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CATARACT

Types , Symptoms, Risk Factors, Diagnosis and Management with recent advances

STATE INSTITUT... E UTTAR PRADESH

Cataract, Types, Symptoms, risk factors, Diagnosis including recent advancements in diagnosis with management

राज्य स्वास्थ्य एवं परिवार कल्याण संस्थान, उ०प्र०

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उत्तर प्रदेश सरकार

ज्ञानावृते न मुक्तिः

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MESSAGE

Shri Partha Sarthi Sen Sharma
Principal Secretary
Department of Medical, Health
and Family Welfare
Government of Uttar Pradesh

The Continuing Medical Education (CME) module consists of educational activities which serve to maintain, develop, or increase the knowledge, skills, and professional performance and relationships that a physician uses to provide services for patients, the public, or the profession.

Medical officers at the primary level face numerous challenges in the treatments of cataract problem. Continuous improvement in knowledge and skills is essential to effectively address these challenges. However, due to their responsibilities in overseeing healthcare centers and implementing government policies, medical officers have limited time available for learning.

To tackle and rectify this situation, the State Institute of Health & Family Welfare (SIHFW) in Uttar Pradesh has designed a specialized CME module focusing on Cataract, Types, Symptoms, risk factors, Diagnosis including recent advancements for Medical Officers in the Provincial Health & Medical Services. This module has been developed in collaboration with experts in the field.

The module offers a comprehensive overview of cataract, types, risk factors and their management including recent advances. Its primary objective is to enhance the expertise and knowledge of Medical Officers, ultimately leading to an enhancement in healthcare services for the general population.

I want to extend my congratulations to SIHFW team and the other subject matter experts who played a role in crafting this comprehensive module. I am optimistic that this CME module will shed light on the treatment of cataract types, risk factors, contributing to improved Ophthalmology outcomes.

(Partha Sarthi Sen Sharma)

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MESSAGE

Dr. Brijesh Rathor
Director General
Medical and Health Services
Uttar Pradesh

Continuing Medical Education (CME) modules provide a means for healthcare professionals to stay abreast of the swiftly evolving practices in the field of Ophthalmology. Particularly in the realm of the Cataract Types, Symptoms, risk factors, Diagnosis including recent advancements in diagnosis with management including recent advances module, it has become increasingly essential for medical officers to stay updated on treatment methods and management approaches.

Medical officers operating at the primary healthcare level encounter numerous challenges in effectively handling cases involving cataract, types, risk factors, diagnosis and their management. Ongoing acquisition of knowledge and skills is imperative to tackle these challenges. However, due to their responsibilities in managing healthcare facilities and implementing government policies, medical officers have limited time for further education and skill development.

To address and rectify this situation, the State Institute of Health & Family Welfare (SIHFW) in Uttar Pradesh has formulated a specialized CME module centered on the treatment of cataract, types and risk factors for Medical Officers in the Provincial Health & Medical Services in Uttar Pradesh. This module incorporates the cataract, timely diagnosis and management of which can decrease the load of preventable blindness in our state. Its primary objective is to enhance the expertise and knowledge of Medical Officers, leading to an improvement in healthcare services for the population.

I want to extend my congratulations to SIHFW team and the subject matter experts who played a role in creating this comprehensive module. I am hopeful that this CME module will shed light on the effective diagnosis and management of Cataract Types, Symptoms, risk factors, Diagnosis including recent advancements in diagnosis with management including recent advances module.

(Dr. Brijesh Rathor)

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MESSAGE

Dr. Shailesh Kumar Shrivastava
Director General Family Welfare,
Directorate of Family Welfare
Uttar Pradesh

Cataract Types, Symptoms, risk factors, Diagnosis including recent advancements in diagnosis with management including recent advances module. is very important in saving lives and serious cataract. The reaching of an effected patient to a center which has facilities for treatment of helps in saving lives and physical impairment.

To meet the specific needs of Medical Officers in the Provincial Health & Medical Services of Uttar Pradesh, the State Institute of Health & Family Welfare (SIHFW) has designed an extensive Continuing Medical Education (CME) program centered on cataract, type, risk factors and their management. This program encompasses the latest advancements in the field and offers detailed guidance on essential management approaches for these conditions at the primary level. The objective is to facilitate early screening, detection, referrals, and treatment of patients.

Upon completion of this CME program, it is anticipated that Medical Officers in Uttar Pradesh will be able to elevate their service delivery through proficient screening, effective case management, appropriate referrals, and provision of treatment within their healthcare facilities. Consequently, communities will enjoy enhanced access to healthcare services, heightened patient satisfaction, and improved overall population health. This CME program not only enriches clinical and technical proficiency but also reinforces the delivery of healthcare services, bridging the gap between theoretical knowledge and practical application in healthcare management.

We extend our warmest wishes to the SIHFW team and look forward to the release of many more customized CME modules in the times ahead.

(Dr. Shailesh Kumar Shrivastava)

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MESSAGE

Dr. Narendra Agarwal
Director General (Training)
Medical Health and Family Welfare
Uttar Pradesh

The effective management of Cataract, types, diagnosis and management is pivotal in preserving lives and preventing serious eye health complications. Cataract is defined as the loss of lens transparency because of opacification of the lens. Age related cataract is the most prevalent type in adults, with the onset between age 45 to 50 years, while in children hereditary and metabolic causes are most common.

This module on Continuing Medical Education (CME) on cataract, types, diagnosis and their treatment for Medical Officers in Provincial Health & Medical Services in Uttar Pradesh provides a coherent and research-based insight to ophthalmological management. It has been designed and written for Medical Officers and healthcare professionals and takes government perspective in consideration, drawing upon and comparing ideas and developments from national and international health care practices.

Medical Officers in Uttar Pradesh will be able to scale up the services delivery in provide screening, management, referral and treatment in cataract, types, risk factors after this CME, thus benefitting communities. In addition to improving clinical and technical area of expertise, this CME will lead to providing improved access to cataract, types, diagnosis and treatment services and enhancing patient satisfaction and population health.

The director and the team at State Institute of Health & Family Welfare, Uttar Pradesh and the team of experts of the field has done a commendable job by publishing this CME module on Cataract Types, Symptoms, risk factors, Diagnosis including recent advancements in diagnosis with management including recent advances module, for Medical Officers in Provincial Health & Medical Services in Uttar Pradesh. I hope the participants coming to attend their upcoming CME will take advantage of this initiative and make the most in their field with this handy module.

(Dr. Narendra Agarwal)

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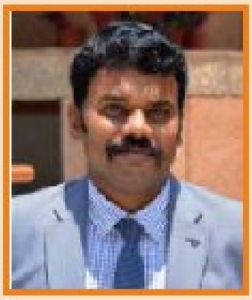
MESSAGE



Dr. Rajaganapathy. R
Director
State Institute of Health and Family Welfare
Uttar Pradesh

The primary goal of Continuing Medical Education (CME) is to ensure that Medical Officers engage in continuous learning and progression, ultimately leading to the delivery of optimal medical care for their patients. CME aims to assist Medical Officers in improving their performance in terms of patient care and satisfaction.

A cataract is a cloudy area in the lens of eye (the clear part of the eye that helps to focus light). Cataracts are usually an age-related condition. They first appear in the 40s or 50s, but may not affect vision until much later. Some cataracts are caused by an injury to the eye, long-term diabetes, the use of corticosteroid medications, or radiation treatment. Cataracts are the world's leading cause of blindness, accounting for half of all cases of blindness.

In the realm of eye healthcare, there has been a notable effort to underscore the importance of effectively managing cataract, types, risk factor, diagnosis among Medical Officers in Provincial Health & Medical Services. I hope that after this CME, Medical Officers in Uttar Pradesh will be able to scale up the services delivery in provide screening, management, referral and treatment in ophthalmic care, thus benefitting communities. In addition to improving clinical and technical area of expertise, this CME will lead to providing improved access to cataract, types, diagnosis and treatment services and enhancing patient satisfaction and population health.

To achieve this objective and enhance knowledge, the research and training faculty at the State Institute of Health and Family Welfare (SIHFW), Uttar Pradesh, in collaboration with the assistance of Dr Vinay Verma, Consulting Ophthalmologist, Lok Bandhu Shri Raj Narayan Combined Hospital, Lucknow and his team, have contributed to the development of this CME module. It is expected that this module will be widely distributed, and feedback on its effectiveness will be gathered in the coming months.

(Dr. Rajaganapathy. R)

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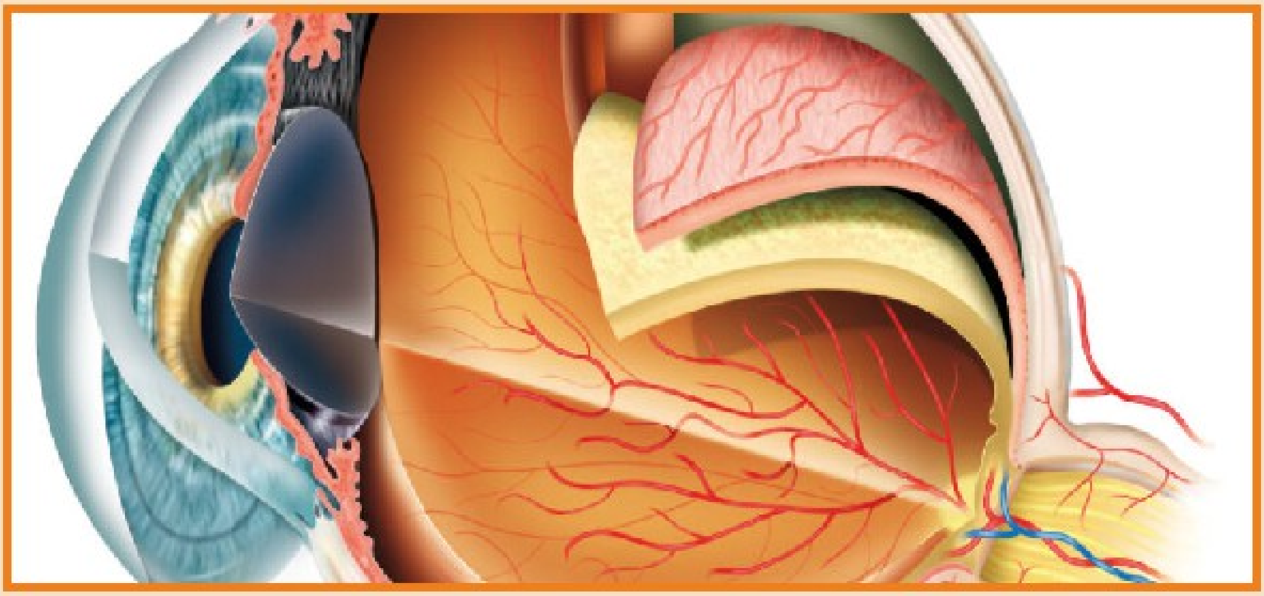
ज्ञानावृते न मुक्तिः

CHAPTER 1

INTRODUCTION TO HUMAN LENS

DEFINITION:

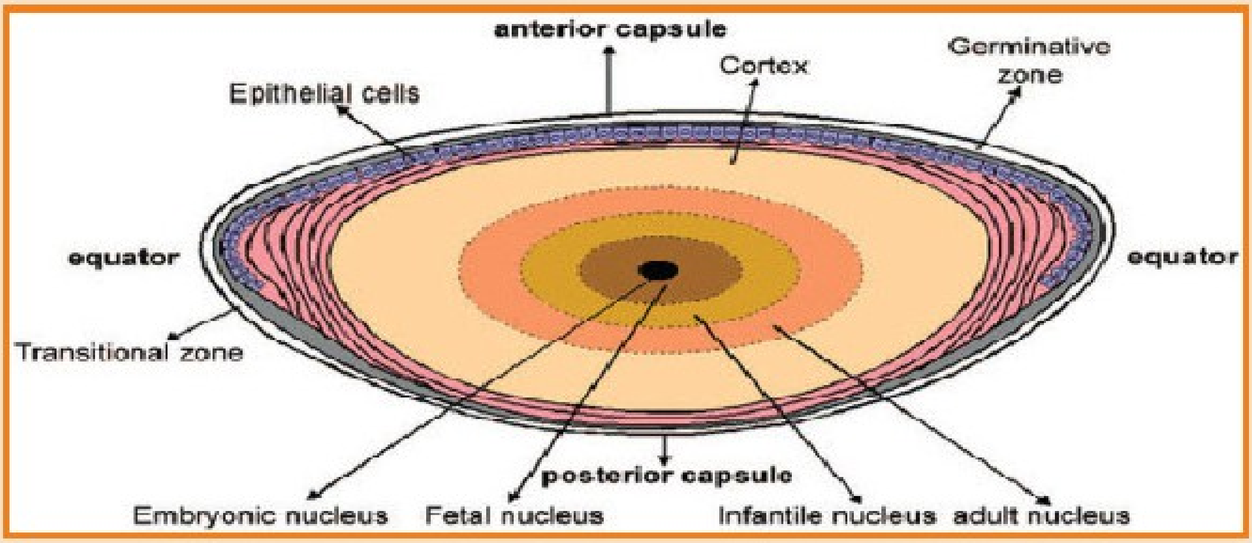
A normally transparent intraocular structure whose function is to alter the pathway of light that has entered the eye to focus the image on the retina.



The lens is a transparent structure that has evolved to alters the pathway of the light entering the eye. In 2002, the World Health Organization estimated that lens pathology (cataract) was the most common cause of blindness worldwide, affecting more than 17 million people across the globe. Cataract surgery is the most common surgical procedure performed in the developed world.

The lens is an asymmetric oblate spheroid that is avascular and lacks nerves and connective tissue. It is located posterior to the iris with its anterior surface in contact with the aqueous and the posterior surface with the vitreous. The lens is suspended by the zonular fibers that arise from the ciliary epithelium and insert 1–2 µm into the outer part of the capsule.

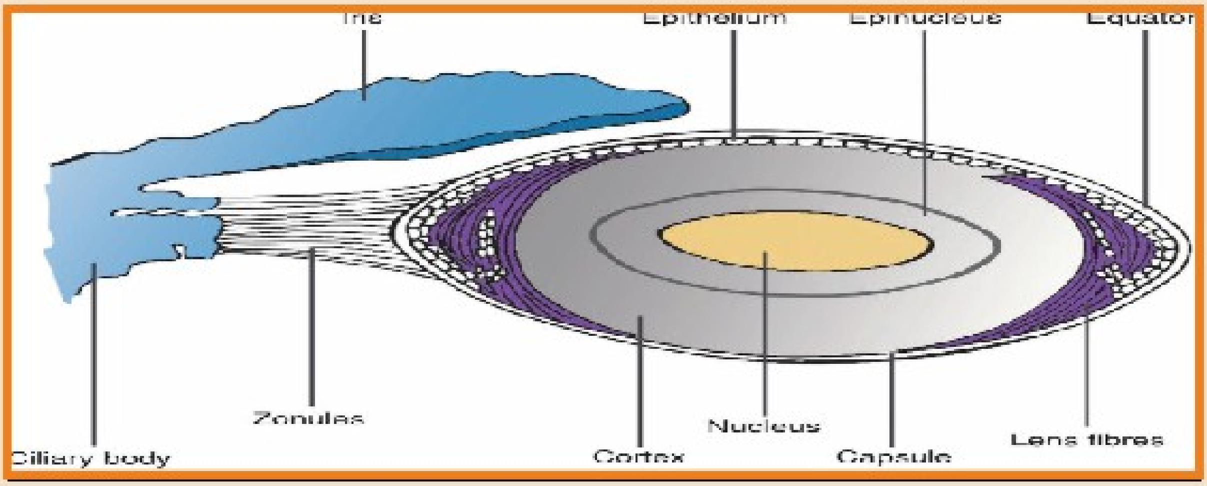
Histologically the lens consists of three major components: capsule, epithelium, and lens substance. The lens acts as spectral filter and readily absorbs the energetic ultraviolet (UV)component of the electromagnetic spectrum that, if transmitted, has the potential to damage the retina.



In conclusion, the lens is a deceptively complex structure that allows for the transmission and refraction of light. An orderly structure, stable metabolic state, and intact antioxidant system are mandatory to maintain clarity. A full understanding of the basic science related to the lens allows for appreciation of the numerous pathologies that affect it and thus their medical and surgical treatment.

ANATOMY OF THE LENS

The adult human lens is an asymmetric oblate spheroid that does not possess nerves, blood vessels, or connective tissue. The lens is located behind the iris and pupil in the anterior compartment of the eye. The anterior surface is in contact with the aqueous; the posterior surface is in contact with the vitreous. The anterior pole of the lens and the front of the cornea are separated by approximately 3.5 mm.The lens is held in place by the zonular fibers (suspensory ligaments), which run between the lens and the ciliary body. These fibers, which originate in the region of the ciliary epithelium, are fibrillin rich and converge in a circular zone on the lens. Both an anterior and a posterior sheet meet the capsule 1–2 mm from the equator and are embedded into the outer part of the capsule (1–2 μm deep). It also is thought that a series of fibers meets the capsule at the equator.

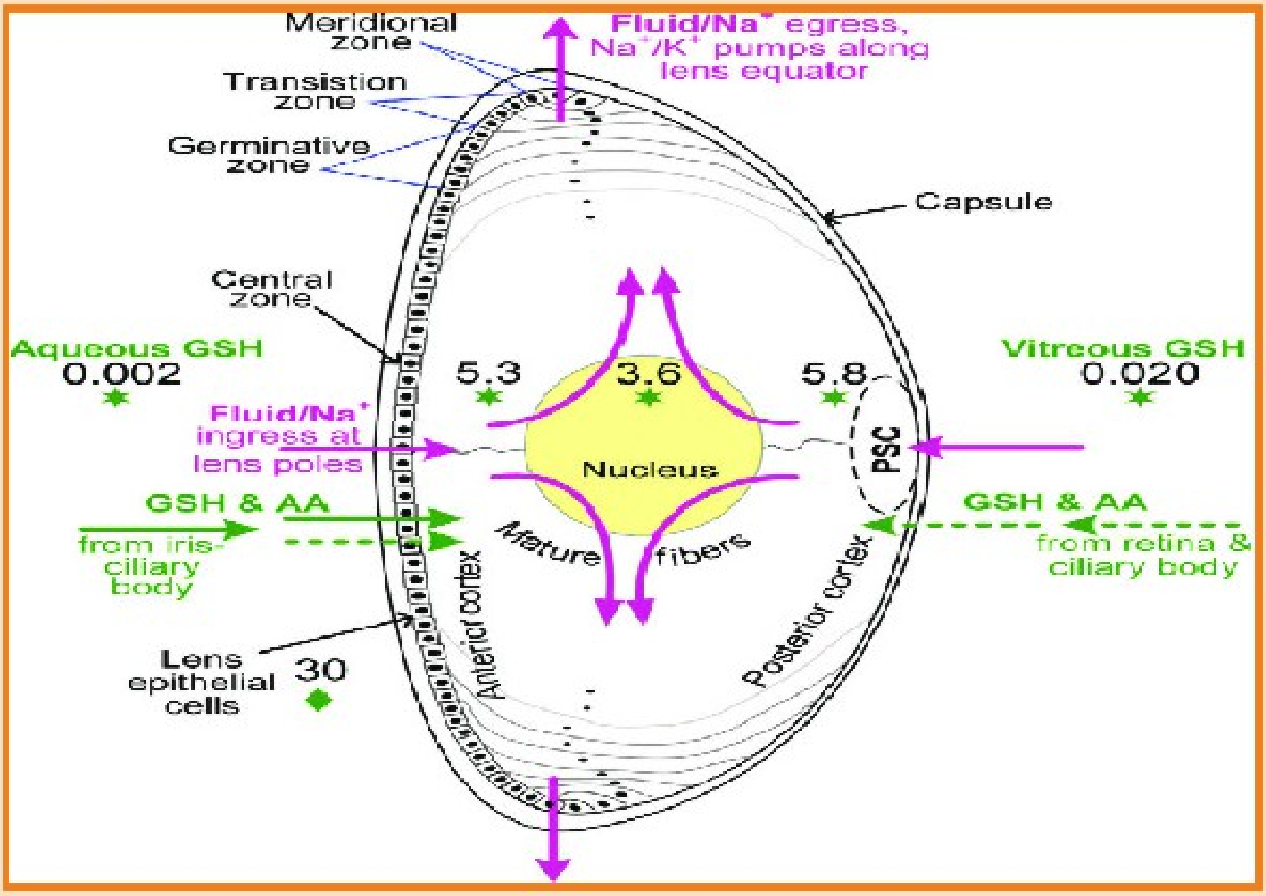


Histologically the lens consists of three major components—capsule, epithelium, and lens substance.

PHYSIOLOGY OF THE LENS

Permeability, Diffusion, and Transport:

After involution of the hyaloid blood supply to the lens, its metabolic needs are met by the aqueous and vitreous humor. The capsule is freely permeable to water, ions, other small molecules, and proteins with a molecular weight of up to 70 kDa. Epithelial cells and fibers possess a number of channels, pumps, and transporters that enable transepithelial movement to and from the extracellular milieu.



Transport of Ions:

Fiber cells contain large concentrations of negatively charged crystallins. As a result, positively charged cations enter the lens cell to maintain electrical neutrality, and the osmolarity of the intracellular fluid becomes greater than that of the extracellular fluid. Fluid flow and swelling are minimized by the resting potential of the plasma membrane being set at a negative voltage through potassium (K+)-selective channels. The Na+ ions that leak into the cells are exchanged actively for K+ ions, which diffuse through the lens down their concentration gradient and leave through ion channels in both the epithelial cells and surface fibers. There is a net movement of Na+ ions from posterior to anterior and of K+ ions from anterior to posterior. Although a pH gradient exists, which increases from the central nucleus to the periphery, the intracellular pH of the lens is approximately 7.0. Lens cells need to continually extrude intracellular protons, which accumulate due to inward movement of positive ions from the extracellular space and lactic acid from anaerobic glycolysis. The pH is regulated by mechanisms capable of increasing and decreasing intracellular acid levels. Molecules, especially proteins, also act as buffers.

Amino Acid and Sugar Transport:

The majority of amino acids and glucose enter the lens from the aqueous across its anterior surface. In addition, the lens can convert keto acids. into aminoacids. The lens acts as a pump–leak system: Amino acids are "pumped" into the lens through the anterior capsule and passively "leak" out through the posterior capsule.

