Evidence-based Approach in Cataract Surgery
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A MARTIN DUNITZ BOOK
This book is dedicated to my wife Suhasini who always encouraged me in writing this book and also my son Shreyas who allowed me to work on this book daily for long hours.
Preface

There have been rapid advances relating to technology and clinical management in the practice of ophthalmology. Who would have imagined our present abilities to remove cataracts using topical anesthesia, through a small self-sealing incision and correcting vision by implantation of a foldable intraocular lens?

Scientific knowledge and literature is growing exponentially and now time has come to spread this knowledge. This book would be beneficial not only to the practicing ophthalmologists for improving their surgical skills but also to resident doctors who are interested in updating their knowledge. This is a book that should remain in an ophthalmologist’s shelf for many years.

Jay Bhopi
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Introduction

EVIDENCE-GUIDED OPHTHALMOLOGY

Evidence-based medicine is the ability to provide our patients with care, that is based on the best evidence currently available. It has become necessary for ophthalmologists to make clinical decisions, based on valid information or evidence rather than intuition, hearsay and peer practice.

Knowledge about new techniques and approaches collected from peer reviewed journals provides framework for evidence-guided ophthalmology. Patients have become very demanding and expect the health care system to offer best practice, based on the latest evidence.

There are certain distinct advantages of practicing evidence-guided ophthalmology.

1. Evidence-based medicine helps to improve clinical practice by evaluating the quality of clinical evidence and ensuring that only the best evidence from clinical research is used in the management of individual patients.
2. Evidence-based medicine has contributed to make the clinicians understand the benefit and harm of treatment as reported in the literature and it acts as an aid to clinical decision making.

Getting the Evidence

The best sources for information are the databases maintained by the National Library of Medicine, such as MEDLINE. After getting a list of references from the search interfaces, the full text of the articles from peer reviewed journals is necessary to learn the results of a study.

Evaluating the Evidence

1. The study design should be considered for validity.
2. The methods of the study should be evaluated to assess, to what degree bias, confounding or chance could have affected the results of the study.
3. The applicability of the results to the practitioner and the patient should be assessed.
4. Finally, all the information is synthesized and assessment-based on the benefits and risks is considered.

This approach of implementing evidence-based practice will help to maximize the chances for good patient outcomes.
Abbreviations

1. CCC: Continuous curvilinear capsulorhexis
2. IOL: Intraocular lens
3. CTR: Capsular tension ring
4. HSM IOL: Heparin surface modified intraocular lens
5. PCO: Posterior capsular opacification
6. PcIOL: Posterior chamber intraocular lens
7. Eto: Ethylene oxide
8. ECCE: Extracapsular cataract extraction
9. CME: Cystoid macular edema
10. BSS: Balanced salt solution
11. RK: Radial keratotomy
12. PRK: Photorefractive keratectomy
13. LASIK: Laser-in-situ-keratomileusis
14. LEC: Lens epithelial cell
Chapter 1
Newer Anesthesia Modalities for Cataract Surgery

Recently, there is a trend toward minimally invasive cataract surgery technique. This has led to a similar evolutionary process in anesthesia for cataract surgery. In addition to advances in different techniques of administration of local anesthetic another concept that has evolved is choice of local anesthetic agent.

1. *Lidocaine and bupivacaine*: Bupivacaine is added to lidocaine to combine the advantages of rapid onset of action with lidocaine and longer duration of action with bupivacaine. But mixing 2% of lidocaine and 0.5% of bupivacaine in a 1:1 ratio dilutes the anesthetic mixture to 1% lidocaine and 0.25% bupivacaine. This leads to reduction in efficacy of both anesthetics.

2. *pH adjustment of anesthetic solution*: Recent studies have demonstrated that pH adjusted solutions of local anesthetics (pH 6.6–7.0) produce more rapid onset of action compared to unmodified commercial preparations. The baseline pH of 0.5% bupivacaine has to be increased from 5.8–6.01 to 6.8–7.0. Hence, 0.08 ml of sodium bicarbonate has to be mixed in 20 ml vial of 0.5% bupivacaine. This should be freshly prepared just before giving block.

   Mechanism of action: The cation form of any local anesthetic is the active form of the drug. The local anesthetics exist in various ratios of cation to noncation concentration, depending on the pH of the drug. Addition of sodium bicarbonate leads to alkalization of a local anesthetic solution. This alkalization of local anesthetic increases the availability of the noncation form. This noncation form penetrates soft tissues and nerve sheath faster. Hence, adjustment of pH increases nerve penetration and decreases onset time. Tarun Sharma et al\(^1\) showed that bicarbonate buffered 0.5% solution of bupivacaine and hyaluronidase without lignocaine improves the efficacy of block in patients undergoing vitreoretinal surgery.

3. *Hyaluronidase (5 units/ml)*: It helps in spreading anesthetic solution within the orbit.

   Mechanism of action: It acts by hydrolyzing C1–C2 bonds between glucosamine and glucuronic acid in ground substance.\(^2\)

4. *Epinephrine*: Epinephrine in the concentration of 1:1,00,000 when added to local anesthetic solution helps in many ways, i.e.

   i. It diminishes bleeding from small vessels, if punctured.
   ii. It prolongs periorbital akinesia
   iii. It reduces orbital volume by causing vasoconstriction.
TOPICAL ANESTHESIA

In the past decade, the most important development in anesthesia for cataract surgery is introduction of topical anesthesia. Cataract surgery is routinely done under local anesthesia. It can be grossly divided into injectional and topical.

Retrobulbar, peribulbar, sub-Tenon’s and sub-conjunctival injections of local anesthetic agent come under “injectional” anesthesia, and topical anesthetic eyedrop application, sponge anesthesia, eyedrop plus intraocular application and gel application come under “topical” anesthesia.

The local and systemic complication due to retrobulbar and peribulbar anesthesia are well-known (Table 1.1). It is now accepted that clear corneal phacoemulsification can be done under topical anesthesia. However, it is well-known that cataract surgery anesthesia requires not only analgesia but also akinesia and amaurosis. The newer sub-Tenon’s technique provide akinesia and amaurosis. There is no evidence in the literature that these are essential for safe cataract surgery in a cooperative patient (Table 1.2).

Table 1.1: Complications of injectional anesthesia

1. Retrobulbar hemorrhage.
2. Optic nerve damage.
3. Accidental injection of anesthetic agent in retrobulbar blood vessels.
5. Conjunctival and lid hemorrhage.

The most attractive aspect of this topical anesthesia is its simplicity.

While converting to this technique certain modifications during surgery are required:

a. Preoperative surgeon-patient interaction is required which is not necessary for conventional injectional techniques. Some surgeons call it “vocal local” and it is in one way a surgical skill that has to be acquired.

Table 1.2: Contraindications to topical anesthesia

1. Absolute
   a. Nystagmus
   b. Allergy to topical anesthetic eyedrops.
2. Relative
   a. Uncooperative patients.
   b. Deaf patients.
   c. Language barrier between surgeon and patient.
   d. Difficult surgery.
   e. Prolonged surgery.
b. The brightness of the operating microscope light has to kept low. It is kept at the lowest level throughout the surgery. This will prevent retinal bleaching and will allow rapid vision recovery.

**Advantages of Topical Anesthesia***

1. Avoidance of severe complication, though rare, that may occur due to injectional anesthesia, i.e. globe perforation, retrobulbar hemorrhage, optic nerve damage, intravascular injection of anesthetic agent.
2. Popularly called “no needle, no patch” technique will allow patients to return home the same day with better vision.

**Topical Eyedrop Anesthesia Alone**

The recommended dose is three drops of lidocaine 4% (unpreserved) instilled every 5 minute starting 15 minutes before surgery. Bupivacaine hydrochloride 0.75% can also be used similarly.

Johnston et al. compared topical with peribulbar anesthesia for clear corneal phacoemulsification. Pain during surgery was slightly more in topical anesthesia group but it was not statistically significant. None of the patients in both the groups required supplemental anesthesia or sedation.

Topically applied anesthetics block the trigeminal nerve endings in the cornea and to a lesser extent, the conjunctiva. The analgesic effect on the iris and ciliary body is very minimal or none and it depends on penetration of anesthetic agent in the anterior chamber.

It is documented in literature that patients may subjectively feel pain during surgery which involve iris manipulation and globe expansion. This led to the concept of topical plus intracameral anesthesia.

**Topical Plus Intracameral Anesthesia***

The recommended dosage is 0.5 ml of non-preserved lidocaine 1 % given intracameral at the start of surgery. Also, 0.5 ml of bupivacaine hydrochloride 0.5% can be used similarly.

Safety of intracameral injection of preservative-free lidocaine 1% or bupivacaine 0.5%.

1. **Effect on corneal endothelium**: There is no difference in the endothelial cell count and morphology noted after 3 months of surgery. This may be due to washout effect caused by irrigation during phacoemulsification. This limits the exposure of endothelium to intracameral anesthetics.

* Fichman first presented his paper on topical anesthesia in American Society of Cataract and Refractive Surgery (ASCRS) meeting in April 1992 that the ventured back in time to revisit the old topical anesthesia approach.
2. Retinal toxicity in case of posterior capsular tear: Liang et al\(^9\) showed that posterior movement of intraocularly injected anesthetics in moderate amounts do not cause long-term adverse effects on retina.

Advantages over topical anesthesia alone: Pain during phacoemulsification with topical anesthesia alone may be perceived in two circumstances:

i. Deepening of the anterior chamber causes posterior displacement of the iris lens diaphragm may be perceived as pain.

* Gills first augmented the depth of local anesthesia with intracameral lidocaine injection\(^{10}\)

ii. IOL implantation and associated zonular stretching may be perceived as pain.

Intracameral lidocaine causes direct anesthetic effect on the iris ciliary body zonular complex. Carino et al\(^6\) demonstrated that topical anesthesia with intracameral lidocaine is more effective than topical anesthesia alone.

**Lidocaine Gel 2%**

Advantages:

i. It provides sustained release of anesthetic hence gives prolonged anesthetic effect.

ii. Single application of gel is enough instead of multiple topical anesthetic drops.

iii. Risk of systemic side effects is less since it is poorly absorbed from ocular mucosa.

iv. Anesthetic effect is comparable to topical plus intracameral lidocaine with double application of gel.\(^{11}\) There is no effect on endothelial cell count and morphology.\(^{12}\)

**Sub-Tenon’s (Parabulbar) Anesthesia**

Since Tenon’s capsule is an anterior extension of dura, it provides access to the retrobulbar space.

*Procedure:* A dissection is made in conjunctiva and Tenon’s capsule down to bare sclera. A blunt curved, metal cannula is used to inject local anesthetic. A few ml of local anesthetic is forced to dissect posteriorly to get the required anesthetic effect.

*Onset of action:* The anesthesia is of rapid onset and it takes few minutes for the globe akinesia to occur.\(^{13}\)

Advantages over peribulbar anesthesia:

i. The chances of globe perforation, retrobulbar hemorrhage, optic nerve damage are almost nil because of the blunt cannula which is used.

ii. Re-injection of local anesthetics is possible, if surgery time is prolonged as required in vitreoretinal surgeries.
REFERENCES

Chapter 2
Newer Incision Techniques in Cataract Surgery

There has been progressive decrease in size of the cataract incision along with newer cataract surgical techniques. The size of wound has progressively decreased from 12.0 mm in intracapsular cataract surgery to 10.5 mm in early extracapsular surgery to 5.25 mm with the advent of phacoemulsification. Foldable IOLs has further reduced the size of incision to 3.0 mm or smaller. Advantages of small size of incision are given in Table 2.1.

<table>
<thead>
<tr>
<th>Table 2.1: Advantages of small incision</th>
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<tr>
<td>1. Minimal surgical trauma.</td>
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<td>3. Controlled capsulorhexis and hydrodissection.</td>
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<td>4. Healing is rapid hence short postoperative rehabilitation period.</td>
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<td>5. Minimal postoperative surgically-induced astigmatism.</td>
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<td>6. Management of pre-existing astigmatism is possible by cataract surgery alone.</td>
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<td>7. Avoid suture-related complications.</td>
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<td>8. Low risk of postoperative leakage.</td>
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TYPES OF INCISION

The two main types of incision according to anatomic location are as follows:

1. Scleral tunnel incision.
2. Clear corneal incision.

Scleral Tunnel Incision

Concept of Incisional Funnel

Surgically induced astigmatism is inversely proportional to the distance of the incision constructed from the limbus. This has led to the concept of incisional funnel. Incisional
funnel is made up of two imaginary curved lines which represent the relationship between induced astigmatism and length of incision. The two curved lines start from the limbus. They diverge and separate as the distance from the limbus increases (Fig. 2.1).

![Incisional funnel](image)

**Fig. 2.1:** Incisional funnel

Incision constructed within this imaginary funnel are astigmatically neutral. Hence, longer incisions should be made away from the limbus to make it astigmatically neutral; small incisions can be made close to the incision.

Scleral tunnel incision can be (a) curvilinear, (b) straight, (c) frown.

*Curvilinear incision:* This incision is constructed along the curve of the limbus. It has highest potential to cause against the rule astigmatism. There is lack of support to prevent the incision edge from falling away from the superior edge. This gap is the cause for against the rule of astigmatism.

The boundaries of curvilinear incision fall out of funnel, giving rise to an unstable wound and greater astigmatism (Fig. 2.2).

![Curvilinear incision fall out of funnel](image)

**Fig. 2.2:** Curvilinear incision fall out of funnel
Straight incision: In this incision, the two terminal points of incision are secured within the sclera. Hence, the chances of sagging of inferior edge of the incision are minimized. The straight incision constructed at the same distance as curvilinear incision falls out of the funnel, but not as much as the curvilinear incision. Hence, the wound is more stable and induces less astigmatism (Fig. 2.3).

Frown incision: To make the incision more stable, the ends of the incision are placed further superiorly in the sclera. The ends of the incision are swept superiorly away from the limbus in a curved fashion exactly opposite to that of curvilinear incision. The chances of sagging of inferior edge of the incision from the superior edge are further minimized. The frown incision at the same distance as straight incision lie entirely within the astigmatic funnel hence induces minimal postoperative astigmatism (Fig. 2.4).
Chevron incision (Fig. 2.5) devised by Sam Pallin\(^2\) is similar to that of frown incision except that it consists of two straight cuts rather than single curved cut.

**Fig. 2.5: Chevron incision**

**Internal Configuration of Scleral Tunnel Incision**

Koch’s basic incision (Fig. 2.6):

i. **External configuration:** It is constructed 0.5 to 1.0 mm from the cornea.

ii. **Internal configuration:** The groove is dissected up to the limbus and only a small distance into the cornea before entering the anterior chamber.

**Fig. 2.6: Koch’s incision**

**Advantages:**

i. This incision can be performed in transition phase of surgeon, from conventional curvilinear incision to self-sealing incision.
ii. Being relatively anteriorly situated, it gives easy maneuverability of instruments during surgery.

