# Lens and Cataract

## Topics of Study

### I. Cataract

- Causes of Cataract
- Global / National distribution & population characteristics of Cataract
- Diagnosis of cataract. Distinction between immature, mature and hypermature.
- Appropriate referral of cataract patient
- Outline of surgical management
- Visual rehabilitation of Aphakia
- Outline of cataract management in young age

### II. Congenital Abnormalities of Lens

- Ectopia Lentis (Subluxation & Dislocation)
- Lenticonus

### Crystalline Lens

### Embryology

- Derived from surface Ectoderm overlying the optic vesicle.
- Ectoderm invaginates and break from surface as two layer structure
- Basement membrane of epithelium, which is now on the outer side, forms the lens capsule.
- Posterior epithelium cells expand to form the embryonic nucleus.
- Anterior epithelium continues to regenerate and develop lens fibers throughout life. These fibers continue to get deposited inwards making earliest fibers the deepest.

### Anatomy

- A globular structure lies behind the iris and in a concavity in the anterior face of vitreous called the Patellar Fossa.
- Suspended from the ciliary processes by Zonules
- In young patients (< 35 years) lens is adherent to vitreous by Ligament of Weigert.

**Layers** (from without inwards):

- Lens capsule (thinnest at posterior pole)
- Epithelium (missing from posterior surface)
- Cortex
- Epinuclear Cortex

**Nucleus** (from without inwards):

- Adult
- Adolescent
- Infantile
- Fetal (contains anterior & posterior Y-sutures)

Epithelium divides most actively in the periphery and differentiates in the lens fibers.

## Physiology

### Functions:

### Refraction of light (+18 D)

Accommodation: ability to increase refractive power in order to focus near objects.

- Metabolism is both aerobic and anaerobic.
- Cations and fluid move actively across anterior capsule but passively across posterior capsule (Pump-Leak Mechanism).
- Metabolic homeostasis is essential for maintenance of lens transparency.
- Glutathione, glutathione reductase and super-oxide dismutase are actively involved in preventing damage from free O2 radical injury.

### Optics

- + 18 Dioptre of refraction is contributed by the lens. And in accommodation this power increases.
- Typical structure of lens in the form of anterior cortex, nucleus and posterior cortex is optically important as each of these three portions act as a separate lens (lenticules) because the refractive index of nucleus is more than that of cortex. This results in an increase in the total power of the lens, decrease in optical aberration and greater effectiveness of the accommodation.
- Accommodation: Contraction of ciliary muscles results in laxity of zonules, which leads to increase convexity of lens due to its inherent elasticity.
- Iris not only controls the amount of light that enters the eye by varying the size of pupil (aperture) but also covers the periphery of the lens thereby cutting the optical (spherical) aberrations from it.

# Cataract

## Definition

Any opacity of the lens or loss of transparency of the lens that causes diminution or impairment of vision is called Cataract.
Although any lens opacity whether or not it leads to decrease in vision is technically cataract, yet an opacity in the periphery of the lens, which is stationary and not hampering vision should be diagnosed just Lens Opacity in order to avoid causing unnecessary anxiety to the patient.

## Classification

- Etiological
- Morphological
- Stage of Maturity

## Etiological Classification

1. Senile
2. Traumatic
   - Penetrating
   - Concussion (Rosette Cataract)
   - Infrared irradiation (Glass Blower's Cataract)
   - Electrocution
3. Metabolic
   - Diabetes (Snow Storm Cataract)
   - Hypoglycaemia
   - Galactosemia (Oil Drop Cataract)
   - Galactokinase Deficiency
   - Mannosidosis
   - Fabry's Disease
   - Lowe's Syndrome
   - Wilson's Disease (Sunflower Cataract)
   - Hypocalcaemia
4. Toxic
   - Corticosteroids
   - Chlorpromazine
   - Miotics
   - Busulphan
   - Gold
   - Amiodarone
5. Complicated
   - Anterior Uveitis
   - Hereditary Retinal & Vitreoretinal Disorders
   - High Myopia
   - Glaucomflecken
   - Intraocular Neoplasia

6. Maternal Infections
   - Rubella
   - Toxoplasmosis
   - Cytomegalovirus
7. Maternal Drug Ingestion
   - Thalidomide
   - Corticosteroid
8. Presenile Cataract
   - Myotonic Dystrophy
   - Atopic Dermatitis (Syndermatotic Cataract)
   - GPUT & GK Enzyme Deficiencies
9. Syndromes with Cataract
   - Down's Syndrome
   - Werner's Syndrome
   - Rothmund's Syndrome
   - Lowe's Syndrome
10. Hereditary
11. Secondary Cataract

## **After-Cataract** (after the cataract surgery)
### Morphological Classification

1. Capsular
   - Congenital (Anterior Polar & Posterior Polar)
   - Acquired
2. Subcapsular
   - Posterior Subcapsular (Cupuliform)
   - Anterior Subcapsular
3. Nuclear
   - Congenital (Discoid, etc.)
   - Senile
4. Cortical
   - Congenital (Coronary, Coralliform, etc)
   - Senile (Cuneiform)
5. Lamellar or Zonular
6. Sutural
7. Others
   - Blue-Dot (Cataracta caerulea)
   - Membranous
   - Cataracta Pulveranta Centralis
   - Reduplicated Cataract

### Stage of Maturity

Immature
Mature
Intumescent
Hypermature
Morgagnian

### Chronological

Congenital (since birth)
Infantile (first year of life)
Juvenile (1 to 13 years of life)
Presenile (13 to 35 years of life)
Senile

## Pathogenesis

Two main pathogenetic processes are involved in most (especially senile) cataract:

- Hydration
- Sclerosis

Hydration

- Increased hydration leads to lamellar separation and collection of protein-deficient fluid between lens fibers.
- Leads to increased scattering of light and loss of transparency.
- Hydration also leads to denaturation of lens proteins and results in irreversible opacification.
- Mechanisms of increased hydration are:

Failure of active pump mechanism
Increased leakage across posterior or anterior capsule
Increased Osmotic pressure

Sclerosis

- This process is seen mostly in senile cataract and involves predominantly the nucleus.
- Increased compaction of lens proteins and fibers due to inter-lamellar binding of proteins by sulfide bonds.
- Resultant aggregates of very high molecular weight proteins lead to increased scattering of light and loss of transparency.
- It is part of normal aging phenomenon.