BIOPHYSICS

Light Transmission:

The lens acts as a spectral filter absorbing long ultraviolet B (UV-B, 300–315 nm) and most of the UV-A (315–400 nm) wavelengths. While there is a transmission band centered around 320 nm of about 8% in children under 10 years, it is reduced to 0.1% by age 22. By age 60, no UV radiation transmits across the lens. The total transmittance of the young lens begins increasing rapidly at about 310 nm and reaches 90% at 450 nm, compared with the older lens, which begins transmitting at 400 nm but does not reach 90% total transmittance until 540 nm . The overall transmission of visible light decreases with increasing age, a feature that arises largely from age-related changes and brunescence in the lens .

Transparency:

The lens is opaque during the early stages of embryonic development. As development continues and the hyaloid vascular supply is lost, the lens becomes transparent. Transparency is due to the absence of chromophores able to absorb visible light and the presence of a uniform structure that scatters light minimally (less than 5% in the normal human lens). Light scatter is minimized in fiber cells once the fibers have elongated and their organelles have degenerated. Although the epithelial cells contain large organelles that scatter light, the combined refractive index of this layer and the capsule is no different from the refractive index of the aqueous, so light scatter is very small.

Refractive Indices:

The refractive index increases from 1.386 in the peripheral cortex to 1.41 in the central nucleus of the lens. Because both the curvature and refractive index of the lens increase from the periphery toward the center, each successive layer of fibers has more refractive power and therefore can bend light rays to a greater extent. The anterior capsular surface of the lens has a greater refractive index than the posterior capsular surface (1.364–1.381 compared with 1.338–1.357). The increase in refractive index from the surface to the center results from changes in protein concentration; the higher the concentration, the greater the refractive power. This increase must occur as a result of both packing and hydration properties, because protein synthesis in the nucleus is minimal.

Chromatic Aberration:

When visible light passes through the lens, it is split into all the colors of the spectrum. The different wavelengths of these colors result in different rates of transmission through the lens and some deviation. As a consequence, yellow light (570–595 nm) is normally focused on the retina; light of shorter wavelengths, for example blue (440–500 nm), falls in front because of its slower transmission and increased refraction compared with yellow light. Light of longer wavelengths, for example red (620–770 nm), falls behind because of the faster transmission and less refraction. Because the amount of dispersion between the red and the blue images is approximately 1.50–2.00 diopters (D), very little reduction occurs in the clarity of the image that is formed. As the lens accommodates, refraction increases as a result of the increasing power of the lens and, therefore, the amount of chromatic aberration also increases.

Spherical Aberration:

The lens of the human eye is designed to minimize spherical aberration since:

(1) refractive index increases from the periphery to the center of the lens;

(2) curvature of both the anterior and the posterior capsule increases towards the poles; and
(3) curvature of the anterior capsule is greater than that of its posterior counterpart.

As a result of these structural features, the focal points of the peripheral and central rays are similar, which ensures that reduction in the quality of the image is minimal. The pupil diameter also affects the amount of spherical aberration, because light rays do not pass through the periphery of the lens (unless the pupil is dilated). The optimal size of the pupil needed to minimize this imperfection is 2–2.5 mm.

Accommodation:

The lens is able to change its shape and thus the focusing power of the eye. This process is known as accommodation, and it enables both distant and close objects to be brought into focus on the retina. At rest, the ciliary muscle is relaxed and the zonules pull on the lens keeping the capsule under tension and the lens flattened. Light rays from close objects are divergent and are focused behind the retina in this configuration. The lens accommodates these objects by contraction of the ciliary muscles, relaxing the zonules, thus increasing the curvature of the anterior surface and decreasing the radius of curvature from 10 mm to 6 mm. The increase in curvature of the anterior surface increases the refractive power, so that the light rays from close objects are refracted toward each other to a greater extent and, therefore, converge on the fovea. Because the front of the lens has moved forward, the depth of the anterior chamber decreases from 3.5 mm to 3.2–3.3 mm. Very little change occurs in the curvature of the posterior capsule, which remains at approximately 6 mm. Accommodation is accompanied by a decrease in pupil size and convergence of the two eyes.

BIOCHEMISTRY

The lens requires energy to drive thermodynamically unfavorable reactions. Adenosine triphosphate (ATP) is the principal source of this energy, the majority of which comes from the anaerobic metabolism of glucose. Nicotinamide adenine dinucleotide phosphate (NADPH), which is produced principally via the pentose phosphate pathway, is used as a reducing agent in the biosynthesis of many essential cellular components, such as fatty acids and glutathione.

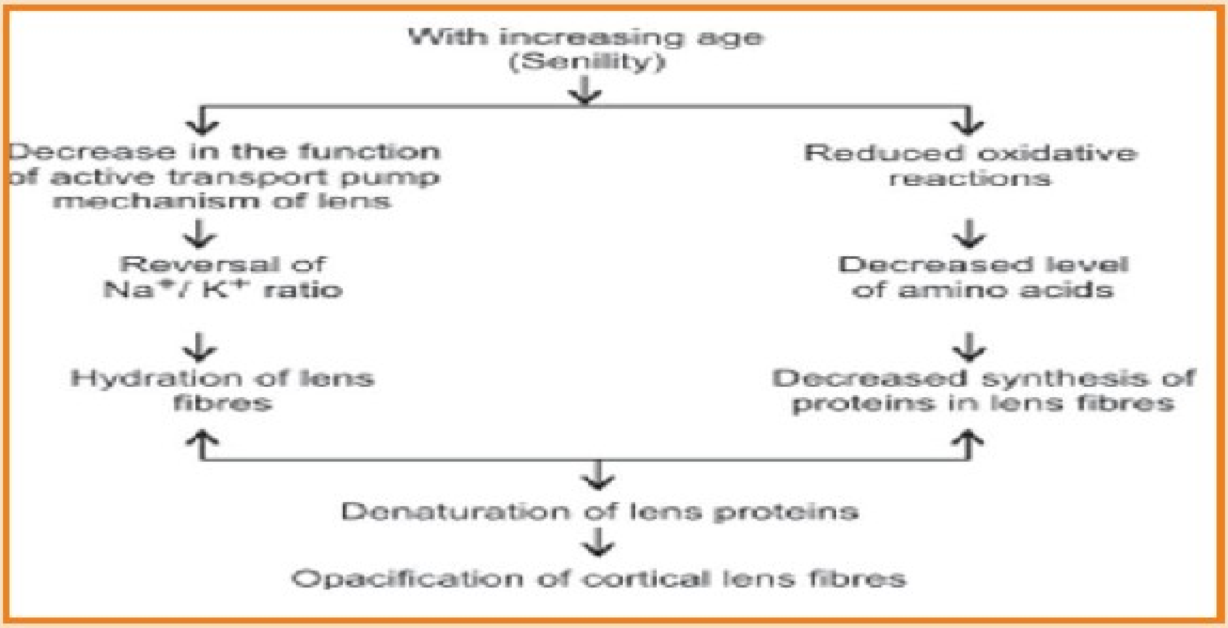
LENS CRYSTALLINS

Up to 60% of the wet weight of the human lens is composed of proteins. These lens proteins can be subdivided into water-soluble (cytoplasmic proteins) and water-insoluble (cytoskeletal and plasma membrane) fractions.

The water-soluble crystallins constitute approximately 90% of the total protein content of the lens.39,40 The crystallins found in all vertebrate species can be divided into the α-crystallin family and the β/γ-crystallin superfamily.. The α-crystallins are the largest. The β-crystallins are composed of light (βL) (c. 52 kDa) and heavy (βH) (150–210 kDa) fractions. The light fraction can be further subdivided into two fractions, βL1 and βL2.39–43 The smallest of the crystallins are the γ-crystallins. Six members of this family, known as γA–γF, have a molecular weight of 20 kDa.

AGE CHANGES

Continued increases in both the mass and dimensions of the lens are greatest during the first two decades of life. This results from the proliferation of lens epithelial cells and their differentiation into lens fibers. The oldest epithelial cells are found in the middle of the central zone under the anterior pole. Because cells are added to the periphery of this zone throughout life, the age of the cells decreases from the pole toward the outer units of this region, so that the newest cells always are found near the pregerminative zone. Because newly formed fibers are internalized as more are added at the periphery of the lens, the oldest fibers are found in the center of the nucleus and the newest fibers in the outer cortex. Each growth shell, therefore, represents a layer of fibers that are younger than those in the shell immediately preceding it. As the lens ages, epithelial cells become flatter, flatten their nuclei, develop end-organ failure bodies and vacuoles, and exhibit a dramatic increase in the density of their surface projections and cytoskeletal components. The basal surface area of the cell increases; thus the number of cells needed to cover a region of the growing anterior capsule is less than that needed to cover a region of the same size in a younger lens. This, in combination with the decrease in proliferative capacity, means that epithelial cell density decreases as the lens ages. Lens fibers show partial degradation or a total loss of a number of plasma membrane and cytoskeletal proteins with age. The most significant degradation is that of MIP26. Early in life spectrin, vimentin, and actin are present in both the outer cortical fibers and the epithelial layer, but they are degraded as the fibers age and are further internalized. By 80 years of age, expression of these cytoskeletal proteins is restricted to the epithelial cells. The cholesterol-to-phospholipid ratio of fiber cell plasma membranes increases throughout life, and consequently membrane fluidity decreases and structural order increases. These changes, which are known to occur from the second decade, are greatest in the nucleus and are therefore partially responsible for the increase in nuclear sclerosis (hardening)Furthermore, the changes in structure of the plasma membrane and the degradation of cytoskeletal components may contribute to the increase in the number of furrowed membranes and microvilli found on the fiber surface. From the fourth decade onward, ruptures are found in the equatorial region of cortical fiber plasma membranes. Reparation of these ruptures often prevents the formation of opacities. Any opacities that do develop become surrounded by deviated membranes and are therefore isolated from the remainder of the lens. The lens capsule thickens throughout life. It also increases in surface area as a result of the growth of the lens. Ultrastructural changes include the loss of laminations and an increase in the number of linear densities. Although the young lens capsule is known to contain collagen type IV and the aged capsule collagen types I, III, and IV, the presence of types I and III collagen in the young capsule has yet to be confirmed, but their synthesis may be age related.



PHYSIOLOGICAL CHANGES

Changes to the cellular junctions and alterations in cation permeability occur with age. The major gap junction protein MIP26 loses some of its amino acids to form new variants, which include polypeptides with molecular weights of 15, 20, and 22 kDa.51,52 The membrane potential of an isolated, perfused human lens may be −50 mV at the age of 20 years, but only −20 mV at the age of 80 years. Potassium (K+) levels remain constant at approximately 150 mmol/L, but the sodium (Na+) content of the lens increases from 25 mmol/L at the age of 20 years to 40 mmol/L by the age of 70 years. Thus, the Na+:K+ permeability ratio increases approximately sixfold, which results in a proportionately greater increase in the sodium content of the lens.54 The change in the ratio of these two ions correlates with the increase in optical density of the lens.55 The change in ion permeability with increasing fiber age is thought to occur due to a decrease in membrane fluidity as a result of the age-related increase in the cholesterol-to-phospholipid ratio. The lens, therefore, becomes more dependent on the Na+,K+-ATPase in the epithelial cells. The decrease in membrane potential also results from changes in the free Ca2+ levels, which increase from 10 mmol/L at the age of 20 years to approximately 15 mmol/L by the age of 60 years. It is thought that the Ca2+-ATPase may be inhibited by the decrease in membrane fluidity, which decreases the rate at which Ca2+ is pumped out of the cell. It also is possible that the increase in Na+ and Ca2+ permeability may result from the increased activity of nonspecific cation channels.

BIOPHYSICAL CHANGES

The absorption of both UV and visible light by the lens increases with age. Free and bound aromatic amino acids (tryptophan, tyrosine, and phenylalanine), fluorophores, yellow pigments, and some endogenous compounds (such as riboflavin) are responsible for the absorption properties of the lens. Tryptophan is cleaved in the presence of sunlight and air to form N-formylkynurenine and a series of other metabolic products, including 3-hydroxykynurenineglucoside (3-HKG). Because more than 90% of the UV radiation that reaches the lens is UV-A (315–400 nm), and 3-HKG absorbs light between 295 and 445 nm whereas tryptophan only absorbs light between 295 and 340 nm, this glucoside has a relative absorbance that is greater than that of tryptophan in the young human lens

(95% compared with 5%) As the lens ages, it changes from colorless or pale yellow to darker yellow in adulthood, and brown or black in old age. The autofluorescent properties of the lens also change with age. These changes in coloration, which are limited to the nucleus, are thought to result from the attachment of 3-HKG and its metabolic derivatives to proteins to produce yellow-pigmented proteins that also absorb light. As the concentration of these yellow pigments increases, they compete with 3-HKG and become the major absorbing species of the lens. Because these yellow proteins are fluorescent species, the wavelength absorbed increases to approximately 500 nm . A blue fluorophore, which absorbs between 330 and 390 nm and fluoresces between 440 and 466 nm, increases as the lens ages. Oxygen-dependent photolysis of the blue fluorophore contributes to the formation of a green fluorophore, which is excited between 441 and 470 nm and emits between 512 and 528 nm.The increased capacity of the lens to absorb visible light, in combination with the increased scattering properties of the lens (because of the aggregation of lens proteins and possibly the release of bound water), results in a decrease in transparency. The increase in the total number of photons absorbed is accompanied by an age-related loss in antioxidant levels, increasing the amount of photo-oxidative stress. Nonenzymatic glycation of proteins by the Maillard reaction results in the formation of advanced glycation end products, which also increase the yellowing of the lens. This reaction is initiated by the attachment of a sugar molecule (e.g., glucose) to an amino acid, normally valine or lysine. In young lenses, 1.3% of lysine residues of human crystallins are glycated, but by the age of 50 this increases to 2.7% and to approximately 4.2% in older lenses. Yellow fluorescent photoproducts also are formed in the presence of ascorbic acid, which is present at high levels in the lens.

REFERENCES:

1. *Kuszak JR, Clark JI, Cooper KE, et al. Biology of the lens: lens transparency as a functionof embryology, anatomy and physiology. In: Albert D, Miller J, Azar D, Blodi B, eds.Albert & Jakobiec's Princi ples and Practice of Ophthalmology. 3rd ed. Saunders; 2008: vol 1,chapter 104.*

2. *Snell RS, Lemp MA. Clinical Anatomy of the Eye. 2nd ed. Blackwell Science; 1998: 197–204.*

3. Hejtmancik JF, Piatigorsky J. Lens proteins and their molecular biology. In: Albert D, Miller J,*Azar D, Blodi B, eds. Albert & Jakobiec's Princi ples and Practice of Ophthalmology. 3rd ed.Saunders; 2008: vol 1, chapter 105.*

4. *Beebe DC. The lens. In: Kaufman PL, Alm A, eds. Adler's Physiology of the Eye: Clinical Application. 11th ed. Mosby; 2011:131–163.*

5. *Glasser A. Accommodation. In: Kaufman PL, Alm A, eds. Adler's Physiology of the Eye: ClinicalApplication. 11th ed. Mosby; 2011:40–69.*

CHAPTER 2

EMBRYOLOGY OF EYE

Development of eye starts around day 22 of gestation.

Formation of optic vesicle: -

- Neural plate shows linear thickened area on either side of it.
- It depresses to form the optic sulcus.
- It then forms the optic vesicle.
- Proximal part of optic vesicle constricts and elongate to form the optic stalk.
- As the optic vesicle grows laterally (3^{rd} week of gestation) it comes in relation with the surface ectoderm .

LENS PLACODE: -

Appears on 27th day of gestation

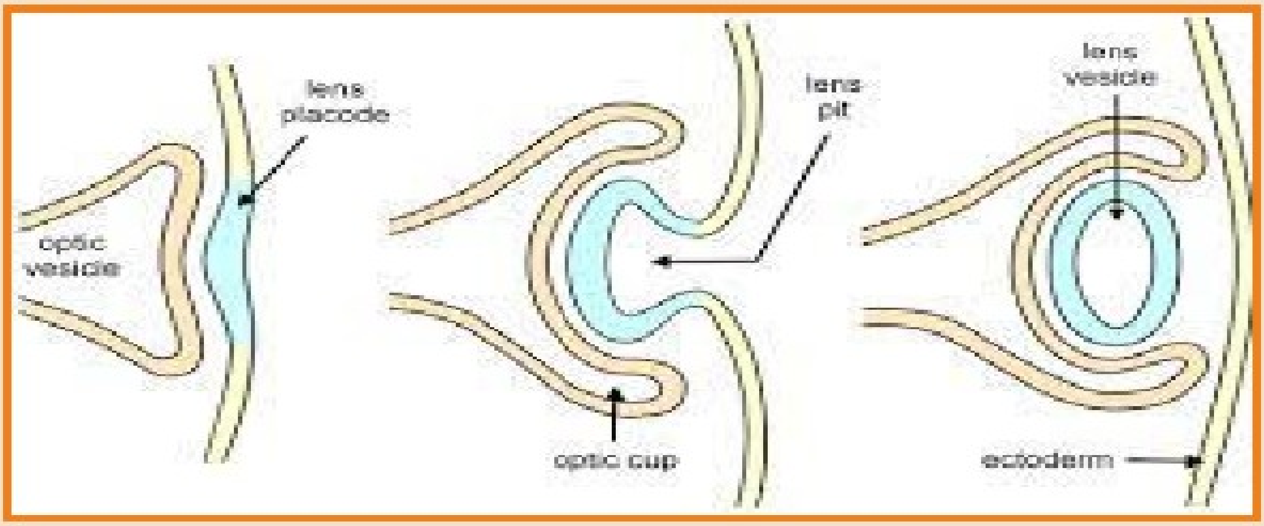
- The area of surface ectoderm overlying optic vesicles thickened to form lens placode or lens plate.

LENS PIT: -

- Appears at the 29th day of gestation.
- Lens placode and adjacent cells of optic vesicle invaginates inward to form lens pit.
- Also known as fovea lentis.

LENS VESICLE: -

- Formed at about 33^{rd} day of gestation.
- Lens pit separates from the surface ectoderm and forms lens vesicle.
- Consists of single layer of cuboidal cells covered by basal lamina.



PRIMARY LENS FIBRES AND THE EMBRYONIC NUCLEUS

- Cells of posterior wall of lens vesicle rapidly elongate and obliterate the cavity of lumen.
- By 45th day of gestation the lumen is completely obliterated and this transparent elongated cells are called primary lens fibres.
- Make up the embryonic nucleus that will ultimately occupy the central area of lens in adult life.

DEVELOPMENT OF LENS EPITHELIUM

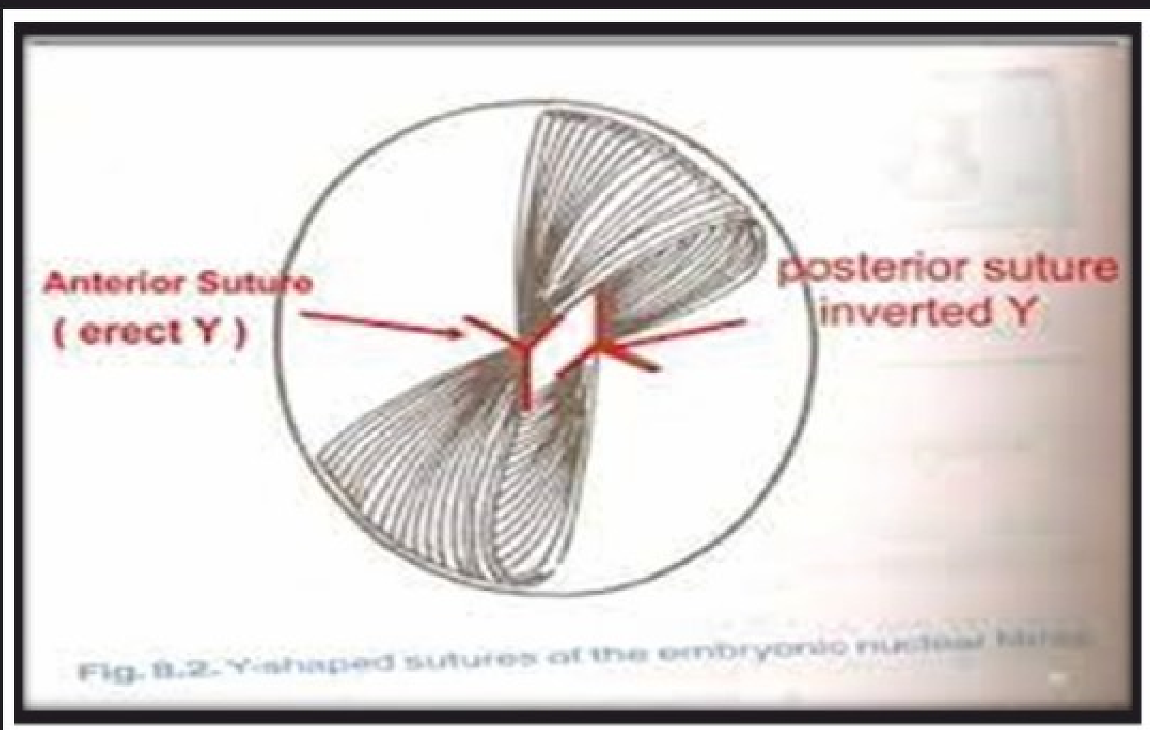
- Cells of the anterior lens vesicle still remain cuboidal and form lens epithelium.

SECONDARY LENS FIBRES

- Pre – equatorial cells of lens epithelium retain their mitotic activity throughout life and form the secondary lens fibres.
- Starting from the 7th week of gestation.
- Anterior aspect of fibres grow towards the anterior pole and posterior aspect grows towards posterior pole of the lens.
- Subsequently get displaced and meet on the vertical.

LENS SUTURE AND FETAL NUCLEUS

- These are formed only during fetal life .
- As secondary fibres are added , the sutures become more complex and dendriform .
- The secondary lens fibres formed between 2nd to 8th months of gestation make up the fetal nucleus.
- Erect Y anteriorly and inverted Y posteriorly.