*Kratz’s scleral pocket incision* (Fig. 2.7):

i. *External configuration:* A vertical groove is made about 2 mm behind the blue zone of the limbus.

ii. *Internal configuration:* About half thickness scleral tunnel dissected from the groove toward the anterior chamber. The anterior chamber is entered with a keratome according to the width of the phaco tip.

*Limitations:* The scleral pocket makes easy maneuverability of instruments difficult.

*Advantages:*

i. More secure wound as compared to Koch’s basic incision
ii. Less surgical induced astigmatism

![Fig. 2.7: Kratz’s incision](image)

*Three-step corneal valve incision* (Fig. 2.8):

i. *External configuration:* The incision is similar to Kratz’s scleral pocket incision.

ii. *Internal configuration:* Scleral tunnel dissected from the groove toward the anterior chamber. This dissection is carried further into the cornea about 1 mm. The anterior chamber is then entered with a keratome in a vertical fashion, making the third step of the incision. This third step acts as a valve (corneal). Postoperatively as the intraocular pressure builds up, the sealing effect of the wound increases.³

![Fig. 2.8: Three-step scleral tunnel incision](image)
Clear Corneal Incision

1. **Site of incision:** At surgical limbus.
2. **Length of incision:** Usually 3.0 mm in length. Clear corneal incision of 5.0 mm induces more surgically-induced astigmatism as compared to scleral frown incision of 5.0 mm.\(^4\) But 3.0 mm clear corneal incision induces same amount of astigmatism as with 3.0 mm scleral tunnel incision.\(^5\)
3. **Instrumentation:** Diamond blade which has four depth settings and a sharp side cut.
4. **Internal configuration:** A 200 µm deep precut made, corneal tunnel is constructed approximately 1.7 to 2.0 mm in length.\(^6\)

*Location of Clear Corneal Incision and Induced Astigmatism*

Surgically induced astigmatism is highest after superior followed by superolateral and lowest after a temporal 3.0 mm clear corneal incision. Corneal flattening of approx 0.7 D occurs in 3.0 mm temporal clear corneal incision* and approximately 1.2 D in 3.0 mm superolateral clear corneal incision by 3 months.\(^7\)

This astigmatism do not extend upto the center of cornea. More corneal flattening in superior and superolateral incisions as compared to temporal might be due to stroking of the upper eyelid in the superior and superolateral clear corneal incision.\(^7\)

*Clear Corneal Incision and Management of Pre-existing Astigmatism*

A 3.0 mm temporal clear corneal incision induces approx 0.53 D to 0.70 D of temporal flattening. There is no effect on the nasal-corneal curvature. A 5.2 mm temporal clear corneal incision can induce 0.84 D of flattening with the rule of astigmatism by one year.\(^8\) Hence, a larger clear corneal incision induces greater flattening effect.\(^9\)

Hence pre-existing astigmatism upto 1.0 D can be managed by taking clear corneal incision on the steepest meridian to benefit from its flattening effect. Opposite clear corneal incision has been suggested when preexisting astigmatism is more than 2.0 D (Fig. 2.9).

* Fine IH in February 1992 first described a new concept of a planar temporal clear corneal sutureless incision for phacoemulsification
In this, clear corneal incision taken at the steepest meridian and similar incision made exactly opposite to the first to enhance flattening effect.\textsuperscript{10}

**INCISION SIZE AND SITE AND CORNEAL ENDOTHELIUM**

The scleral tunnel incision causes less postoperative endothelial damage as compared to clear corneal incision. Scleral tunnel incision being posteriorly placed as compared to clear corneal incision, there is less direct trauma to endothelium, i.e. by phaco tip and IOL implantation.\textsuperscript{11}

**INCISION SITE AND RISK OF POSTOPERATIVE INFECTION**

Recent literature reported increased risk of postoperative endophthalmitis in temporal clear corneal incision as compared to superior sclerocorneal incision. Its probably due to bacterial invasion through a temporal corneal incision may be easier than through a superior corneoscleral incision.\textsuperscript{12}

**REFERENCES**

Chapter 3
New Phacoemulsification Technologies

Since Dr Charles Kelman* has invented phacoemulsification it has undergone plenty of modifications. The recent trend is toward less traumatic cataract surgery and early visual rehabilitation. This has emerged new phacoemulsification technologies for reducing the size of incision and using less phaco energy.

CONVENTIONAL PHACOEMULSIFICATION

Conventional ultrasonic phacoemulsification is created in a phacoemulsification handpiece when an electric current is passed through piezoelectric crystals. These crystals convert electrical energy to mechanical vibrations at the tip of the phaco-needle. The phaco-needle tip is used to emulsify the lens material at frequencies between 25 and 62 KHz. Heat is produced by frictional forces. The heat is removed from the eye by fluid flowing through an irrigation sleeve and around the incision that surrounds the phacoemulsification needle. The irrigation sleeve diameter is larger than the phaco-needle diameter. In case of diminished flow, conventional ultrasonic phacoemulsification with an irrigation sleeve has the potential for thermal injury.

MODERN PHACOEMULSIFICATION SYSTEM

Modern phacoemulsification systems has two goals for atraumatic cataract surgery.

1. Reduction of heat produced due to friction during ultrasound phacoemulsification.
2. Reduction of power required for cataract extraction.

To achieve these two goals various modifications in phacoemulsification systems have been done (Table 3.1).

a. Sonic phacoemulsification system is a new approach for elimination of heat thus reducing chances of thermal injury.

b. Modification of ultrasound energy through refinement of power modulation is another route leading to decrease of heat and reduction in incision size (WhiteStar technology).

* Dr. Charles Kelman got an inspiration for inventing phacoemulsification in the dentist’s chair while having his teeth, ultrasonically cleaned
c. The introduction of innovative oscillatory tip motion in association with power modulation allows further reduction of phaco power (NeoSonix phacoemulsification system).
d. Erbium: YAG laser (Phacolase) and Neodymium: YAG laser such as Photon phacolysis and Dodick photolysis offers new approach for eliminating thermal energy and decreasing power during phacoemulsification. These two laser systems are being clinically investigated and clinical trials are underway. And only these lasers are commercially available.

**Table 3.1: Newer phacoemulsification system**

1. Sonic phacoemulsification system
2. WhiteStar technology
3. NeoSonix phacoemulsification system
4. Laser systems
   a. Erbium: YAG laser system
   b. Neodymium; YAG laser phacoemulsification
      i. Dodick photolysis
      ii. Photon laser phacolysis

**Erbium: YAG Laser System**

Laser phacoemulsification is one of the emerging technology for removal of cataract.

*Advantages Over Ultrasound Phacoemulsification*

i. Minimal energy required for removal of cataract.
ii. Decreased chances of thermal injury to the cornea.
iii. The incision size is reduced to 1.0 mm.

*Limitations*

i. Hard cataract with nuclear sclerosis of grade 3 or more cannot be removed.
ii. Phacoemulsification time is usually longer than the ultrasound phacoemulsification.

*Instrumentation*

i. *Erbium: YAG laser:* It has produces a wavelength of 2.94 \( \mu m \), which falls in infrared spectrum.
ii. *The phacolase Er: YAG laser:* It has variable pulse energy from 5 to 50 mJ.
iii. *Frequency:* It is available in variable frequency from 10 to 100 Hz.
iv. *Irrigation/aspiration (I/A) pump:* The phacolase system is coupled to a Megatron I/A pump. The megatron has a peristaltic pump with Venturi-like effect.
v. **Handpiece:** The phacolase handpiece contains laser fiber inside the aspiration port.

vi. **Footswitch:** The footswitch is bidirectional which separates irrigation and aspiration from laser energy. Foot pedal if moved laterally increases the repetition rate in linear fashion. Foot pedal if pushed down gives control of vacuum linearly.

**Mechanism of Action**

*Cavitation bubble formation:* Cavitation is the formation of vacuoles in a liquid by a swiftly moving solid body. The collapse of the vacuoles releases energy that vaporizes and crushes lens material (Fig. 3.1).

These cavitation bubbles form and collapse instantaneously. But, the collapse of the bubbles occurs more slowly in the nucleus. The laser beam travels across the first bubble and forms a second bubble in line with the first. Similarly if the third bubble is formed, effective range of the laser is increased to 3.0 mm.

![Cavitation bubble](image)

**Fig. 3.1:** Cavitation bubble formation due to vacuum from phacoemulsification needle backstroke

*Direct concussive effect:* Direct concussive effects of laser energy propagation wave causes disruption of lens material. An emulsate is created which is aspirated from eye.

**Neodymium: YAG Laser Phacoemulsification**

**Dodick Photolysis**

Photolysis is a Q-switched Nd: YAG laser introduced first by Dodick in 1991.

*Advantages:*

i. No heat is produced at the laser tip.²  
ii. Silicone sleeve for cooling is not required as no heat is produced thus cataract extraction is possible through 1.25 mm incision.

*Instrumentation:* 1064 nm Nd: YAG laser system.

*Mechanism of action:* Pulsed Nd: YAG laser of energy transmitted through quartz fiber strikes a titanium target. On this titanium surface there is optical breakdown and plasma formation. This optical breakdown produces shock waves which move toward the distal end of the probe which is open. The shock waves here come in contact with the
lens material. The shock waves disrupt the lens material at the distal end of the probe and fragmented material is aspirated out. Plasma formation and these shock wave generation produce photolysis of lens material (Fig. 3.2).

**Fig. 3.2:** Mechanism of nucleus removal by Dodick photolysis

**Surgical technique**

i. Groove and crack technique with the laser.
ii. Sculpting in a bimanual fashion then cracking the nucleus methods are described.

**Photon Laser Phacolysis**

*Instrumentation:* 1064 nm Nd: YAG laser, delivered through a special tip of the probe, its diameter being 1.8 mm. The tip has three functions, i.e. fragmentation, aspiration and irrigation. Laser energy travels along an optical fiber and also across an open area called photofragmentation zone. The nuclear material is aspirated into this zone (2.5 mm). The nuclear fragments which occur are removed from the eye by aspiration and irrigation. The distal end of the tip is bent upward to provide backstop of the laser energy. This prevents the laser beam from damaging non-target tissues (Fig. 3.3).
Fig. 3.3: Mechanism of nucleus fragmentation using photon laser photolysis

Sonic Phacoemulsification

Sonic technology uses sonic rather than ultrasonic technology for removing cataract. The operating frequency is in the range of 40 to 400 Hz. Hence, there is no heat generation and no generation of cavitation energy. The sonic tip moves back and forth without changing its dimensional length as against ultrasonic tip motion.

The same handpiece and tip can be used for both sonic and ultrasonic modes. The modes can be used alternately or simultaneously with varying percentages of sonic and ultrasonic energy.

NeoSonix Phacoemulsification

NeoSonix technology consists of dual mode comprising of low frequency oscillatory movement that may be used alone or in combination with conventional high frequency ultrasonic phacoemulsification.

Instrumentation

In the NeoSonix mode, the phaco tip has a variable rotational oscillation up to 2 degrees at 120 Hz.

Advantage of NeoSonix Handpiece

The lower frequency, as in sonic phacoemulsification does not produce significant thermal energy and thus minimizes the risk of thermal injury. The NeoSonix thus permits non-thermal cataract extraction when used alone and with reduced energy when used in conjunction with ultrasonic energy.
Use of NeoSonix Handpiece During Surgery

i. Softer grades of nuclear sclerosis may be completely removed by low frequency modality and denser grades of cataracts may be removed by additional use of ultrasound mode.

ii. The low frequency mode may be used to burrow the tip into the nucleus for stabilization before chopping. This can be done by setting the lower limit of NeoSonix to 0% phacopower. When straight tip is used, it acts like an apple cores to impale the nucleus.

iii. NeoSonix handpiece may be used in conjunction with ultrasound at 10 or 20% power level.

WhiteStar Technology

Recent advances in phacoemulsification are mainly toward decreasing the incision size for removal of cataract. For this, concept of separating irrigation from aspiration came forward and removing the cataract through two stab incisions. In conventional phacoemulsification, irrigation through the same tip helps to keep the temperature down of the phaco tip, thus preventing wound burn.

WhiteStar micropulse technology is a software modification that allows extremely short bursts of ultrasound energy. Thus decreases heat build-up with the retained efficiency of continuous ultrasound.\(^5\)

Evolution of WhiteStar Technology

It was assessed if the ultrasound is turned on and off in millisecond (ms) and possibly even submillisecond ranges, whether it will of any practical benefit for removing that cataract. Experiments were conducted in rabbits. And it was apparent that ultrasound pulses could be very short as to produce effective phacoemulsification of the nucleus. It was then evaluated length of downtime (ultrasound off) that can be kept in relation to on time (ultrasound on) without loosing its efficiency. It was found that down-time could go to double the on time with minimal and often no sense of loss of efficiency (Fig. 3.4).
Fig. 3.4: Phacoemulsification using WhiteStar technology showing phacoemulsification tip without irrigation sleeve and irrigating chopper through side port

**Advantages**

*Chatter and microchatter:* Chatter is a phenomenon, in which ultrasound energy along with irrigation flow pushes a nuclear fragment away from the tip. The harder the nuclear fragment, the more evident the chatter.

Pulsing technology in WhiteStar helps to eliminate chatter. We know that “contact” is critical in the removal of nuclear fragments. During the down-time in WhiteStar, the aspirational flow brings the particle back to the ultrasound tip where contact again occurs which is necessary for removal of nuclear fragment.

*Jackhammer effect and cavitation energy:* Ultrasound creates a mechanical Jackhammer effect from the oscillation of the tip, and also creates cavitation energy. Cavitation is the formation of vacuoles in a liquid by a swiftly moving solid body such as the ultrasound tip. The collapse of the vacuoles releases energy that vaporizes and crushes lens material. Cavitational effect is more important of the two in emulsifying nucleus fragments.

With conventional ultrasound, cavitational energy is greatest when the ultrasound is first turned on and drops after a few milliseconds of utilization due to air dispersal and depletion from water (the source of cavitation). WhiteStar ultrapulse technology, but turning off so fast, can minimize this decrease and more efficiently use cavitation energy than continuous ultrasound.

*Fragment followability:* Increased followability wherein nuclear fragments stay with the emulsification tip and don’t bounce off, has been reported. Followability is certainly related to a decrease of microchatter, with the off time allowing aspirational forces to more efficiently hold the particles in place for eventual emulsification.
Thus extremely short bursts of ultrasound energy leads to decrease in chatter and microchatter, increased fragment followability with improved cavitational energy. Hence, one can have same efficiency with one-half to one-third the energy utilization in comparison with cavitational energy.

Absence of thermal energy obviates the need for an irrigation sleeve on the phaco tip, permitting a reduction in incision size and allowing irrigation through a second instrument, placed through the side port.

**Phaconit**

The main difference from conventional phacoemulsification is that phaco tip is used without the infusion sleeve and separating the irrigation. This allows removal of cataract through 0.9 mm incision. The function of sleeve is to prevent thermal burns by insulating and continuously irrigating the vibrating tip and reducing the temperature rise from ultrasonic vibration. A constant irrigation fluid is required for sufficient cooling of the phaco-needle.