Senile Cataract

## Epidemiology

Global

- 38 million people are blind
- 41 % because of cataract

National

- 71 % of blindness in Nepal is because of cataract
- About 72 % of blindness in India is caused by Cataract

## Progression

I. Stage of Lamellar Separation
- Hydration leads to separation of cortex from nucleus
- Appreciated on slit lamp biomicroscopy

II. Stage of Incipient Cataract
- Early opacities appear
- Vision unaffected but other symptoms e.g., glare, appear.

III. Immature Cataract

Opacification leading to diminution of vision.

Two morphological forms are seen:

1. Cuneiform Cataract: Wedge shaped opacities appear in the peripheral cortex and progress towards the nucleus. Vision is worse in low ambient illumination when the pupil is dilated.
2. Cupuliform Cataract: A disc or saucer shaped area of the cortex beneath the posterior capsule undergo opacification. The opacity being central, the vision is worst in bright ambient illumination when the pupil is constricted.
   - Lens appears grayish white in color.
   - Iris shadow can be seen on the opacity with oblique illumination.

IV. Intumescent Cataract
- Sometime during the course maturation the lens imbibes lot of fluid and becomes swollen.
- Anterior chamber becomes shallow.
- Angle of anterior chamber may close resulting in glaucoma (Phacomorphic Glaucoma).

V. Mature Cataract
- Entire cortex becomes opaque.
- Vision reduced to just perception of light
- Iris shadow is not seen
- Lens appears pearly white.

VI. Hypermature Cataract
This may take any of two forms:

1. Liquefactive or Morgagnian Type: The cortex undergoes auto-lytic liquefaction and turns uniformly milky white. The nucleus loses support and settles to the bottom.
2. Sclerotic Cataract: The fluid from the cortex gets absorbed and the lens becomes shrunken. There may be deposition of calcific material on the lens capsule. Anterior chamber deepens and iris becomes tremulous (Iridodonesis). The zonules become weak increasing the risk of subluxation / dislocation of lens.

- Liquefied cortex may leak out of the lens resulting in either uveitis or glaucoma (Phacolytic Glaucoma).
- Very rarely the entire cortex and nucleus can get completely liquefied and absorbed leaving behind clear anterior and posterior capsules (Pseudo-aphakia). Vision improves to about finger counting at 1 meter.

## Nuclear Cataract

Goes through stage of immaturity and maturity but never becomes intumescent or hypermature.
Urochrome or melanin pigment deposition may take place giving nucleus a typical color:

- Yellow
- Black (Cataracta nigra)
- Brown (Cataracta brunescnence)
- Red (Cataracta rubra)

In early stages there is shift of refraction towards myopia. This improves the near vision of the patient. Consequently the patient who so far required thick near glasses for reading, can read small print easily without them (phenomenon of Second Sight).

## Clinical Presentation

### Symptoms

Glare: When patient looks at a point source of bright light the diffusion of white and colored light around it drastically reduces vision. Night driving becomes especially troublesome. Posterior subcapsular cataract (cupuliform) notably causes disabling glare.

Image Blur: Opacification of lens leads to diminution of vision which is characteristically painless and progressive (& does not improve with pin-hole). From a normal of 6/6 the vision continues to deteriorate as the cataract progresses, but as long as the cataract is immature patient will at least be able to count fingers. When cataract matures the vision is reduced to barely perception of light. In hypermature, rarely, the vision may improve a little if the cortex gets absorbed (but not better that finger counting at 1 meter).
In early stages, however, the near vision may sometimes improve (the phenomenon of Second Sight).

Diurnal Variation of Vision: In central (cupuliform) cataract the vision is worse in bright light of the noon (day-blindness or hemerelopia) but improves as the sun sets. Whereas in peripheral cortical cataract (cuneiform) the reverse is true i.e. vision is better in bright light than dim light.

Distortion: Cataract may make straight edges appear wavy or curved (Metamorphopsia).
Colored Halos: Ring of colors of rainbow may be seen around point source of bright light. Since colored halos are important symptom of glaucoma therefore, they have to be differentiated. This can be done easily by Fincham's Test in which a vertical slit in a black disc (Staenopic Slit) is passed across patient's eye while he gazes at a point source of bright light. Colored halos caused by cataract (lenticular) seem to break into a moving fan but not that caused by glaucoma (corneal) which only become slightly dim. Moreover, the VIBGYOR of the rainbow is within outwards in lenticular halos and without inwards in corneal halos.

Diplopia / Polyopia: Multiple images of one object may form on the retina due to irregular refraction from the cataractous lens giving rise to Monocular Diplopia or Polyopia. This can be differentiated from binocular diplopia by cover-test and pin-hole test. Binocular diplopia disappears on covering any of the eye. Monocular diplopia does not disappear if the other eye is covered, however, it disappears if a pin-hole is placed in front of this eye.
Altered Color Perception: The yellowing of lens nucleus is steadily progressive leading to change in color saturation of the image seen. The artists with cataract may render their paintings browner or yellower than real.

Black Spots: Patient may complaint of seeing black spots fixed in his field of vision. This is unlike black spots seen in vitreo-retinal disorders, which seem to move around as floaters (muscae volitantes).

Behavioral Changes: Seen especially in children with cataract, who can not verbalize their complaints. Stumbling over objects, poor performance in school, loss of interest in surroundings, etc. can be some of the changes that may draw parents attention towards child's visual handicap.

## Signs

Visual Acuity: Vision is diminished proportionate to the degree of cataract (immature from 6/9 to finger counting close to face; mature perception of light or hand movements). However, vision recorded in dimly lit room may not sometimes give true estimate of the patient's disability especially in small central opacities.

Leukocoria: "White pupil", infact the pupil appears grayish white in immature, pearly white in mature and milky white in hypermature stages of cataract.