REFERENCES:

1. *Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. Br J Ophthalmol. 2012;96(5):614–618.*

2. *The Italian- American Cataract Study Group. Incidence and progression of cortical, nuclear,and posterior subcapsular cataracts. Am J Ophthalmol. 1994;118(5):623–631.*

3. *Kahn HA, Leibowitz HM, Ganley JP, et al. The Framingham Eye Study. I. Outline and majorprevalence findings. Am J Epidemiol. 1977;106(1):17–32.*

4. *Klein BE, Klein R, Lee KE. Incidence of age- related cataract: The Beaver Dam Eye Study. ArchOphthalmol. 1998;116(2):216–225.*

5. *Livingston PM, Carson CA, Stanislavzky YL, Lee SE, Guest CS, Taylor HR. Methods for a population- based study of eye disease: The Melbourne Visual Impairment Proj ect. Ophthalmic Epidemiol. 1994;1(3):139–148.*

6. *Leske MC, Connell AM, Wu SY, Hyman L, Schachat A. Prevalence of lens opacities in the Barbados Eye Study. Arch Ophthalmol. 1997;115(1):105–111.*

7. *Varma R, Richter GM, Torres M, et al; Los Angeles Eye Study Group. Four- year incidenceand progression of lens opacities: the Los Angeles Latino Eye Study. Am J Ophthalmol.2010;149(5):728–734.*

8. *Feng YR, Meuleners LB, Fraser ML, Brameld KJ, Agramunt S. The impact of first and secondeye cataract surgeries on falls: a prospective cohort study. Clin Interv Aging. 2018;13:1457–1464.*

9. *Fong CS, Mitchell P, Rochtchina E, Teber ET, Hong T, Wang JJ. Correction of visual impairment by cataract surgery and improved survival in older persons: The Blue Mountains Eye Study cohort. Ophthalmology. 2013;120(9):1720–1727.*

CHAPTER 3

EPIDEMIOLOGY OF CATARACTS

In 2010 the Vision Loss Expert Group funded by the Bill & Melinda Gates Foundation, Fight for Sight, and others calculated that cataracts caused blindness (visual acuity in the better eye of less than 3/60) in 10.6 million people and moderate to severe visual impairment (MSVI, visual acuity of between 6/18 and 3/60) in 34.4 million people. However, wide regional variations exist in the prevalence of cataracts. In North America, the prevalence of blindness and MSVI was 0.3% and 0.4%, respectively. In South Asia, the respective prevalence was 2% and 6.8%. Sub-Saharan Africa is similar. However, cataract blindness and MSVI have declined since 1990 due to better provision of cataract surgery. Once again the decline in prevalence shows wide regional variations, with the greatest decline in East Asia, Latin America, and Western Europe, where the prevalence fell by more than half. The region with the least decline was Sub-Saharan Africa. The world's population is increasing (predominantly in developing countries), and people will live to greater ages. So without accessible, efficient cataract surgery, the prevalence will increase. Developing countries bear an increasing burden for cataract blindness because cataracts occur earlier in life, and the incidence is higher. In India, visually significant cataract occurs 14 years earlier than in the United States, and the age-adjusted prevalence of cataract is three times that of the United States.

Cataracts are the leading cause of blindness in middle- and low-income countries, accounting for 50% of blindness but cause 5% of blindness in developed countries. Low-cost small-incision cataract surgery with lens implantation is a proven clinical strategy. The socioeconomic effect of cataract surgery is substantial. It allows people to increase their economic output to 1500% of the cost of the surgery in the first postoperative year, but if left untreated, it can result in a person being removed from work and dependent on a caregiver who is also removed from work.

The cataract prevalence is influenced by the Cataract Surgical Rate (CSR or number of cataract surgeries performed per million people per year), which varies from less than 200 to over 6000 in different regions. The CSR is determined by the effectiveness of strategies for stimulating demand from patients because of good outcomes and how well easily accessible cataract surgery is delivered. So a high cataract prevalence rate in some developing countries is not for want of a clinical solution but partially due to ineffective implementation. For example, Sub-Saharan Africa is resource poor with low surgeon productivity (number of procedures done per year).

To reduce cataract prevalence, the resource base (infrastructure, equipment, ophthalmologists, and other ophthalmic workers) must improve, as must management of the resources to build the right processes for maximal cost-effective resource utilization. Future solutions will have to address these challenges.

CHAPTER 4

CATARACT: CAUSES, ASSOCIATIONS AND PREVENTION

AGE

The cumulative effect of many environmental factors (UV light, x-irradiation, toxins, metals, corticosteroids, drugs, and diseases, including diabetes) causes age-related cataracts. Gene expression changes result in altered enzyme, growth factor, and other protein levels. Protein modification, oxidation, conformational changes, aggregation, formation of the nuclear barrier, increased proteolysis, defective calcium metabolism, and defense mechanisms occur with increasing age. Compromised ion transport leads to osmotic imbalances and intercellular vacuolation. Age-related abnormal cellular proliferation and differentiation also produce opacities. There is also an increased incidence of diseases such as diabetes that causes cataracts.

SUNLIGHT AND IRRADIATION

UV-B light causes oxidative damage, which is cataractogenic. The level of free UV filters in the lens decreases with age, and breakdown products of the filters act as photosensitizers that promote the production of reactive oxygen species and oxidation of proteins in the aging lens. The risk of cortical and nuclear cataract is highest in those with high sun exposure at a younger age. Exposure later in life was more weakly associated with these cataracts. Wearing sunglasses, especially when younger, has some protective effect. Unfortunately, the risk attributable to sunlight exposure is small, and cortical cataracts are less debilitating than nuclear or posterior sub capsular cataracts. Therefore, reducing sunlight exposure may have a limited benefit in delaying the onset of cataracts. Exposure to high levels of X-rays and whole-body irradiation also causes cataracts.

SMOKING AND ALCOHOL

Smoking causes a threefold increase in the risk of developing nuclear cataracts, and cessation of smoking reduces this risk. Smoking also may be associated with posterior subcapsular cataracts. Smokers are more likely to have a poor diet and high alcohol consumption, which also are risk factors for cataract. Smoking causes a reduction in endogenous antioxidants. Tobacco smoke contains heavy metals such as cadmium, lead, and copper, which accumulate in the lens and cause toxicity. No association between passive smoking and cataract has been demonstrated. Alcohol use has little, if any, association with cataract risk, and study reports are mixed.

BODY MASS INDEX

A number of health-related factors—diabetes, hypertension, and body mass index (BMI)—are associated with various forms of lens opacity, and they may be interrelated. A high BMI increases the risk of developing posterior subcapsular and cortical cataracts. A high BMI also is associated with diabetes and hypertension, which are associated with cataracts. Severe protein-calorie malnutrition is a risk factor for cataracts. Therefore, a moderate calorie intake may be optimal to reduce the risk of developing cataracts. Myopia After controlling for age, gender, and other cataract risk factors (diabetes, smoking, and education), posterior subcapsular cataracts are associated with myopia, deeper anterior chambers, and longer vitreous chambers

TRAUMA

Blunt trauma that does not result in rupture of the capsule may allow fluid influx and swelling of the lens fibers. The anterior subcapsular region whitens and may develop a characteristic flower-shaped pattern or a punctate opacity. A small capsular penetrating injury results in rapid fiber hydration and a localized lens opacity, and a larger rupture results in complete lens opacification. Penetrating injuries can be caused by accidental or surgical trauma such as a peripheral iridectomy or during a vitrectomy. Electric shocks as a result of lightning or an industrial accident cause coagulation of proteins, osmotic changes, and fernlike, grayish white anterior and posterior subcapsular opacities. Ionizing radiation, such as from X-rays, damages the capsular epithelial cell DNA, affecting protein and enzyme transcription and cell mitosis. An enlarging posterior pole plaque develops. Nonionizing radiation, such as infrared, is the cause of cataract in glassblowers and furnace workers working without protective lenses. A localized rise in the temperature of the iris pigment epithelium causes a characteristic posterior subcapsular cataract, which may be associated with exfoliation of the anterior capsule.

SYSTEMIC DISORDERS

In uncontrolled type 1 diabetes mellitus in young people, hyperglycemia causes glucose to diffuse into the lens fiber, where aldose reductase converts it to sorbitol. The cell membrane is impermeable to sorbitol, and therefore it accumulates. The osmotic effect draws water into the lens fibers, which swell and then rupture. The cataract progresses rapidly with the development of white anterior and posterior subcapsular and cortical opacities. In type 2 diabetic adults, an early onset age-related type of cataract occurs and is more prevalent with longer duration of the diabetes. Many mechanisms are involved and include sorbitol accumulation, protein glycosylation, increased superoxide production in the mitochondria, and phase separation. During hyperglycemia, glucose is reduced to sorbitol, depleting antioxidant reserves, and less glutathione is maintained in the reduced form, which causes other oxidative damage. Levels of lens $Ca2+$ also are elevated, which activates calpains, causing unregulated proteolysis of crystallins. The cataracts are usually cortical or posterior subcapsular or, less frequently, nuclear and progress more rapidly than age-related cataract. Galactosemia is an autosomal recessive disorder in which a lack of one of the three enzymes involved in the conversion of galactose into glucose causes a rise in serum galactose levels. Galactitol accumulates in the lens fibers, drawing water into them. Infantile anterior and posterior subcapsular opacities progress to become nuclear. Galactose 1-phosphate uridyltransferase galactosemia is associated with failure to thrive, mental retardation, and hepatosplenomegaly. Dietary restriction of galactose prevents cataract progression. Galactokinase deficiency is associated with galactosemia and cataract but without the systemic manifestations.Fabry's disease is an X-linked lysosomal storage disorder that results in accumulation of the glycolipid ceramide trihexoside. The patient suffers from episodic fever, pains, hypertension, renal disease, and a characteristic rash. In the affected man and the carrier woman, a typical mild, spokelike, visually insignificant cataract develops. Lowe's or oculocerebrorenal syndrome is a severe X-linked disorder that results in mental retardation, renal tubular acidosis, metabolic acidosis, and renal rickets. Congenital glaucoma, cataracts, and corneal keloids can cause blindness. The lens is small and discoid with a total cataract. Female carriers may show focal dot opacities in the cortex. Alport's syndrome is a dominant, recessive, or X-linked trait disease causing hemorrhagic nephropathy and sensorineural deafness. Congenital or postnatal cortical cataract, anterior or posterior lenticonus, and microspherophakia occur. Dystrophia myotonica is a dominantly inherited disorder and results in muscle wasting and tonic relaxation of skeletal muscles. Other features include premature baldness, gonadal atrophy, cardiac defects, and mental retardation. Cataract is a key diagnostic criterion and may develop early, but usually occurs after 20 years of age and progresses slowly, eventually becoming opaque. Early cataract consists of polychromatic dots and flakes in the superficial cortex. As the opacities mature, a characteristic stellate opacity appears at the posterior pole. Other ocular features include hypotony, blepharitis, abnormal pupil responses, and pigmentary retinopathy. Rothmund–Thomson syndrome is an autosomal recessive disorder characterized by poikiloderma, hypogonadism, saddle-shaped nose, abnormal hair growth, and cataracts, which develop between the second and fourth decades of life and progress rapidly. Werner's syndrome or adult progeria is an autosomal recessive disorder with features that include premature senility, diabetes, hypogonadism, and arrested growth. Juvenile cataracts are common. The condition usually leads to death at about 40 years of age. Cockayne's syndrome causes dwarfism but with disproportionately long limbs with large hands and feet, deafness, and visual loss from retinal degeneration, optic atrophy, and cataracts.

DERMATOLOGICAL DISORDERS

The skin and the lens are of ectodermal origin embryologically. Therefore, skin disorders may be associated with cataract formation. Atopic dermatitis and eczema may affect any part of the body, especially the limb flexures. Localized proliferation of lens epithelium occurs in some atopic adults, usually as a bilateral, rapidly progressive "shield" cataract (a dense, anterior subcapsular plaque with radiating cortical opacities, and wrinkling of the anterior capsule). Posterior subcapsular opacities also may occur. Ichthyosis is an autosomal recessive disorder that features hypertrophic nails, atrophic sweat glands, cuneiform cataracts, and nuclear lens opacities. Incontinentia pigmenti is an X-linked dominant disorder that affects skin, eyes, teeth, hair, nails, and the skeletal, cardiac, and central nervous systems. Blistering skin lesions occur soon after birth, followed by warty outgrowths. Ocular pathology includes cataract, chorioretinal changes, and optic atrophy.

CENTRAL NERVOUS SYSTEM DISORDERS

Neurofibromatosis (types I and II) is an autosomal dominant disorder causing numerous intracranial and intraspinal tumors and acoustic neuromata. Ocular features include combined hamartoma of the retina and retinal pigment epithelium, epiretinal membranes, Lisch nodules (a diagnostic sign), and posterior subcapsular or cortical cataracts that develop in the second or third decade of life. Zellweger syndrome, also known as hepatocerebrorenal syndrome, is an autosomal recessive disorder characterized by renal cysts, hepatosplenomegaly, and neurological abnormalities. Ocular features include corneal clouding, retinal degeneration, and cataracts. Norrie's disease is an X-linked recessive disorder that causes leukokoria and congenital infantile blindness and is associated with mental retardation and cochlear deafness. In the eye, vitreoretinal dysplasia, retinal detachment, vitreous hemorrhage, and formation of a white retrolental mass occur. Eventually, a cataract forms.\

OCULAR DISEASE AND CATARACTS

Inflammatory uveitis (e.g., Fuchs' heterochromic cyclitis and juvenile idiopathic arthritis) usually results in posterior subcapsular or posterior cortical lens opacities. Infective uveitis (e.g., ocular herpes zoster, toxoplasmosis, syphilis, and tuberculosis) can cause cataracts, but the organism does not penetrate the lens. In maternal rubella infection, after 6 weeks of gestation, the virus can penetrate the lens capsule, causing unilateral or bilateral, dense, nuclear opacities at birth, or they may develop several weeks or months later. Corticosteroid treatment can cause cataracts. Retinal pigment degenerations such as retinitis pigmentosa, Usher's syndrome, and gyrate atrophy are associated with cataracts, which are usually posterior subcapsular opacities. Retinal detachment and retinal surgery may cause a posterior subcapsular cataract particularly in association with vitrectomy, silicone oil injection, and tamponade, or an anterior subcapsular form may develop because of metaplasia of the lens epithelium after vitreoretinal surgery. High myopia is associated with posterior cortical, subcapsular, and nuclear cataracts. Ciliary body tumors may be associated with cortical or lamellar cataract in the affected quadrant. Anterior segment ischemia may cause a subcapsular or nuclear cataract, which progresses rapidly.

TOXIC CAUSES

Topical, inhaled, and systemically administered corticosteroids can cause posterior subcapsular cataracts. Direct mechanisms included interaction of corticosteroids with enzymes that affects their function, e.g., corticosteroid modulation of Na+,K+-ATPase may cause sodium–potassium pump inhibition affecting osmotic regulation. Corticosteroids also induce crystallin conformational changes, causing aggregation and affect intracellular Ca2+ homeostasis, causing protein bonding. Indirectly, corticosteroids affect DNA/RNA synthesis of proteins and enzymes, causing metabolic changes, and also may affect ciliary body growth hormone levels responsible for lens cellular differentiation, causing posterior subcapsular opacities.26 Chronic use of long-acting anticholinesterases previously used in the treatment of chronic open-angle glaucoma may cause anterior subcapsular vacuoles and posterior subcapsular and nuclear cataracts. Pilocarpine, a shorter acting agent, causes less marked changes. The mechanism of action is unknown. Phenothiazines, such as chlorpromazine, may cause deposition of fine, yellow-brown granules under the anterior capsule in the pupillary zone and may develop into large stellate opacities but are not usually visually significant. The development of the opacities may be related to the cumulative dose of the medication, and photosensitization of the lens may play a role. Allopurinol used in the treatment of gout is associated with cataracts. Psoralen–UV-A therapy for psoriasis and vitiligo has been shown to cause cataracts in very high doses in animal studies but is rare in humans; concomitant UV exposure may be a risk factor. Antimitotic drugs used in the treatment of chronic myeloid leukemia, such as busulfan, may cause posterior subcapsular cataract. The antimalarial chloroquine (but not hydroxychloroquine), which is also used in the treatment of arthritis, may cause white, flake-like posterior subcapsular lens opacities. Amiodarone is used to treat cardiac arrhythmias and causes insignificant anterior subcapsular opacities and corneal deposits. The relationship between statins and cataracts is still controversial. Siderosis, from a ferrous intraocular foreign body, causes iron deposits in the lens epithelium and iris and results in a brown discoloration of the iris and a flower-shaped cataract. Wilson's disease, an autosomal recessive disorder of copper metabolism, causes a brown ring of copper deposition in Descemet's membrane and the lens capsule, resulting in a sunflower cataract—an anterior and posterior capsular disc-shaped polychromatic opacity in the pupillary zone with petal-like spokes that is not usually visually significant. Hypocalcemia in hypoparathyroidism is associated with cataracts. In children, the cataract is lamellar; in adults it produces an anterior or posterior punctate subcapsular opacity.

CONGENITAL AND JUVENILE CATARACTS

Congenital cataracts are noted at birth, infantile cataracts occur in the first year, and juvenile cataracts develop during the first 12 years of life. Hereditary cataracts may be associated with other systemic syndromes, such as dystrophia myotonica. About one-third of all congenital cataracts are hereditary and unassociated with any other metabolic or systemic disorders. Trisomy 21, or Down syndrome, is the most common autosomal trisomy, with an incidence of 1 per 800 births. Systemic features include mental retardation, stunted growth, mongoloid facies, and congenital heart defects. Ocular features include visually disabling lens opacities in 15% of cases, narrow and slanted palpebral fissures, blepharitis, strabismus, nystagmus, light-colored and spotted irides (Brushfield spots), keratoconus, and myopia. Cataract also is associated with trisomy 13 (Patau's syndrome), trisomy 18 (Edwards' syndrome), Cri du chat syndrome (deletion of short arm of chromosome 5), and Turner's syndrome (X chromosome deletion). A total cataract is a complete opacity present at birth. It may be hereditary (autosomal dominant or recessive) or associated with systemic disorders such as galactosemia, rubella, and Lowe's syndrome. Infantile cataracts cause amblyopia if unilateral and may cause strabismus and nystagmus if bilateral. The incidence is about 0.4% of newborns, but the majority of cases are not associated with poor vision. Amblyopia depends on the size, location, and density of the cataract. The causes of infantile cataracts are many and include maternal infections (such as rubella), systemic diseases, hereditary disorders, and ocular disease.

PREVENTION OF CATARACTS

The roles and mechanisms of action of dietary antioxidant vitamins and minerals in the biochemistry and metabolism of the lens are not clear. Ascorbate is a water-soluble antioxidant. Vitamin E is a lipid-soluble antioxidant that inhibits lipid peroxidation, stabilizes cell membranes, and enhances glutathione recycling. Beta-carotene, the best-known carotenoid, is a lipid-soluble antioxidant and a vitamin A precursor and is one of 400 naturally occurring carotenoids. There are mixed reports in the literature with some studies showing no benefit and others showing some benefit with vitamin A, carotenoids, and combinations of vitamins C and E and beta-carotene supplements. Potential anticataract compounds include aldose reductase inhibitors, pantethine, and aspirin-like drugs such as ibuprofen. However, none of these agents has been shown to prevent cataracts in a trial setting. No convincing evidence exists that N-acetylcarnosine reverses cataract or prevents progression of cataract. A decreased risk of developing cataracts occurs with estrogen replacement therapy.29–34 New drugs are under investigation, including lanosterol, which decreased protein aggregates in vitro, reduced cataract severity, and increase transparency in rabbit cataractous lenses in vitro and cataract severity in vivo in dogs.Anticataract agents would need to be safe for long-term use and sufficiently inexpensive to compete with increasingly cost-effective cataract surgery. Understanding the causes of age-related cataract will be helpful in preventing or delaying cataract formation, but our knowledge is incomplete. Minor risk factors such as UV-B exposure and smoking can be modified but are not likely to result in large reductions in visual disability. The most important risk factor, aging, cannot be modified. Other strategies such as nutritional, pharmacological, and specific medical and genetic interventions may be helpful in the future but are of unproved benefit at present. Integrated and innovative approaches to the provision of surgery, resource management, training, start-up capital equipment and consumables, and cost-recovery mechanisms are required.

REFERENCES:

1. *Age- Related Eye Disease Study Research Group. Risk factors associated with age-relatednuclear and cortical cataract: a case- control study in the Age- Related Eye Disease Study,AREDS Report No. 5. Ophthalmology. 2001;108(8):1400–1408.*

2. *Chew EY, SanGiovanni JP, Ferris FL, et al; Age- Related Eye Disease Study 2 (AREDS2)Research Group. Lutein/zeaxanthin for the treatment of age- related cataract: AREDS2randomized trial report no. 4. JAMA Ophthalmol. 2013;131(7):843–850.*

3. *Keel S, He M. Risk factors for age- related cataract. Clin Exp Ophthalmol. 2018;46(4):327–328.Pesudovs K, Elliott DB. Refractive error changes in cortical, nuclear, and posterior subcapsularcataracts. Br J Ophthalmol. 2003;87(8):964–967.*

4. *Shiels A, Bennett TM, Knopf HL, et al. The EPHA2 gene is associated with cataracts linked tochromosome 1p. Mol Vis. 2008;14:2042–2055.*

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CHAPTER 5

CLASSIFICATION AND TYPES

A. Etiological classification

I. Congenital and developmental cataract

II. Acquired cataract

1. Senile cataract

2. Traumatic cataract

3. Complicated cataract

4. Metabolic cataract

5. Electric cataract

6. Radiational cataract

7. Toxic cataract e.g.,

- **i.** Corticosteroid-induced cataract
- **ii.** Miotics-induced cataract
- **iii.** Copper (in chalcosis) and iron (in siderosis) induced cataract.

