, intermediate and near focus [15]. Toric IOLs are used in patients with corneal astigmatism to give a sharp and clear vision, post cataract surgery. Calculation of preoperative astigmatism is of utmost importance prior to toric IOL implantation for accurate results [19]. In addition, proper centration and rotational orientation of toric IOL is very much necessary [16].

For people with inherent astigmatism, who want spectacle free option have Toric multifocal IOL as an excellent alternative [15]. Along with it, there are two more categories of premium IOLs, namely: Accommodative and extended depth of focus (EDF) IOLs. Accommodative IOLs provide a dynamic refractive power with contraction and relaxation of the ciliary muscles [15]. Accomodative IOLs are not the preferred choice nowadays, eventhough it is FDA approved [20]. EDF IOLs on the other hand, is based on the principle of extended focus, provides a fairly good distance, intermediate and near vision in patients [15].

1.4.1.7 Single-piece vs. three-piece IOLs

Three-piece IOLs are more versatile and they can be placed within the capsule or in the ciliary sulcus in the case of posterior capsule rupture or in case of weak zonules [13]. Single-piece IOLs are not designed to be placed in the ciliary sulcus, as it might lead to various complications like UGH (uveitis, glaucoma, hyphema) syndrome, due to movement of the lens over time [13, 15, 21]. The main advantage of single-piece IOLs is of softer, longer haptics, which unfolds smoothly and in a evenly distributed manner, causing relatively less stress on to the capsule and a more uniform contact holding it in place, which reduces capsular wrinkling [14]. So, single-piece IOLs are more widely used by the surgeons for patients with an intact lens capsule [13, 22].

1.5 Corneal dystrophies

Corneal dystrophy is a non-inflammatory, bilateral, symmetric, genetic condition which results in accumulation of abnormal material in the cornea, affecting its transparency. They can be asymptomatic in some individuals, while in others can affect the vision significantly, requiring corneal transplantation. Dystrophies begin early in life, are slowly progressive, increase with age, and may not become clinically apparent until years later. These deposits result from genetic mutations that lead to transcription of aberrant proteins. Many patients with corneal dystrophies associated with deposits present with symptoms of recurrent corneal erosion or blurred vision due to either irregular astigmatism or stromal opacification.
The International Committee for Classification of Corneal Dystrophies (IC3D) developed a “new classification system for corneal dystrophies” based upon the information on phenotype, pathology and genetics. There are numerous shortcomings in the traditional corneal dystrophy classification system, which was based upon the layer of involvement of the cornea. But the drawback with this classification is that, some of the dystrophies involve more than one layer of the cornea an not limited strictly to one layer. A category number from 1 to 4 is assigned depicting the level of evidence supporting the existence of the particular dystrophy [23].

Corneal transplantation is a surgical procedure where a damaged or diseased cornea is replaced by a donor corneal tissue. Corneal dystrophies such as Reis-Bückler, Salzmann’s nodular dystrophy and lattice, granular, or macular dystrophy can be treated with lamellar keratoplasty. Lamellar keratoplasty involves the removal and replacement of diseased or deformed anterior corneal tissue (epithelium, Bowman’s layer, and stroma) while maintaining the host’s Descemet’s layer and endothelium. Lamellar keratoplasty is an endothelium sparing procedure, which significantly decreases the chances of endothelial graft rejection [24]. Also, complications like endophthalmitis, expulsive hemorrhage, glaucoma, and cataract are significantly reduced.

Penetrating keratoplasty is usually performed for endothelial decompensation and corneal edema arising from endothelial dystrophies like Fuch’s endothelial dystrophy. Penetrating keratoplasty involves surgical removal of diseased or damaged cornea from the host and replacement with a full thickness donor cornea [25].

Endothelial keratoplasty is a relatively new field of corneal transplant surgery which involves the selective replacement of the recipient diseased endothelium, leaving the normal anterior surface of the cornea [26]. A modification of this procedure is DLEK (Deep Lamellar Endothelial Keratoplasty) where the incision size was reduced to 5 mm and the tissue folded in half for insertion. Another modification is DSEK (Descemet’s Stripping Endothelial Keratoplasty) wherein the Descemet’s membrane is stripped from the recipient and the donor tissue is placed directly on the posterior surface [27]. The visual recovery and acuity in endothelial keratoplasty is far better than in standard full thickness penetrating keratoplasty. The postoperative corneal is more regular after lamellar keratoplasty as compared to penetrating keratoplasty [28].

1.6 Glaucoma

Glaucoma is an optic nerve disease with a raised intraocular pressure (IOP), with loss of ganglion cells and visual field loss.

All the treatment modalities are directed towards lowering the IOP. Medical management included IOP lowering eyedrops and lasers. When these modalities fail to control the raising IOP, surgical options are considered.