Anterior Chamber: Depth of anterior chamber is normal except in intumescent cataract where it is shallow, and hypermature shrunken cataract where it is deep. It may contain cells and flare in case if lens induced uveitis.

Cornea & Conjunctiva: These are usually normal. Cornea may become hazy due to edema if the IOP is increased by lens induced glaucoma. Conjunctiva may be congested in lens induced glaucoma or uveitis, or if there is associated infection.

Iris Shadow: In immature cataract a crescentic shadow of the iris is seen in the pupil on oblique illumination. In mature cataract iris shadow is not visible as the opacity extends right to the anterior capsule.

Distant Direct Ophthalmoscopy (DDO): Viewing the dilated pupil using an ophthalmoscope from a distance of 25 cm reveals the cataract as black patches against the background of red glow from the fundus. This is very helpful in differentiating early immature cataract from nuclear sclerosis. Although the lens appears grayish white in both these conditions but on DDO cataract shows up as black patches but clear red glow is seen in nuclear sclerosis. Also, in mature cataract no red glow is seen as the lens becomes completely opaque.
Fundus: In early stages of cataract the retina may be seen by ophthalmoscopy and appear normal. It may appear deep red in color in nuclear cataract. In advanced cataract the retina cannot be seen.
Intraocular Pressure: IOP is normal in cataract unless lens induced glaucoma (phacolytic or phacomorphic) develops. It may be low in lens induced uveitis.

Purkinje-Sanson Images: All optical interfaces (junction of media to different refractive index) of the eye not only refract the light but also reflect it forming images (Catoptric) which the observer can see. Purkinje (pronounced as pur kine') described 4 such images (or reflections) arising from anterior and posterior surfaces (1 & 2) of cornea, and from anterior and posterior surfaces of the lens (3 & 4). To this Sanson added 2 more images arising from anterior and posterior surfaces of the nucleus (5 & 6). So using a point source of bright illumination and with subject's pupil dilated one can observe 6 reflected (catoptric) Purkinje-Sanson images from the eye.
In immature cataract the 4th image arising from the posterior surface of lens disappears and in mature cataract 4th, 5th and 6th images disappear.

Other Signs: Signs of aging may be observed along with cataract and are just co-incidental e.g., arcus senilis, skin laxity (dermatochalasis), senile entropion or ectropion, senile ptosis, age related macular degeneration (ARMD), grayish white granular material on lens surface or iris in pseudoexfoliation, scrolls of split layers of anterior capsule (exfoliation), tremulous lens (Phacodonesis) if the zonules are very lax or broken, dry eye syndrome, etc.

### Differentiating Various Stages of Cataract

| Features | Immature | Mature | Hypermature |
|---|---|---|---|
| Vision | 6/9 - FC | HM - PL | HM – FC |
| Anterior Chamber | Normal (shallow in intumescent) | Normal (shallow in intumescent) | Normal to deep |
| Color of Lens | Grayish white | Pearly white | Milky white (with brown crescent of nucleus) or chalky white |
| Iris shadow | Seen | Not seen | Not seen |
| Distant Direct Ophthalmoscopy | Black patches against red glow | No red glow seen | No red glow seen |
| Purkinje-Sanson Images | 4th image not seen | 4, 5 & 6th images not seen | 4, 5 & 6th images not seen |

## Complications of Cataract

I. Lens Induced Glaucoma

Cataract in give rise to secondary glaucoma in any of 3 ways:

- Phacomorphic Glaucoma: Lens may swell up by absorbing fluid resulting in shallow anterior chamber. The angle may close blocking the trabecular meshwork and IOP rises. A type of secondary angle closure glaucoma.
- Phacolytic Glaucoma: In hypermature stage the lens proteins leak out into the anterior chamber and are engulfed by macrophages. These swollen macrophages clog the trabecular meshwork leading to increase in IOP. A type of secondary open angle glaucoma.
- Phacotopic Glaucoma: Hypermature lens may dislocate and can give rise to increase in IOP by physically blocking the pupil or angle, or displacing the vitreous which causes the block.

II. Lens Induced Uveitis

Lens proteins are sequestered antigens i.e. not exposed to the body's immune mechanisms during development. When these leak into theanterior chamber they are treated as foreign, inciting immune reaction. This results in anterior uveitis (inflammation involving iris and ciliary body). This is characterized by ciliary congestion and cells and flare in the aqueous.

III. Subluxation or Dislocation of Lens

In stage of hypermaturity the zonules of the lens may weaken and break. This leads to subluxation of the lens (when at least some zonules are still intact and a part of the lens still lies in the patellar fossa) or dislocation (when all zonules have broken and no part of the lens lies in the patellar fosssa.

## Investigation

It involves further evaluation of the eye and general condition of the patient with regards to the feasibility and prognosis of surgical management of cataract.
Pupillary Reflexes: Special emphasis is placed on examining the pupillary signs as they may reveal presence of any visual pathway (afferent) or 3rd nerve (efferent) disorder. This may affect the final visual outcome e.g., afferent pupillary defect caused by optic atrophy may prognosticate poor visual result. Special care should be taken to look for presence of Marcus-Gunn Pupil in which although both direct and consensual reflexes are present in both the eyes and pupils appear to be normal, yet on doing swinging flash light test (i.e. rapidly shifting light from one eye to the other and back) one pupil seems to dilate in response to light whereas the other constricts. This denotes presence of a relative afferent pupillary defect (RAPD) in the eye whose pupil seems to dilate. Note that the defect is partial and unequal in the two eyes.
Intraocular Pressure: Presence of lens induced glaucoma or co-existent primary glaucoma should always be looked for because increased IOP seriously affect the course and result of surgery. The IOP has to be well under control before the surgery for cataract is under-taken because not only high pressure increases the risk of intra-operative complications (viz. Vitreous loss, expulsive hemorrhage, etc.) but also there is a high risk of loosing vision (or visual field) postoperatively as the IOP tends to rise to high level about 2 hours after cataract operation even in an otherwise normal eye.