8. Cataract associated with skin diseases (Dermatogenic cataract).

9. Cataract associated with osseous diseases.

10. Cataract with miscellaneous syndromes e.g.,

- **i.** Dystrophica myotonica
- **ii.** Down's syndrome.
- **iii.** Lowe's syndrome
- **iv.** Treacher - Collin's syndrome

B. Morphological classification

1. Capsular cataract - It involves the capsule and may be:

   i. Anterior capsular cataract

   ii. Posterior capsular cataract

2. Subcapsular cataract - It involves the superficial part of the cortex (just below the capsule) and includes:

   i. Anterior subcapsular cataract

   ii. Posterior subcapsular cataract

3. Cortical cataract - It involves the major part of the cortex.

4. Supranuclear cataract - It involves only the deeper parts of cortex (just outside the nucleus).

5. Nuclear cataract - It involves the nucleus of the crystalline lens.

6. Polar cataract - It involves the capsule and superficial part of the cortex in the polar region only may be:

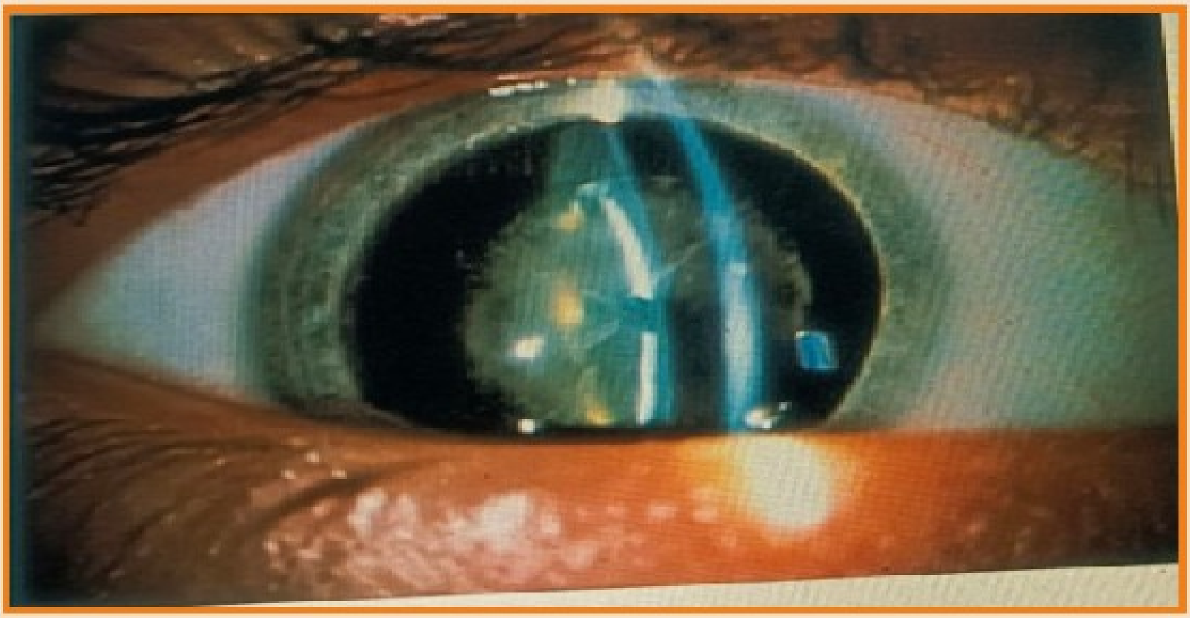
   i. Anterior polar cataract

   ii. Posterior polar cataract

CONGENITAL CATARACT

1. Lamellar cataract

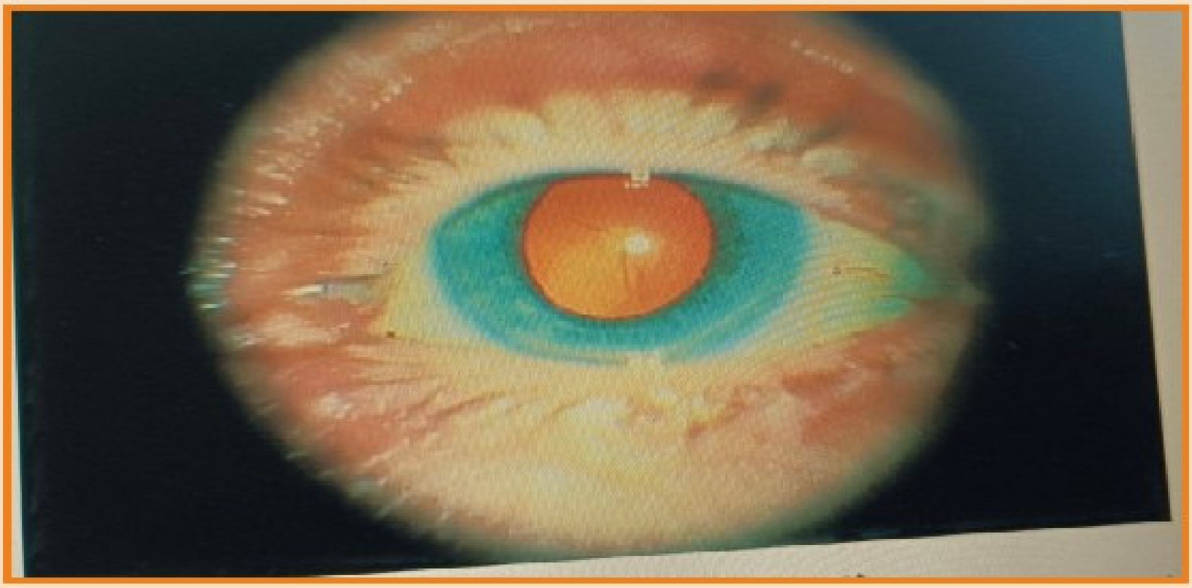
   - Opacification of specific zone of the lens
   - B/L and symmetrical
   - Inherited /AD



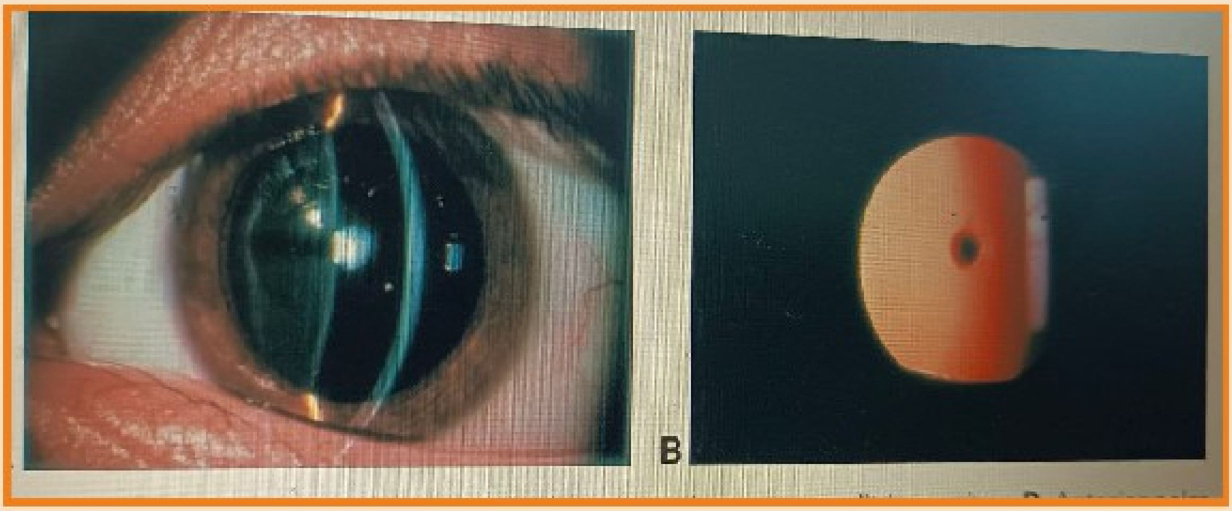
2. **Sutural cataract:**

   - opacification of Y -sutures of the fetal nucleus
   - do not affect vision

Bilateral and symmetrical



Anterior polar cataract	Posterior polar cataract
Congenital and sporadic	Familial or sporadic
Bilateral ,small	Unilateral or bilateral ,large
Do not impair vision	Profound vision loss
Associated with microphthalmia ,persistent pupillary membrane and anterior lenticonus	Associated with remnant of tunica vasculosa



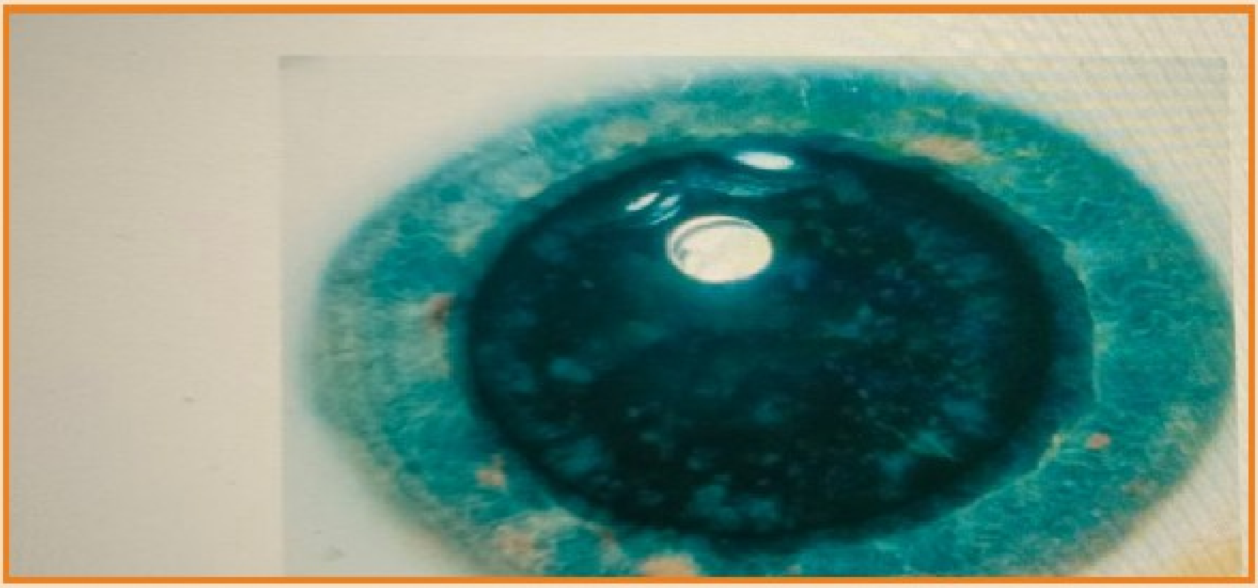
4. Coronary cataract:

- Group of club -shaped cortical opacities around the equators of the lens
- Do not affect vision

5.Cerulean cataract:

- Blue dot cataract
- Nonprogessive

No visual impairment



6. Complete cataract:

- U/L or B/L
- All the lens fibres opacified
- Profound visual impairment
- Seen in rubella infection

7. Nuclear cataract:

8. Capsular cataract

9. Membranous cataract:

SENILE CATARACT:

1. Nuclear cataract
2. Cortical cataract
3. Posterior Subcapsular Cataract

Cortical cataract:

Local disruption of the structure of mature lens fibres cell

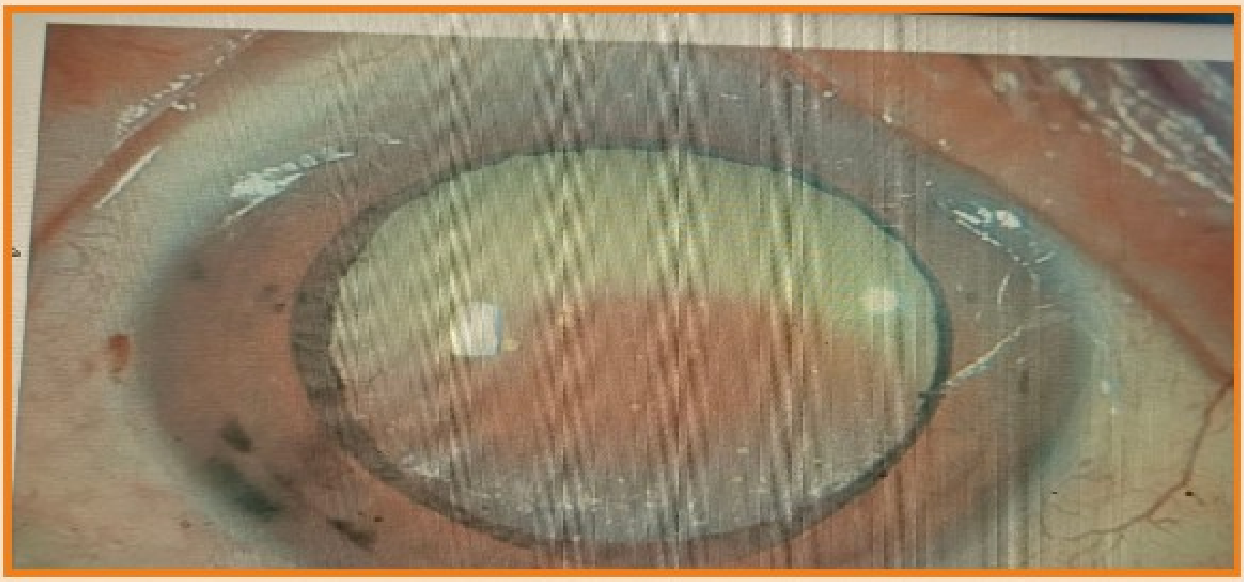
- Hydration of lens fibre f/b protein coagulation
- Stages of cortical cataract:

- Stage of lamellar separation: demarcation of cortical fibres owing to its separation by fluid
- Incipient cataract: wedge shaped spokes of opacity with clear area between them in the periphery of the lens with pointed end toward the centre

- On slit lamp examination :1st visible sign is vacuoles and water cleft in the anterior and posterior cortex and appears as white opacities and on retro illumination, appears as dark shadow.

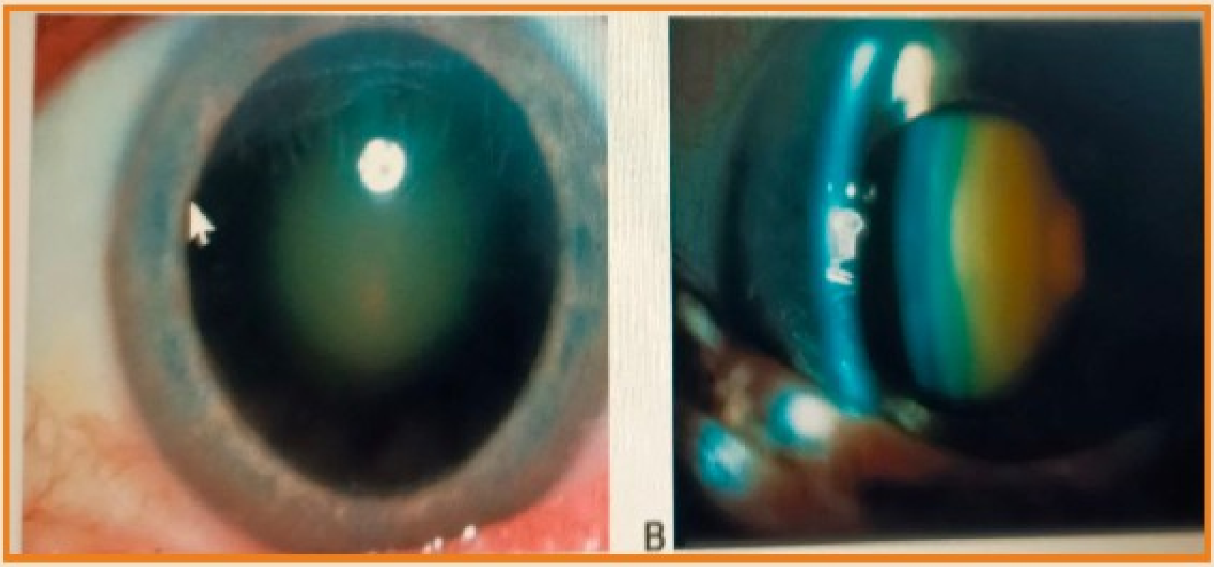
- Intumescent cataract: progressive hydration of cortical layer causes swelling of lens making the angle shallow leads to angle closure glaucoma
- Mature cataract: entire cortex become white and opaque

- Hypermature cataract: cortex becomes degenerated and transform into pultaceous mass
- The lens becomes inspissated and shrunken and yellow in appearance leads to shrunken cataract.
- When the cortex liquified and nucleus may sink to the bottom of the lens allows free movement of the nucleus leads to morgagnian hyperamature cataract



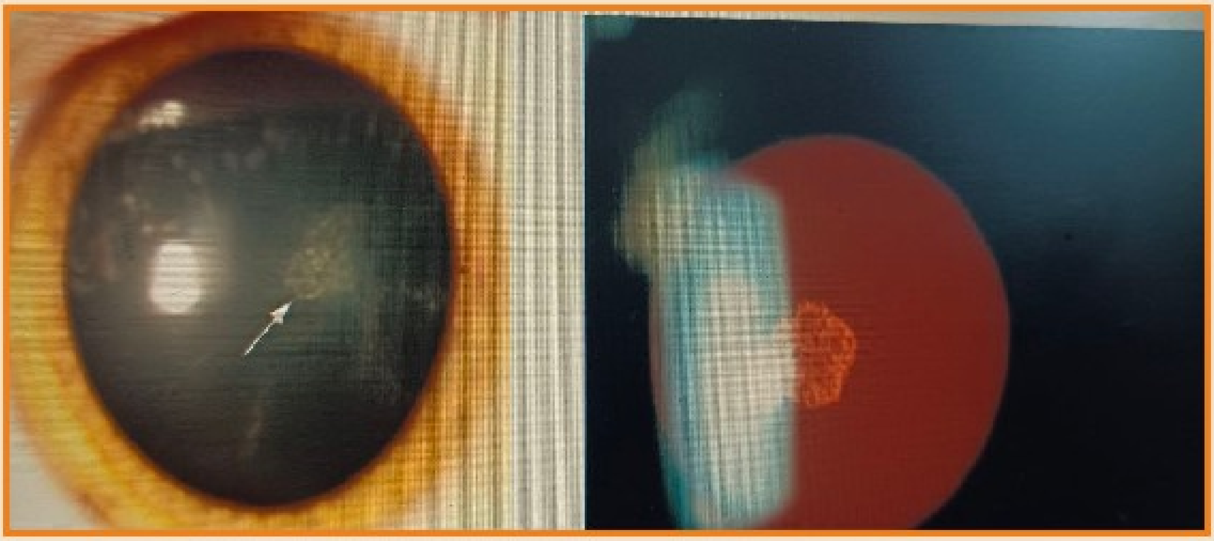
Nuclear cataract:

- Slowly progressive sclerosis of lens nucleus
- As time progresses, nucleus become diffusely cloudy ,cloudiness spread towards the cortex
- B/L but asymmetrical
- Greater impairment of distant vision than of near vision
- In advanced cases, lens becomes increasingly opaque and brown and black and is called brunescent nuclear cataract and cataracta nigra respectively .



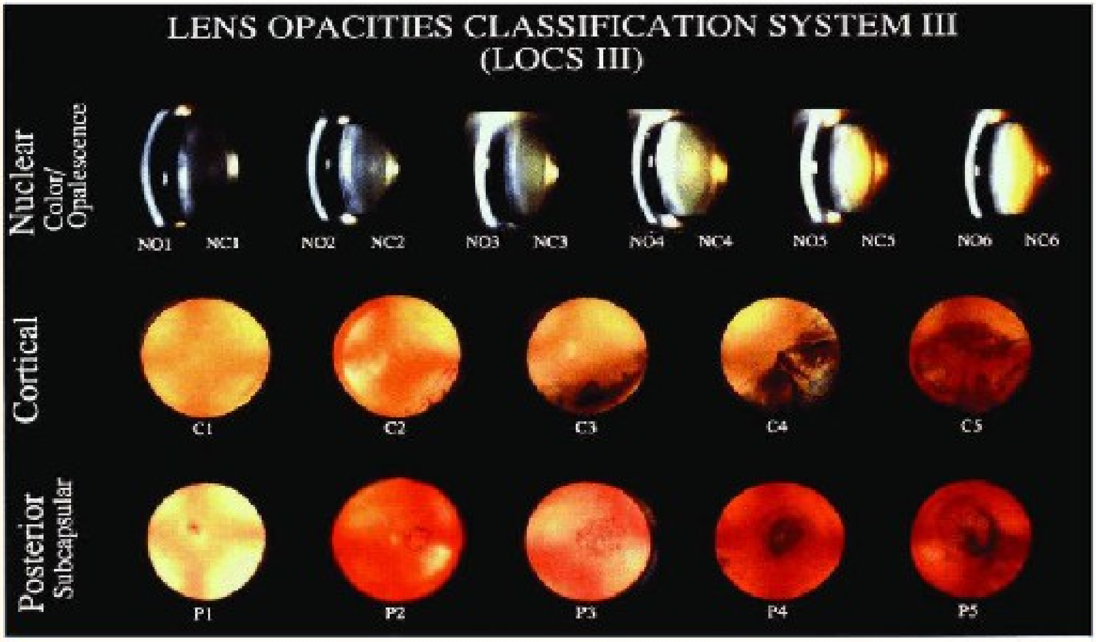
Posterior subcapsular cataract:

- Located in posterior cortical layer
- Causes significant visual deteorioration when the encroaches the visual axis
- On slit lamp : initially appears as subtle iridescent sheen in posterior cortical layer Later stages , granular opacities and plaques like opacity seen
- Near vision is more affected
- Histologic exam :a/w posterior migration of kens epithelial cells from equator to the visual axis on the inner surface of the posterior capsule

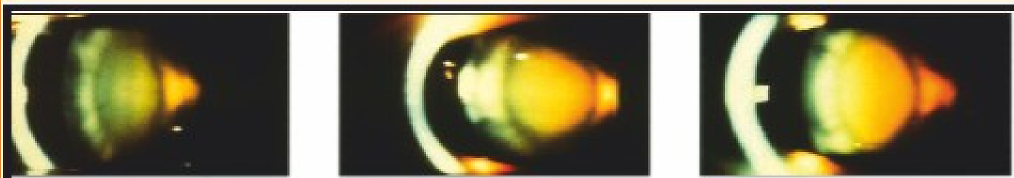


Cataract Grading:

1. LOC III SYSTEM
2. NUCLEAR SCLEROSIS GRADING



NUCLEAR SCLEROSIS GRADING

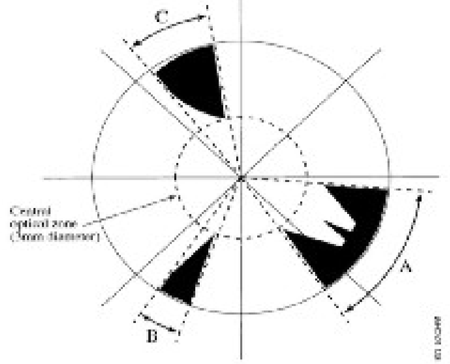


NS tr or 1+: Nucleus clearer than anterior/posterior sections

NS 2+: Nucleus equal to the anterior/posterior sections (same opacity level throughout)

NS 3+ Nucleus denser than anterior/posterior sections

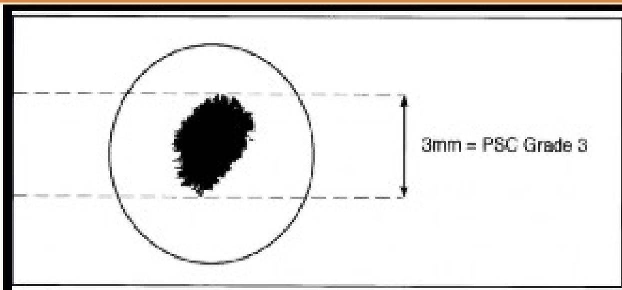
NS 4+ Brunescent: Cataract completely opaque/brown



CS 1+: ⅛ to ¼ of the total area

CS 2+: ¼ to ½ of the total area

CS 3+: ½ or more of the total area



PSC 1+: 1 mm to 2 mm

PSC 2+: 2 mm to 3 mm

PSC 3+: >3 mm

Examination	Nuclear cataract	ISC	MSC	HMSC(M)	HMSC(S)
1. Visual acuity	6/9 to PL+	6/9 to FC+	HM+ to PL+	PL+	PL+
2. Colour of lens brown, black or red	Grey, amber,	Greyish white	Pearly white with sinking brownish nucleus	Milky white hyper-white spots	Dirty white with
3. Iris shadow	Seen	Seen	Not seen	Not seen	Not seen
4. Distant direct ophthalmoscopy with dilated pupil	Central dark area against red fundal glow	Multiple dark areas against red fundal glow	No red glow but white pupil due to complete cataract	No red glow milky white pupil	No red glow
5. Slit-lamp examination	Nuclear opacity clear cortex cortex	Areas of normal with cataractous	Complete cortex is cataractous	Milky white sunken brownish nucleus	Shrunken cataractous lens with thickened anterior capsule

ISC: Immature senile cataract, MSC: Mature senile cataract, HMSC (M) Hypermature senile cataract (Morgagnian), HMSC (S): Hypermature senile cataract (Sclerotic), PL: Perception of light, HM: Hand movements, FC: Finger counting.