The basic principles in the surgical management are:

1. Improve aqueous flow through the trabecular meshwork
2. Increase aqueous egress
3. Reduce aqueous production by the ciliary body.
2. Trabeculectomy

It is an external filtration surgery and is considered as the gold standard in glaucoma surgery.
A small opening in the sclera is made along with removal of a portion of the meshwork is done to increase the aqueous drainage under the conjunctiva. Intraoperative mitomycin-c may also be used to improve the success rate of the procedure.

3. Tube shunts

Is useful in cases of neovascular glaucoma, uveitic glaucoma, iridocorneal endothelial syndrome, fibrous ingrowth, epithelial downgrowth, history of previous vitreoretinal surgery or penetrating keratoplasty.
Few examples of tube shunts are:

a. Ahmed & Baerveldt devices

b. ExPress shunt

4. Microinvasive glaucoma surgery (MIGS)

Ideal candidates are: those with mild to moderate glaucoma, patients with poor control of IOP with topical medications and laser trabeculoplasty.
Unique features of MIGS are:

1. Lower incidences of post-operative complications

2. Ab interno approach

3. Rapid recovery in the post-operative period

5. Approaches

First approach, involves enhancing outflow across the trabecular meshwork and through Schlemm's canal. Juxtacanalicular trabecular meshwork is usually the site of maximum resistance. It can be overcome through bypassing or removing this tissue to lower IOP through increased outflow.
Bypass is achieved by placing a stent which allows aqueous to flow directly through it from the anterior chamber and into Schlemm's canal or procedures like goniotomy or trabeculotomy can be performed, where surgical incision and/or excision of trabecular meshwork is done, which improves aqueous outflow into Schlemm's canal. Alternatively, dilation of Schlemm's canal through cannulation and expansion with viscoelastic can be done to improve outflow through the normal physiologic aqueous outflow system.
Second MIGS approaches, increases the outflow via alternate pathways. The uveoscleral outflow pathway can be increased by accessing the suprachoroidal space with the placement of a microstent.
Third MIGS approach involves decreasing the aqueous production by ablation of the ciliary body, known as endocyclophotocoagulation. Here, an endoscopic laser probe is inserted through a clear corneal incision and under direct visualization ablates the ciliary body.

5.1 **Refractive eye procedures**

Patients who have refractive errors like, myopia, hyperopia & astigmatism, would need glasses for clear vision.

For people who wish to get rid of their glasses for their day to day activities would need either one of the below procedures:

1. LASIK (laser in situ keratomileusis)
2. PRK (photorefractive keratectomy)
3. SMILE (small incision lenticule extraction)
4. Phakic intraocular lens implantation

Ideal candidates would be:

- 19–50 year old
- Stable refraction
- No associated ocular morbidity

Exercise caution in patients who have thin corneas, corneal ectasia, borderline corneal topography and those with collagen vascular disorder.

LASIK: a thin corneal flap is created using, either microkeratome or femtosecond laser, then the excimer laser reshapes the underlying cornea stroma. Flap is then folded back.

PRK: rather than creating a flap, corneal epithelium is removed and then excimer laser is used to reshape the cornea. Bandage contact lens is placed for epithelium to grow back.

SMILE: femto second laser is used to create a refractive lenticule in the intrastromal pocket, which is then removed via a small incision in the cornea.

Advantages being:

- Early recover
- Better corneal biomechanical strength

5.1.1 **Phakic intraocular lens implantation**

If a patient is not eligible for laser refractive procedure, like in high refractive errors & thin corneas, phakic lens implantation is a good alternative.

These are usually made up of collamer, acrylic, silicone.

Preoperative evaluation of the biometry and lens sizing is very important to avoid any post-operative issues like secondary glaucoma and cataract.
After a clear corneal micro incision is made, the lens is injected and placed behind the iris and infront of the crystalline lens in the sulcus.

6. Conclusion

The advent of advanced technologies have revolutionized the eye care treatment. Refinement in the surgical techniques have decreased the duration of hospital stay, faster recovery and better post-operative vision quality.

Latest biometry devices have made intraocular lens power calculation more easy and predictable. Never intraocular lens also induce less aberrations, provide sharper vision and induce lesser posterior capsular opacification.

Laser refractive procedures are provide more accurate visual results and have greater safety profile.

Overall, surgeons have different technologies and machines to correct various vision related ocular conditions and patients now have the comfort to choose the best treatment for themselves.

Conflict of interest

None.

Author details

Hariprasad Vokuda*, Srinivasa, Roopashree Rao and Kinjal H. Porwal

1 ShreeHari Netralaya, Udupi, Karnataka, India

2 Minto Eye Hospital, Bangalore Medical College and Research Institute, Bangalore, Karnataka, India

3 Bangalore Medical College and Research Institute, Bangalore, Karnataka, India

*Address all correspondence to: hariprasad.vokuda@gmail.com
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