Various modifications are made for the following:

a. Adequate cooling of the vibrating tip and
b. To prevent destabilization of the anterior chamber, i.e. surge.

- **Irrigating chopper:** It has dual function, i.e. anterior chamber maintainer and chopper.
- **Assistant** has to continuously pour cooled balanced salt solution over the phaco-needle.
- **Antichamber collapser** is used which injects air into the infusion bottle. This pushes more fluid into the eye through irrigating chopper and prevents surge.
- **Pump with micropore air filter** is used to push sterile air in the bottle.
- **Two BSS bottles** instead of one is suggested to improve irration inside the anterior chamber. A Y-shaped infusion (transurethral resection commercially available) is used to connect these 2 bottles to the irrigating chopper.

**REFERENCES**

Intraocular lens material and design is constantly evolving and improving as also occurring with modern cataract surgery. Improvements in intraocular lens material and design are aimed at the following:

a. Better refractive correction postoperatively.
b. Smaller incision size.
c. Minimal incidence of posterior capsular opacification.

Various intraocular lens materials have evolved in this process with varying water content, refractive index and tensile strength. Similarly intraocular lens design has undergone changes to restrict lens epithelial cell migration and reflection of internal and external light.1

Sir Harold Ridley*, in 1949, first introduced an intraocular lens. The IOL which Ridley implanted was of polymethyl-methacrylate (PMMA). Polymethyl-methacrylate is still considered the standard with which other materials are compared (Table 4.1).

Sir Nicholas Harold Ridley besides inventing an IOL, very few of us know he did pioneering work in other fields of ophthalmology like definitive characterization of onchocerciasis, first successful penetrating keratoplasty on a leper, first to televise eye operations and take fundus photograph, did ground work on power point presentation, used for presentations in seminars and congresses today39

<table>
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INTRAOCULAR LENS MATERIALS

Polymethyl-Methacrylate (PMMA)

Intraocular lens made of PMMA has following characteristics:

1. Water content of <1%
2. Refractive index of 1.49, which is higher than silicone but less than some acrylic copolymers.
3. Inert, light weight, durable and resistant to changes caused by aging.

Limitations

Biocompatibility of PMMA is already proven but with few limitations:

i. Intraocular lenses made of PMMA are rigid hence cannot be implanted through small (3.2 mm) incision.

ii. Higher incidence of posterior capsular opicification than hydrophobic acrylic and some silicone IOLS.²⁴

However, lens design is considered an important factor for development of PCO than the lens material.⁵⁻⁷

Silicone IOL

Silicone intraocular lenses are made of polymers of silicone and oxygen. The most common silicone in IOLs are elastomers baged on the dimethylsiloxane backbone. These IOLs are relatively inert, non-adherent to tissue and stable at a variable range of temperatures.

Advantages

Decreased cell adhesion: Silicon’s angle of water contact is 99° which makes it more hydrophobic when compared to hydrophobic acrylic, which has an angle of water contact of 73.⁸ It is known that hydrophobicity may decrease host cell responses. It is found that giant cell deposition on silicone IOLs is comparable to hydrophobic foldable acrylic IOLs.⁹

Newer generations of silicone: They have a higher refractive index of 1.41 to 1.46. Hence these lenses have thinner optics, resulting in smaller wound size.

Limitations

i. Incidence of posterior capsular opacification—with first generation silicone IOLs, the incidence of PCO is more than foldable hydrophobic acrylic IOLs and is found to be equal to that of PMMA. Second generation silicone IOLs have been found to be equal to hydrophobic acrylic IOLS with truncated edges, for the development of PCO.¹⁰,¹¹
ii. Silicone IOLs show a lower threshold for YAG laser damage as compared to hydrophobic acrylic IOL.\textsuperscript{12,13}

iii. Being slippery, it is difficult to manipulate, especially if wet. During insertion in the bag it unfolds rapidly, which can lead to uncontrolled insertion and intraocular damage.

iv. Not suitable for patients with vitreoretinal disease needing silicone oil implantation. Because there is tendency for adherence of silicone oil to the silicone IOL.\textsuperscript{14}

### Designs

There are various designs of silicone IOLs

i. Single piece plate type (spherical and toric)

ii. Three-piece (monofocal and multifocal)

#### Single Piece Plate Type

**Advantages:** It can be inserted through a small incision (3.2 mm) as against PMMA IOL.

**Limitations:**

i. The large contact area with the anterior capsule makes these lenses more susceptible to contraction and fibrosis of the anterior capsule and formation of anterior capsule opacification.\textsuperscript{15}

ii. These IOLs have tendency to dislocate posteriorly after Nd: YAG capsulotomy.\textsuperscript{16,17}

![Fig. 4.1: Single piece plate type silicone IOL](image)

**Toric Single Piece Plate Type Silicone IOL**

The major requirements for a toric IOL are rotational stability and contraction which is provided by this IOL. Postoperative toric IOL rotation of 30° off axis still shows astigmatism reducing effect.\textsuperscript{18} Plate haptic IOL design does not induce a specific deviation of rotation (clock wise or anticlockwise) (Fig. 4.2).
Factors affecting IOL rotation:

i. Large capsular bag diameter.
ii. Eyes with high axial myopia.
iii. Implantation axis: More rotation of IOL is seen when the axis of IOL implantation is vertical.\textsuperscript{18}

Preoperative and intraoperative modifications for implanting toric single piece plate type silicone IOL:

i. Staar SRK/T toric version 1.0 software is used for calculating IOL power.
ii. Before making incision, cylindrical axis is marked on the corneal limbus with the aid of a Mendez gauge.\textsuperscript{19}

Three-piece Monofocal Silicone IOL

Silicone IOL with squared off and truncated lens edge prevents PCO formation comparable with that of hydrophobic acrylic IOL. The squared edge is known to create capsular bend which prohibits migration of lens epithelial cells and thus PCO.\textsuperscript{20}

Multifocal IOL

A pseudophakic patient usually needs spectacle bifocal lenses postoperatively to achieve best visual acuity for distance and near. A multifocal IOL provides clear vision both for distance and for near without wearing bifocal spectacle lenses.

Defractive multifocal IOL: Approximately 25 concentric annular zones are cut on the posterior surface of a conventional IOL with microscopic steps between coterminous annuli. The stepheight is in the range of the wavelength of light (Fig. 4.3).
The spacing of the rings and the step-profile of these lenses determine the near add. The closer the rings on the IOL, the higher the add. Thus, with the defractive IOL, both distance and near objects are simultaneously in focus. Hence, these lenses may result in excessive glare and halos. These are very difficult to tolerate more so if the IOL is decentered.

*Refractive multifocal IOL:* To overcome the problems of glare and halos due to defractive IOLs, these IOLs have evolved. The AMO Array foldable silicone multifocal IOL is the single refractive multifocal IOL commercially available. This IOL is a zonal progressive IOL with five concentric zones on the anterior surface. Zones 1, 3 and 5 are for distance, whereas zones 2 and 4 are for near. The lens has an aspherical component and thus each zone repeats the entire refractive sequence corresponding to distance, intermediate and near foci. There is no loss of light through defraction and hence no degradation of image quality as a result of surface discontinuities.

The optic of the lens is of silicone which is 6.0 mm in diameters. The haptics are made of polymethyl-methacrylate and its diameter is 13.0 mm. Hence, the lens can be inserted through clear corneal or scleral tunnel incision that is 2.8 mm wide.

Refractive multifocal IOL such as Array, is superior to defractive multifocal IOLs by giving better contrast sensitivity and less glare.

In conclusion, both distance and near vision correction is possible postoperatively, decreasing the need for spectacles. Decreased contrast sensitivity and haloes at sight may be disturbing to patients with multifocal IOLS. Defractive multifocal IOLs cause more decrease in contrast sensitivity and haloes as compared to newer refractive multifocal IOLs (Figs 4.4a and b).
Figs 4.4a and b: Multifocal IOLs. (a) Defractive IOL, (b) Refractive array multifocal IOL

Hydrophobic Foldable Acrylic IOL

Hydrophobic acrylic lenses are made of copolymers of acrylate and methacrylate, which make them flexible. They have refractive index of 1.44 to 1.55 which is higher than silicone (1.41 to 1.46) and PMMA (1.49). Hence these lenses are thinner.

Comparison with Silicone IOL

i. Hydrophobic acrylic IOLs, because of their lack of elasticity and increased stiffness, they require larger wounds than similar silicone IOLs.

ii. The acrylic copolymers allow for a slower unfolding action hence provides a more controlled insertion and manipulation as against silicone IOLs.

iii. The softer nature of this acrylic copolymer makes it fragile and more susceptible to cracks, dents and scratches.

iv. Hydrophobic acrylic IOLs have been shown to have the least amount of damage from the Nd: YAG laser as against silicone IOL\textsuperscript{12,13}

v. In patients who had undergone vitreoretinal surgery with silicone oil implantation the acrylic lenses have less problems with adherence with the silicone oil than silicone IOLs.\textsuperscript{14}

Newer acrylic IOLs have a squared off edge profile. This sharp, truncated edge creates a capsular bend, preventing migration of lens epithelial cells to form PCO (Figs 4.5a and b).\textsuperscript{6}
Figs 4.5a and b: (a) IOL with rounded edge. (b) Hydrophobic acrylic IOL with sharp, truncated, squared off edge

These squared off edges, however, allow for reflection of light internally and thus, patients report a higher rate of glare, visual aberrations and pseudophakic dysphotopsia.27,28

Newer designs with a frosted edge or rounded anterior edge may diminish these unwanted images.

Hydrophilic Acrylic IOL

Hydrophilic acrylic IOLs are composed of a mixture of a hydroxyethyl methacrylate (poly-HEMA) backbone and a hydrophilic acrylic monomer. These IOLs have varying water content, and are soft and have excellent relatively hydrophilic lens surface.

1. These IOLs show little or no surface alterations or damage from folding with insertion, because of their soft flexible surface.29 In terms of the host foreign body response, they have a low incidence of epitheloid and giant cells deposition.30

2. If a Nd: YAG capsulotomy is needed these lenses have high threshold for Nd: YAG laser damage.13 These IOLs have low surface energy and in patients requiring vitreoretinal surgery, these IOLs have minimal adherence to silicone oil.14

Types

Hydrophilic acrylic lenses can be of several types depending on its water content.

Memory lens: It is a poly-HEMA acrylic mixture with a moderate water content and polypropylene loops. Jehan FS et al.31 reported delayed onset, acute, sterile, toxic anterior segment syndrome (TASS) with these memory lens. These patients present postoperatively with unexplained inflammation in the anterior segment. Most patients with TASS improved with intensive topical steroids. Residual polishing compound on IOL is considered the underlying cause.

Hydroview lenses: Werner L et al reported vision threatening granular deposits of variable sizes within this lens optics. These granules are distributed in a line parallel to the anterior and posterior curvatures of the optic, with a clear zone beneath the optic
surface. X-ray spectroscopy revealed presence of calcium within these deposits. The mechanism of this calcification is still unclear.\textsuperscript{32}

**Heparin Surface Modified PMMA IOLs**

The surface of the PMMA is modified with heparin. It is found to reduce inflammatory cell adhesion to the IOL surface. These modified IOLs have better biocompatibility than PMMA lenses.\textsuperscript{33}

More inflammatory reaction is expected in patients undergoing cataract surgery with uveitis, diabetes and traumatic cataract, due to breakdown of blood aqueous barriers. It is found that heparin surface modified PMMA IOLs show reduced adhesion of inflammatory cells in these cases.\textsuperscript{33}

It is found in one study that metal implantation forces can damage the heparin surface coating over IOL surface, while insertion. There is increased deposition of inflammatory cells seen where the heparin surface coating is accidentally removed by forceps. This can be prevented by using a forceps with silicone sleeves covering the tips.\textsuperscript{34}

**INTRAOCULAR LENS IMPLANTATION IN CHILDREN**

**Ideal IOL Material**

Polymethyl-methacrylate (PMMA) has been in use since 50 years now, this long safety record should not be ignored until similar follow-up is done with other biomaterials. Foldable hydrophilic material is found to be more biocompatible than PMMA and silicone. Hence, the next biomaterial which is suitable for pediatric IOLs is hydrophilic acrylic, i.e. hydroxy ethylmethacrylate (HEMA) and its derivatives.\textsuperscript{35}

**Ideal IOL Size**

It is not true that large sized IOL is more stable. Oversized and malpositioned IOL can cause damage to intraocular structures. Pediatric IOLs should not exceed 12.0 mm in overall diameter because ciliary sulcus rarely exceeds 11.5 mm in diameter.

*Factors Deciding the Size of IOL*

i. Size of implantation whether in the bag or ciliary sulcus.
ii. Corneal diameter
iii. Age at the time of IOL implantation.

Pediatric IOLs should be in diameters of 10.5 mm, 11 mm and 12 mm.\textsuperscript{36,37}

An example of PMMA pediatric IOL is kidlens (IOL Technologies, France). Its overall diameter is 10.75 mm, and optic diameter is 5.5 mm (Fig. 4.6a). The haptics are encircling and contain eyelet holes.\textsuperscript{38}

Another example of pediatric IOL is a palmlens, made of 34% water content HEMA. Its overall diameter is 10.75 mm, and optic diameter is 5.75 mm (Fig. 4.6b). The flanges
of the lens are structured like the webs of aquatic birds feet or fish fins. These membranes can absorb the eventual capsular bag contraction without causing lens valuating. This lens is easily exchangeable because HEMA material does not adhere strongly to ocular structures.

**Figs 4.6a and b:** (a) Kidlens, single piece PMMA posterior chamber IOL of overall diameter 10.75 mm. (b) Palmlens, a foldable posterior chamber IOL of overall diameter 10.75 mm

**Future Intraocular Lens**

*Thermodynamic injectable IOL (Smartlens Medennium):* It is reducible at room temperature to a rod 2.0 mm in diameter which can be inserted through a microincision. Once inside the eye, it will unfold to a diameter of 9.5 mm with an average thickness of 2.0 to 3.0 mm. It is a biconvex lens and will fill the entire capsular bag and remain perfectly centred without the aid of haptics. The gellike hydrophobic acrylic material of the lens is pliable and has a high refractive index. This means that small changes in the central thickness will result in large changes in accommodative amplitude. Since, the lens fills the entire capsule it may prevent the migration of lens epithelial cells and thus prevents PCO. It is impossible to decenter, no edge glare or spherical aberration.

**REFERENCES**


Chapter 5
Phacoemulsification in Difficult Situations

In the last decade several advances have taken place in surgical techniques for removal of cataracts in difficult situations such as posterior polar cataract, total cataract, subluxated cataract, and cataract in patients with uveitis. Hard cataract itself can pose a challenge to surgeons. In addition, phacoemulsification can be difficult if the structures (e.g. weak zonular apparatus leading to subluxated cataract) and conditions around it (e.g. posterior polar cataract) are not very favorable.1

PHACOEMULSIFICATION IN HARD CATARACTS

The fibers of a hard nucleus are described as leathery which are cohesive and tenacious. These fibers resist all the conventional methods of nuclear division like divide and conquer. There is also risk of hard nuclear fragments coming in contact with corneal endothelium and damaging it.