ASSESSMENT AND GRADING OF CATARACTS

Grading and classifications of cataracts are useful in research, to explore causation, and in trials of anticataract drugs. Slit-lamp direct and retroillumination of nuclear, cortical, and posterior subcapsular cataracts is used in the Lens Opacification

Classification System II (LOCS-II). LOCS-II is reproducible and has been validated.36 A number of Scheimpflug camera and optical coherence tomography devices have been developed for objectively quantifying lens opacification.

VISUAL EFFECTS OF CATARACTS

The effect of cataract on vision varies according to the degree of the cataract and the cataract morphology.

Visual Acuity

Reduction in visual acuity has been the standard measure of the visual effect of cataracts. However, visual acuity can remain good despite other cataract-related effects on vision that compromise the patient's ability to function.

Contrast Sensitivity, Glare, and Wave front Aberrometry

Cataracts cause reduced contrast sensitivity and increased wavefront aberrations, reducing visual acuity especially at low ambient light levels.Glare, which occurs as a result of forward scatter of light, may be produced by opacities that do not lie within the pupil diameter and, therefore, affect visual function.

Other Effects

The natural aging of the human lens produces a progressive hyperopic shift. Nuclear changes induce a modification of the refractive index of the lens and produce a myopic shift. Cortical opacities may cause localized changes in the refractive index of the lens, which may result in monocular diplopia. Color perception is affected by the yellowing of the lens nucleus. The morphology, density, and location of lens opacities may cause changes in the visual field.

ANOMALIES OF LENS GROWTH

The lens is ectodermal and the vascular capsule is mesodermal in origin. A number of exogenous or endogenous influences can affect ectodermal or mesodermal development and can have multiple manifestations in the eye.

Aphakia

Aphakia is the absence of the lens. Primary aphakia is a rare absence of the lens. Secondary aphakia is more common, and there are lens remnants. Both occur in isolation or with other abnormalities of the anterior segment such as microphthalmos, microcornea, and nystagmus.

Microspherophakia

Microspherophakia is the presence of a small, spherical crystalline lens with an increased antero–posterior thickness and steeper than normal anterior and posterior lens curvatures. It is bilateral and may be familial, may occur as an isolated defect, or may be associated with other mesodermal defects, such as the Weill–Marchesani and Marfan's syndromes. The condition causes lenticular myopia and may be associated with lens dislocation (usually downward) and pupil block.

Lenticonus and Lentiglobus

Abnormalities of the central lens curvature include lenticonus (conical) and lentiglobus (spherical) and may be anterior or posterior. They may be associated with abnormalities of the lens epithelium, by traction from hyaloid remnants, or by localized areas of capsule weakness, which causes bulging. They may be inherited as an autosomal recessive trait or associated with other abnormalities, such as Alport's syndrome (familial hemorrhagic nephritis) or Lowe's oculocerebral syndrome (associated with posterior lenticonus). They can cause lenticular myopia with irregular astigmatism Lens.

Coloboma Lens

coloboma is a unilateral, congenital indentation of the lens periphery that occurs as a result of a localized absence of zonules. It may be associated with coloboma of the iris, ciliary body, or choroid, or with ectopia lentis, spherophakia, or localized lens opacities. It may occur because persistence of mesodermal vascular capsules remnants prevents the development of zonules in that area.

Ectopia Lentis

Ectopia lentis, or displaced lens, is usually a bilateral condition caused by extensive zonular malformation. The lens is subluxated in the opposite direction to the weak zonules (usually superomedially) and usuallypresents in childhood or young adulthood. The lens may dislocate completely into the anterior chamber or vitreous or become cataractous. It may be an autosomal dominant or recessive trait or may be associated with other developmental abnormalities of the eyes such as iris coloboma, microspherophakia, aniridia, and ectopia pupillae congenita. It may be associated with systemic disorders such as Marfan's syndrome , Weill–Marchesani syndrome, homocystinuria, sulfite oxidase deficiency, and hyperlysinemia. The clinical features of a subluxed lens include iridodonesis (tremulous iris), fluctuating anterior chamber depth and vision, and phacodonesis (a visibly mobile lens). Vitreous may herniate into the anterior chamber. Pupil block may occur with iris apposition to the vitreous face or an anterior dislocated lens (into the anterior chamber).

REFERENCES:

1. *Chylack LT Jr, Wolfe JK, Singer DM, et al. The Lens Opacities Classification System III. TheLongitudinal Study of Cataract Study Group. Arch Ophthalmol. 1993;111(6):831–836.*

2. *Gali HE, Sella R, Afshari NA. Cataract grading systems: a review of past and pre sent. Curr OpinOphthalmol. 2019;30(1):13–18.*

3. *Fraunfelder FT, Fraunfelder FW, Chambers WA. Drug- Induced Ocular Side Effects. 7th ed.Saunders; 2015.*
4. *Shah M, Shah S, Upadhyay P, Agrawal R. Controversies in traumatic cataract classificationand management: a review. Can J Ophthalmol. 2013;48(4):251–258.*
5. *Jones NP. Cataract surgery in Fuchs' heterochromic uveitis: past, pre sent and future. J CataractRefract Surg. 1996;22(2):261–268.*

6. *Geloneck MM, Forbes BJ, Shaffer J, Ying GS, Binenbaum G. Ocular complications in childrenwith diabetes mellitus. Ophthalmology. 2015;122(12):2457–2464.*

7. *Klein BE, Klein R, Wang Q, Moss SE. Older- onset diabetes and lens opacities. The Beaver DamEye Study. Ophthalmic Epidemiol. 1995;2(1):49–55..*

8. *Musch DC, Gillespie BW, Niziol LM, et al; Collaborative Initial Glaucoma Treatment StudyGroup. Cataract extraction in the Collaborative Initial Glaucoma Treatment Study:incidence, risk factors, and the effect of cataract progression and extraction on clinical andquality- of- life outcomes. Arch Ophthalmol. 2006;124(12):1694–1700.*

9. *Klein BE, Lee KE, Danforth LG, Schaich TM, Cruickshanks KJ, Klein R. Selected sunsensitizingmedi cations and incident cataract. Arch Ophthalmol. 2010;128(8):959–963.*

CHAPTER 6

PATIENT WORKUP FOR CATARACT SURGERY

MEDICAL HISTORY AND CURRENT THERAPEUTIC REGIMEN

A history of cardiac, bronchopulmonary, or cerebrovascular incidents influences the timing and management of surgery, especially if it is recent. Diabetes mellitus and systemic hypertension are common in the population predisposed to operable cataract formation, and these conditions may adversely influence both the surgery and the postoperative course of events. Ram and coworkers carried out a study of more than 6000 patients who underwent cataract surgery and discovered multiple morbidities that arose from a variety of conditions. The major causes included pulmonary disease, cardiovascular and hypertensive disorders, diabetes mellitus, and significant orodental problems that required intervention. Ram et al. also noted significant postoperative problems in 1.27% of their patients, nearly half of whom required hospitalization. Fisher and Cunningham and Hamed et al. noted an even higher morbidity in their cohort of patients who had cataract surgery. There are many factors that may affect cooperation and difficulty during surgery, varying from ventilation difficulties to substance abuse (including examination of identified cataract morphological findings), that may influence both the surgeon's and the anesthesiologist's decision about the form of anesthetic to use and the sedation required and potentially both the pre- and postoperative management.

GENERAL OPHTHALMIC HISTORY AND EXAMINATION

Both eyes are assessed fully by routine ophthalmological workup, which includes tonometry, slit-lamp biomicroscope examination, and posterior segment observations under mydriasis to estimate the visual outcome and risk category of surgery for the patient. Intercurrent ophthalmic disorders may prejudice the visual outcome. For example, uveitis may be exacerbated, herpes zoster may have left an anesthetic cornea,6 atopic disease may predispose the eye to infection, and Fuchs' endothelial dystrophy may predispose the eye to corneal edema. Diabetes mellitus increases the prospects of postoperative macular edema.The presence of open-angle glaucoma warrants further comment. The aforementioned disease processes need pickup and assessment to avoid deleterious effect on the eye after cataract surgery. The action of successful cataract surgery on glaucoma and ocular hypertension, however, has been demonstrated to have a positive effect on intraocular pressure (IOP) control. With the advent of the new minimally invasive glaucoma surgery (MIGS) procedures, the surgeon should now consider using one of these devices at the end (or beginning) of a cataract procedure to further facilitate improved aqueous outflow, lower IOPand improve glaucoma control, potentially reducing or eliminating the use of topical glaucoma drugs, which themselves can have an adverse influence on the ocular surface and visual quality both before and after cataract surgery. There are a number of MIGS devices available. Patient counseling on the procedure and explanation of postoperative expectation are vital elements of the preoperative workup. A written explanation of the background and process of cataract surgery is invaluable

CLASSIFICATION OF LENS OPACITIES

Nuclear Opacities Initially, an increase in optical density of the nucleus occurs (nuclear sclerosis). The fetal nucleus is first involved and then the whole adult nucleus. The increase in density is followed by an opacification, which implies a change in color, namely from an initial clear to yellow to a subsequent brown (brunescent cataract). In certain instances, crystals appear in the adult nucleus (or in the cortex, usually posteriorly) that, on slit-lamp examination, appear to be of different colors (polychromatic luster). Cortical Opacities The changes in transparency involve most of the cortex of the lens.

changes evolve as follows:

- Hydration of the cortex with development of subcapsular vacuoles.
- Formation of ray-like spaces filled with liquid (morgagnian globules), which is at first transparent and later becomes opaque.
- Lamellar separation of the cortex with development of parallel linear opacities.
- Formation of cuneiform opacities that originate at the periphery of the lens and spread toward the center.

Posterior subcapsular opacities may develop as isolated entities or may be associated with other lens opacities. The opacity begins at the posterior polar region and then spreads toward the periphery. Often, granules and vacuoles are detectable in front of the posterior capsule.

ADVANCED CATARACTS

The crystalline lens may swell and increase in volume because of cortical processes (intumescent cataract). Complete white opacification of the lens is called a mature or morgagnian cataract. If the liquefied cortical material is not—or is only partially—reabsorbed, the solid nucleus may "sink" to the bottom. Reabsorption of the milky cortex causes a reduction in the lens volume, resulting in capsular folding (hypermature cataract).

GRADING OF LENS OPACITIES

Gradations and classifications of cataracts are useful in determining the potential difficulty of cataract surgery, in cataract research, in studies to explore causation, and in trials of putative anticataract drugs. Devices designed to quantify lens opacification have been developed; these instruments (such as the Kowa Early Cataract Detector and the Scheimpflug photo slit lamp) appear to be more accurate when used to assess the formation of nuclear cataracts than that of cortical cataracts. A rapid method for the gradation of cataract in epidemiological studies has been reported by Mehra and Minassian; the area of lenticular opacity is assessed by direct ophthalmoscopy and graded on a scale from 0 to 5. Highly reproducible, validated systems for cataract classification have been developed by Chylack and coworkers to define the effects of specific cataract type and extent very accurately; these enable the effects of specific cataract types on specific visual functions to be quantified.

Lens Opacities Classification System III for nuclear opalescence (NO) or nuclear color (NC), a slit beam is focused on the lens nucleus and the density of the lens is compared with a set of standard photographs. If the density is less than that corresponding to the f irst photograph, NO or NC is zero or "no nuclear cataract"; if NO or NC is 1, the density is equal to or less than that for the second photograph, and so on. The photographs represent lens nuclei of increasing density, and the patient's cataract is graded accordingly. For cortical cataracts (category "C"), a retroillumination (red reflex) view through the dilated pupil is used to view the lens, focused first at the anterior capsule and then at the posterior capsule. The photographs are compared with standard photographs—each succeeding photograph shows the pupillary area covered by more cortical cataract. For posterior subcapsular cataract (category "P"), a retroillumination (also red reflex) view of the lens is used, focused at the posterior capsule. Again, the patient's cataract is graded according to standard photographs.

EFFECTS OF OPACITIES ON VISION

Visual Acuity Reduction

Measurement of visual acuity can remain high despite age-related lens opacities. The severity of the visual disability measured using high-contrast Snellen acuity charts is not sensitive to visual disability characterized by loss of contrast sensitivity. Usually, visual acuity testing is conducted under ideal circumstances that are not normally met in the real world. Although not a definitive measurement of visual dysfunction, simple Snellen acuity is the most used index to determine whether cataract surgery should be performed. The Preferred Practice Pattern of the American Academy of Ophthalmology recommends Snellen acuity as the best general guide to the appropriateness of surgery but recognizes the need for flexibility with due regard to a patient's particular functional and visual needs, environment, and risks, which may vary widely. When the cataract is very dense and opaque, visual acuity may be reduced to light perception only (cataract is still the major cause of blindness throughout the world).

CONTRAST SENSITIVITY

Reduction N03 NC3 N04 NC4 C3 P3 Patients with cataracts commonly complain of loss of the ability to see objects outdoors in bright sunlight and of being blinded easily by approaching headlamps in nighttime driving.Typically, loss of contrast sensitivity in patients who have cataracts has been reported to be greater at higher spatial frequencies. All cataracts lower contrast sensitivity—the posterior subcapsular opacities have been reported to be the most destructive. According to the morphology, the density, and the location of the opacities, the field of vision may be affected.

INVESTIGATIONS FOR FURTHER SURGICAL REFINEMENT

Myopic Shift The natural aging of the human lens produces a progressive hyperopic shift. Nuclear changes induce a modification of the refractive index of the lens and produce a myopic shift that may be of several diopters or greater. It is possible to predict that an aging person who had emmetropia previously but who can now read with no correction ("second sight") is developing nuclear cataract. Together with this aging effect goes the loss of the negative asphericity of the lens in youth, balancing the positive asphericity of the natural cornea. The shift to more positive asphericity of the lens with progressive nuclear cataract also reduces visual quality. If the lens structure becomes heterogeneous, with cortical spoke cataract for example, the change in refractive index may be uneven and may produce some degree of internal irregular astigmatism and disturbance of the higher-order aberrations of Zernike (third order).

MONOCULAR DIPLOPIA

Monocular diplopia is common in patients who have lens opacities, particularly cortical spoke cataract, and in conjunction with water clefts that form radial wedge shapes and contain a fluid of lower refractive index than the surrounding lens. In some cases, patients may complain of polyopia.

GLARE

Even minor degrees of lens opacity cause glare because of the forward scatter of light. Such patients often see more poorly in daylight conditions than in the context of night driving. Unlike contrast sensitivity reduction, some glare may be produced by opacities that do not lie within the pupil diameter. The differences between measured visual acuity in a darkened room and acuity in ambient light that produces glare are useful as subjective criteria for the justification of surgery.

COLOR SHIFT

The cataractous lens becomes more absorbent at the blue end of the spectrum, especially with nuclear opacities. Usually patients are not aware of this color visual defect until after cataract surgery and visual rehabilitation.

GOOD CLINICAL PRACTICE (SOCIAL AND LEGAL ASPECTS)

The indications for surgery vary from patient to patient, especially with the current minimally invasive nature of cataract and lens implant surgery (compared with such surgery performed only a few years ago). The visual needs of patients vary according to their ages, occupations, and leisure interests. A cataract may not be symptomatic. Visual symptoms and outcome expectation affect the risk–benefit ratio. Although the risks of technically well-performed small incision surgery are few in a healthy eye, patients require enough information on which to base their decision to proceed. Most patients are inclined to accept the professional judgment of the ophthalmic surgeon, but it is implicit that an adult of sound mind has the right to determine whether surgery should proceed. Therefore, in the context of cataract surgery, how much information is it necessary for an ophthalmologist to disclose to a patient? To what extent should an ophthalmologist shield a patient from the anxieties that can accompany a full explanation of diagnosis and treatment? An ophthalmologist must strike a balance between providing enough information to enable the patient to give informed consent with respect to treatment and engendering the confidence and trust that encompasses a joint decision to proceed. The surgeon shoulders the major responsibility for this, which should be accepted as a consequence of medical and specialist training. In the application of professional judgment, the consideration of alternative management strategies, risks, and benefits allows a patient to make some sort of informed evaluation of the options. Statistical information based on published data may be confusing: Where does the patient fit into the statistics? What are the personal outcome statistics for the surgeon who offers advice? What guarantees are there that a particular surgeon will perform the surgery? A problem arises if potential material risks and dangers are not disclosed to a patient before surgery and a complication occurs. The patient may claim that, with prior knowledge of such a risk, he or she would not have consented to the surgery. A risk is material when a rational patient considers the risk of undergoing a certain type of treatment to be significant. Problems that arise from consent to perform surgical procedures can be minimized but not completely avoided, because every contingency cannot be reviewed completely. Taking the following steps will ensure that a thorough approach has been used. Appropriate patient education is required—the procedure is described in a manner that allows the patient to appreciate what will be done to treat the eye. Although the decision to proceed has to be the patient's, the surgeon must not pass all the responsibility on to the patient; instead the surgeon should communicate the appropriate degree of confidence in the procedure's outcome. The surgeon has to assume much of the responsibility for treatment advice, because the patient cannot appreciate the intricacies of every surgical situation. Ultimately, the patient has to have faith in the ability of the surgeon not only to carry out the procedure but also to make the judgment that the benefits far outweigh the risks. An analogous situation might be that of a passenger contemplating a journey on a commercial airliner. If the passenger inquires of the pilot what the potential risks are, common sense suggests that the answer would be that they are high in number but low in expectation. A passenger who decides to make the trip has conf idence in the airline and the crew to complete a successful journey. So it is with surgery: The patient must have confidence in the ability of the surgeon and the surgical team to carry out a successful procedure without knowing each and every pitfall that exists. Alternative approaches to the management of an ophthalmic condition are explained to the patient to enable patient participation in the final direction of treatment. When uncertainties exist, the patient is advised of the predictability of the planned procedure, its stability, and its safety. Statistical information on outcome is of limited value when given in a general sense. Few surgeons are in a position to give specific statistical information about the outcome of their own practices or of certain procedures. The patient must be given adequate time to decide. At the end of the consultation, a patient must have an opportunity to consider the treatment that has been advised or to reverse a decision to proceed. It is inappropriate to obtain a patient's signed consent for a procedure and then proceed at very short notice (the same day) with that treatment. The delay between consent and treatment must be sufficient to allow the patient to consider the matter fully. The patient should sign a consent form that states that the procedure has been explained fully in language that is comprehensible and that there has been sufficient opportunity to ask questions and reconsider consent prior to surgery. A written guide helps patients comprehend the nature of the planned surgery. Any surgical intervention is essentially a matter of trust and confidence—the trust of the patient in the surgeon's ability and integrity and the trust of the surgeon in the patient's ability to comprehend and follow the process and to comply with prescriptions for managing the condition before, during, and after surgery.

REFERENCES:

1. *Pesudovs K, Wright TA, Gothwal VK. Visual disability assessment: valid mea sure ment ofactivity limitation and mobility in cataract patients. Br J Ophthalmol. 2010;94(6):777–781.*

2. *Steinberg EP, Tielsch JM, Schein OD, et al. The VF-14. An index of functional impairment inpatients with cataract. Arch Ophthalmol. 1994;112(5):630–638.*

3. *American Acad emy of Ophthalmology Cataract and Anterior Segment Panel, Hoskins Centerfor Quality Eye Care. Preferred Practice Pattern® Guidelines. Cataract in the Adult Eye.American Acad emy of Ophthalmology; 2016. www . aao . org / ppp*

4. *Wiggins MN, Irak- Dersu I, Turner SD, Thostenson JD. Glare testing in patients with cataractafter dilation. Ophthalmology. 2009;116(7):1332–1335. Melki SA, Safar A, Martin J, Ivanova A, Adi M.*

5. *Potential acuity pinhole: a simple method to measure potential visual acuity in patients with cataracts, comparison to potential acuity meter. Ophthalmology. 1999;106(7):1262–1267.*

CHAPTER 7

IOL POWER CALCULATION

OCULAR BIOMETRY

Accurate biometry is of vital importance in achieving a predictable postoperative refraction following cataract surgery. Norrby1 analyzed the sources of error in IOL power calculation by analyzing the precision of the biometric and clinical measurements. He concluded that the three greatest sources of error were axial length (AL), effective lens position (ELP), and postoperative refraction, contributing 79% of the total error.

ULTRASOUND BIOMETRY

AL has traditionally been measured using ultrasound biometry. With the applanation technique, the ultrasound probe is placed in direct contact with the cornea, and corneal compression typically causes the AL to be falsely shortened. Applanation biometry has given way to noncontact methods. Although the immersion technique has been shown to be more reproducible than the applanation technique, both require mindfulness of the properties of ultrasound. In eyes with high to extreme axial myopia, the presence of a posterior staphyloma should be considered. Erroneously long AL readings may occur in eyes with staphylomata. An immersion A/B-scan approach for AL measurement has been described in the setting of posterior staphyloma.2 With A-scan biometry, errors in AL measurement account for 54% of IOL power error when two-variable formulas are used.