Fundus Examination: Detailed retina examination to rule out any pathology in the posterior segment (behind the lens) which may compromise visual outcome.

Lacrimal Syringing: It is important to rule out any block or focus of infection in the lacrimal drainage system by doing syringing. Focus of infection around the eye or even elsewhere in the body (e.g. teeth, chest, urinary tract, etc.) increase the risk of postoperative intraocular infection or Endophthalmitis which can be devastating for vision.

Blood Pressure: Hypertension not only leads to development of hypertensive retinopathy but also increases the chances of expulsive hemorrhage during surgery. In expulsive hemorrhage choroidal blood vessels rupture leading to bleeding between choroid and scleral, which pushes the choroid inwards and, if severe, expelling the contents of the globe.
Hypertension must be well under control in the peri-operative period and the use of phenylepherine or adrenalin should be avoided. Anti-hypertensives must be added to the preoperative medication.

Blood Sugar: Diabetes must be ruled out, and if present must be controlled before surgery. Diabetes can adversely affect any part of the eye especially the retina (diabetic retinopathy), wound healing is impaired and the risk of infection is extremely high. Blood sugar should be carefully monitored and kept in strict control in the peri-operative period.
On the day of operation, however, the anti-diabetics (hypoglycemics) are omitted to avoid the chance of severe hypoglycemia, and are resumed from the first postoperative day.

General Investigation: General body check-up and some investigations like hemoglobin, blood sugar, urine examination, ECG and X-ray Chest (where required) should be done to rule out any significant systemic disorder. If any disease is detected patient should be referred to concerned specialist for appropriate treatment.

Macular Function Tests: These are done to preoperatively assess the postoperative visual outcome (potential vision) based on which a prognosis is given to the patient.

These tests are:

**With clear media**

- Visual Acuity: as tested by Snellen's charts, if disproportionately less than what can be explained by the degree of cataract points to possibility of macular dysfunction.
- Color Vision: Color appreciation and discrimination is best at macula because of aggregation of cones. It can be deranged in any macular pathology.
- Photostress Test: Visual acuity of patient is determined and then his macula is dazzled by bright light of a 3.5 Volt Ophthalmoscope. Then the time it takes for his visual acuity to return to initial level is noted.
- Normal is 52 seconds but if it takes longer macular function is abnormal.
- Haidinger Brushes: Using an instrument called Synoptophore a rotating beam of plane polarized blue light is shown to the patient. An image of rotating blue brushes is seen if the macula is healthy because of typical radial distribution of nerve fibers at the macula.
- Potential Acuity Meter (PAM) or Visometer: Using this device reduced Snellen's Chart is projected onto patient's macula through the clear area in his lens. The smallest line that patient reads gives patient's potential vision. This test correlates the best with final postoperative visual acuity of the patient.

**With opaque media**

- Two Point Discrimination Test: A cardboard with 2 pinholes 2 mm apart is placed 2 cm from patient's eye and a light is shone 2 feet behind it. If patient reports seeing two lights then his macula is probably normal.
- Maddox Rod Test: Maddox Rod is a set of small high power red cylindrical lenses placed close to each other (or grooves cut in a red glass). A point source of white light seen through it appears as a red line. If macula is deranged the line would appear distorted, irregular, broken or would just not be seen.
- Entoptic View: Rubbing a lighted bare bulb of a torch pressed over closed eyelids makes individual's own retinal (macular) blood vessels visible as dark red branches of a tree against an orange background. In macular pathology the vessels are either not seen or black patches are seen scattered with the vessels. This test should first be done on the normal eye to demonstrate to patient what he is expected to observe.
- Laser Interferometry: Two beams of plane polarized light are projected on to patient's pupil. These beams undergo interference and form interference fringes of light and dark bands behind

patient's lens. Then the width of these fringes is reduced and the narrowest fringes seen by the patient are indicative of his visual potential.

- Visually Evoked Response (VER): Stimulation of retina by light pattern leads to suppression of alpha-wave of the EEG recorded from the occipital cortex. The smallest pattern stimulus which generates this response denotes the potential vision of the patient. Other electrophysiological tests can also be used to assess the function of the macula especially Electroretinogram (ERG) with focal foveal stimulation.

9. Ultrasonography (USG B-Scan): If the cataract is advanced then the retina cannot be visualized by ophthalmoscopy, therefore, ultrasound (B-scan) is used to detect any structural abnormalities.

10. Intraocular Lens Power Calculation: The power of the intraocular lens to be implanted has to be calculated for each individual.

Three parameters are required as follows:

- Keratometry (K): gives the refractive power of the cornea (in diopters), using an instrument called Keratometer.
- Biometry or Axial Length of Globe (L): The distance (in mm) from the apex of cornea to the posterior pole of the eye is measured by a special ultrasound the A-Scan Biometer.
- A Constant (A): It is supplied by the IOL manufacturer and it's value depend on the design of the lens and it's intended location in the eye (anterior or posterior chambers).

These values are put in a formula (SRK Formula) to get the power of the lens to be implanted:

IOL Power = A – 2.5L – 0.9 K

This would make the patient emmetropic. However, in some cases it is desirable to deliberatively induce a preplanned refractive error postoperatively e.g. when the other eye has a high refractive error then the planned refractive error in eye to be operated should be within + 2.5 dioptre of the other eye, in order to avoid anisometropia (unequal refrctive error) and aniseikonia (unequal image size).

## Indications for Cataract Surgery

Classified in 3 groups:

### I. Optical indications

Whenever the vision of the patient is diminished to an extent that it interferes with his normal daily life, the cataract can be operated. There is no sharp cut-off level of visual acuity below which cataract should be operated rather the decision about timing of surgery is subjective to the patient's own visual requirement. A word of caution here is that in mild diminution of vision e.g. 6/12, patient should be informed about the disadvantage of loss of accommodation that results from cataract surgery, which may offset the advantage of gain of 2-3 lines in visual acuity. Glare is another optical indication especially in individuals involved in night driving.