Modifications in surgical technique for removal of hard cataracts are as follows:

1. Peribullar anesthesia is preferred over topical anesthesia.
2. There are more chances of burns during phacoemulsification of hard cataracts because of excessive phacoenergy used. Hence wide temporal clear corneal incision and high aspiration flow rates are recommended.
3. Double capsulorhexis is recommended, initial smaller one enables phacoemulsification in the bag followed by larger.
4. Sculpting by Kelman tip is recommended since deep sculpting is possible with it.
5. Creation of central space in the form of trench or crater is necessary. This central space is necessary for maneuvering the divided lens fragments.

Pure chop technique for nuclear division provides little room for the pieces to be removed. Especially first nuclear piece is difficult to remove. Vasavada et al has described step by step chop in situ followed by lateral separation in hard nuclei.2 The phacoemulsification tip is buried into the cracked nuclear half at 6 O’clock. The chopper is placed adjacent to the phacoemulsification tip. The vertical element of the chopper is depressed posteriorly. This leads to initiation of a crack. However, this crack never reaches the bottom of the nucleus. The chopper is positioned next in the depth of the crack and pushed laterally. The movement extends the crack to the bottom and nuclear piece is separated. In this way, fragments of small size are created. The left hand, with a chopper, continues chopping and dividing the large fragments into small pieces till all the fragments are phacoaspirated (Fig. 5.1).
**Fig. 5.1:** Step by step chop *in situ* and lateral separation

**Posterior Polar Cataract**

Surgeons should be careful when operating eyes with posterior polar cataract because the capsule around the opacity tends to be weak leading to posterior capsule rupture. The incidence of posterior capsule rupture during phacoemulsification is reported as 26% by Osher et al.\(^3\) and 36% by Vasavada et al.\(^4\) Serious complications like dropped nucleus can be avoided if appropriate alternative techniques for cataract surgery are employed.

*Continuous Curvilinear Capsulorhexis (CCC) (Fig. 5.2)*

Diameter of continuous curvilinear capsulorhexis should not be larger than 5.0 mm. In the event of posterior capsular tear during phacoemulsification, an IOL can be implanted in the ciliary sulcus with optic capture through the capsulorhexis.
**Fig. 5.2:** Continuous curvilinear capsulorhexis not larger than 5.0 mm in posterior polar cataract

**Hydrodissection and Hydrodelineation**

Hydrodissection should be avoided as posterior polar opacities adhere firmly to the posterior capsule around the opacity. If at all it is done, it should be performed gently in multiple quadrants with minimal fluid. A fluid wave should not be allowed to pass across the posterior capsule in the center where the posterior capsule is weak. Hydrodelineation is also performed with minimal fluid. Not more than 0.2 cc of irrigating fluid should be used for hydrodissection and hydrodelineation (Fig. 5.3).

**Fig. 5.3:** Careful hydrodelineation in posterior polar cataract

**Phacoemulsification of Nucleus**

Infusion bottle should be lowered and extremely low power settings for phacoemulsification is used. A fine Nagahara chopper is used to incise the endonucleus in perpendicular meridians, dividing the nucleus into small quadrants. This should be done without countertraction and embedding the phacoemulsification tip. The quadrants are then phacoaspirated.
**Epinucleus Removal**

Epinucleus can be effectively removed using viscodissection. Viscoelastic is injected under the anterior capsular margin in one quadrant. The epinucleus is elevated with viscoelastic and is injected under the floor of epinucleus. Then the central epinucleus is elevated and aspirated using I/A handpiece (Fig. 5.4).

![Viscodissection of the epinucleus in posterior polar cataract](image)

**Fig. 5.4:** Viscodissection of the epinucleus in posterior polar cataract

**Cortex Aspiration**

The peripheral cortex is aspirated first using I/A handpiece. To avoid fluctuations in anterior chamber depth an attempt should be made to keep the I/A tip always occluded. The central posterior portion of cortex is elevated with viscoelastic and aspirated. With all these precautions, if the defect in posterior capsule is seen, conversion of posterior defect into posterior capsulorhexis, followed by anterior vitrectomy is necessary. IOL can be implanted in the ciliary sulcus and optic is captured in the bag.6

Sometimes the opacity comes off spontaneously due to infusion pressure during removal of the peripheral cortex, but in some cases, part of the opacity remains adhered firmly to the posterior capsule and could not be separated. In such cases, residual plaque can be left in place during surgery and later removed by Nd: YAG capsulotomy.6,7 Thus, the amount of material that can enter the vitreous is reduced.

**Phacoemulsification in Subluxated Cataract**

Reinforcement of zonules in eyes with zonular dehiscence is necessary before phacoemulsification. This can be done by the following:

1. Capsular tension ring
2. Nylon hooks.

**Capsular Tension Ring**

Capsular tension ring is an implantation device made of polymethyl methacrylate (PMMA) which is used for zonular reinforcement in eyes with weak zonular apparatus. The causes for weak zonular apparatus can be hereditary like Marfan syndrome, Weill-
Marchesani syndrome, homocystinuria, etc. Trauma either blunt or penetrating can lead to weak zonular apparatus. Other conditions like pseudoexfoliation syndrome and high myopia can have weak zonular apparatus.

**Designs:** The capsular tension ring is composed of an open, flexible, horseshoe shaped filament of polymethyl methacrylate (PMMA), with fixation eyelets at either end (Fig. 5.5a). It is available in three sizes 12.5, 13.5 and 14.5 mm.

![Figs 5.5a and b: (a) Capsular tension ring, (b) Modified capsular tension ring](image)

A modification of the ring designed by Cionni consists of a comma shaped filament of PMMA swedged onto the main ring, emanating at an angle of 90°, at the distal end of this filament is another eyelet (Fig. 5.5b). This CTR is used with profound zonular deficiency.

**Technique of insertion:**

i. The CTR can be inserted with forceps or by injectors. Capsular tension ring inserter consists of a spring loaded plunger assembly with a hook at its distal end. Easiest way is by Macpherson forceps or a Sinskey hook.

ii. It can be inserted through tunnel or paracentesis.

iii. In profound zonular weakness, a CTR should not be dialed into the capsular bag. In such cases, the leading fixation hole is positioned at its desired location and then “tire-ironed” into the capsular bag.

iv. Another method is, a CTR can be inserted above the anterior capsular rim. Eyelets can be engaged.
v. For localized zonular dehiscence, a CTR should be positioned so that the body of the ring is coincident with the weakened zonular fibers.

vi. In profound zonular weakness, the modified ring by Cionni can be sutured to the scleral wall. Preplaced 10–0 prolene suture taken through eyelet. Each of the two needles is then placed through the incision and diverted over the area of maximum zonular dialysis to exit through the ciliary sulcus and scleral wall. The ring is then inserted in the capsular bag and the fixating element captures itself anterior to the residual anterior capsular rim (Fig. 5.7).9

Fig. 5.6: Capsular tension ring being “tire-ironed” into the capsular bag

Fig. 5.7: Modified capsular tension ring by cionni sutured to the scleral wall
Time of insertion during surgery: The CTR can be inserted after capsulorhexis, but there are chances of cortex getting trapped against the capsular bag making cortical clean-up difficult later. To prevent this, following steps are advisable:

i. Hydrodissection should be performed.
ii. Aspiration of anterior and equatorial cortex.
iii. A viscoelastic is placed under anterior capsular rim thus displacing the remaining cortex posteriorly and creating space for the insertion of CTR.¹⁰–¹³

Disposable Nylon Hooks
Disposable nylon iris hooks are placed in the capsulorhexis in the quadrant where zonules are weak to support the lens. This can be done after capsulorhoxis is performed (Fig. 5.8).¹⁴

![Disposable nylon iris hooks](image)

**Fig. 5.8:** Disposable nylon iris hooks placed under the capsulorhexis in subluxated cataract before phacoemulsification

Hydrodissection and Hydrodelineation
One has to be extremely careful, multiple locations are used for partial cortical cleaving hydrodissection. During hydrodissection, the cannula should depress the posterior lip of the incision. This allows easy outflow of viscoelastic or fluid out of the eye and thus will prevent overinflation of anterior chamber with irrigating solution.

During phacoemulsification following are extremely useful:

i. Two handed rotations of the lens nucleus is recommended because the forces can be truly tangential and divided by using opposite sides of the same meridian.
ii. High cavitation tip (e.g. Kelman tip) have a great advantage because they can obliterate nuclear material in advance of the tip without exerting forces on the lens or the lens zonules. Variation of phaco sweep procedure can be performed in which initial groove formed, then without rotating the nucleus, a lateral and rotational motion of the phaco probe grooves is made in a lateral direction.
iii. Nucleus has to be stabilized during sculpting, through sideport with second
        instrument.
iv. Nonrotational cracking is least traumatic method.
v. Cortical aspiration is biggest threat to the zonules. Most of it removed during flipping
        and evacuation of the epinuclear shell. Viscodissection can be helpful to separate
        cortex from capsule.
vi. Aspiration of residual cortex is safer after the IOL has been implanted because IOL
        stabilizes the capsular bag.
vi. Foldable IOL optic with PMMA haptics sized for in-the-bag placement is ideal.
        PMMA haptics helps to increase haptic resistance and attempt to prevent capsule
        contraction syndrome and lens decentration.12

PHACOEMULSIFICATION IN WHITE CATARACT

In India, mature and hypermature cataracts constitute a significant proportion of
        cataracts. Phacoemulsification is ideally suited for immature cataracts in which red reflex
        is adequate for a continuous curvilinear capsulorhexis.

The two steps that make phacoemulsification challenging in eyes with white cataract
        are as follows:

1. Continuous curvilinear capsulorhexis
2. Emulsification of the hard nucleus—the uses of vital dyes like trypan blue has made it
        possible to deliver the benefits of phacoemulsification in these cases.

Continuous curvilinear capsulorhexis technique has improved significantly the safety of
        phacoemulsification technique (emulsifying the nucleus safely in the bag). The coaxial
        light of the operating microscope produces red fundus reflex which is necessary to
        visualize the anterior capsule while performing capsulorhexis. In mature and hypermature
        cataracts, this retroillumination is absent. The advancing edge of the anterior
        capsulorhexis is very difficult to visualize in this situation. There is risk of peripheral
        extension of the advancing edge of the capsulorhexis with its attendant complications.
        This can be avoided if the anterior capsule is temporarily stained with contrasting dye
        trypan blue (0.1%) that can be used to stain the anterior capsule thus helping its
        visualization during CCC.

Techniques

Trypan blue dye can be injected using the following:

i. Classic air bubble technique.
ii. Dispersive viscoelastic material.
iii. Intracameral subcapsular injection.
Classic Air Bubble Technique

Steps:

a. Air is injected in the anterior chamber through a 26 gauge needle. Single large uniform bubble essential for homogenous staining.

b. A 0.2 ml trypan blue (0.1%) injected under air bubble through 26 gauge needle (Fig. 5.9). The air allows to spread the dye over the capsule and also prevents dilution of the dye. The dye is bordered by the peripheral rim of the iris thus preventing direct endothelial touch.

c. Anterior chamber is thoroughly irrigated with irrigating solution after 5 to 10 seconds.

Fig. 5.9: Trypan blue (0.1%) injected under single large air bubble through 26 gauge needle

Using Dispersive Viscoelastic Material

Alternatively the dye can be injected under viscoat (sodium hyaluronate 3.0%—condroitin sulfate 4.0%) instead of air bubble. It is possible, to stain the anterior capsule with concentrations lower than 0.1% by this method.

Intracameral Subcapsular Injection

The dye is trapped in the subcapsular space, giving sufficient time for the surgeon to perform CCC. Posterior surface of the anterior capsule is stained hence when capsular flap is inverted during CCC, it enhances visualization of the advancing edge.
Advantages of Trypan Blue Staining

1. Trypan blue does not stain the corneal endothelium because it selectively stain dead corneal endothelial cells. Hence, it does not hamper surgical view while phacoemulsification either by coating the endothelium or by causing corneal edema.
2. Peripheral stained rim of anterior capsule is visible during phacoemulsification thus avoiding damage to the capsular rim by phaco tip.

Precautions

Trypan blue being potentially carcinogenic vital dye its lowest effective concentration, i.e. 0.1% should be used. Permanent blue discoloration of hydrogel IOL by intraoperative use of trypan blue has been reported. Hence, hydrogel IOL should be avoided.

Indocyanine green (ICG) dye can be as effective as trypan blue in staining the anterior capsule. Its disadvantages being apart from expensive, it has to be reconstituted and its shelf life is only 10 hours.

Nonstaining Techniques

Various nonstaining techniques for performing CCC in mature and hypermature cataracts are as follows:

1. CCC using diathermy is described in case of intumescent cataract in absence of red reflex. Its dis-advantage being fibrosis of margins of CCC due to development of heat and its margins possess less strength than usual CCC margin.
2. Use of endoilluminator described for visualizing anterior capsule during CCC.
3. Initially, Gimble reported two-step CCC method in which small CCC created first followed by second CCC around the first. He found phacoemulsification difficult with small CCC and there were increased chances of rupture of CCC margin during phacoemulsification.

Emulsification of Nucleus in Total White Cataract

In white cataract, hydrodissection and hydrodelineation are not necessary because the nuclei are mobile as the corticocapsular adhesions are minimal. Hydrodissection can make the nucleus excessively mobile by washing out the cortical material. For nuclear fragmentation and aspiration divide and conquer and phaco chop techniques are equally effective. The mature and intumescent cataracts are not very hard, however hypermature cataracts are relatively hard to emulsify.

Deep anterior chamber should be maintained everytime during phacoemulsification. This prevents rupture of the posterior capsule as it is not protected by an epinuclear cushion.
CATARACT SURGERY IN A PATIENT WITH UVEITIS

Cataract surgery in a patient with uveitis is more complex because it involves the following:

1. Meticulous control of perioperative inflammation.
2. Appropriate surgical timing.
3. Modified surgical techniques to remove cataract in presence of posterior synechia and undilating pupils.
4. Type and material of IOL to be used.

Preoperative Control of Intraocular Inflammation

Complete abolition of all active inflammation for at least 3 months prior to surgery is necessary for good surgical outcome in uveitic cataract. One exception for this is protein leaking lens (phacolytic glaucoma) in which immediate surgery is mandatory.

Supplementary perioperative anti-inflammatory therapy recommended is as follows:

1. One mg/kg/day of prednisone and a drop of 1% prednisolone acetate eight times a day 2 days before surgery.
2. Oral nonsteroidal anti-inflammatory agent twice daily and a topical nonsteroidal anti-inflammatory agent such as flurbiprofen four times daily.24

Surgical Technique in Uveitic Cataract

A small pupil presents a challenging problem for cataract surgeons. Disposable nylon iris hooks are most effective means of increasing the size of rigid small pupils. And these are increasingly being used during phacoemulsification in small pupils.25 Simple stretching of the iris is effective when pupil diameter is 4 to 5 mm (Fig. 5.10).