OPTICAL BIOMETRY

Optical biometry has been shown to be significantly more accurate and reproducible and is rapidly becoming the most prevalent methodology for the measurement of AL. The most commonly used optical biometers are IOLMaster (Carl Zeiss Meditec, Jena, Germany) and Lenstar (Haag-Streit, Koeniz, Switzerland).

• **IOLMaster:**

The IOLMaster 500 was introduced in 2000 as the first optical biometer. Based on partial coherence interferometry technology, it uses a 780-nm laser diode to measure AL. The device also provides measurements of keratometry, anterior chamber depth (ACD), and white-to-white (WTW) distance. The newer version of this device (IOLMaster 700) uses an optical configuration that allows telecentric and thus distance-independent keratometry measurement. It uses swept-source optical coherence tomography (OCT) to is measure axial length, central corneal thickness (CCT), and lens thickness (LT). It displays a full-length OCT image, showing anatomical details of a longitudinal cuts through the entire eye (Fig. 5.5.1).

• **Lenstar:**

Based on optical low-coherence reflectometry technology, the Lenstar uses an 820-nm laser diode to measure AL, ACD, CCT, and LT. It calculates keratometry from an array of 32 light reflections projected off the anterior corneal surface.

• **Argos (Movu Inc, Komaki, Japan) and OA-2000 (Tomey, Nagoya,Japan):** These are two other new swept-source biometers that recently been introduced. Studies4–6 have shown that the repeatability of theIOLMaster and Lenstar for all biometric parameter measurements is excellent and that agreement between these devices is good. The differences in AL, ACD, and LT between these devices were not shown to produce a statistically significant difference in IOL power calculation.

Although measurements with optical biometry are mostly operator independent, careful alignment during the scan and inspection of the measurement quality are still necessary for optimal refractive outcomes. The primary limitation of optical biometry is its inability to measure through dense cataracts and other media opacities that obscure the macula. It was reported that with use of an earlier generation of IOLMaster, approximately 10% of eyes could not be accurately measured due to such opacities or fixation difficulties. The IOLMaster 700 showed better penetration in dense posterior subcapsular cataracts, measuring AL successfully in 96% of cases.

IOL POWER FORMULAS

The first IOL power formula was published by Fyodorov in 1967. Subsequent formulas were developed and traditionally were classified as the second, third, fourth, and newer generations of IOL formulas. Due to the development of more advanced IOL formulas, a new classification based on how they work is more appropriate.

Vergence Formulas

The majority of IOL formulas are vergence-based formulas. Based on the number of variables they use to calculate ELP, these formulas can be categorized into the following groups:

- **Two-variable formulas:**

These include the Holladay 1, Hoffer Q, and SRK/T, and they use AL and keratometry to calculate the distance from the principal plane of the cornea to the thin lens equivalent of the IOL (i.e., ELP). Thus, a short eye or an eye with a flatter cornea will have a shallower anterior chamber. However, Holladay has shown that exceptions to these assumptions exist.7

Three-variable formula: The Haigis formula uses AL, keratometry, and ACD.

Five-variable formula: The Barrett Universal II formula uses AL, keratometry, ACD, LT, and WTW.

Seven-variable formula: The Holladay 2 formula uses preoperative refraction, age, AL, keratometry, ACD, LT, and WTW.

Ray Tracing Formulas

- **PhacoOptics:** With PhacoOptics, IOL power is calculated based on exact ray tracing (Snell's law of refraction). It incorporates the latest generation ACD prediction algorithms based on the complex relationship between the preoperative ocular dimensions (ACD and LT) and the postoperative position of the IOL (postoperative ACD).8 Measurements of the anterior and posterior corneal curvatures as along with conic coefficients (Q-values) obtained by modern anterior segment imaging systems can be used directly by the program.

• **Okulix:** Okulix9 is a program package that calculates single rays using Snell's law. AL can be entered either manually or by a computer link to the measuring device. As an alternative to entering corneal radii by hand, they also can be taken from a two-dimensional corneal topographic map.

Artificial Intelligence Formulas

• **Radial basis function (RBF):** The Hill-RBF calculator10 is an advanced, self-validating method for IOL power selection employing pattern recognition and a sophisticated form of data interpolation. Based on artificial intelligence, this methodology is entirely data driven. Pattern recognition for selecting an IOL power is achieved through the process of adaptive learning, the ability to learn tasks based solely on data. Unlike static theoretical formulas, this approach will be an ongoing project and continuously updated as a "big data" exercise. The greater the number of surgical outcomes that are fit to the RBF model, the greater the overall depth of accuracy.

• **Neural network:** Clarke11 developed a computational method based on neural network in which the software is trained to predict IOL powers using large amount of clinical data from one surgeon with one IOL. Clinical data include preoperative AL, keratometry, ACD, and LT.

Combination Formulas

• **Super formula:** The Ladas super formula12 amalgamates outcomes from the above-mentioned two-variable and three-variable vergence formulas and has a small component of artificial intelligence.

All of these formulas have some element of regression, as they include constants that are derived from prior patient outcomes. Note that two critical data points are not measured: posterior corneal curvature (although this is slowly being integrated) and ELP. Better predictive formulas for estimating ELP will likely require more sophisticated measurements, possibly to include lens diameter, lens volume, and certain angle and iris features.

EVOLUTION OF INTRAOCULAR LENS

Generation I (Original Ridley Posterior Chamber Lens)

Ridley's first IOL operation was performed November 29, 1949, on a 49-year-old woman at St Thomas' Hospital in London.4 His original IOL was a biconvex polymethyl methacrylate (PMMA) disc designed to be implanted after extracapsular cataract extraction (ECCE) .

Generation II (Early Anterior Chamber Lenses)

As a consequence of the relatively high incidence of dislocations with the Ridley lens, a new implantation site was considered, with fixation of the lens in the angle recess. The anterior chamber was chosen because less likelihood existed of dislocation within its narrow confines. In addition, anterior chamber lenses could be implanted after either an intracapsular cataract extraction (ICCE) or an ECCE. Late endothelial atrophy, corneal decompensation, and pseudophakic bullous keratopathy were observed with the original Baron anterior chamber lens and also developed with many subsequent anterior chamber lens designs. The entity now termed uveitis–glaucoma–hyphema (UGH) syndrome was described first when ocular tissue damage occurred that was clearly the result of poorly manufactured early anterior chamber lenses.

Generation III (Iris-Supported Lenses)

Binkhorst was an early advocate of iris-supported IOLs. His first lens was a four-loop, iris-clip IOL design. Although Binkhorst initially believed that IOL contact with the iris would not cause problems, he soon noted that iris chafing, pupillary abnormalities, and dislocation developed with the early iris-clip lens. Also, in an effort to circumvent dislocation, Binkhorst made the anterior loops of his four-loop lens longer, but this led to increased corneal decompensation from peripheral touch. His initial implantations were done after ICCE, but occasionally he implanted his four-loop lens following ECCE. His positive experience with this procedure prompted him to modify his iris-clip lens design for implantation following ECCE. Binkhorst's change from ICCE to ECCE and the introduction of his two-loop iridocapsular IOL in 1965 were important advances in both IOL design and mode of fixation.

Generation IV (Intermediate Anterior Chamber Lenses)

As iris-supported IOLs underwent major modifications from the early 1950s up to the beginning of the 1980s, several designs of anterior chamber IOLs were introduced. The problems of tissue chafing and difficulties in correct sizing associated with rigid IOLs were addressed by the development of anterior chamber lenses with more flexible loops or haptics. Unlike the ill-fated, nylon-looped lenses introduced by Dannheim in the early 1950s, the fixation elements of these anterior chamber IOLs were made from more stable polymers, usually PMMA and polypropylene. The best lenses were the various rigid7 and flexible, open-loop, one-piece PMMA designs, such as the three- and four-point fixation Kelman IOLs.8 Modifications of the latter have been in use since the late 1970s and are the styles most commonly implanted today.

Generation V (Improved Posterior Chamber Lenses)

The return to Ridley's original concept of IOL implantation in the posterior chamber occurred after 1975. Pearce9 of England implanted the first uniplanar posterior chamber lens since Ridley. It was a rigid tripod design with the two inferior feet implanted in the capsular bag and the superior foot implanted in front of the anterior capsule and sutured to the iris. Shearing10 of Las Vegas introduced a major lens design breakthrough in early 1977 with his posterior chamber lens. The design consisted of an optic with two flexible J-shaped loops. Simcoe of Tulsa introduced his C-looped posterior chamber lens shortly after Shearing's J-loop design appeared. The flexible open-loop designs (J-loop, modified J-loop, C-loop, or modified C-loop) still account for the largest number of IOL styles available today. One obvious major theoretical advantage that a posterior chamber IOL has over an anterior chamber IOL is its position behind the iris, away from the delicate structures of the anterior segment. The return to posterior chamber lenses coincided with the development of improved ECCE surgery. Shearing identified four major milestones that have marked the evolution of ECCE surgery: microscopic surgical techniques; phaco; iridocapsular fixation; and flexible posterior chamber lenses.

Generation VI (Modern Capsular Lenses

Rigid PMMA, Soft Foldable, and Modern Anterior Chamber) Modern One-Piece, all-Polymethyl Methacrylate, Kelman-Style anterior Chamber Lenses of Four-Point and three-Point Fixation Designs. note the excellent polishing and tissue-friendly Choyce-Kelman–style footplates. These represent modern, state-of-the-art lenses that should be distinguished clearly from the earlier, unsatisfactory, closed-loop anterior chamber lenses. more stable polymers, usually PMMA and polypropylene. The best lenses were the various rigid7 and flexible, open-loop, one-piece PMMA designs, such as the three- and four-point fixation Kelman IOLs. Modifications of the latter have been in use since the late 1970s and are the styles most commonly implanted today.

REFERENCES:

1. *Donaldson KE, Gorscak JJ, Budenz DL, Feuer WJ, Benz MS, Forster RK. Anterior chamberand sutured posterior chamber intraocular lenses in eyes with poor capsular support. JCataract Refract Surg. 2005;31(5):903–909.*

2. *Dhital A, Spalton DJ, Gala KB. Comparison of near vision, intraocular lens movement, anddepth of focus with accommodating and monofocal intraocular lenses. J Cataract RefractSurg. 2013;39(12):1872–1878.*

3. *Braga- Mele R, Chang D, Dewey S, et al; ASCRS Cataract Clinical Committee. Multifocal Intraocular lenses: relative indications and contraindications for implantation. J Cataract Refract Surg. 2014;40(2):313–322.*

4. *Cochener B; Concerto Study Group. Clinical outcomes of a new extended range of vision intraocular lens: International Multicenter Concerto Study. J Cataract Refract Surg. 2016;42(9):1268–1275.*

5. *Miyake T, Kamiya K, Amano R, Iida Y, Tsunehiro S, Shimizu K. Long- term clinical outcomes oftoric intraocular lens implantation in cataract cases with preexisting astigmatism. J CataractRefract Surg. 2014;40(10):1654–1660.*

CHAPTER 8

INDICATIONS FOR CATARACT SURGERY

The indications for lens surgery today may be classified into two main categories:

- Medical – surgical or pathological indication, and
- Optical – or refractive lens exchange.

Medical Indications for Lens Surgery

I. Lenticular opacification (cataract)
II. II. Lenticular malposition A. Subluxation B. Dislocation
III. Lenticular malformation A. Coloboma B. Lenticonus C. Lentiglobus D. Spherophakia
IV. Lens-induced inflammation A. Phacotoxic uveitis (phacoanaphylaxis) B. Phacolytic glaucoma C. Phacomorphic glaucoma
V. Lenticular tumor A. Epithelioma B. Epitheliocarcinoma
VI. Facilitatory (surgical access) A. Vitreous base B. Ciliary body C. Ora serrata

REFRACTIVE INDICATIONS FOR LENS SURGERY

Refinements in measurement technology, ocular anesthesia, incision technology, lensectomy techniques, ophthalmic viscosurgical devices (OVD) tissue protection, and IOL technology has allowed the accurate and successful correction of refractive errors. Almost all the operable tissues and spaces of the eye have, over decades, come under investigation as locations for refractive surgical modulation: corneal epithelial surface, corneal stroma, corneal endothelial surface, anterior chamber, iris, pupil, posterior chamber, lens, and sclera. The lens, therefore, assumes its role among the others as a popular location for surgical refractive modulation, sparing the other tissues where appropriate or necessary. Clear lens replacement stands as a viable procedure today for both myopia and hyperopia, with the abilities now to control astigmatism modulate higher-order aberration, and reduce presbyopic symptoms. Patient demand for these services has increased dramatically in recent times. Multifocal IOLs represent some of the first attempts at the intraocular correction of presbyopia. Other attempts at the development of a truly accommodative pseudophakos have included the intracapsular injection of liquid siliconeand the intracapsular placement of high-water-content poly-HEMA lenses, a liquid silicone-filled intracapsular balloon, multiple IOLs (polypseudophakia) and the flexing haptic accommodative IOLs.

Lens Surgery techniques

I. Lens repositioning ("couching")

- **A.** Extracapsular
- **B.** Intracapsular
  - **1.** Physical (instrumental) zonulysis
  - **2.** Pharmacological (enzymatic) zonulysis

II. Lens removal

- **A.** Total (intracapsular)
  - **1.** Capsule forceps
  - **2.** Suction erysiphake
  - **3.** Cryoextraction

- **B.** Partial (extracapsular)
  - **1.** Anterior capsulotomy/capsulectomy
    - **a.** Discontinuous
    - **b.** Continuous (capsulorrhexis)
    - **c.** Linear
  - **2.** Nucleus removal
    - **a.** Assembled delivery (large incision)
      - **(1)** Expression ("push")
      - **(2)** Extraction ("pull")
    - **b.** Disassembled extraction
      - **(1)** Phacosection
      - **(2)** Phacoemulsification-aspiration

(a) Ultrasound
(i) linear
(ii) torsional
(b) Laser
(c) Water jet
(d) Impeller

3. Cortex removal
a. Irrigation
b. Aspiration

III. Lens replacement (intraocular lens implantation)

A. Locations
1. Anterior chamber
a. Angle fixation
b. Iris fixation
2. Pupil
3. Posterior chamber
a. Iris fixation (sutured or enclavated)
b. Ciliary sulcus (sutured or unsutured)
4. Lens capsule
a. Anterior capsule
(1) Haptic sulcus/optic bag
(2) Optic posterior chamber/haptic bag
b. Intracapsular ("in the bag placement")
c. Posterior capsule (haptic bag/optic Berger's space)
5. Pars plana (sutured)

B. Optic materials
1. Hydrophobic
a. Polymethyl methacrylate (PMMA)
b. Silicone
c. Acrylic

2. Hydrophilic
    a. Poly hydroxyethyl methacrylate (poly-HEMA)
    b. Acrylic
    c. Collagen-copolymer

C. Optic types
  1. Monofocal
    a. Spherical
      (1) Plus
      (2) Minus
    b. Toric
    c. Telescopic
    d. Prismatic
  2. Multifocal
  3. Accommodative

IV. Lens enhancement: reversal of presbyopia by scleral expansion
  A. Ciliary cerclage
  B. Radial anterior ciliary sclerotomy

Details of popular types of IOL lens

Below are the major types of IOL Lens:

1. Monofocal

Monofocal IOLs are one of the most traditional and widely used OL lens types. They offer a single focal point, which means that they provide clear vision for one specific distance – either near, intermediate, or far. Individuals who prefer a monofocal IOL often opt for clear distance vision and rely on reading glasses or other corrective measures for close-up tasks.

Advantages:

- **Predictable Results:** Monofocal IOLs are an excellent choice for patients who have straightforward vision needs.
- **Cost-Effective:** These IOLs tend to be more cost-effective compared to multifocal or premium lenses.
- **Low Risk of Visual Disturbances:** Monofocal IOLs have a lower risk of visual issues like halos and glare, making them suitable for night driving.

2. Multifocal

As the name suggests, Multifocal lenses provide multiple focal points within a single lens. It allows individuals to see clearly at different distances, eliminating the need for glasses. These types of IOLs lenses can correct presbyopia, a condition that affects near vision as people age.

Advantages:

- **Reduced Dependence on Glasses:** Offer the convenience of clear vision at various distances.
- **Enhanced Quality of Life:** Improved quality of life due to their ability to perform a wide range of activities.

3. Extended Depth-of-Focus Lens

Extended depth-of-focus IOLs are the most recent innovation in all Intraocular lens types that aim to provide continuous and seamless vision across various distances. Unlike multifocal IOLs, it does not have distinct focal points. Instead, it offers a continuous range of focus, helping patients easily achieve superb vision at varying distances.

Advantages:

- **Continuous Range of Vision:** Reduces the likelihood of visual disturbances associated with multifocal lenses.
- **Improved Intermediate Vision:** Excellent at providing clear vision for intermediate tasks, such as using a computer or reading a menu at a restaurant.

- **Enhanced Night Vision:** Offer better night vision compared to some multifocal options.

4. Light-Adjustable Lens

The light-adjustable lens is the most innovative development in the field of Intraocular lens types. It can be customized and fine-tuned after cataract surgery to reshape the lens, optimizing the patient's vision as required.

Advantages:

- **Personalized Vision:** It can be adjusted and personalized to meet each patient's unique visual requirements.

- **Reduced Need for Multiple Surgeries:** It can be modified after the initial cataract surgery, eliminating the need for additional surgeries to address changing vision needs.

- **High Precision:** High level of precision in correcting vision, potentially leading to excellent outcomes.

5. Toric Intraocular Lens

Toric IOLs are specifically designed to address astigmatism. These type of IOLs lenses have a toric shape, which allows them to work effectively for the irregular curvature of the cornea in astigmatic eyes.

Advantages:

- **Astigmatism Correction:** Eliminates astigmatism, improving the overall quality of vision.

- **Reduced Need for Glasses:** Reduces dependence on glasses for distance vision.

- **Improved Contrast Sensitivity:** Enhances contrast sensitivity, leading to sharper and clearer vision, especially in low-light conditions.

6. Accommodating IOL Lens

Accommodating IOLs are IOL lens options designed to enhance the natural flexibility of the eye's crystalline lens. These lenses can adjust their shape in response to the eye's focusing muscles, providing a range of clear vision at varying distances.

Advantages:

- **Near-Natural Vision:** Provides a more natural vision experience.
- **Reduced Dependence on Glasses:** Offer improved near and intermediate vision.
- **Less Risk of Visual Disturbances:** Lower risk of visual disturbances compared to multifocal IOLs.

7. Custom and Enhanced Intraocular Lens

Custom and enhanced IOLs are designed to cater to patients with specific vision needs or unique anatomical considerations. These IOL lens types can be tailored to correct a wide range of refractive errors and can be combined with other advanced technologies.

Advantages:

- **Individualized Solutions:** It can be customized to address an array of visual imperfections.
- **Comprehensive Correction:** It addresses not only cataracts but also other refractive errors like myopia, hyperopia, and presbyopia.
- **Enhanced Visual Outcomes:** Offers excellent and often superior visual outcomes.

REFERENCES:

1. *Bjeloš Rončević M, Bušić M, Cima I, Kuzmanović Elab jer B, Bosnar D, Miletić D. Intraobserverand interobserver repeatability of ocular components mea sure ment in cataracteyes using a new optical low coherence reflectometer. Graefes Arch Clin Exp Ophthalmol.2011;249(1):83–87.*

2. *Ianchulev T, Hoffer KJ, Yoo SH, et al. Intraoperative refractive biometry for predictingintraocular lens power calculation after prior myopic refractive surgery. Ophthalmology.2014;121(1):56–60.*

3. *Koch DD, Jenkins RB, Weikert MP, Yeu E, Wang L. Correcting astigmatism with toricintraocular lenses: effect of posterior corneal astigmatism. J Cataract Refract Surg. 2013;39(12):1803–1809.*

4. *Narvaez J, Zimmerman G, Stulting RD, Chang DH. Accuracy of intraocular lens powerprediction using the Hoffer Q, Holladay 1, Holladay 2, and SRK/T formulas. J CataractRefract Surg. 2006;32(12):2050–2053.*

5. *Wang L, Tang M, Huang D, Weikert MP, Koch DD. Comparison of newer intraocular lenspower calculation methods for eyes after corneal refractive surgery. Ophthalmology.2015;122(12):2443–2449.*

CHAPTER 9

PHARMACOTHERAPY FOR CATARACT SURGERY

Pupil Dilatation

Sympathomimetic mydriatic agents (phenylephrine 2.5%) and parasympatholytic cycloplegics (tropicamide or cyclopentolate 1.0%) usually are used together before extracapsular nuclear expression, phacoemulsification (phaco), or femtosecond laser-assisted cataract surgery (FLACS). Topical nonsteroidal anti-inflammatory drugs (NSAIDs) are commonly used in cataract surgery to prevent pupillary miosis, reduce surgically induced inflammation, and prevent postoperative cystoid macular edema.2 NSAIDs inhibit cyclooxygenase, decreasing prostaglandin synthesis from arachidonic acid.Intracameral mydriatic solutions using cyclopentolate 0.1%, phenylephrine 1.5%, xylocaine 1% or tropicamide 0.5%, phenylephrine 5%, and diclofenac 0.1%, in preservative-free solutions are safe to the corneal endothelium and effective in producing and maintaining pupillary dilatation and are used in various combinations .

Anti-infective Prophylaxis

No worldwide consensus exists on prophylactic topical antibiotics in cataract surgery, although their use has been an accepted practice for decades. A large randomized study of preoperative topical antibiotics for the prevention of endophthalmitis has yet to be carried out. The most important source of potential infectious organisms is the patient's own natural conjunctival and skin flora.Before cataract surgery, topical anti-infective regimens historically included gramicidin–neomycin–polymyxin B sulfate; aminoglycosides, such as gentamicin or tobramycin (which provide Gram-negative and pseudomonas coverage); and the fluoroquinolones— ciprofloxacin, norfloxacin, ofloxacin 0.3%7,16,17 or levofloxacin 0.5%. Of these, levofloxacin provided superior coverage and anterior-chamber penetration, before fourth-generation fluoroquinolone (G4FQ) became available.The G4FQs gatifloxacin 0.3% and moxifloxacin 0.5% are currently preferred because they offer better penetration compared with previous generations (moxifloxacin appears to be better than gatifloxacin), broader-spectrum coverage, lower incidence of bacterial resistance, and equal safety.