### II. Medical Indications

In following conditions cataract needs to be removed urgently even if patient is not interested in visual gain or the visual prognosis is not favorable:

- Hypermature cataract
- Lens induced glaucoma
- Lens induced uveitis
- Dislocated / subluxated lens
- Intra-lenticular foreign body
- Diabetic Retinopathy to give Laser photocoagulation
- Retinal Detachment or any other posterior segment pathology, the dignosis or treatment of which is being hindered by opacity of the lens.

### III. Cosmetic Indication

If the vision is permanently lost because of some retinal or optic nerve pathology e.g. optic atrophy, but the white pupil caused by cataract is cosmetically unacceptable to a young patient, cataract surgery is indicated just make the pupil appear black even though is known that the vision will not recover.

## Surgery for Cataract

### Choice of Operation

The operation of choice for cataract is:

Extra-Capsular Cataract Extraction with Posterior Chamber Lens Implantation
Or simply
ECCE with PCL
Unless contraindicated or better technique (Phacoemulsification & Foldable IOL) is available.

### Operative techniques available:

Extra-capsular cataract extraction (ECCE)
Intra-capsular cataract extraction (ICCE)
Pars plana lensectomy
Phacoemulsifiation

### Intra-ocular lens (IOL) types:

Posterior chamber lens (PCL)
Anterior chamber lens (ACL)
NB: The best position for implantation of IOL is within the capsular bag in the posterior chamber. The IOLs are made of PMMA (Polymethyl Methacrylate), Silicone or Acrylic (foldable).

### Principles of Various Techniques

### Extra-capsular Cataract Extraction (ECCE)

The nucleus and the cortex is removed out of the capsule leaving behind

intact posterior capsule, peripheral part of the anterior capsule and the zonules. This not only provides support of placement of IOL but also prevents vitreous from bulging forwards and acts as a barrier between anterior and posterior segment. All this results in decreasing the incidence of complications viz. Vitreous loss, corneal edema, endophthalmitis, cystoid macular edema, aphakic glaucoma, etc. However, capsular remnants are prone to develop after-cataract.

### Intra-capsular Cataract Extraction

The lens is removed in toto as one single piece i.e., the nucleus and the cortex are removed within the capsule of the lens after breaking the zonules. There is no support left for posterior chamber IOL, therefore, only anterior chamber IOL (ACL) can be implanted which has risk of adverse corneal complications. Also, there is no barrier left between anterior and posterior segment, which increases the incidence of other complications e.g., vitreous loss, aphakic glaucoma, cystoid macular edema, endophthalmitis, etc. However, the only advantage is that after-cataract does not develop as the entire capsule is removed.

### Pars Plana Lensectomy

A special technique used in very young children. The lens and anterior part of vitreous is nibbled out using an instrument called Vitrectomy Probe or VISC (Vitreous Irrigation Suction Cutting) probe which is introduced through the pars plana region of the ciliary body about 3.5 mm behind the limbus. The advantage being that the body's active immune mechanism is not exposed to the sequestered lens protein antigens thereby preventing inflammatory response, and removal of anterior vitreous removes scaffold for deposition of fibrous tissue deposition. Inflammatory response to lens protein and extensive fibrosis are troublesome consequences of cataract surgery in very young children.

### Phacoemulsification

It is essentially an advancement in the method of doing ECCE. Here the nucleus is converted into pulp or emulsified using high frequency (40,000 MHz) sound waves, and then is sucked out of the eye through a small (3.2 mm) incision. A special foldable IOL is then inserted into the posterior chamber through the same incision. The advantages being no or negligible surgically induced astigmatism and rapid recovery of the patient.

In contrast to this, in conventional ECCE the incision is large (about 8 mm), therefore, surgical astigmatism poses problems postoperatively and the wound healing being slow, the visual rehabilitation of the patient is delayed to about 6-8 weeks.

So, if facilities are available, phacoemulsification is the choice of operation for cataract.

## ECCE vs. ICCE

| | ECCE | ICCE |
|---|---|---|
| Lens removal | Nucleus removed out of the capsule and cortex sucked out | Lens removed as single piece within its capsule |
| Posterior capsule & zonules | Intact | Removed |
| Incision | Smaller (8 mm) | Larger (10 mm) |
| Peripheral iridectomy | Not performed | Required to avoid pupillary block glaucoma |
| Sophisticated equipment | Required | Not required |
| Time taken | More | Less |
| IOL Implantation | Posterior chamber | Anterior chamber (with its associated risk of damage to corneal endothelium leading to Pseudo-phakic Bullous Keratopathy) |
| Expertise required | Difficult technique | Easier to learn |
| Cost | More | Less |
| Complications which are increased | After-Cataract | Vitreous prolapse & loss Cystoid Macular Edema Endophthalmitis Aphakic Glaucoma Fibrous & Endothelial ingrowth Neovascular Glaucoma in Proliferative Diabetic Retinopathy After-Cataract |
| Compications which are decreased | All the complications mentioned for ICCE | Dislocated Lens Subluxated Lens (>1/3rd zonules broken) Chronic Lens Induced Uveitis Hypermature Shrunken Cataract with thick anterior capsule Intra-lenticular Foreign Body when integrity of posterior capsule is compromised. |
| Indications | A routine procedure for all forms of cataract (except where contra-indicated) | Young Patients (<35 years) who have strong attachment between lens and vitreous (Ligament of Weigert) |
| Contraindications | Dislocated lens Subluxated lens (>1/3rd zonules broken) | |

## Preoperative Preparation

Patient preferably admitted to the hospital on previous evening (however, surgery can also be done on OPD basis).
Informed consent is taken.
The eye-lashes of the eye to be operated are trimmed carefully and the eye is cleaned with Povidone-Iodine 5 % solution, and marked.
Antibiotic drops are instilled every 6 hourly
A mild sedative (Diazepam 5 mg) may be given on the night before if the patient is anxious.
On the day of surgery patient is kept fasting (NPO or nil per orally) since morning.
Pupils are dilated by instillation of following eye-drops starting about 2 hours before operation:
Tropicamide 1% or Homatropine 2% being parasympatholytic relax the sphincter pupillae.
Phenylepherine 5-10% (avoided in hypertensive patient) being sympathomimetic contract the dilator pupillae.
Flurbiprofen 0.3% a non-steroidal anti-inflammatory drug prevent release of prostaglandins during surgery thereby preventing intraoperative constriction of pupil that may be caused by surgical trauma.
These drops are instilled every 15 minutes.
Other medications may be given as required e.g., antiglaucoma drugs, antihypertensives, anti-asthamatics, etc. But anti-diabetic drugs are omitted on the day of surgery to prevent hypoglycaemia, and are resumed from the first postoperative day.

