Abstract
Glaucoma is one of the most common ophthalmic conditions encountered in primary and secondary care. The glaucoma is a group of progressive optic neuropathies characterized by degeneration of retinal ganglion cells and resulting changes in the optic nerve head. It is usually associated with an increase in intraocular pressure (IOP) above the normal value—usually estimated at 21 mm Hg. Loss of ganglion cells is related to the level of intraocular pressure, but other factors may also play a role. Reduction of intraocular pressure is the only proven method to treat the disease. Although treatment is usually initiated with ocular hypotensive drops, laser trabeculoplasty and surgery may also be used to slow disease progression.

Introduction
Glaucoma is a leading cause of irreversible blindness throughout the world. In India glaucoma constitute 2% of total blindness (1). Moreover, the management of glaucoma has an enormous impact in our society in terms of patient's morbidity, loss of productivity, number of ophthalmic consultations and health costs, as these patients may have to continue the therapy for the whole life. However, new glaucoma medications have increased efficacy, reduced dosing frequency and improved side effect profiles; but there is need for comparing the cost of new glaucoma medication with the traditional one (2).

Glaucoma is an optic neuropathy in which the optic nerve is damaged with typical loss of nerve fibers and increasing cupping of the optic disc, leading to progressive, irreversible loss of vision. It is often, but not always, associated with increased pressure of the fluid in the eye. The nerve damage involves loss of retinal ganglion cells in a characteristic pattern. There are many different sub-types of glaucoma but they can all be considered a type of optic neuropathy. Raised intraocular pressure (IOP) is a significant risk factor for developing glaucoma (3).

Untreated glaucoma leads to permanent damage of the optic nerve and resultant visual field loss, which can progress to blindness. Glaucoma has been nicknamed the “sneak robber of sight” because the loss of vision normally occurs gradually over a long period of time and is often only recognized when the disease is quite advanced. Once lost, this damaged visual field cannot be recovered. Worldwide, glaucoma is the second leading cause of blindness and affects approx 66 million people in the world. In some countries, e.g. United States of America were approximately 100000 people are totally blind and approx 300000 are blind in one eye from glaucoma, it is the leading cause of blindness. Glaucoma affects 1 in 200 people aged fifty and younger, and 1 in 10 over the age of eighty (4, 5 & 6).

Glaucoma is one of the most common ophthalmic conditions encountered in primary and secondary care. The World Health Organization estimated that in 2010 glaucoma accounted for 2% of visual impairment and 8% of global blindness. Disability adjusted life years
attributable to glaucoma more than doubled between 1990 and 2010 due to the worldwide increase in the number of older people. Glaucoma is the leading cause of irreversible blindness in the world (7, 8).

Glaucoma was probably recognized as a disease entity in the 17th Century where the term was derived from the Greek term glauk’oma meaning cataract or opacity of the lens implying the lack of understanding of this disease process. Today we understand that glaucoma is a group of diseases with common end point characteristics affecting the optic nerve. It is defined as an optic neuropathy characterized by specific structural findings in the optic disk (increased vertical cup disk ratio (VCDR). In the past, raised intraocular pressure (IOP) was used as a defining characteristic for glaucoma; but now IOP is considered as just an important risk factor for glaucoma (9).

However, surveys show that 20-52% of patients with glaucoma have IOP within the normal range. Primary open angle glaucoma is the most common type of glaucoma, accounting for over 70% of cases. It is an IOP related optic neuropathy that gives rise to characteristic optic disc changes and visual field loss. In its early stages it affects peripheral visual field only, but as it advances it results in loss of visual acuity and can cause blindness. Some patients with statistically normal IOP develop the characteristic changes associated with open angle glaucoma and are said to have low tension or normal pressure glaucoma (3, 10).

Epidemiology
It is estimated that there are more than 60 million cases of glaucoma worldwide and it will increase to 80 million by 2020 (11, 12). The estimated prevalence of glaucoma is 2.65% in people above 40 years of age. Globally, primary open-angle glaucoma (POAG) is more prevalent than primary angle closure glaucoma (PACG) and responsible for around three fourth of all glaucoma cases. Overall glaucoma is the second major cause of blindness after cataract. It is the most common cause of irreversible blindness globally. It is estimated that more than 3 million people are blind due to glaucoma (13).

In India, the estimated number of cases of glaucoma is 12 million, around one fifth of the global burden. In the Indian population an equal proportion of open-angle and closed-angle glaucoma is seen (10,11 & 13).