Anesthetics

Local injection anesthesia, both retrobulbar and peribulbar, has fallen increasingly out of favor, and the use of intracameral isotonic nonpreserved lidocaine 1%, preceded by topical lidocaine, has become the standard in many centers. Lidocaine gel is claimed to provide increased corneal hydration and anesthesia equal to that of injections and drops while minimizing patient discomfort.

INTRAOPERATIVE MEDICATIONS

To prevent intraoperative miosis, nonpreserved epinephrine (1 : 1000) 0.5 mL/500 mL is the most frequently used additive.

A new U.S. Food and Drug Administration (FDA)–approved combination drug, phenylephrine 1.0%–ketorolac 0.3% (Omidria) has been studied for the treatment of intraoperative miosis and postoperative ocular pain.

Vancomycin (20 µg/mL (0.02 mg/mL)) combined with gentamicin (8 µg/mL (0.008 mg/mL)) in the irrigating solution, has been reported to eradicate Gram-positive, coagulase-negative micrococci,53 with minimal associated complications.

Rapid miosis can be produced at the end of the surgical procedure by using intraocular parasympathomimetics acetylcholine chloride 1% or carbachol 0.01%.

Agents currently under investigation include low-molecular-weight heparin, enoxaparin (10 IU/mL added to standard irrigating solution), which produces a decreased inflammatory response immediately after cataract surgery with minimal side effects (e.g., hemorrhage)

Irrigating Solutions: In the early days of phaco, the only irrigating solutions available were normal saline, Plasma-Lyte, and lactated Ringer's solution. Their main adverse effect was endothelial cell toxicity.

Several comparative studies found BSS Plus to be protective of the corneal endothelium and hence superior to BSS and other irrigating solutions. Unlike BSS, BSS Plus is physiologically similar to human aqueous and vitreous, especially with regard to calcium concentration and the addition of glucose, glutathione, and bicarbonate. BSS Plus maintains endothelial cell function over periods ranging from 15 minutes to in excess of a few hours.

OPHTHALMIC VISCOSURGICAL DEVICES

Antibiotics

Postoperative regimens of topical antibiotics vary but generally consist of one drop to the operated eye four to six times daily for 1 to 2 weeks. Recent studies support the practice of starting topical antibiotics immediately after cataract surgery, rather than waiting until the first postoperative day.94–96 The duration of treatment varies from 5 days in uncomplicated surgery to weeks if prolonged inflammation occurs. Injections and collagen shields are increasingly falling out of favor.

Corticosteroids and Nonsteroidal Anti-inflammatory Drugs

The use of topical corticosteroids and NSAIDs after cataract surgery reduces postoperative noninfectious inflammation. Both are efficacious in decreasing inflammation, with no difference between them in terms of astigmatic decay. The development of an intraocular biodegradable drug delivery system containing dexamethasone appears to be an effective alternative to topical drops, and because a variety of drugs may be bound to the polymer matrix, it may play a role in the long-term prevention or treatment of cystoid macular edema. Topical NSAIDs have a specific advantage over corticosteroids if there are contraindications to corticosteroid use in a particular patient, as in those with corticosteroid-responsive elevations of intraocular pressure, recurrent herpes simplex infection, or concern about delayed wound healing. Ketorolac 0.5% has shown similar efficacy as a single agent in antimiotic and anti-inflammatory activity to an NSAID–prednisolone 1% combination. However, an increased risk of corneal or scleral perforation in the presence of an epithelial defect exists when NSAIDs are used without concomitant administration of topical corticosteroids, most commonly reported with diclofenac.

ANAESTHESIA

Retrobulbar Block

With this technique, the aim is to block the oculomotor nerves before they enter the four rectus muscles by depositing the local anesthetic directly into the posterior intraconal space . Although the resultant akinesia is usually profound, serious complications, such as brainstem anesthesia, globe perforation, and myotoxicity, have rendered the technique relatively obsolete. For sharp needle anesthesia, peribulbar block offers a safer, equally effective method.

Peribulbar Block

The principle of this technique is to instill the local anesthetic outside the posterior muscle cone and thereby avoid accidental injection into the optic nerve (which would cause brainstem anesthesia). This utilizes higher volumes (6–10 mL) of the local anesthetic compared with the traditional retrobulbar block, and the application of a pressure device is often needed. Technique With the eye in primary gaze, local anesthetic drops are applied to the cornea. At the inferotemporal lower orbital margin, a 25-gauge, 25-mm needle is advanced parallel to the plane of the orbital floor either transcutaneously or transconjunctivally. A degree of upward and inward angulation may be needed once the needle goes past the equator of the globe. Local anesthetic (4–6 mL) is injected at a depth of about 20 mm from the inferior orbital rim (in an eye of normal axial length). No resistance to injection should be felt, and prior aspiration should be performed

Local Anesthetic Agent

The most common agent used is lidocaine 2% plus hyaluronidase 15 IU/ mL. If greater duration of anesthesia is required, the lidocaine can be mixed in a ratio of 50 : 50 with bupivacaine 0.5%. Other agents used include 2-chloroprocaine 2%–3%, mepivacaine 1%–2%, bupivacaine 0.25%–0.75%, prilocaine 3%, and ropivacaine 0.75%.31 Levobupivacaine is the L-isomer of bupivacaine with a higher safety index, especially in terms of cardiac toxicity.

Complications

Most serious complications of peribulbar anesthesia are associated with the use of sharp needles.

- **Globe perforation/penetration:**Incidence 1.4–1.9 per 10 000.38–40 More common in high myopes (>26 mm axial length) and with inexperience. Usually results in marked visual loss because of permanent retinal damage
- **Retrobulbar hemorrhage:** Incidence 0.6–4.2 per 10 000.38–40 More common in those taking anticoagulants. May require surgical decompression.
- **Extraocular myotoxicity**: Incidence 25–100 per 10 000.41,42 Related to inadvertent direct injection of the local anesthetic into the muscle belly. Myocyte cell death is followed by hypertrophic regeneration and shortening.43,44 These serious complications have led some authorities to recommend abandoning sharp needle techniques altogether.42 The UK Royal College of Ophthalmologists has also stated: "Sharp needle local anaesthetic techniques have a higher risk of ocular and systemic complications than sub-Tenon's or topical techniques and should only be used when the anaesthetist and surgeon consider it absolutely necessary."45 In 2017 the UK National Institute for Health and Care Excellence (NICE) concluded that peribulbar anesthesia should no longer be used for routine cataract surgery where Topical or sub-Tenon's anesthesia is possible.

Sub-Tenon's Block

Technique: The conjunctiva is anesthetized first with a topical local anesthetic of choice. The most common approach is via the infranasal quadrant because this allows for good distribution of the anesthetic while decreasing the risk of damage to the vortex veins. The eye is cleaned with 5% iodine, and the patient is asked to look upward and outward. Aseptically, the conjunctiva and Tenon's capsule are held 3–5 mm from the limbus using nontoothed Moorfield's forceps. A small incision is made through these layers using blunt-tipped, sprung Westcott scissors, exposing the sclera. A cannula is then advanced into the sub-Tenon's space and around the globe. Sub-Tenon's anesthesia can be broadly divided into anterior and posterior techniques. In the former, the cannula tip remains anterior to the globe equator. This reduces the risk of inadvertent misplacement but increases the rate of chemosis and can make akinesia difficult to achieve. For more profound akinesia, the cannula tip should be placed posterior to the equator but must be positioned with care, gently following the curve of the globe . Numerous cannulae have been described.55 The plastic Greenbaum cannula (12-mm 15-gauge) is suitable for anterior blocks, whereas a metal Stevens cannula (25-mm 19-gauge) is most suitable for posterior techniques.

SEDATIVE AGENTS

Sedation is a useful adjunct to local anesthesia for many patients— particularly those who are unduly anxious. Midazolam, a short-acting, water-soluble benzodiazepine with a half-life of 2 hours, has both amnesic and anxiolytic properties, lacks venous sequelae, and allows rapid patient recovery. It is given intravenously in 0.5- to 1-mg increments. Adequate time between doses must be allowed in older adults, or oversedation could result. Overdoses can be reversed with f lumazenil, a specific benzodiazepine antagonist, but its half-life is 1 hour, so resedation can occur. Propofol, a short-acting phenol, is an intravenous induction agent suitable for infusion and sedation. It is characterized by the patient's rapid and clear-headed recovery and is associated with a low incidence of nausea and vomiting. It causes respiratory depression and a fall in blood pressure.

REFERENCES:

1. *Schimek F, Fahle M. Techniques of facial nerve block. Br J Ophthalmol. 1995;79(2):166–173.Zhao LQ, Zhu H, Zhao PQ, Wu QR, Hu YQ. Topical anesthesia versus regional anesthesia forcataract surgery: a meta- analysis of randomized controlled trials. Ophthalmology. 2012;119(4):659–667.*

2. *Sykakis E, Karim R, Parmar DN. Management of patients with herpes simplex virus eye disease having cataract surgery in the United Kingdom. J Cataract Refract Surg. 2013;39(8): 1254–1259.*

3. *Yoshida J, Kim A, Pratzer KA, Stark WJ. Aqueous penetration of moxifloxacin 0.5% ophthalmic solution and besifloxacin 0.6% ophthalmic suspension in cataract surgery patients. J Cataract Refract Surg. 2010;36(9):1499–1502.*

4. *Bowen RC, Zhou AX, Bondalapati S, et al. Comparative analy sis of the safety and efficacy ofintracameral cefuroxime, moxifloxacin, and vancomycin at the end of cataract surgery: ameta- analysis. Br J Ophthalmol. 2018;102(9):1268–1276.*

5. *Chang DF, Braga- Mele R, Henderson BA, Mamalis N, Vasavada A; ASCRS Cataract Clinical Committee. Antibiotic prophylaxis of postoperative endophthalmitis after cataract surgery: results of the 2014 ASCRS member survey. J Cataract Refract Surg. 2015;41(6):1300–1305.*

6. *Behndig A, Cochener B, Guell JL, et al. Endophthalmitis prophylaxis in cataract surgery: overview of current practice patterns in 9 Eu ro pean countries. J Cataract Refract Surg. 2013;39(9):1421–1431.*

7. *Riedel PJ. Ophthalmic viscosurgical devices. Focal Points: Clinical Modules for Ophthalmologists.*

8. *American Acad emy of Ophthalmology; 2012, module 7.*

CHAPTER 10

CATARCT SURGERY

INTRACAPSULAR CATARACT EXTRACTION

The intracapsular cataract extraction (ICCE) method of lens removal has not been the procedure of choice in industrialized nations since the development of modern extracapsular techniques in the late 1970s, primarily because of lower rates of postoperative posterior segment complications such as hemorrhage, vitreous loss, retinal detachment, and cystoid macular edema. Current indications for planned intracapsular cataract surgery are therefore related only to situations where zonular laxity or deficiency exists and where capsular bag instability is predicted. Under these circumstances, safe and successful extracapsular surgery with intra-ocular lens implant, is often unlikely. Conditions likely to be associated with these conditions are physical trauma to the eye, diseases processes such as Marfans Syndrome and psuedoexfoliation, and isolated congenital anomalies. Significant subluxation or dislocation of the crystalline lens necessitates removal of the entire organ, done either by intracapsular cataract surgery or by pars plana fragmentation and aspiration. Traditionally, ICCE involved removal of the complete intact lens through a large incision measuring 12–14 mm. In earlier years these eyes were left aphakic, with aphakic spectacle correction offered where available. Bilateral surgery was invariably necessary to minimize aniseikonic problems, although contact lens correction was satisfactory. Many of these eyes have subsequently had secondary IOLs implanted, with the choice of IOL being angle based, iris fixed (anterior or posterior), or sutured to the ciliary sulcus. Modern sulcus fixation IOLs now have design features that enable them to fibrose into the ciliary processes and sulcus , minimizing the chances of posterior dislocation common in previous sulcus fixation IOLs. In addition, these lenses are foldable, allowing small-incision surgery and adherence to the principles of astigmatism avoidance and correction. In the majority of primary situations for ICCE, the wound needs to be large and hence constructed appropriately for minimization of astigmatism induction.

EXTRACAPSULAR EXTRACTION (LARGE-INCISION NUCLEAR EXPRESSION CATARACT SURGERY)

This technique became popular in the 1980s, as surgeons who had been performing large-incision ICCE and anterior chamber implantation desired the benefits derived from an intact posterior capsule and posterior chamber implantation. The technique persists today and is performed in large numbers, particularly in developing countries, where the more advanced small-incision techniques of phacoemulsification (phaco) and foldable lens implantation are not yet available for the masses. The only indications for nuclear delivery now relate to (1) hard nuclei that cannot be safely emulsified by phaco and (2) capsule rupture with vitreous presentation mid procedure. Cataracts with high-risk corneas (e.g., Fuchs' endothelial dystrophy, corneal graft) were previously considered to be best dealt with by nuclear expression via continuous linear capsulotomy and intercapsular techniques.20,21 With optimal use of OVDs ("soft shell")22 and good technique,23 however, small-incision procedures are now the procedure of choice.

Small-Incision Nuclear Expression Cataract Surgery ("Mini-nuc" and Other Techniques)

The indications for these techniques24,25 relate in the majority to the benefits of smaller incision surgery. Socioeconomic factors and instrumentation availability together with surgeon experience also play a significant part in the choice of this type of surgery.

Advantages of ECCE over ICCE

1. ECCE is a universal operation and can be performed at all ages, except when zonules are not intact; whereas ICCE cannot be performed below 40 years of age.
2. Posterior chamber IOL can be implanted after ECCE, while it cannot be implanted after ICCE.
3. Postoperative vitreous related problems (such as herniation in anterior chamber, pupillary block and vitreous touch syndrome) associated with ICCE are not seen after ECCE.

4. Incidence of postoperative complications such as endophthalmitis, cystoid macular oedema and retinal detachment are much less after ECCE as compared to that after ICCE.
5. Postoperative astigmatism is less, as the incision is smaller.

Advantages of ICCE over ECCE

1. The technique of ICCE, as compared to ECCE, is simple, cheap, easy and does not need sophisticated microinstruments.
2. Postoperative opacification of posterior capsule is seen in a significant number of cases after ECCE. No such problem is known with ICCE.
3. ICCE is less time consuming and hence more useful than ECCE for mass scale operations in eye camps.

Types of extracapsular cataract extraction

The surgical techniques of ECCE presently in vogue are:

- Conventional extracapsular cataract extraction (ECCE),
- Manual small incision cataract surgery (SICS),
- Phacoemulsification

SURGICAL TECHNIQUES FOR CATARACT EXTRACTION

INTRACAPSULAR CATARACT EXTRACTION

Presently, the technique of intracapsular cataract extraction (ICCE) is obsolete and sparingly performed worldwide. However, the surgical steps are described in detail as a mark of respect to the technique which has been widely employed for about 50 years over the world and also to care for the emotions of few elderly surgeons who are still performing this operation (though unethical) at some places in developing countries.

Surgical steps of the ICCE technique are as follows:

1. Superior rectus (bridle) suture is passed to fix the eye in downward gaze

2. Conjunctival flap (fornix based) is prepared to expose the limbus and haemostasis is achieved by wet field or heat cautery. All surgeons do not make conjunctival flap.
3. Partial thickness groove or gutter is made through about two-thirds depth of anterior limbal area from 9.30 to 2.30 O'clock (150o) with the help of a razor blade knife
4. Corneoscleral section. The anterior chamber is opened with the razor blade knife or with 3.2mm keratome
5. Iridectomy A peripheral iridectomy may be performed by using iris forceps and de Wecker's scissors to prevent postoperative pupil block glaucoma.
6. Methods of lens delivery. In ICCE the lens can be delivered by any of the following methods:
   i) **Indian smith method:** Here the lens is delivered with tumbling technique by applying pressure on limbus at 6 O'clock position with lens expressor and counterpressure at 12 O'clock with the lens spatula. With this method lower pole is delivered first.
   ii) **Cryoextraction:** In this technique, cornea is lifted up, lens surface is dried with a swab, iris is retracted up and tip of the cryoprobe is applied on the anterior surface of the lens in the upper quadrant. Freezing is activated (–40oC) to create adhesions between the lens and the probe. The zonules are ruptured by gentle rotatory movements and the lens is then extracted out by sliding movements. In this technique, upper pole of the lens is delivered first
   iii) **Capsule forceps method:** The Arruga's capsule holding forceps is introduced close into the anterior chamber and the anterior capsule of the lens is caught at 6 O'clock position. The lens is lifted slightly and its zonules are ruptured by gentle sideways movements. Then the lens is extracted with gentle sliding movements by the forceps assisted by a pressure at 6 O'clock position on the limbus by the lens expressor.
   iv) **Irisophake method:** This technique is obsolete and thus not in much use.
   v) **Wire vectis method:** It is employed in cases with subluxated or dislocated lens only. In this method the loop of the wire vectis is

slide gently below the subluxated lens, which is then lifted out of the eye.

7. Formation of anterior chamber. After the delivery of lens, iris is reposited into the anterior chamber with the help of iris repositor and chamber is formed by injecting sterile air or balanced salt solution.
8. Implantation of anterior chamber (ACIOL)
9. Closure of incision is done with 5 to 7 interrupted sutures (8-0, 9-0 or 10-0 nylon)
10. Conjunctival flap is reposited and secured by wet-field cauery.
11. Subconjunctival injection of dexamethasone 0.25 ml and gentamicin 0.5 ml is given.
12. Patching of eye is done with a pad and sticking plaster or a bandage is applied.

CONVENTIONAL EXTRACAPSULAR CATARACT EXTRACTION

Surgical steps of conventional ECCE are :

1. Superior rectus (bridle) suture is passed to fix the eye in downward gaze
2. Conjunctival flap (fornix based) is prepared to expose the limbus and haemostasis is achieved by wet field cautery. Many surgeons do not make conjunctival flap.
3. Partial thickness groove or gutter is made through about two-thirds depth of anterior limbal area from 10 to 2 O'clock with the help of a razor blade knife
4. Corneoscleral section. The anterior chamber is opened with the razor blade knife or with 3.2-mm keratome.
5. Injection of viscoelastic substance in anterior chamber. A viscoelastic substance such as 2% methylcellulose or 1% sodium hyaluronate is injected into the anterior chamber. This maintains the anterior chamber and protects the endothelium.
6. Anterior capsulotomy. It can be performed by any of the following methods:

i) Can-opener's technique. In it, an irrigating cystitome (or simply a 26 gauge needle, bent at its tip) is introduced into the anterior chamber and multiple small radial cuts are made in the anterior capsule for 360o

ii) Linear capsulotomy (Envelope technique). Here a straight incision is made in the anterior capsule (in the upper part) from 2-10 O'clock position. The rest of the capsulotomy is completed in the end after removal of nucleus and cortex.

iii) Continuous circular capsulorrhexis (CCC). Recently this is the most commonly performed procedure. In this the anterior capsule is torn in a circular fashion either with the help of an irrigating bent-needle cystitome or with a capsulorrhexis forceps

7. Removal of anterior capsule. It is removed with the help of a Kelman-McPherson forceps

8. Completion of corneoscleral section. It is completed from 10 to 2 O' clock position either with the help of corneo-scleral section enlarging scissors or 5.2-mm blunt keratome

9. Hydrodissection. After the anterior capsulotomy, the balanced salt solution (BSS) is injected under the peripheral part of the anterior capsule. This manoeuvre separates the corticonuclear mass from the capsule.

10. Removal of nucleus. After hydrodissection the nucleus can be removed by any of the following techniques:

i) Pressure and counter-pressure method. In it the posterior pressure is applied at 12 O'clock position with corneal forceps or lens spatula and the nucleus is expressed out by counter-pressure exerted at 6 O'clock position with a lens hook

ii) Irrigating wire vectis technique. In this method, loop of an irrigating wire vectis is gently passed below the nucleus, which is then lifted out of the eye.

11. Aspiration of the cortex. The remaining cortex is aspirated out using a two-way irrigation and aspiration cannula

12. Implantation of IOL. The PMMA posterior chamber IOL is implanted in the capsular bag after inflating the bag with viscoelastic substance

13. Closure of the incision is done by a total of 3 to 5 interrupted 10-0 nylon sutures or continuous sutures

14. Removal of viscoelastic substance. Before tying the last suture the visco-elastic material is aspirated out with 2 way cannula and anterior chamber is filled with BSS.
15. Conjunctival flap is reposited and secured by wet field cautery.
16. Subconjunctival injection of dexamethasone 0.25 ml and gentamicin 0.5 ml is given.
17. Patching of eye is done with a pad and sticking plaster or a bandage is applied.

MANUAL SMALL INCISION CATARACT SURGERY

Manual small incision cataract surgery (SICS) is becoming very popular because of its merits over conventional ECCE as well as phacoemulsification technique highlighted above. In this technique ECCE with intraocular lens implantation is performed through a sutureless self-sealing valvular sclerocorneo tunnel incision.

Surgical steps of manual SICS are:

1. Superior rectus (bridle) suture is passed to fix the eye in downward gaze . This is specifically important in manual SICS where in addition to fixation of globe, it also provides a countertraction force during delivery of nucleus and epinucleus.
2. Conjunctival flap and exposure of sclera A small fornix based conjunctival flap is made with the help of sharp-tipped scissors along the limbus from 10 to 2 O'clock positions. Conjunctiva and the Tenon's capsule are dissected, seperated from the underlying sclera and retracted to expose about 4 mm strip of sclera along the entire incision length.
3. Haemostasis is achieved by applying gentle and just adequate wet field cautery.
4. Sclero-corneal tunnel incision. A self-sealing sclero-corneal tunnel incision is made in manual SICS. It consists of following components:
    i) External scleral incision. A one-third to halfthickness external scleral groove is made about 1.5 to 2mm behind the limbus. It varies from 5.5 mm to 7.5 mm in length depending upon the

hardness of nucleus. It may be straight, frown shaped or chevron in configuration

ii) Sclero-corneal tunnel. It is made with the help of a crescent knife. It usually extends 1-1.5 mm into the clear cornea

iii) Internal corneal incision. It is made with the help of a sharp 3.2 mm angled keratome

5. Side-port entry of about 1.5-mm valvular corneal incision is made at 9 o'clock position . This helps in aspiration of the sub-incisional cortex and deepening the anterior chamber at the end of surgery.
6. Anterior capsulotomy. As described in conventional ECCE, the capsulotomy in manual SICS can be either a canopner, or envelope or CCC. However, a large sized CCC is preferred
7. Hydrodissection. hydrodissection is essential to separate corticonuclear mass from the posterior capsule in SICS.
8. Nuclear management. It consists of following manoeuvres :
   i) Prolapse of nucleus out of the capsular bag into the anterior chamber is usually initiated during 191 hydrodissection and completed by rotating the nucleus with Sinskey's hook
   ii) Delivery of the nucleus outside through the corneo-scleral tunnel can be done by any of the following methods: Irrigating wire vectis method (It is the most commonly used method). Blumenthal's technique, Phacosandwitch technique, Phacofracture technique, and Fishhook technique.
9. Aspiration of cortex. The remaining cortex is aspirated out using a two-way irrigation and aspiration cannula from the main incision and/or side port entry.
10. IOL implantation. A posterior chamber IOL is implanted in the capsular bag after filling the bag with viscoelastic substance
11. Removal of viscoelastic material is done thoroughly from the anterior chamber and capsular bag with the help of two-way irrigation aspiration cannula.
12. Wound closure.The anterior chamber is deepened with balanced salt solution / Ringer's lactate solution injected through side port entry. This leads to self-sealing of the sclero-corneal tunnel incision due to valve effect. Rarely a single infinity suture may be required to seal the wound. The

conjunctival flap is reposited back and is anchored with the help of wet field cautery.