## Anesthesia

Most cases of cataract are operated under local anesthesia except in young children. The techniques used are:

Retrobulbar anesthesia.*
Peribulbar anesthesia
Facial nerve block*
* These two are given in combination.

The anesthetic agent used is a solution of following;

- Lignocaine or Xylocaine 2 % which the main anesthetic agent
  Bupivacaine 0.75 % which has a prolonged duration of action and analgesia. It is used primarily for increasing duration of action and for postoperative analgesia.
- Adrenalin 1 in 200,000 leads to constriction of blood vessels thereby decreasing absorption of anesthetics and thus prolonging duration of action and decreasing side effects. It should be avoided in hypertensive patients.
- Hyaluronidase 7-15 IU per mL is used to promote diffusion of the anesthetic into the orbital tissues.
- Retrobulbar Anesthesia
  Patient is asked to look straight up. A point is chosen 2 mm above the junction of medial 2/3rd and lateral 1/3rd of the inferior orbital margin. A 2.5 inch 20 G needle with rounded tip is introduced vertically at this point for 2 cm. Then the direction of the needle is turned towards the apex of the orbit i.e., posterior, superior and medially, and needle is advanced fully into the muscle cone. About 2-4 mL of above solution is injected and the needle is withdrawn. Pressure is applied intermittently over a cotton pad placed on the eye, to diffuse the anesthetic agent and to bring down the intra-ocular pressure.

## Effects:

Analgesia
Akinesia
Mydriasis
Decrease in IOP
Loss of Oculo-cardiac reflex (reflex stimulation of vagus caused by painful stimulus of the globe or pulling of muscle, which leads to bradycardia and can even cause cardiac arrest).

## Complications:

Retrobulbar hemorrhage (operation has to be postponed for 2 weeks and hyperosmotic agents given to decrease IOP).
Damage to the optic nerve
Perforation of globe
Accidental injection into the optic nerve sheath from where it tracks to the brain

## Infection

- Peribulbar Anesthesia
  This technique virtually eliminates the risk of above complications. With patient looking straight ahead, a point is chosen 2 mm the junction of medial 2/3rd and lateral 1/3rd of the inferior orbital margin. A 26 G 1 inch needle is introduced vertically in completely and 5 mL of the above anesthetic solution is injected. Then another point is chosen diagonally opposite to it i.e., 2 mm below the junction of medial 1/3rd and lateral 2/3rd of the superior orbital margin and 3 mL of the solution is injected. Intermittent pressure is applied as described above.
- Facial Nerve Block
  The technique commonly used is called O'Briens Technique. The condylar process of the mandible is palpated anterior to the tragus by asking the patient to open and close his mouth. A point is chosen 1 cm below this marking the position of neck of the mandible. A 23 G needle is introduced at this point till it strikes the bone (neck of mandible) and then withdrawn a little. 5 mL of the above anesthetic solution is injected at this point and the needle withdrawn. The effect of the block is observed by asking to forcibly close his eyes or to show his teeth, an inability to close the eye or angulation of mouth to the other side indicated blockage of facial nerve. This prevents squeezing of the eyes by the patient. However, with peribulbar anesthesia facial block is not required because some anesthetic solution diffuses directly into the orbicularis oculi muscle and cause its anesthesia.
- Extra-Capsular Cataract Extraction
  After anesthesia the eye is cleaned with Povidone-Iodine solution 5% and a sterile drape is put to isolate the surgical field. Povidone-Iodine 2% is irrigated in the conjunctival sac and washed with Normal Saline.
- Eye-lids are retracted using a wire speculum.
  Superior rectus bridle suture is passed to turn the superior limbus down and stabilize the globe. Superior rectus forceps are used to hold the insertion of superior rectus and a 4.0 Silk suture is passed under it.
- Fornix based conjunctival flap is raised by cutting the conjunctiva where it is attached to the limbus from 10 O'clock to 2 O'clock meridian. Bleeding points and large vessels are coagulated using a bipolar electro-cautery.
- A groove or partial thickness incision is made at the limbus (mid or blue limbus) using a piece of razor mounted on blade breaker-holder. This groove extends from 10 O'clock to 2 O'clock meridian and is perpendicular to the limbal surface.
- Anterior chamber is entered by stabbing within this groove at the 11 O'clock meridian keeping the blade obliquely (parallel to iris plane). Thus the incision gets a two plane or bi-planar configuration.
- A visco-elastic fluid (Poly-propyl hydroxy methyl cellulose or sodium hyaluronate) is injected into the anterior chamber. This fluid coats the corneal endothelium preventing any damage to it, and deepens the anterior chamber giving more working space.
- An opening is made in the anterior capsule of the lens called the anterior capsulotomy, using a bent hypodermic 26 or 30 G needle. There are various techniques of performing anterior capsulotomy e.g., bear-can opener, Christmas tree, envelope, capsulorrhexis, etc.
- The limbal incision or section is enlarged by cutting in the groove to its entire extent, using a corneal scissors keeping its blades parallel to the iris plane. So a bi-planar incision is made extending from 10 O'clock to 2 O'clock meridian.
- The nucleus is expressed by applying alternating pressure at 12 O'clock and 6 O'clock meridian.
- The cortex which remains is removed by suction. This is performed by a special cannula called the IA Cannula (Irrigation-Aspiration) which has two channels in it; one for the fluid to go in (irrigation) and second for the fluid and cortex to be

sucked out (aspiration). A balanced salt solution (BSS) or Ringer's Lactate solution is constantly irrigated into the eye while the cortex is sucked out.