Figs 5.10a and b: Disposable nylon iris hooks for increasing pupil size: (a) Classic technique, (b) Modified diamond technique
Technique

Classic technique for using iris hooks: Four flexible nylon iris retractors are used and inserted at 90° apart from one another. The retractors are placed through 4 paracentesis wounds at the limbus. These are used to retract the iris, resulting in a pupil of square shape (Fig. 5.10a).

Modified diamond technique: This technique is a modified form of classic technique, devised mainly to prevent iris prolapse during surgery through a clear corneal wound. The phaco incision is shifted 45° to an area just anterior to one of the iris hooks. Thus, giving the shape of diamond to the pupil instead of square (Fig. 5.10b).

Complications

The use of these iris hooks may lead to certain intraoperative problems:

i. Iris chafing and iridodialysis: In a fully dialated pupil, the iris lies anterior to its anatomical position, which is posterior to the limbus. Between the two iris hooks there is wide platform of iris, that is elevated. This can lead to entanglement of an instrument and iris chafing.

ii. Iris prolapse: It can occur through clear corneal incision in classic method. Hence subincisional iris hooks with a diamond shaped configuration of the pupil is recommended.

iii. Damage to anterior capsule: During engagement of pupillary edge with iris hooks, the tip of the hook may damage anterior capsule. Hence, a bolus of viscoelastic material has to be injected between iris and capsule.

iv. During phacoemulsification: Small nuclear fragments may get stuck underneath the iris hooks. This can be prevented by doing in-the-bag phacoemulsification.

v. Localized Descemet’s membrane detachment: This can occur during insertion and removal of iris hooks hence one has to be gentle while doing this maneuver.

In addition to adequate pupil dilatation, peripheral iridectomy, synechiolysis are additional procedures needed in uveitic cataract surgeries.

The anterior capsulotomy recommended is capsulorhexis, because it allows the surgeon to be certain that the IOL is in-the-bag. Difficulty encountered during capsulorhexis is irregular fibrotic anterior capsular bands. These tend to inhibit consistent tearing of the anterior capsule. The capsulorhexis may be extended through the fibrous bands with capsulotomy scissors and then continued with forceps.

Capsule contraction syndrome is found frequently with capsulorhexis postoperatively. This is frequently encountered with small capsulorhexis. Hence, capsulorhexis should have a minimum diameter of 5.0 mm. It is found that twice as much epithelium can be removed with 5.5 mm capsulotomy as with a 4.0 mm capsulotomy. Some authors proposed a 6.0 mm anterior capsulotomy. It is recommended to do a well-centered capsulorhexis which should be as circular as possible.

Another fact influencing capsule shrinkage is lens epithelial cells. The more epithelium is left, the greater the potential for capsule contraction syndrome. Hence, vacuuming the undersurface of the anterior capsule to remove maximum lens epithelial cells is recommended.
The advantages of phacoemulsification are small incision, shorter surgical duration and thus less surgical trauma. All these may decrease the inflammatory response compared to ECCE. But carefully done ECCE with complete cortex removal is likely to achieve similar long-term results. In Juvenile rheumatoid arthritis, it is recommended a combination of surgical procedures like phacoemulsification followed by pars plana vitrectomy for total removal of lens. There are fewer chances of loss of lens fragments in vitreous with pars plana lensectomy and vitrectomy, though similar results can be achieved with this technique.

**IOL Implantation**

A posterior chamber IOL resting on the ciliary body or anterior chamber lens should be avoided to minimize haptic uveal contact in eyes with uveitis. If the posterior capsule ruptures to an extent that precludes IOL implantation in the bag, lens implantation should be aborted. In-the-bag posterior chamber lens is only well-tolerated in patients with uveitis. PMMA optic with polypropylene haptics should be avoided because polypropylene haptics are known to cause complement mediated inflammation. Hence, all polymethylmethacrylate (PMMA) IOLs are recommended.

Heparin surface modified (HSM) IOL has been recommended in patients with uveitis. Short-term clinical evaluation revealed significantly less anterior chamber reaction and lower IOL deposits in eyes with HSM IOL. Though, over the long-term, there was no statistically significant difference in postoperative visual acuity, corneal edema, anterior chamber reaction, amount of posterior synechia formation and IOL deposits. Hydrophobic acrylic IOL has the lowest incidence of aqueous cells in the first postoperative week as compared with the silicone, hydrophilic acrylic, PMMA and HSM PMMA IOLs. But cell reaction was similar in all these foldable IOL (Hydrophobic acrylic, hydrophilic acrylic and silicone) after 6 months of surgery.

Hydrophobic material IOL has shown to have a good effect on capsular biocompatibility and a sharp edged optic design reduces most effectively the formation of PCO in nonuveitic uncomplicated eyes. However, in uveitic eyes apart from IOL material optic edge design, the grade of postoperative inflammation is important factor in the development of PCO.

**Addition of Heparin in the Irrigating Solution**

Heparin, in addition to its anticoagulant activity, is known to have anti-inflammatory and antiproliferative effects. Heparin has been shown to induce apoptosis in human peripheral neutrophils, which may explain its anti-inflammatory effects. One ml of heparin sodium adding to irrigating solution which makes a diluted concentration of 10 IU/ml. Adding heparin sodium to irrigation might help control of easily postoperative inflammation after cataract surgery. In addition, it is safe and economical. However, it is not advocated as an alternative to HSM IOLs because the surface modification has a longer acting effect on flare and the cellular reaction on the IOL.
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Chapter 6
Recent Trends in Management of Cataract Surgery Complications

Technological advances has evolved cataract surgery dramatically over the last two decades. This increased instrumentation and technology has lead to increased complexity of cataract surgery and the advent of complications unique to these advances. Cataract surgeons should be able to avoid, quickly identify and manage these complication efficiently.

CATARACT SURGERY COMPLICATIONS

Orbital Hemorrhage

Factors that can lead to orbital hemorrhage during injectional anesthesia are as follows:

1. Excessive needle manipulation by the surgeon.
2. Patient movement during block retrobulbar (30%) and less commonly peribulbar (0.44%)
3. Patients on anticoagulant therapy.¹

In patients with bleeding disorders anticoagulation therapy should be discontinued before surgery. Alternative forms of anesthesia such as topical anesthesia should be preferred in whom anticoagulation therapy cannot be discontinued.

Management

i. Surgery can be safely done in cases of mild orbital hemorrhage.
ii. In severe cases, orbital hemorrhage produces positive pressure which needs canceling the surgery.
iii. Very rarely orbital hemorrhage leads to elevation of intraocular pressure which is enough to threaten vision.²,³

Orbital hemorrhage is considered severe, if

1. There is progressive proptosis.
2. A tight orbit.
3. Increased resistance to retropulsion.
In such cases, retinal arterioles should be evaluated for flow and pulsations. If retinal arteriolar pressure is compromised, urgent decompression should be performed. It can be done by the followings:

i. Dissection of the periocular space with a scissor.
ii. Lateral cantholysis.4

**Intraoperative Iris Prolapse with Small Incision Surgery**

Intraoperative iris prolapse can be very frustrating to the surgeon. Because it leads to the followings:

i. Risk of trauma to the iris.
ii. Makes introduction of instruments into the anterior chamber difficult.
iii. Distorts the pupil leading to cosmetic havoc.

**Causes**

i. Increased intraocular pressure from external or internal etiologies.
ii. Incision that is too large or placed too posterior.
iii. Improper placement of speculum.

**Management**

i. Aspiration of fluid and viscoelastic material from the anterior chamber via the second incision leads to lowering of intraocular pressure. Then the prolapsed iris can be gently repositioned.
ii. Judicious use of viscoelastic materials injected in the anterior chamber to maintain the iris within the anterior chamber.
iii. If this maneuver fails, small peripheral iridectomy should be performed at the site of prolapse. This neutralizes the pressure gradient between anterior and posterior chamber.
iv. At the conclusion of surgery a miotic agent is injected intracameraly. This will help reposition the iris in the anterior chamber.
v. Wound can be secured by placing deep sutures. This reduces the possibility of spontaneous prolapse with iris incarceration in the wound.

**Positive Pressure**

Positive pressure can lead to the followings:

1. Shallowing of the anterior chamber.
2. Iris prolapse.
3. Posterior capsule becomes convex, making it more susceptible to tearing.
4. Difficult to aspirate cortex and implantation of IOL.
Cause

1. Tight lids due to narrow palpebral fissures.
2. Inadequate lid akinesia.
3. Excessive traction from a fixation suture.
4. Misdirection of irrigating fluid into the vitreous cavity. This can occur due to a radial tear in the anterior capsule with extension to the posterior capsule, zonular disruption or any tear of the posterior capsule.\(^5,6\)

When positive pressure exists, following maneuvers are recommended:

i. Avoid excessive hydrodissection.
ii. Use highly viscous viscoelastic agents.
iii. Low aspiration rate.
iv. Short bursts of phacoemulsification power.
v. Intravenous mannitol for dehydrating vitreous.

Posterior Capsular Tear

Posterior capsular tear during phacoemulsification is the most significant complication for a cataract surgeon. Because, it increases the intraoperative risk of dropped nucleus or lens fragments and postoperative risks of cystoids macular edema and retinal detachment.\(^7\)

The main objectives in management of posterior capsular tear are as follows:

1. To prevent vitreous movement into the anterior chamber.
2. To prevent loss of nuclear and cortical material in the vitreous.

**Fig. 6.1:** Rent in posterior capsule during phacoemulsification

Immediate steps in case of posterior capsular tear are as follows:

1. Immediate lowering of the infusion bottle
2. Maintaining a stable anterior chamber. Before withdrawing instruments from the anterior chamber it is necessary to stabilize and replace volume in the anterior
chamber with irrigating solution or viscoelastic. Viscoelastic agent should be introduced over the rent (Fig. 6.1).

3. A lens glide is effective in securing the nucleus in the anterior segment.

If additional phacoemulsification is required, low aspiration and irrigation rates, low bottle height, low vacuum and short bursts of ultrasound power are used. If additional cortical removal is required, it can be done by the followings:

1. Automated irrigation and aspiration.

If automated irrigation and aspiration is to be performed:

1. The infusion bottle should be lowered immediately. This will decrease inflow and turbulence that may enlarge the capsule tear.
2. The irrigation and aspiration tip should be embedded into the cortex before the initiation of vacuum. This avoids removing the viscoelastic and promoting vitreous prolapse.

The safest way to remove the remaining cortex is by dry manual irrigation and aspiration. Cortex, that is too difficult to remove must be left behind. But every attempt should be made to clear the visual axis.

Surgeons’ new objective should be avoiding the extension of the tear. Hence, conversion of tear to posterior continuous curvilinear capsulorhexis (PCCC) must be attempted (Figs 6.2a to c).

**Figs 6.2a to c:** (a) Closed chamber vitrectomy through separate incisions. (b) Posterior CCC done by using cystitome, (c) Posterior CCC

This has following advantages:
1. It strengthens posterior capsule which allows vitrectomy with decreased chance of tear enlargement.
2. In-the-bag IOL implantation becomes possible.\(^8\)

\textit{Vitrectomy}

If vitreous prolapse occurs, vitrectomy is necessary. During vitrectomy, care must be taken to preserve anterior capsulorhexis. Vitrectomy can be performed either by anterior or by posterior approach.

i. \textit{Anterior vitrectomy}: Anterior vitrectomy can be performed by one-handed or two-handed technique.

   The one-handed technique allows the surgeon to use other instruments in the second-hand such as light pipe to better visualize the vitreous strands.

   The two-handed technique gives better control of the placement of infusion and thus allows better followability of the aspiration vitrector. In this technique, vitrectomy cutter should be inserted in the anterior chamber through a new paracentesis. This will create a closed system and therefore will minimize fluid outflow through the main incision during vitrectomy.\(^8\)

ii. \textit{Posterior vitrectomy}: This is an alternative to anterior approach and has to performed through pars plana.

iii. \textit{Dry vitrectomy}: Alternatively, dry vitrectomy is very effective for limiting the amount of vitreous removed. Anterior chamber is filled with viscoelastic and either an anterior or posterior vitrectomy is performed behind the viscotemponade.

A suspension of Kenalog (triamcinolone acetonide) can be used to highlight and help visualize vitreous in the anterior chamber. This is a method of visualizing vitreous gel in the anterior chamber.

\textit{Method}: 0.2 ml of injectable triamcinolone 40 mg/ml captured in a 5 mm filter and rinsed with 2 ml of balanced salt solution (BSS). It is then re-suspended in 5 ml of BSS and recaptured to thoroughly remove the preservative. The Kenalog particles are ultimately resuspended in 2 ml of BSS and injected into the anterior chamber using 27 gauge cannula. The Kenalog particles are trapped on and within the vitreous gel, making it clearly visible.

   Thus, helps surgeon in easily identifying and removing the vitreous from the anterior chamber. This reduces tendency for vitreous strands to remain incarcerated within the wound after vitrectomy.\(^9\)

\textbf{Dropped Nucleus}

A dropped nucleus is one of the cataract surgeons biggest fears because of the followings:

1. It requires additional surgery by the vitreoretinal specialist.
2. It increases the risk of postoperative cystoid macular edema, retinal detachment and persistent ocular inflammation.\(^10,11\)
Anticipation of this complication before it happens and pre-emptively works to prevent it is necessary. Immediately steps necessary on anticipating this complication are as follows:

1. Infusion should be immediately reduced by lowering the bottle height.
2. Descent of the nucleus and cortical material should be prevented.

If the surgeon decides to convert into extracapsular cataract extraction, following procedures have to be performed to prevent descent of the lens material.

Viscoelastic is injected behind the nucleus to establish a barrier. Hyperviscous agents such as sodium hyaluronate* can

1. create a stable shelf to prevent dislocation of the nucleus posteriorly.
2. the use of lens glide to cover the tear may be beneficial.
3. manual removal of nucleus and cortex can be done.

If the surgeon decides to continue with phacoemulsification, Kelman’s posterior assisted levitation (PAL) technique can be performed to save a dropped nucleus, which is an emergency maneuver. This has to be performed quickly.

* Andre Balaz in the mid 1970s pioneered the first successful viscoelastic sodium hyaluronate which allowed ophthalmic surgeons to protect corneal endothelium during cataract surgery

(Posterior Assisted Levitation)

Posterior assisted levitation is a challenge to the surgeon when during phacoemulsification, the entire nucleus or part of it starts to sink in the vitreous cavity. Attempts to retrieve a sinking nucleus by anterior approach usually fails. And, it may actually push the nucleus further back. In this situation Kelman’s posterior assisted levitation

(PAL) maneuver is invaluable. Kelman advocates performing this maneuver even on the suspicion of a posterior capsule rupture (Fig. 6.3).
**Fig. 6.3:** Posterior assisted levitation

*Method:* A spaluta is inserted via the pars plana and placed behind the nucleus or its major remnant. Then it is lifted forward into the anterior chamber. Relaxing incision to the anterior capsular rim may be required if anterior capsulorhexis is small and its rim is intact.\(^\text{12}\)

Phacoemulsification can be continued with low settings of flow, bottle height, vacuum and aspiration. Short bursts of ultrasound energy minimizes the chance of prolonged occlusion and surge with associated fluctuations in anterior chamber pressure and volume.