PHACOEMULSIFICATION

This technique of nucleus removal has been performed through incisions ranging from 3.2 mm down to less than 1.0 mm. Combined with foldable lens implantation, the major advantage of phaco is the small incision. Many phaco techniques have been described, as have some nonultrasound techniques of which very few can compete with ultrasound). Current techniques use phaco through self-sealing, sutureless scleral and clear corneal incisions measuring 1.9–3.2 mm. The smaller incisions are astigmatically neutral. These corneal incisions, if made on the steep axis of astigmatism and made wider or moved centrally from the limbus, can be used to titrate the amount of astigmatic correction. These effects can be doubled by making similar incisions on the opposite side of the steep axis on the cornea as well. The presence therefore of corneal cylinder is an indication for phaco and foldable lens implantation just as is the absence of corneal cylinder.

PHACOEMULSIFICATION TECHNIQUES

I. Location
- **A.** Anterior chamber (Kelman, Brown)
- **B.** Iris plane (Kratz)
- **C.** Posterior chamber (supracapsular) (Maloney)

D. Capsule (endolenticular, in situ)
- **1.** Anterior capsulectomy (Sinskey)
- **2.** Anterior capsulotomy (intercapsular) (Hara)

II. Techniques
- **A.** Carousel
- **B.** Chip-and-flip (Fine)
- **C.** Phacofracture
  - **1.** Divide-and-conquer (Gimbel)
  - **2.** Four-quadrant pregrooved (Shepherd)
  - **3.** Nonstop chop (Nagahara)

4. Stop-and-chop (Koch)
5. Double chop (Kammann)

SURGICAL STEPS OF FEMTO SECOND LASER

The newest of the cataract surgery techniques involves a combination of techniques, using femtosecond laser-assisted phaco, where the femtosecond laser can cut precise corneal incisions, an accurately sized and truly circular capsulorrhexis and partial fragmentation of the lens nucleus, permitting less ultrasonic energy release. Where necessary, this technique can be combined with posterior vitrectomy in a safe manner.

- Clear corneal incision
- Arcuate corneal incision
- Capsulorrhexis
- Lens fragmentation

Post Femto second laser Surgical steps

- Corneal incision are opened up with fine iris repositor
- Anterior chamber is filled with viscoelstic material
- capsulorrhexis flap is removed with forceps
- Lens fragments are phacoaspirated
- Foldable IOL is implanted in the capsular bag and procedure is completed

REFERENCES:

1. *Seibel BS. Phacodynamics: Mastering the Tools and Techniques of Phacoemulsification Surgery.4th ed. Slack; 2005.*

2. *Chang DF. Phaco Chop and Advanced Phaco Techniques: Strategies for Complicated Cataracts.2nd ed. Slack; 2013.*

3. *Dewey S, Beiko G, Braga- Mele R, Nixon DR, Raviv T, Rosenthal K; ASCRS Cataract ClinicalCommittee, Instrumentation and IOLs Subcommittee. Microincisions in cataract surgery.J Cataract Refract Surg. 2014;40(9):1549–1557.*

CHAPTER 11

COMPLICATIONS OF CATARACT SURGERY AND THEIR MANAGEMENT

Complications encountered during surgical management of cataract can be enumerated under the following heads:

(A) Preoperative complications

(B) Intraoperative complications

(C) Early postoperative complications

(D) Delayed (late) postoperative complications

(E) IOL-related complications

Preoperative complications

1. **Anxiety:** Some patients may develop anxiety, on the eve of operation due to fear and apprehension of operation. Anxiolytic drugs such as diazepam 2 to 5 mg at bed time usually alleviate such symptoms.
2. **Nausea and gastritis:** A few patients may develop nausea and gastritis due to preoperative medicines such as acetazolamide and/or glycerol. Oral antacids and omission of further dose of such medicines usually relieve the symptoms.
3. Irritative or allergic conjunctivitis may occur in some patients due to preoperative topical antibiotic drops. Postponing the operation for 2 days along with withdrawal of such drugs is required.
4. Corneal abrasion may develop due to inadvertent injury during Schiotz tonometry. Patching with antibiotic ointment for a day and postponement of operation for 2 days is required.
5. Complications due to local anaesthesia Retrobulbar haemorrhage may occur due to retrobulbar block. Immediate pressure bandage after instilling one drop of 2% pilocarpine and postponement of operation for a week is advised.
6. Oculocardiac reflex, which manifests as bradycardia and/or cardiac arrhythmia, has also been observed due to retrobulbar block. An intravenous injection of atropine is helpful.

7. Perforation of globe may also occur sometimes. To prevent such catastrophy, gentle injection with blunt-tipped needle is recommended. Further, peribulbar anaesthesia may be preferred over retrobulbar block.
8. subconjunctival haemorrhage is a minor complication observed frequently, and does not need much attention. Spontaneous dislocation of lens in vitreous has also been reported (in patients with weak and degenerated zonules especially with hypermature cataract) during vigorous ocular massage after retrobulbar block. The operation should be postponed and further management is on the lines of posterior dislocation of lens

OPERATIVE COMPLICATIONS

1. Superior rectus muscle laceration and/or haematoma, may occur while applying the bridle suture. Usually no treatment is required.
2. Excessive bleeding may be encountered during the preparation of conjunctival flap or during incision into the anterior chamber. Bleeding vessels may be gently cauterised.
3. Incision related complications depend upon the type of cataract surgery being performed.
   - i) In conventional ECCE there may occur irregular incision. Irregular incision leading to defective coaptation of wound may occur due to blunt cutting instruments.
   - ii) In manual SICS and phacoemulsification following complications may occur while making the self-sealing tunnel incision. Button holing of anterior wall of tunnel can occur because of superficial dissection of the scleral flap. As a remedy, abandon this dissection and re-enter at a deeper plane from the other side of the external incision. Premature entry into the anterior chamber can occur because of deep dissection . Once this is detected, dissection in that area should be stopped and a new dissection started at a lesser depth at the other end of the tunnel. Scleral disinsertion can occur due to very deep groove incision. In it there occurs complete separation of inferior sclera from the sclera superior to the incision. Scleral disinsertion needs to be managed by radial sutures.

4. Injury to the cornea (Descemet's detachment), iris and lens may occur when anterior chamber is entered with a sharp-tipped instrument such as keratome or a piece of razor blade. A gentle handling with proper hypotony reduces the incidence of such inadvertent injuries.
5. Iris injury and iridodialysis (tear of iris from root) may occur inadvertently during intraocular manipulation.
6. Complications related to anterior capsulorhexis. Continuous curvilinear capsulorhexis (CCC) is the preferred technique for opening the anterior capsule for SICS and phacoemulsification. Following complications may occur: Escaping capsulorhexis i.e., capsulorhexis moves peripherally and may extend to the equator or posterior capsule. Small capsulorhexis. It predisposes to posterior capsular tear and nuclear drop during hydrodissection. It also predisposes to occurrence of zonular deshiscence. Therefore, a small sized capsulorhexis should always be enlarged by 2 or 3 relaxing incisions before proceeding further. Very large capsulorhexis may cause problems for in the bag placement of IOL. Eccentric capsulorhexis can lead to IOL decentration at a later stage.
7. Posterior capsular rupture (PCR). It is a dreaded complication during extracapsular cataract extraction. In manual SICS and phacoemulsification PCR is even more feared because it can lead to nuclear drop into the vitreous. The PCR can occur in following situations: During forceful hydrodissection, By direct injury with some instrument such as Sinskey's hook, chopper or phacotip, and During cortex aspiration (accidental PCR).
8. Zonular dehiscence may occur in all techniques of ECCE but is especially common during nucleus prolapse into the anterior chamber in manual SICS.
9. Vitreous loss: It is the most serious complication which may occur following accidental rupture of posterior capsule during any technique of ECCE. Therefore, adequate measures as described below should be taken to prevent vitreous loss. To decrease vitreous volume: Preoperative use of hyperosmotic agents like 20 percent mannitol or oral glycerol is suggested. To decrease aqueous volume: Preoperatively acetazolamide 500 mg orally should be used and adequate ocular massage should be carried out digitally after injecting local anaesthesia. To decrease orbital volume adequate ocular massage and orbital compression by use of superpinky, Honan's ball, or 30 mm of Hg pressure by paediatric sphygmomanometer should be carried out.

Better ocular akinesia and anaesthesia decrease the chances of pressure from eye muscle. Minimising the external pressure on eyeball by not using eye speculum, reducing pull on bridle suture and overall gentle handling during surgery. Use of Flieringa ring to prevent collapse of sclera especially in myopic patients decreases the incidence of vitreous loss. When IOP is high in spite of all above measures and operation cannot be postponed, in that situation a planned posterior-sclerotomy with drainage of vitreous from pars plana will prevent rupture of the anterior hyaloid face and vitreous loss. Management of vitreous loss. Once the vitreous loss has occurred, the aim should be to clear it from the anterior chamber and incision site. This can be achieved by performing partial anterior vitrectomy, with the use of automated vitrectors. 199 A meticulously performed partial anterior vitrectomy will reduce the incidence of postoperative problems associated with vitreous loss such as updrawn pupil, iris prolapse and vitreous touch syndrome.

10. Nucleus drop into the vitreous cavity. It occurs more frequently with phacoemulsification, less frequently with manual SICS and sparingly with conventional ECCE. It is a dreadful complication which occurs due to sudden and large PCR. Management. Once the nucleus has dropped into the vitreous cavity, no attempt should be made to fish it out. The case must be referred to vitreoretinal surgeon after a thorough anterior vitrectomy and cortical clean up.
11. Posterior loss of lens fragments into the vitreous cavity may occur after PCR or zonular dehiscence during phacoemulsification. It is potentially serious because it may result in glaucoma, chronic uveitis, chronic CME and even retinal detachment. Management. The case should be managed by vitreoretinal surgeon by performing pars plana vitrectomy and removal of nuclear fragments.
12. Expulsive choroidal haemorrhage. It is one of the most dramatic and serious complications of cataract surgery. It usually occurs in hypertensives and patients with arteriosclerotic changes. It may occur during operation or during immediate postoperative period. Its incidence was high in ICCE and conventional ECCE but has decreased markedly with valvular incision of manual SICS and phaco emulsification technique. It is characterised by spontaneous gaping of the wound followed by expulsion of the lens,

vitreous, retina, uvea and finally a gush of bright red blood. Although treatment is unsatisfactory, the surgeon should attempt to drain subchoroidal blood by performing an equatorial sclerotomy. Most of the time eye is lost and so evisceration operation has to be performed.

EARLY POSTOPERATIVE COMPLICATIONS

1. **Hyphaema:** Collection of blood in the anterior chamber may occur from conjunctival or scleral vessels due to minor ocular trauma or otherwise. Treatment. Most hyphaemas absorb spontaneously and thus need no treatment. Sometimes hyphaema may be large and associated with rise in IOP. In such cases, IOP should be lowered by acetazolamide and hyperosmotic agents. If the blood does not get absorbed in a week's time, then a paracentesis should be done to drain the blood.
2. **Iris prolapse:** It is usually caused by inadequate suturing of the incision after ICCE and conventional ECCE and occurs during first or second postoperative day. This complication is not known with manual SICS and phacoemulsification technique. Management: A small prolapse of less than 24 hours duration may be reposited back and wound sutured. A large prolapse of long duration needs abscission and suturing of wound.
3. **Striate keratopathy:** Characterised by mild corneal oedema with Descemet's folds is a common complication observed during immediate postoperative period. This occurs due to endothelial damage during surgery. Management. Mild striate keratopathy usually disappears spontaneously within a week. Moderate to severe keratopathy may be treated by instillation of hypertonic saline drops (5% sodium chloride) along with steroids.
4. **Flat (shallow or nonformed) anterior chamber:** It has become a relatively rare complication due to improved wound closure. It may be due to wound leak, ciliochoroidal detachment or pupil block.
   i) Flat anterior chamber with wound leak is associated with hypotony. It is diagnosed by Seidel's test. In this test, a drop of fluorescein is instilled into the lower fornix and patient is asked to blink to spread the dye evenly. The incision is then examined with slit lamp using cobalt-blue filter. At the site of leakage, fluorescein will be diluted by aqueous. In most cases wound leak is cured

within 4 days with pressure bandage and oral acetazolamide. If the condition persists, injection of air in the anterior chamber and resuturing of the leaking wound should be carried out.

ii) **Ciliochoroidal detachment:** It may or may not be associated with wound leak. Detached ciliochoroid presents as a convex brownish mass in the involved quadrant with shallow anterior chamber. In most cases choroidal detachment is cured within 4 days with pressure bandage and use of oral acetazolamide. If the condition persists, suprachoroidal drainage with injection of air in the anterior chamber is indicated.

iii) Pupil block due to vitreous bulge after ICCE leads to formation of iris bombe and shallowing of anterior chamber. If the condition persists for 5-7 days, permanent peripheral anterior synechiae (PAS) may be formed leading to secondary angle closure glaucoma. Pupil block is managed initially with mydriatic, hyperosmotic agents (e.g., 20% mannitol) and acetazolamide. If not relieved, then laser or surgical peripheral iridectomy should be performed to bypass the pupillary block.

5. Postoperative anterior uveitis can be induced by instrumental trauma, undue handling of uveal tissue, reaction to residual cortex or chemical reaction induced by viscoelastics, pilocarpine etc. Management includes more aggressive use of topical steroids, cycloplegics and NSAIDs. Rarely systemic steroids may be required in cases with severe fibrinous reaction.
6. **Bacterial endophthalmitis:** This is one of the most dreaded complications with an incidence of 0.2 to 0.5 percent. The principal sources of infection are contaminated solutions, instruments, surgeon's hands, patient's own flora from conjunctiva, eyelids and air-borne bacteria. Symptoms and signs of bacterial endophthalmitis are generally present between 48 and 72 hours after surgery and include: ocular pain, diminshed vision, lid oedema, conjunctival chemosis and marked circumciliary congestion, corneal oedema, exudates in pupillary area, hypopyon and diminished or absent red pupillary glow. Management. It is an emergency and should be managed energetically.

LATE POSTOPERATIVE COMPLICATIONS

These complications may occur after weeks, months or years of cataract surgery.

1. **Cystoid macular oedema (CME):**Collection of fluid in the form of cystic loculi in the Henle's layer of macula is a frequent complication of cataract surgery. However, in most cases it is clinically insignificant, does not produce any visual problem and undergoes spontaneous regression. In few cases, clinically significant CME typically produces visual diminution one to three months after cataract extraction. On funduscopy it gives honeycomb appearance. On fluorescein angiography it depicts typical flower petal pattern due to leakage of dye from perifoveal capillaries. In most cases it is associated with vitreous incarceration in the wound and mild iritis. Role of some prostaglandins is being widely considered in its etiopathogenesis. Therefore, immediate preoperative and postoperative use of antiprostaglandins (indomethacin or flurbiprofen or ketorolac) eyedrops is recommended as prophylaxis of CME. In cases of CME with vitreous incarceration, anterior vitrectomy along with steroids and antiprostaglandins may improve visual acuity and decrease the amount of discomfort.
2. Delayed chronic postoperative endophthalmitis is caused when an organism of low virulence (Propionobacterium acne or staph epidermidis) becomes trapped within the capsular bag. It has an onset ranging from 4 weeks to years (mean 9 months) postoperatively and typically follows an uneventful cataract extraction with a PCIOL in the bag.
3. Pseudophakic bullous keratopathy (PBK) is usually a continuation of postoperative corneal oedema produced by surgical or chemical insult to a healthy or compromised corneal endothelium. PBK is becoming a common indication of penetrating keratoplasly (PK).
4. **Retinal detachment (RD):** Incidence of retinal detachment is higher in aphakic patients as compared to phakics. It has been noted that retinal detachment is more common after ICCE than after ECCE. Other risk factors for aphakic retinal detachment include vitreous loss during operation, associated myopia and lattice degeneration of the retina.Types of after cataract:

A. dense membranous;
B. Soemmering's ring;
C. Elschnig's pearls.

5. **Epithelial ingrowth:** Rarely conjunctival epithelial cells may invade the anterior chamber through a defect in the incision. This abnormal epithelial membrane slowly grows and lines the back of cornea and trabecular meshwork leading to intractable glaucoma. In late stages, the epithelial membrane extends on the iris and anterior part of the vitreous.
6. Fibrous downgrowth into the anterior chamber ay occur very rarely when the cataract wound apposition is not perfect. It may cause secondary glaucoma, disorganisation of anterior segment and ultimately phthisis bulbi.
7. **After cataract:** It is also known as 'secondary cataract'. It is the opacity which persists or develops after extracapsular lens extraction. Causes. (i) Residual opaque lens matter may persist as after cataract when it is imprisoned between the remains of the anterior and posterior capsule, surrounded by fibrin (following iritis) or blood (following hyphaema). (ii) Proliferative type of after cataract may develop from the left-out anterior epithelial cells. The proliferative hyaline bands may sweep across the whole posterior capsule. Clinical types. After cataract may present as thickened posterior capsule, or dense membranous after cataract or Soemmering's ring which refers to a thick ring of after cataract formed behind the iris, enclosed between the two layers of capsule or Elschnig's pearls in which the vacuolated subcapsular epithelial cells are clustered like soap bubbles along the posterior capsule Treatment is as follows :
   i. Thin membranous after cataract and thickened posterior capsule are best treated by YAG-laser capsulotomy or discission with cystitome or Zeigler's knife.
   ii. Dense membranous after cataract needs surgical membranectomy.
   iii. Soemmering's ring after cataract with clean central posterior capsule needs no treatment.
   iv. Elschnig's pearls involving the central part of the posterior capsule can be treated by YAGlaser capsulotomy or discission with cystitome.
8. Glaucoma-in-aphakia and pseudophakia

IOL-related complications

In addition to the complications of cataract surgery, following IOL-related complications may be seen:

1. Complications like cystoid macular oedema, corneal endothelial damage, uveitis and secondary glaucoma are seen more frequently with IOL implantation, especially with anterior chamber and iris supported IOLs. UGH syndrome refers to concurrent occurrence of uveitis, glaucoma and hyphaema. It used to occur with rigid anterior chamber IOLs, which are not used now.
2. Malpositions of IOL: These may be in the form of decentration, subluxation and dislocation. The fancy names attached to various malpositions of IOL are:
    - Decentered IOL:Sun-set syndrome (Inferior subluxation of IOL).
    - Sun-rise syndrome (Superior subluxation of IOL). Lost lens syndrome refers to complete dislocation of an IOL into the vitreous cavity.
    - Windshield wiper syndrome: It results when a very small IOL is placed vertically in the sulcus. In it the superior loop moves to the left and right, with movements of the head.
3. Pupillary capture of the IOL may occur following postoperative iritis or proliferation of the remains of lens fibres.
4. Toxic lens syndrome: It is the uveal inflammation excited by either the ethylene gas used for sterilising IOLs (in early cases) or by the lens material

REFERENCES:

1. *Endophthalmitis Study Group, Eu ro pean Society of Cataract & Refractive Surgeons. Prophylaxis of postoperative endophthalmitis following cataract surgery: results of the ESCRS multicenter study and identification of risk factors. J Cataract Refract Surg. 2007;33(6):978–988.*

2. *Jun JH, Hwang KY, Chang SD, Joo CK. Pupil- size alterations induced by photodisruptionduring femtosecond laser- assisted cataract surgery. J Cataract Refract Surg.2015;41(2):278–285*

3. *Varma DK, Belovay GW, Tam DY, Ahmed II. Malignant glaucoma after cataract surgery.J Cataract Refract Surg. 2014;40(11):1843–1849.*

4. *Jacob S. Management of late lens implant and capsule dislocation. Focal Points: Clinical Practice Perspectives. American Academy of Ophthalmology; 2017, module 3.*

5. *Ronbeck M, Zetterstrom C, Wejde G, Kugelberg M. Comparison of posterior capsule opacification development with 3 intraocular lens types: five- year prospective study. J Cataract Refract Surg. 2009;35(11):1935–1940*

6. *Bodnar Z, Clouser S, Mamalis N. Toxic anterior segment syndrome: update on the most common causes. J Cataract Refract Surg. 2012;38(11):1902–1910.*

7. *Chang DF, Mamalis N; Ophthalmic Instrument Cleaning and Sterilization Task Force. Guidelines for the cleaning and sterilization of intraocular surgical instruments. J CataractRefract Surg. 2018;44(6):765–773.*

8. *Endophthalmitis Study Group, Eu ro pean Society of Cataract & Refractive Surgeons. Prophylaxis of postoperative endophthalmitis following cataract surgery: results of the ESCRS multicenter study and identification of risk factors. J Cataract Refract Surg. 2007;33(6):978–988.*

9. *Haripriya A, Chang DF, Ravindran RD. Endophthalmitis reduction with intracameral moxifloxacin prophylaxis: analy sis of 600 000 surgeries. Ophthalmology. 2017;124(6):768–775.*

10. *Shorstein NH, Winthrop KL, Herrinton LJ. Decreased postoperative endophthalmitis rate after institution of intracameral antibiotics in a Northern California eye department. J Cataract Refract Surg. 2013;39(1):8–14.*

11. *Clark A, Morlet N, Ng JQ, Preen DB, Semmens JB. Risk for ret i nal detachment after phacoemulsification: a whole- population study of cataract surgery outcomes. Arch Ophthalmol. 2012;130(7):882–888.*