- If IOL implantation is planned, visco-elastic substance is injected again into the anterior chamber.
- IOL is inserted into the capsular bag and then rotated into proper position.
- Visco-elastic substance is aspirated out using IA cannula.
- The limbal incision is sutured using 10.0 Prolene or Nylon sutures passed to about 3/4th the depth of cornea and sclera (& not full thickness) in a interrupted or continuos fashion. If the knots are properly buried under the surface, these sutures are not required to be removed. If the knots are not buried or thicker suture is used (9.0, 8.0, etc.) they are removed after about 6-8 weeks. Corneal wounds take about 6-8 weeks for an acceptable level of healing and about 1-3 years for complete healing.
- The conjunctiva is repositioned back to cover the limbal wound. A combination of an antibiotic and a steroid is injected sub-conjunctivally, and the eye is patched for 24 hours.
- Intra-Capsular Cataract Extraction
  The steps of entering into the eye and the closure of the limbal wound are the same as described above for ECCE. However, the method of removal of lens is different and also the fact that the incision is a little larger (9:30 O'clock to 2:30 O'clock or more) and a peripheral iridectomy is performed before removing the lens. The techniques used for removal of lens are:
- Cryo-extraction: by applying a cryoprobe through which N--2O is passed leading to lowering of the temperature at the tip to about – 40 C. This causes adherence of the lens to the probe. Then the lens is delivered out of the eye by gentle side and up-wards motion. This is the most commonly used technique.
- Erysiphake
- Sliding Technique
- Tumbling technique
- Lens Forceps technique
- Wire-vectis technique

## Postoperative Care

24 hours after the operation the bandage is removed and the eye is cleaned. The eye is examined thoroughly with special emphasis on the visual acuity, discharge in conjunctival sac, apposition of the wound, corneal clarity, anterior chamber for depth and hyphaema, etc., pupil, IOL, posterior capsule, retina and intra-ocular pressure. If any problem is encountered, it has to be dealt with appropriately.

Topical antibiotic-steroid eye drops are advised to be instilled every 4-6 hourly and ointment to be instilled at bed time. These drugs are used to control postoperative inflammation and infection, and are gradually tapered over next 4-6 weeks.

Patient is instructed to avoid head-bath for 1 week, lifting heavy weights for about 3 months and abstain from contact-sports for about 1 year.

Complications of Cataract Surgery

These can be grouped as:

Intra-operative

Post-operative

- Early
- Late

## Intra-operative Complications

The most important are:
- Damage to corneal endothelium.
- Rupture of posterior capsule.
- Vitreous prolapse and loss.
- Hyphaema
- Expulsive hemorrhage
- Dislocation of nucleus into vitreous

## Post-operative Complications

Early
- Corneal edema
- Wound leak
- Iris prolapse
- Shallow or flat anterior chamber
- Hyphaema
- Hypotony
- Glaucoma
- De-centered or displaced IOL
- Endophthalmitis

Late
- After-cataract
- Cystoid macular edema (CME)
- Vitreous touch syndrome
- Vitreous wick syndrome
- Irvine Gass syndrome (vitreous touch or wick & CME)
- UGH syndrome (uveitis, glaucoma and hyphaema)
- Bullous Keratopathy
- Glaucoma
- Visual Rehabilitation after Cataract Surgery (Aphakia)

## The Problem

Removal of the lens from the eye or aphakia leads to:
- Absolute high hypermetropia (caused by loss of about 18 dioptre of convergence power).
- Astigmatism
- Loss of accommodation
- Altered Color Perception
- More of UV rays (in A-band) reach the retina
- The hypermetropia is high (about 10 dioptre) because of loss of convergence provided by the lens and it is absolute because no part of it can be compensated by exertion of accommodation as theaccommodation is lost.

## Rehabilitation

Three methods are mainly used to tackle the problems of aphakia:
Intra-Ocular Lens (IOL)

## Spectacles

- Contact-Lenses
- IOL Implantation

  This the best method to manage the optical and visual problems of aphakia. Currently available IOLs are safe, inexpensive and of good optical quality. Implantation of IOL is easy if done at the time of removing cataract. As a secondary procedure it may be difficult and

risky. The advantages of IOL become obvious when one looks at the disadvantages of aphakic spectacles as follows. However, the problem of loss of accommodation is still not solved with IOLs and the patient may need to wear near correction for reading (although multi-focal IOL are available but they are not very successful).

- Aphakic Spectacles

  To correct the refractive error in aphakia about 10 dioptre of convex lenses are required for distance vision and about 13 dioptre for near vision. Such high power lenses are associated with numerous physical and optical problems. And these problems become even more troublesome if the aphakia is unilateral (the other eye being normal). The most important of these problems are:

  - Physical Problems: These glasses are heavy and wearing them constantly can be associated with great physical discomfort. IOL does not cause any discomfort.
  - Magnification: Each dioptre of convex power leads to about 3 % magnification of image and a difference of image size between the two eyes of about 7 % is tolerable. Thus 10 dioptre aphakic spectacles lead to about 30 % magnification of the image which give rise to diplopia i.e., two images of one object are seen one small (from normal eye) and other larger (from aphakic eye). Moreover, when the objects appear larger they appear falsely closer than reality, and this leads to physical in-coordination. In IOL magnification is only about 1-2 %.
  - Roving Ring Scotoma: The edge of a convex lens acts as a prism and the higher the power of the convex lens the greater is the prism angle (alpha). The light falling on the prism bends towards its base by an angle alpha/2 , therefore, greater the angle alpha the more will be the bending. In aphakic spectacles, the angle alpha being large, the light falling at the edge of the lens bends towards the center of the lens (base of prism) and does not reach the pupil and is, therefore, not seen. This results in an area of the visual field which is not visible to the patient, or scotoma. And because the edge of the lens is present all around the lens like a ring, so it gives rise to a ring shaped scotoma. The position of this scotoma is not fixed in the visual field because the eye keeps moving (or roving) in relation to the aphakic spectacle. Hence, the result is a roving ring scotoma. This is not seen with IOL.
  - Jack-in-the-box Phenomenon: The presence of the above scotoma leads to another interesting phenomenon. If an interesting object appears in the periphery of the patients visual field, it appears blurred (because the light is passing from the side of the spectacle frame). The person tends to move his head towards the object in order to see it clearly. But as he turns the head the object comes to lie in the area of scotoma and thus disappears. As he turns his head further the object comes to lie in from of the spectacle in the visible area and so reappears again clear and sharp. This sudden disappearance and sharp reappearance of the objects is called jack-in-the-box phenomenon. Not seen with IOL.
  - Pin Cushion Effect: The magnification of image is more at the periphery of the lens due to prism effect. Therefore, all the objects appear stretched out at the corners like a pin-cushion. Not seen with IOL.