If the lens nucleus disappears then:

i. The cortex should be removed in combination with an anterior vitrectomy.

ii. If the nucleus does not appear during vitrectomy, surgeon can direct stream of irrigation fluid into the vitreous. If the nucleus becomes visible, it can be recovered by PAL technique, viscoelevation or by inserting a lens loop behind it.

iii. If the nucleus does not appear, the surgeon should remove cortex as much as possible, place an appropriate IOL over the anterior capsular rim, secure the wound with sutures and refer the patient to a vitreoretinal specialist.

### Acute Suprachoroidal Hemorrhage

Acute suprachoroidal hemorrhage is one of the most serious vision threatening complications of cataract surgery. It can be expulsive or nonexpulsive. Expulsive, when the bleeding pushes choroids and retina out of the wound and nonexpulsive when the bleeding remains confined within the globe.

Acute suprachoroidal hemorrhage is more likely to occur in older patients, history of arteriosclerosis, systemic hypertension, diabetes and patients on anticoagulant therapy.\(^\text{13}\)
Local factors like pre-existing uveitis, glaucoma, high myopia are predisposing factors for development of acute suprachoroidal hemorrhage. An essential factor in the development of acute suprachoroidal hemorrhage is sudden intraocular hypotension during surgery. The sudden drop in IOP when the eye is opened, creates a gradient between intravascular and extravascular pressure in the eye. Hence, incidence of acute suprachoroidal hemorrhage is more in patients undergoing extracapsular cataract extraction (0.13%) as compared to patients undergoing phacoemulsification (0.03%).

**Mechanism of Occurrence**

Sudden drop in IOP when the eye is opened, causes primary diffusion of fluid from the veins into the suprachoroidal space creating a suprachoroidal effusion, or a primary hemorrhage when a weakened artery ruptures. Or an acute suprachoroidal effusion can develop into a secondary hemorrhage. The arteries in the suprachoroidal space are stretched and then rupture because of increased distance between the sclera and the detached choroids.

**Management**

Cataract surgery in patients with all these predisposing factors should be performed using a small incision technique. If at all it occurs early recognition is important for proper management. The early signs are as follows:

i. Sudden shallowing of anterior chamber.
ii. Loss of red reflex.
iii. Globe becomes firm, abruptly.
iv. Patient complains of pain in spite of adequate anesthesia.

Once it is detected following steps are recommended:

i. Incision should be closed as quickly as possible. This can be done with manual tamponade using an index finger. The incision should be closed with strong sutures.
ii. Administration of mannitol intravenously. This dehydrates the vitreous and decreases the intraocular pressure.
iii. Creation of sclerotomies to drain the hemorrhage. This is made with stab sclerotomies in the involved quadrant 5 to 7 mm posterior to the limbus.
iv. The surgery should be aborted once the eye is closed.

Visual activity is often permanently reduced despite aggressive treatment.

**Descemet’s Membrane Detachment**

Large Descemet’s membrane detachment results in persistent postoperative corneal edema with a severe reduction in the patient’s visual acuity.
Prevention

i. Corneal incision are usually triplanar, the phaco tip should be introduced in a similar fashion. Hence, it is necessary to push the tip posterior when entering the anterior chamber.

ii. Avoiding forcing an instrument or IOL through a tight incision.

iii. A sharp blade is used to made the incision to avoid detachment of Descemet’s membrane.

Management

Small Descemet’s membrane detachment:

i. At the conclusion of surgery, it can be reattached by applying pressure on the posterior lip of the incision at the site of the tear to generate an egress of fluid.

ii. A small air bubble or viscoelastic agent can be used to tamponade a Descemet’s membrane flap into position during suturing of the wound.

Large or total detachment of Descemet’s membrane:

i. Reattachment of Descemet’s membrane is done by taking transcorneal mattress sutures to fixate Descemet’s membrane to the cornea in combination to intracameral air injection.19

ii. Air does not last long enough to hold totally detached Descemet’s membrane. Hence, intracameral injection of sulfur hexafluoride (SF6) or perfluoropropane (C3F8) is most effective means of managing this complication.20

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Chapter 7
IOL Power Calculation in Special Situations

The refractive results of cataract surgery has greatly improved due to recent advances in biometry. Accurate measurement of preoperative axial length is required for accurate IOL power calculation. Postoperative refractive surprises due to error in axial length and keratometry measurements are common. A 54% of all IOL power calculation surprises are due to wrong axial length measurements. Under ideal circumstances, an error of 1.0 diopter is seen in 15% of eyes.

The established method for determining axial length is ultrasound A-scan biometry. Partial coherence interferometry by IOL Master and corneal topography have improved spherical correction to the point that the new standard of error is only 0.50 diopters.

Table 7.1: Disadvantages of ultrasound A-scan biometry for axial length measurement

| 1. Local anesthetic has to be used. |
| 2. Risk of corneal epithelial abrasion and infection. |
| 3. The resolution of ultrasound is limited to 200 µm (using 10 MHz transducer). |
| 4. Accuracy reported is 100 to 200 µm. |

Recently, noninvasive optical biometry methods for measuring axial length has been developed. They are based on the principle of partial coherence interferometry (PCI). It is made commercially available as (IOL Master by Carl Zeiss (Tables 7.1 and 7.2).

Table 7.2: Advantages of partial coherence interferometry

| 1. Noncontact method, hence minimal error is avoided due to indentation of cornea as in ultrasound A-scan biometry method. |
| 2. No topical anesthesia required. |
| 3. Accuracy is reported to be between 5 µm and 30 µm. |

**Principle:** Principle is similar to conventional ultrasound A-scan which uses ultrasonic pulse echo-imaging technique. It measures the echo-delay and intensity using infrared light reflected back from internal tissue interfaces. Since the velocity of light is high,
echo-delay times cannot be measured directly and interferometric techniques have to be used.

The IOL Master can also measure corneal radius and anterior chamber depth. But the corneal radius and anterior chamber depth measurements are not based on the PCI principle but on the image analysis principle, in which distances between light reflection on cornea, iris and lens are measured.6

This IOL Master provides axial length measurements comparable to those by the immersion method (A-scan) and provides observer independent measurement results (Table 7.3).

Table 7.3: Limitations of partial coherence interferometry

1. Measurements not possible in total cataract.
2. Measurements not possible in patients with associated nystagmus.

IOL POWER CALCULATION

IOL Power Calculation after Corneal Refractive Surgery

An increasing number of cataract surgeries in eyes after keratorefractive surgery is expected within next few decades. Although cataract extraction seems to be possible without major technical obstacles, IOL power calculation turned out to be problematic. Feeding of measured average K-reading into standard IOL power calculation formulas results into overestimation of keratometric diopters, hence underestimation of IOL power leading to postoperative hyperopia.

Keratometry*

Manual keratometry analyzes only four points on two orthogonal meridians separated 3 mm on the paracentral cornea. Hence, asymmetry of corneal surface cannot be measured with this keratometry. Automated keratometry was found to be as accurate as manual keratometry with less variability than manual keratometry.8 A still small central area of the cornea (2.6 mm) is taken into consideration. In post-RK eyes with optic zone less than 3 mm, automated keratometers may be more accurate than manual keratometers. Computerized topography system

* Hermann von Helmholtz had five major accomplishments relating to ophthalmology, i.e. invention of an ophthalmoscope (1850), confirmation of the Thomas Young theory of color vision (1852), elucidation of the mechanism of accommodation (1854) and development of an ophthalmometer (1854). Ophthalmometer was the first device to measure corneal curvature accurately. Although, his ophthalmometer was a research tool, later modifications led to clinically useful models like keratometer7
measures more than 1000 points within the central 3 mm and more than 5000 points over the entire cornea. Hence topography analysis provides greater accuracy in determining the corneal power with irregular astigmatism compared with keratometers.

The main reason for underestimation of IOL power after keratorefractive surgery (RK, PRK and LASIK) lies in inaccurate determination of keratometric diopters.

Cause of inaccurate determination of keratometric diopters in PRK and LASIK:

i. Current keratometers and topography systems primarily measure radius of curvature of anterior surface of central cornea.

ii. Keratometric diopters are derived from this radius of curvature using an effective refractive index. Such an effective refractive index characterizes the refraction of a fictitious single refractive lens representing single anterior and posterior surface, (*Gullstrands model eye). This effective refractive index is considered valid as long as radius of anterior and posterior surface of the cornea are proportionate and resembles that of the model eye (Fig. 7.1).

iii. In PRK and LASIK, the radius of curvature of anterior surface is considerably increased and distance between both refractive surface is decreased.

iv. Hence, this method calculating keratometric diopters from anterior radius of curvature becomes inaccurate.9,10

Causes of inaccurate determination of keratometric diopters in RK:

i. There is mismeasurement of the anterior radius of curvature, main reason for inadequate prediction of keratometric diopters.10

* Herman von Helmholtz in his book “Handbook of Physiologic Optics” published the first accurate model eye. Helmholtz’s numbers were later slightly modified by his student, Alvar Gullstrand, in the model, that is used today as “Gullstrands model eye”7
ii. The location of the keratometry mires which are 3 mm apart from each other fall over an area of the paracentral “Knee” (Fig. 7.2).

iii. This results in measurement that is too steep.

**Fig. 7.2:** Anterior corneal curvature, post-RK

*Methods of Estimating Keratometric Power*

*Indirect method:*

a. The clinical history method: This method requires preoperative average reading, preoperative refraction and stable postoperative refraction. The stable postoperative refraction should not be due to cataract.

*Steps:*

i. Change in spherical equivalent refraction (post-refractive surgery refraction—pre-refractive surgery refraction), e.g. a patient of $-10.00$ sphere undergoes LASIK for correction of full $-10.00$ sphere and has stable postoperative refraction of plano.

\[
\text{SEQ} = \text{OD} - (-10.00 \text{ D})
\]

0\(+\)10.00 D

+10.00 D

ii. This has to be subtracted from preoperative keratometric power, (K pre) e.g. 44 D.

\[
\text{K post} = \text{K pre} - \text{SEQ}
\]

K post=44.00 D−10.00 D

K post=34.00 D

iii. The contact lens over refraction method: When pre-refractive surgery data are not available this method is used. Following parameters are needed to calculate the postrefractive surgery keratometric dioptries.

i. Power (P) and base curve (BC) of rigid contact lens.

ii. Spherical equivalent refraction without contact lens (MRx).

iii. Spherical equivalent refraction with contact lens on (ORx).
The post-refractive surgery keratometric diopters, K post will be
\[ K_{\text{post}} = BC + P + (OR_x - MR_x) \]
e.g. A plano rigid contact lens of base curve 41.00 D if used and a patient has a spherical equivalent manifest refraction of −2.00 D and over-refraction of −3.00 D.
\[ K_{\text{post}} = 41.00 + 0 + [-3 - (-2)] \]
\[ = 41.00 + 0 + [-1] \]
\[ = 40.00 \text{ D} \]

**Direct Method (Ignoring Posterior Curvature Change)**

Modern corneal topography machines has various algorithms to calculate estimated keratometric diopters. They can give power of the anterior corneal surface over a specified area, e.g. central 3 or 5 mm optic zone.

i. Sim-K: Simulated keratometric diopter or Sim-k measures more than 1000 points over a 3 mm annular zone.\(^\text{11}\)

ii. Effective refractive power (Eff R P): It is the mean refractive power of the cornea over the central 3 mm.\(^\text{12}\)

iii. Average corneal power (ACP): Maeda N et al developed the average corneal power parameter, which looks at the corneal power within the region demarcated by the entrance pupil of the TMS-1 tomography unit.\(^\text{13}\)

The problem with each of these techniques is that none of them take into account the posterior curvature, which is believed to be a highly variable between normal individuals.

**IOL Power Calculation in Pediatric Cataract**

In infants, there is rapid growth of the eye and thus increase in axial length during the first 2 years of life. This must be taken into account when choosing the diopteric power of the IOL in infants. In toddlers and older children, the eye continues to grow, although at a slower pace. As against the axial length, the corneal power drops considerably during the first 2 years of life.

Gordon RA et al showed a steep axial length growth rate, increasing by 6 mm (~20 D), from premature babies to age 2 years, while corneal power drops from 54 D to 44 D, offsetting 10 D.\(^\text{14}\)

Between the ages 2 to 5 years axial length growth slows to about 0.4 mm per year and only increases another 1 mm from 5 to 10 years, while corneal power remains stable.

It is recommended that childrens’ eyes should be undercorrected at the time of surgery, to offset the myopic shift that occurs in there growing eyes.\(^\text{15–17}\)

Dehan E et al advices to categorize the children as children younger than 2 years and children older than 2 years of age.\(^\text{15}\) For children under 2 years they advice to undercorrect the IOL Power by 20%, since axial length and keratometry readings change rapidly. For children older than 2 years they advice to undercorrect IOL power by 10%. This helps in minimizing the need for an IOL exchange later in life, when myopic shift occurs.

**IOL Power Calculation in Patients with High Myopia**
The various formulas for calculation of IOL power work best for eyes with normal axial lengths.18–21

Posterior pole staphyloma temporal to the fovea is commonly present in eyes with axial lengths longer than 30 mm. The distance from corneal vertex to fovea is 0.5 to 1.5 mm shorter than the distance from corneal vertex to the bottom of the staphyloma. The A-scan usually finds the perpendicular axis between corneal vertex to the bottom of the staphyloma and records the axial length.22 Hence, current third and forth generation IOL power calculation formulas have a tendency to give the IOL power lower than what is necessary, leaving patients with postoperative hyperopia. The use of B-scan ultrasonography to identify the location of a posterior pole staphyloma is necessary. Few refinements in preoperative measurement techniques helps to improve the accuracy of IOL calculation in eyes with extreme myopia.

IOL Power Calculation of Silicone Oil Filled Eyes

This condition arises when vitreous is replaced with silicone oil as in vitreoretinal surgeries. The refractive index of silicone oil is much less than that of vitreous. Hence, it acts as negative lens in the eye. This silicone oil refractive effect must be offset with more power in the IOL. The effect is dependent on the back surface of the IOL. A biconvex IOL creates the worst problem and a concave posterior surface (no longer available) causes practically none. Plano convex lens which is between the two is recommended. With a plano convex lens, 2 to 3 D must be added to the IOL power to compensate for this effect.23

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Chapter 8
Posterior Capsule Opacification

Posterior capsule opacification (PCO) a major post-operative complication following cataract surgery occurs in 20 to 50% of adult patients. Migration and proliferation of lens epithelial cells (LECs) onto the posterior capsule is considered the primary step in two major forms of PCO, posterior capsular fibrosis and Elshnig pearls. Inflammatory cells also plays a role in formation of PCO, in patients who have significant postoperative inflammation following cataract surgery.

INHIBITION OF POSTERIOR CAPSULE OPACIFICATION

Posterior capsule opacification being most common complication of primary cataract surgery, it continues to stimulate important work toward understanding its causes and thus preventing it from occurring (Table 8.1).

Table 8.1: Factors known to decrease posterior capsule opacification

1. Trauncated squared posterior IOL edge 360°.
2. Overlap of anterior capsular rim on the anterior IOL surface 360°.
3. Thorough clean-up of cortical matter.
5. Minimum postoperative posterior capsular folds.

Intraocular Lens Material

Sandwich Theory

An IOL can be biocompatible in a bioinert or bioactive way. PMMA and silicone are bioinert and acrylic is bioactive. For an IOL which is bioactive sandwich theory of PCO is proposed which is as follows:

i. The anterior rim of continuous curvilinear capsulorhexis forms a bond over the IOLs bioactive (acrylic) surface. When the bond is complete, the IOL and the capsular bag are a closed system (Fig. 8.1a).

ii. Another bioactive bond is formed between LECs, posterior capsule and bioactive IOL (acrylic) which has 90° edge to its optic (Fig. 8.1b).
The sandwich is formed and the cell-posterior capsule and the cell-bioactive IOL surface junctions prevent more cells from migrating behind the IOL, thus preventing PCO.

Figs 8.1 a and b: (a) Bioactive bond is formed between IOL anterior surface and capsulorhexis. (b) Bioactive bond is formed between LECs, posterior capsule and bioactive IOL (acrylic) which has 90° edge to its optic

Hence without this bond, LEC freely migrate and proliferate behind the IOL, causing higher rate of PCO, as seen in PMMA and silicone IOL.1

Anterior Capsule Rim Stability and PCO

Continuous curvilinear capsulorhexis (CCC) has become common because it increases surgical safety during phacoemulsification and allows fixation of IOL in the bag. Overlap of the anterior capsular rim for 360 on the anterior surface of IOL optic helps in preventing PCO. A “shrink-wrap” phenomenon is produced due to sequestration of the IOL in the capsule.12

The relationship of the anterior capsule to the IOL is dynamic, and anterior capsule contraction or retraction can occur. Initial large CCC≥5.5 mm tends to retract and smaller than 5.0 mm CCC constrict. This is because, when the CCC is large, there is small area between the IOL and anterior capsular rim causing the retraction forces to dominate.
With small CCC, relatively more LECs come in contact with the IOL surface and undergoes fibrous metaplasia, causing a constriction of the capsular opening.

In acrylic IOL, the anterior capsule remains in the same position on the anterior surface of the IOL from the immediate postoperative phase till 1 year after surgery. The reason for this is that there is bioadhesion between the anterior capsular rim and the IOL. This also explains clear anterior capsule and less PCO in acrylic IOL as compared to PMMA and silicone IOL. 

**Intraocular Lens Design**

1. A convex plano IOL was found to be superior to the biconvex lens in inhibiting migration of LECs. A convex plano IOL forms a firm contact between IOL and the posterior capsule which blocks migration of LECs migration behind the IOL.

2. The squared off edge of the acrylic IOL creates a sharp bend in the posterior lens capsule. This prevents migration of the LECs behind the IOL. A typical PMMA IOL with rounded edge do not prevent migrating LECs. But when the edges of PMMA lens were also squared off, a similar inhibition effect is observed. The truncated edges is equally effective in PMMA, hydrophobic acrylic, hydrophilic acrylic and silicone IOLs.

**Position of Intraocular Lens**

The IOL haptics both in-the-bag creates a barrier effect for development of PCO. This is the best position to place the IOL for preventing development of PCO.

**Surgical Technique**

1. Polishing the undersurface of anterior capsular rim and posterior capsule removes remaining LECs, this helps in preventing PCO. Retained cortex increases inflammation and inflammation has been shown to increase PCO formation. The impact of the truncated edge of an IOL is overcome by this retained cortex allowing lens epithelial cell growth behind IOL.

   Conversely, aggressive removal of lens epithelial cells on the anterior capsule may increase PCO. The reason behind this is, there is decrease in anterior capsular reaction which is necessary in pushing the truncated edge of IOL over the posterior capsule thereby producing a discontinuous bend.

2. An in vitro study found no significant difference in the rate of cell growth on the posterior capsule with the two surgical techniques, i.e. phacoemulsification and extracapsular cataract extraction.

3. In pediatric cataract surgeries, of the different methods for management of posterior capsule and anterior vitreous, the only method which prevents PCO formation is posterior continuous curvilinear capsulorhexis with anterior vitrectomy. Even posterior capsulorhexis without vitrectomy with or without optic capture does not prevent development of PCO.
4. A capsule bending ring made of PMMA which has a sharp edge is inserted in the bag. The idea is to induce contact inhibition of the migrating LECs after cataract surgery, thus preventing PCO. The ring is inserted

**PLATE 1**

Figs 8.2a and b: (a) Slit lamp retroillumination photograph. (b) Slit lamp retroillumination photograph, wedge is checked if 50% of the wedge is opacified
Fig. 8.3: Software for quantification of posterior capsular opacification into the capsular fornix before IOL insertion. The PCO is found to be reduced in eyes with this ring.  

Capsular Folds

Folds in the posterior capsule increase the incidence of PCO. The folds occur due to long haptic length or if the haptics are too stiff. However, haptics that are too short and flaccid will also result in PCO by not filling out the capsular bag.

ASSESSMENT OF PCO

Amount of PCO can be quantified. Various methods described are as follows:
1. **Photographic image analysis system**: Standardized slit lamp retroillumination photographs are analysed (Figs 8.2a and b, Plate 1). A posterior capsule opacification score calculated by multiplying the density of the opacification graded from 0 to 4 by the fraction of the capsule area behind the IOL optic that is opacified.  

2. **High resolution digital retroillumination imaging**: A system is developed that uses coaxial illumination and imaging with a digital camera directly linked to a computer for verification of image analysis (Fig. 8.3, Plate 2).

## Treatment of PCO

Nd: YAG laser posterior capsulotomy is the definitive treatment of PCO.

1. Elschnig pearl formation along the posterior capsulotomy margin after Nd: YAG laser capsulotomy is a common and significant complication. It can be noted within 1 year after capsulotomy.

   **Mechanism of formation**: When the posterior capsule is disrupted by the Nd: YAG laser, intravitreal growth factors can directly affect LECs. Aqueous humor may dilute these factors to diminish their activities in aphakic eyes. Intraocular lens implantation and CCC may promote Elschnig pearl formation. This is because, IOL in the bag, due to compartmentalization of anterior chamber, hinders the dilution of these factors.

2. Spontaneous disappearance of Elschnig pearls after Nd: YAG laser posterior capsulotomy* is described. It may take several years after capsulotomy. Probable causes are as follows:

   • Falling of pearls into the vitreous through the capsulotomy
   • Phagocytosis of pearls by macrophages
   • Cell death by apoptosis

* Doctor Danielle Avon Rosa first demonstrated that Nd: YAG laser posterior capsulotomy was a safe and effective therapy for the treatment of PCO.

## Newer Treatments of PCO

**Posterior capsule polishing by neodymium**: YLF picosecond laser in a model eye is studied. This eye model consisted of a latex posterior capsule facsimile to demonstrate micron level polishing to treat posterior capsule opacification. Energy treatment levels ranged from 5 to 15 ml. The polishing effect was seen with all energy settings. IOL was found to be safe with energy setting below 5 ml. The authors feel it is a safe and effective procedure in human eyes also.

**Elimination of LECs at Time of Surgery**

Caffeic acid phenethyl ester which is the active component of propolis produced by Honeybees was studied in rabbit eyes.
i. This material shows selective toxicity to certain transformed fibroblasts in carcinoma cell lines but not to normal cells.  
ii. A new immunotoxin (IMT) is studied for its effectiveness to inhibit PCO following cataract surgery. The IMT is specific to human LECs and has been shown to be cytotoxic to these cells in vitro.  
iii. Catalin was examined in rabbit eyes to test its inhibitory effects on PCO. The degree of PCO was found to be much less as compared to placebo group in which corneal absorption of catalin is very poor, hence the frequency of its administration to produce these results should be more.  
iv. Carbon dioxide laser has been used in sheep and rabbits to burn the LECs in the equatorial and anterior peripheral regions of lens capsule. A major limitation of this technique is laser probe has to be used under air, because a viscoelastic agent plugs the hollow probe and absorbs laser energy.

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Chapter 9
Prophylaxis for Postoperative Endophthalmitis

MODERN OPHTHALMIC OPERATING ROOM AND INSTRUMENT STERILIZATION TECHNIQUES

PREVENTION OF INFECTIONS IN OPERATING ROOM

Prevention of postoperative endophthalmitis is the final goal in any cataract surgery. Hence maintenance of asepsis in operating room rather operating room complex is important.

The prevention of surgical infection in the operating theater is a complex pursuit. These many facets that may be divided into four main components as in Table 9.1.

Location of Operating Room Complex

Operating room complex should be located on a separate floor (top floor) of a building or at least in a separate wing of a floor. It should be away from wards where indoor patients are admitted to avoid cross-contamination. Operating room should be exclusively for ophthalmic surgical procedures and should never be shared with other surgical specialities. Toilets for both patients and operating room staff should not be in operating room complex.

Window air conditioner is preferable over central air conditioning since the filter from window air conditioner can be easily removed and cleaned regularly.

Design of the operating room complex should be such that asepsis maintenance can be managed easily in all its four areas, i.e. changing room, scrubbing area, transfer area and operating room proper.

There should be a separate room for changing clothes. It should be situated at the entrance of the operating room complex. It should have separate entrance and exit doors. Entrance door from where one enters with usual clothes and exit through which one enters inside the operating room complex with operation room dress, cap, mask and slippers.

Operating room should have scrubbing area which is situated just outside. The length of the scrubbing area should be such that one surgeon and one assistant can scrub simultaneously without touching each other elbows. The washbasin should be at waist height so as to avoid the arms touching the basin. The tap should have a long handle for opening or closing with ones elbow with arms folded. Running tap water from an overhead tank preferably through a filter (Aquaguard) should be used for hand scrubbing.
And stored water in a container should never be used. Opening of an overhead tank should always be kept closed and its regular cleaning is necessary.

Use of brush during scrubbing should be discouraged. As it itself can cause minute skin abrasions which can harbor bacteria. Washbasin should have a sufficient depth so that water running down from scrubbed hands should not spillover it again (Fig. 9.1).

There should be separate entrance to the patient in the operating room complex. This area contains a redline drawn on the floor. This redline demarcates the area where patient is shifted from outer trolley to inner one. The operating room proper* should not be more than 20×20 feet in length and breadth. It should have one entrance door and a separate service window for receiving sterilized surgical trays and instruments and disposing them after use.

The door should be swing door, so that it remains closed all the time. To enable proper cleaning and disinfection, dirt resistant less porous material (granite or marble) should be used for flooring and walls with minimum joints. The head end of the operating table should be away from the entrance door and it should be placed in such a way that there is enough space around it at all sides. Each operating room should not have more than one operating table. Operating room door should be closed from inside just before starting the surgery and opened only after completion of surgery. If multiple serial surgeries are to be performed instrument tray for next surgery should be opened only after shifting previous patient outside and next patient inside the operating room.

**Sterile Corridor**

This area has operating room on one side and sterilization room on other side. The sterilized instrument trays and linen can be supplied from the sterilization room to the operating room through the service window (Fig. 9.2).

**Operating Room Environment**

Circulating air entering inside the operating room should be filtered air. The high efficiency particulate air (HEPA) filter system removes microorganisms ranging in size from 0.5 to 5.0 µ. As sizes of most bacteria and fungi are in the range of 0.5 to 5.0 µ diameter. Frequent opening and closing of doors should be avoided. The operating room door should be always kept closed. Hairs of operating room personal should be properly covered under the cap. Number of people inside the operating room should be kept minimum. Temperature inside the operating room should be 18 to 24°C and humidity of 55 to 80%.

**Cleaning and Disinfection of the Operating Room**

Disinfectants can be divided into high level, intermediate level and lower level disinfectants. Glutaraldehyde 2%, formaldehyde 6% and hydrogen peroxide 6% are considered as high level disinfectants. Phenol is considered as intermediate level disinfectant. Alcohols 70 to 90%, sodium hypochlorite and quaternary ammonium compounds are considered as lower level disinfectants.
Low level disinfectants are effective against bacteria, fungi, lipophilic viruses but not against spores and tubercle bacilli. An intermediate level disinfectant destroys all these and tubercle bacilli but not spores. A high level disinfectant destroys all these and also spores. Rutala WA divided operating room items into critical, semicritical and noncritical for determining which level of disinfectant needed for which item.11

High level disinfectant needed for critical items like operating instruments, also high level disinfectant needed for semicritical items, i.e. instrument which touches mucous membrane, e.g. suture removal forceps, Bowman’s lacrimal probe, punctum dilator and intermediate to low level disinfectant for noncritical items which touches intact skin.11

Frequent wet mopping of all hard surfaces using a phenolic solution is recommended to keep the operating room environment clean.

**Regimen for Frequency of Decontamination in the Operating Room**

In the morning, before shifting first patient inside the operating room, items recommended for cleaning are operating table mat and sides, instrument trolleys, stools and chairs and floor.

After each patient’s surgery is over, cleaning of operating table mat and sides, instrument trolleys and floor is necessary. Infected cases should be operated in separate operating room meant for the same. If the operating room is soiled or contaminated due to any reason, recommended items for cleaning are entire operating table, chair, stools, anesthesia equipment and walls.12 Washing of operating room walls, floor, tables and trolleys with detergent should be done weekly. This enhance the effect of daily cleaning and disinfection.

Operating room should be fumigated with formaldehyde once in fortnight or after surgery on an infected case. Samples should be taken from various areas in the operating room for culture of microorganisms after fumigation.

**Formaldehyde Fumigation**

Before fumigation, adhesive tape is applied to all apertures in doors and windows of the operating room. Consider operating room of dimension 10 feet×10 feet of length and breadth and 10 feet in height. One litre of water is mixed with 500 ml of formaldehyde (40%). This mixture is put into an electric boiler or a large bowl is kept over an electric hot plate. After turning on the boiler or hot plate, the operating room is sealed. For the next 8 to 10 hours, the operating room is kept closed. To neutralize the formaldehyde, ammonium solution is introduced and kept in the room for another few hours. For every 1 litre of 40% formaldehyde used, one litre of water plus one litre of ammonium solution used.13

**Alternative Methods for Fumigation**

*Permanganate method:* Operating room of 1000 cu ft space, 5 ounces (1 ounce=28.2 gm) of potassium permangnate is placed in a jar, 10 to 15 ounces of formalin (40%) diluted with equal amount of water is poured over it. As soon as these reagents are mixed, a violent effervescence takes place and formaldehyde is set free.
**Paraform method:** Formalin when heated, the aldehyde changes into the solid polymeride paraform. Gas is generated by heating paraform tablets. For 1000 cu feet space of operating room 30 tablets are needed.