- Spherical Aberrations: The light converges more near the edge of the lens than at the center so the rays of light falling near the edge are brought to focus in front of the rays falling at the center. This results poor quality of image despite appropriate correction of refractive error. Less with IOL.
- Chromatic Aberrations: The shorter the wave-length the more is the refraction a ray of light undergoes. Therefore, in VIBGYOR the violet end undergoes greater refraction than the red end of the spectrum. This causes diffraction of light and makes the edges of white object appear rain-bow colored. Less with IOL.

These optical problems can be minimized to a some extent by making some modification is construction of aphakic lenses:

- Aspherical lenses
- High index lenses
- Lenticular lenses
- Large lenses with their edge cut off

## Contact Lenses

Contact lenses, also, solve most of the problems related to the aphakic spectacles and reduce the magnification to about 3-4 %. But for the old patients handling the contact lenses is difficult due poor vision and lack of physical dexterity. In the young they are a very good alternative to aphakic spectacles and sometimes the only choice e.g., in unilateral aphakia (in absence of adequate support for IOL).

## Pediatric Cataract

Cataract occurring in a child assumes special importance because of some characteristic differences in the way a child's developing eye behaves. Following are the main problems to be tackled while managing pediatric cataract:

- Visual Assessment: It is very difficult to assess visual acuity of a pre-verbal child and also young children do not complain of diminished vision. Therefore, cataract is usually discovered in children by their parents in advanced stages when the pupil appears white or the child becomes severely visually handicapped.
- Vision Deprivation Amblyopia: The young developing visual system of a child needs constant stimulation by a clear image on the retina in order to develop normally. If visual stimulus is absent or disturbed by poor vision due to cataract or any other cause then the development of visual system is arrested leading to amblyopia. If macula is deprived of clear image in the first 6-8 weeks of life then it can lead to failure of development of fixation and causes nystagmus. This problems is even worse if only one eye has the problem and the other is normal.

Therefore, if cataract is detected in a young child it has to be treated urgently and the postoperative visual rehabilitation also involves treatment of amblyopia.

Postoperative Inflammation and Fibrosis: The immune system of the child being very active responds violently to surgery and thereby, leads to severe postoperative uveitis and fibrosis. This severely mar the results of operation. To deal with this problem some surgeons advocate Pars Plana Lensectomy as the technique of choice for removal of cataract in children. But this technique make implantation of IOL difficult.

After-cataract: The epithelial cells of the anterior capsule being very actively dividing a child is very prone to develop dense and thick after-cataract. This can be very difficult to treat because the children do not cooperate for YAG Laser treatment and being thick the laser sometimes fail to penetrate it. Therefore, some surgeons make an opening in the posterior capsule at the end of operation for cataract (Primary Posterior Capsulotomy).
IOL Power Calculation: As the eyeball of the child is still growing it poses a problem in calculating the power of the IOL to be implanted as the later is based on the axial length of the globe. If a IOL of emmetropic power is implanted this leads to myopia as the child grows up. Therefore, it is recommended that the child be made hypermetropic by about 3 dioptre, so that as the child grow the eye becomes nearly emmetropic.

## Dislocation of Lens

### Causes

Congenital
Familial
Ectopia lentis
Ectopia lentis et pupillae
Marfan's Syndrome
Weil-Marchesani Syndrome
Homocystinuria
Hyperlysinemia
Sulphite-di-oxide Deficiency
Aniridia
Acquired
Hypermature cataract
Trauma
Chronic uveitis
Intra-ocular tumor
High myopia
Buphthalmos

### Treatment

- Spectacles: If the clear lens is subluxated in such a way that most of the pupil is still occupied by the lens then spectacle correction of the refractive error is all that requires to be done.
- Extra-capsular Cataract Extraction: If the subluxated lens is cataractous but only 1/3rd zonules are broken then ECCE with IOL can be done.
- Intra-capsular Cataract Extraction (Wire vectis technique): If more than 1/3rd zonules are broken or the lens is dilocated into the anterior chamber then it can be removed by ICCE using the wire vectis technique. An instrument shaped like a loop of wire is inserted behind the lens to remove it.

- Pars Plana Surgery: If the lens is dislocated into the vitreous then pars plana route is used to remove it. The lens is nibbled out if it is soft using a VISC probe. If lens is hard then it is first brought to anterior chamber from where it is removed using a wire vectis.

## Miscellaneous Conditions of Lens

### Lenticonus

Anterior surface of the lens (rarely posterior surface) is projected into a conical projection giving rise to high myopia. This condition is commonly associated with renal anomalies in Alport's Syndrome.

### Lens Coloboma

A notch shaped defect is found as a rare congenital anomaly in the equator of the lens. It can even be acquired if an intra-ocular tumor presses on the lens.

### After-Cataract

Opacification of posterior capsule after ECCE or Pahcoemulsification caused by proliferation of lens epithelial cells from the anterior capsule, is called after-cataract. If it leads to significant diminution of vision (> 2 lines on Snellen's Chart) then an opening can be created in the posterior capsule with the help of Nd-YAG Laser (Neodymium - Yttrium Aluminium Garnet Laset with a wavelength of 1064 nm) by photodisruption. This opacification may take two characteristic forms: Elschnig's pearls & Ring of Sommering.

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