**Formalin spray:** In this method 250 cc formalin (40%) is mixed with 5 liters of tap water. This makes dilution of 1:20. Aeromax vaporizer is used to fumigate an operating room in this method. This is vaporized for 30 minutes.

**Disadvantages:** Spraying is not a satisfactory method as compared to vaporization of formaldehyde by boiling because fine aerosol has poor penetration.

In the west, formalin fogging is no longer a preferred method because of its carcinogenic nature. Manual cleaning with high level disinfectant is considered more effective infection control measure.\(^\text{12}\)

**STERILIZATION PROCESSES**

Sterilization processes can be divided into following heads (Table 9.2).

**Steam Sterilization**

Steam sterilizers are of two types (Figs 9.3a and b):

a. Downward displacement sterilizer (Gravity displacement sterilizer).

b. Prevacuum sterilizer.

The downward displacement sterilizer displaces air from the chamber and load (packed instrument tray to be autoclaved) by gravity. Prevacuum sterilizer displaces air from the chamber and load by vacuum pump. Hence, sterilization is much faster in prevacuum sterilizer than gravity displacement sterilizer because speed of air removal is faster in the prevacuum sterilizer.

Microprocessor control (i.e. automatic control of the sterilization process by computer or microprocessor) system is preferred over manual control system. Effective sterilization is considered when holding time of 121°C for 15 minutes is recorded.

Cleaning and drying of surgical instruments should be done before packaging.

**Packaging**

After cleaning and drying of surgical instruments, they should be properly packaged for loading into the sterilizer. Since, linen or textile is reusable, cheap it is commonly used for wrapping surgical trays. It should be used in a minimum of two thicknesses. It should be of a good quality muslin having a specification of 140 thread count.\(^\text{14}\)

The linen wrappers are being substituted by paper products for packaging recently. The reason being linen is poorly water repellant and also not a good bacteriological barrier. The various types of paper used are follows:

i. Medical grade Kraft paper.

ii. Laminated paper.

iii. Crepe paper.
iv. Non-glazed butter paper.

Plastic film cannot be used as packaging material for steam sterilization as water cannot penetrate plastic films in liquid or vapor form. Sterilizer rack should be used inside the sterilizer so that all the surfaces of instrument trays are directly exposed to steam. Instrument trays should be placed upright.

The instrument trays should be perforated (Holes) at the bottom.

After sterilization, trays should be left in the sterilizer till all the steam has escaped and it has undergone initial cooling.

**Monitoring of Sterilization Process**

For prevacuum sterilizer.

**Bowie Dick test:** It is a diagnostic test of a sterilizers’ ability to removes air from the chamber. Indirectly, it checks vacuum pump in a high vacuum sterilizer. It should be done daily. An adhesive tape which is printed with chemical substance (indicator) is fixed in a shape of a cross to a piece of suitable paper. This sheet is placed at center of a folds of multiple towels above and below. This is loaded inside the sterilizer. The color change should occur within 3½ minutes at 135°C.14

**Chemical indicators:** It should be used in each pack and in every cycle. These indicators show exposure to sterilization processes by means of physical or chemical change. These should be used inside and outside individual backs. Internal chemical indicator indicates whether penetration of sterilant was adequate.

**Biological indicators:** Bacillus stearothermophilus, a highly resistant spore forming microorganism used in spore form on paper strips for checking effectiveness of sterilization in steam sterilizer. Biological indicators are indicated during installation and after major repairs.

**Dry Heat Sterilization**

**Working Principle**

Heat is distributed equally throughout the chamber which is done by forced circulation of air with the help of fan, by which sterilization is achieved.

**Efficacy**

Since, hot air is a poor conductor and does not penetrate well, dry heat sterilization is less effective than steam sterilization.

**Indications**

Sterilization of sharp instruments which can be damaged by moist heat in steam sterilization method.
Sterilization Procedure

The sterilization of contents occurs at a temperature of 160°C for 60 minutes or 180°C for 30 minutes. There is destructive oxidation of constituents inside the cell (Bacterial) by sterilization. Automatically controlled dry heat sterilizers are preferred over manually controlled.

Monitoring

i. Chemical indicator should be used with each sterilization cycle.
ii. Biological indicator (Bacillus subtilis) should be used once a week.

Chemical Sterilization: Ethylene Oxide (Eto) Sterilization

Working Principle

Ethylene oxide alters the DNA of microorganisms by a process of alkylation thus killing them.

Efficacy

Ethylene oxide sterilization kills all organisms including tubercle bacilli and spores.

Indications

The Eto should be used only for those instruments that are liable for damage due to heat, e.g. phacoemulsification tubings, cryoprobes, laser probes, light pipe and vitrectomy culters.

Sterilization Procedure

Recommended parameters are as follows:

i. Temperature 37 to 60 °C depending on items.
ii. Exposure time 105 to 300 minutes.
iii. Humidity 45 to 75%.

Specially designed plastic bags made of polyethylene are used for packing instruments. Plastic pouches designed for Eto should have paper on one side. The plastic films should be in the range of 1 to 3 mils (fractions of a inch) in thickness. Excess of air should be removed before sealing the plastic bag to avoid bursting of seams during sterilization.

Advantages

i. There is minimal damage to sterilized instruments.
ii. Can pack the instruments before hand and once sterilized can be stored for relatively long time.

**Disadvantages**

i. Eto is toxic gas hence proper training of operating persons is necessary.
ii. Eto sterilized material that absorb Eto have to be properly aerated before use.

**Chemical Sterilization by Liquid Chemical Agents**

Liquid chemical agents are classified according to their germicidal activity as:

1. Low level disinfectant.
2. Intermediate level disinfectant.
3. High level disinfectant.

Only high level disinfectant destroys all bacteria, fungi, lipophylic virus and spores. Hence, surgical instruments require high level disinfectant for sterilization. A 2% glutaraldehyde is the commonest high level disinfectant used.

**Properties of 2% Glutaraldehyde**

i. It is noncorrosive, hence can be used for plastic or rubber material.
ii. It has low surface tension which allows easy access to inner surfaces of instruments.
iii. Stable in alkaline solution, hence it is available commercially with separate alkaline buffer which has to be added before its use.

**Indications**

For sterilization of sharp instruments which are liable to get damaged by heat. When used for an extended time it destroys all spores and is considered sterilant.

**Procedure**

Instruments to be sterilized are left in the solution for few hours. Thorough rinsing of instruments with normal saline is necessary before use because residual glutaraldehyde is very irritating to ocular tissues.

**Limitations**

Sterilization by glutaraldehyde is not recommended due to:

1. Lack of adequate monitoring system.
2. Effect of several variables on the efficacy of the process.

**Cleaning of Surgical Instruments**
i. All reusable operating instruments should be cleaned thoroughly prior to sterilization.

ii. It is not possible to sterilize an instrument without cleaning it first. Because the presence of soil on instruments inhibits the contact of a sterilant with microbial cell thus reducing its effectiveness.

iii. Cleaning should be started as soon as possible after use.

iv. The instruments, if composed of more than one part should be disassembled before cleaning.

Method

i. Tip of the instruments are cleaned using distilled water.

ii. Any blood or debris are removed from its surface using an instrument wipe or sponge.

iii. Then washing of instruments done in detergent solution. Alkaline detergents easily removes protein soils and protein-enzyme dissolving solution should be used for devices having lumens, e.g. phacoemulsification tips.

iv. Cleaning method can be either manual or mechanical.

a. Manual method: It includes rinsing the instrument with plenty of tap water to remove detergents (deionized and distilled water preferred over tap water) followed by drying.

b. Mechanical method: It is done in ultrasonic cleaners. In ultrasonic cleaners, sound waves are passed at high frequency (100,000 Hz.) through liquids. Submicroscopic bubbles are generated by these waves. When these bubbles collapse they create a negative pressure on the particles in the suspension. By this action bacteria are disintegrated and there is coagulation of protein matter.12,14,15

Phaco and irrigation/aspiration handpieces which contain lumen should not be cleaned in ultrasonic cleaners. Irrigating their lumen with high pressure water jet is recommended before sterilization.

v. Drying of instruments is necessary before packing in trays.

PROCEDURES FOR POSTCATARACT SURGERY ENDOPTHALMITIS PROPHYLAXIS

The surgical team and the patient are the prime sources of contamination during an operation, as evidenced by the good matches between bacteria of infected wounds and those of the team or the patient and by the poor matches between bacteria of infected wounds and airborne bacteria.16

Postoperative endophthalmitis is one of the most serious conditions that can occur after routine and otherwise uncomplicated cataract surgery. Fortunately its occurrence is rare (5 to 10 cases/1000). This can be one of the factors that hinders investigation of prophylactic measures.17 There are large number of variables in operating techniques among various surgeons. Hence, carefully controlled prospective and masked studies of systems for infection prevention have not been reported.18

SOURCES OF INFECTIONS
Origins for infection includes the followings:

1. Patients own ocular flora, lids and adnexa.
2. Surgical instruments, IOLs, irrigating solutions, viscoelastics.
3. Skin and respiratory flora of surgeon and assistant.
4. Operating room environment.

**Causative Organisms**

Ninety percent of causative organisms are gram-positive aerobic bacteria, 7% of organisms are gram-negative bacteria and fungi constitutes only 3% of all causative organisms.\(^{19}\) *Staphylococcus epidermidis and Staphylococcus aureus* are the two most common organisms causing postoperative endophthalmitis.\(^{20,21}\) These organisms are the most common organisms which can be recovered from patients eyelids.\(^{22,23}\)

Patients own ocular flora was found to be the main source of postoperative infection.\(^{20}\) Various prophylactic interventions recommended for this are preoperative topical antibiotic, preoperative use of povidone iodine, etc.

Irrigating solutions and viscoelastics are recommended to inspect before the use for intact packing and for obvious contamination of vial in the form of particulate matter.

It is recommended to scrub hands and arms above elbow for 7–8 minutes with soap alone. Recommended methods of hand hygiene include handwashing (washing hands with plain soap), hygienic handwash (washing hands with medicated soap) and hygienic hand-rub (use of antiseptic rubs).\(^{24}\) Of these hygienic hand-rub is the best technique.

Chlorhexidine can be used for hand disinfection system. It is found to reduce rate of nosocomical infections more effectively than alcohol and soap.\(^{25}\) The 7.5% povidone iodine scrub is another hand disinfecting agent. Scrubbing twice with 7.5% povidone iodine scrub, for 2 minutes each is adequate (Fig. 9.4, Plate 3).
Fig. 9.4: 7.5% povidone iodine scrub
A number of sources of postoperative infection may be targeted for prophylaxis. Commonly used prophylactic interventions can be applied preoperatively, intraoperatively and postoperatively. There are a number of prophylactic techniques to decrease the risk of postoperative endophthalmitis. But, justification of their use from the past literature is unclear.

**Preoperative Topical Antibiotics**

The role of topical preoperative antibiotics in reducing postoperative infection is documented. Topical antibiotics should be instilled only one day before surgery and should never be instilled more than 6 to 8 times on that day. Instillation of topical antibiotics for more than one day preoperatively leads to alteration of patients own bacterial flora and replaced by more virulent organisms. Hence it should be discouraged.

**Preoperative Use of Povidone Iodine**

Topical 5% povidone iodine applied once preoperatively has been shown to reduce the incidence of endophthalmitis by a factor of three (Fig. 9.5, Plate 3). There is no need for irrigating it out of one eye before surgery. Povidone iodine is bactericidal in 30 seconds.
There are no adverse reactions due to topical povidone iodine noted. Current literature strongly recommends the use of preoperative povidone iodine antiseptic for postoperative endophthalmitis prophylaxis in cataract surgery.29

**Preoperative Preparation of the Eye**

The regimens for preoperative antisepsis used to prepare the ocular surface are as follows:

1. Cleaning the lids, lid margins and adjacent skin with 5% povidone iodine.
2. Eyelash trimming.
3. Saline irrigation of conjunctiva.

i. Five percent povidone iodine used for cleaning of lids, lid margins and adjacent skin, is an effective method of eliminating microbes.30

ii. There is no evidence supporting lash trimming as a means of decreasing the ocular surface flora.31 Schmitz S et al showed that lash trimming is not associated with any reduction in the incidence of postoperative infection.32 Current trend is not trimming the lashes but isolating them with sterile adhesive drapes. This prevents to reduce passage of microorganisms into the eye.30

*Recommended procedure:* Lids, lid margins and surrounding skin after cleaned with 5% povidone iodine twice and allowed to dry. The adhesive drape is applied after opening the lids widely. The drape is cut between the lids and the eye speculum is applied such that the drape is under the arms of speculum thus isolating the eyelashes.27

iii. Saline irrigation of conjunctival sac, preoperatively is commonly practiced. This intervention has not been shown to reduce ocular surface flora aqueous contamination. Schmitz S et al found no reduction in the incidence of endophthalmitis with this intervention.32

**Antibiotics in Irrigating Solution**

Another intervention for postcataract surgery endophthalmitis prophylaxis is supplementing irrigating solutions with antibiotics. But, studies evaluating aqueous contamination rates show mixed results. Beigi B et al found 20% positive anterior chamber aspirate cultures in the group that received no antibiotics in irrigating solution as compared to 2.7% cultures from group that received antibiotics in irrigating solution (vancomycin 20 mg/L and gentamicin 8 mg/L).33 On the contrary, few literatures suggest no beneficial effect of antibiotics in irrigating solution as postoperative endophthalmitis antisepsis. The reasons for this being as follows.

i. Exposure to antibiotics for a short duration as in intraocular surgery has little effect on organisms responsible for endophthalmitis.34

ii. The half-life of gentamicin in the anterior chamber after completion of phacoemulsification is 51 minutes. It is cleared from the anterior chamber very quickly. Hence, the bactericidal levels required for reliable antibiotic prophylaxis is never maintained.35
Heparin in Irrigating Solution and Heparin Surface Modified IOL

This intervention for postcataract surgery endophthalmitis prophylaxis also has mixed result. Bacterial strains, i.e. *S. epidermidis*, *S. aureus* and *P. aeruginosa* were found attached in significantly lower numbers to heparin surface modified IOLs than to PMMA IOLs alone. Heparin in irrigating also inhibits attachment of *S. epidermidis* to regular PMMA IOLs. This is due to heparin reduces adherence of those bacteria by placing a highly hydrated layer between the bacteria and surface of IOL.36

But, there is no significant difference found in the rate of culture positive anterior chamber aspirates between the heparinized group and the control group.37

Subconjunctival Antibiotics

Subconjunctival antibiotics after cataract surgery is found to reduce postoperative infection but this reduction was found to be statistical insignificant. Literature is not conclusive regarding the choice of antibiotic though gentamicin is found to be most effective drug.38

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