Etiology (14, 15, 16 & 17) : The following are groups at higher risk for developing glaucoma.
1. African Americans: After cataracts, glaucoma is the leading cause of blindness among African Americans and people of African descent. Glaucoma is six to eight times more common in African Americans than in Caucasians.
2. People Over 60 : Glaucoma is much more common among older people. You are six times more likely to get glaucoma if you are over 60 years old.
3. Family Members with Glaucoma : The most common type of glaucoma, primary open-angle glaucoma, is hereditary. If members of your immediate family have glaucoma, you are at a much higher risk than the rest of the population. Family history increases risk of glaucoma four to nine times.
4. Hispanics in Older Age Groups : Recent studies indicate that the risk for Hispanic populations is greater than those of predominantly European ancestry, and that the risk increases among Hispanics over age 60.
5. Asians : People of Asian descent appear to be at increased risk for angle-closure glaucoma. Angle-closure glaucoma accounts for less than 10% of all diagnosed cases of glaucoma. People of Japanese descent are at higher risk for normal-tension glaucoma.
6. Steroid Users : Some evidence links steroid use to glaucoma. A 1997 study reported in the Journal of American Medical Association demonstrated a 40% increase in the incidence of ocular hypertension and open-angle glaucoma in adults who require approximately 14 to 35 puffs of steroid inhaler to control asthma. This is a very
high dose, only required in cases of severe asthma.

7. Eye Injury: Injury to the eye may cause secondary open-angle glaucoma. This type of glaucoma can occur immediately after the injury or years later.

   - Blunt injuries that “bruise” the eye (called blunt trauma) or injuries that penetrate the eye can damage the eye’s drainage system, leading to traumatic glaucoma.

   - The most common cause is sports-related injuries such as baseball or boxing.

   Open-Angle Glaucoma
   - Most people have no symptoms
   - Once vision loss occurs, the damage is already severe
   - Slow loss of side (peripheral) vision (also called tunnel vision) as shown in fig: 1
   - Advanced glaucoma can lead to blindness

<table>
<thead>
<tr>
<th>GLAUCOMA TYPE</th>
<th>ETIOLOGY (16)</th>
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<tbody>
<tr>
<td>PRIMARY OPEN ANGLE GLAUCOMA</td>
<td>Drainage channels are partially blocked. This causes the fluid to drain out of the eye too slowly</td>
</tr>
<tr>
<td>PRIMARY CLOSURE ANGLE GLAUCOMA</td>
<td>Complete blockade of drainage channel. This causes increase in pressure</td>
</tr>
<tr>
<td>DEVELOPMENTAL GLAUCOMA</td>
<td>Congenital</td>
</tr>
<tr>
<td>PIGMENTARY GLAUCOMA</td>
<td>Pigment granules from your iris build up in the drainage channels (trabecular meshwork)</td>
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Fig 1: Tunnel vision observed by Glaucoma patient

Glaucoma: A Review
ANGLE-CLOSURE GLAUCOMA
Symptoms may come and go at first, or steadily become worse (20, 21). Symptoms are as follows:
· Sudden, severe pain in one eye
· Decreased or cloudy vision, often called “steam” vision
· Nausea and vomiting
· Rainbow-like halos around lights as shown in fig: 3
· Red eye as shown in fig :2
· Eye feels swollen

CONGENITAL GLAUCOMA (21, 22)
Symptoms are usually noticed when the child is a few months old.
· Light sensitivity (photophobia)
· Corneal opacification (hazy gray cornea)
· Enlarged eye and cornea
· Epiphora (overflow of tears)
· Vision loss

A cloudy cornea is the earliest and most common sign of childhood glaucoma. The healthy cornea is transparent. The loss of this transparency is caused by edema, or swelling of tissue from excess fluid. This occurs in the corneal epithelium (outermost layer of the cornea) and in the corneal stroma (middle layer of the corneal tissue). Careful inspection of the cornea may also reveal defects in its inner layer, which is further proof of a raised eye pressure (IOP).

In most cases of glaucoma affecting children under three years of age, the cornea and eye enlarges. Review of early photographs of your child may reveal the presence of glaucoma months before the diagnosis was actually made.

In addition to eye problems, secondary systemic (body) symptoms may occur. These secondary symptoms are especially common with acute glaucoma. Examples include irritability, loss of appetite, and vomiting. These symptoms may be misunderstood before the glaucoma is recognized. Young children with glaucoma are often unhappy, fussy, and poor eaters.

A slow chronic increase in eye pressure is probably not painful. In contrast, there is discomfort and pain when the eye pressure increases rapidly during an acute onset or with the rapid return of glaucoma following unsuccessful glaucoma surgery. Lowering high eye pressure relieves these painful symptoms quickly.

SECONDARY GLAUCOMA (22)
· Symptoms are usually related to the underlying problem causing the glaucoma
· Depending on the cause, symptoms may either be like open-angle glaucoma or angle-closure glaucoma

Types of Glaucoma (13, 14)
Glaucoma is actually a group of diseases. The most common type is hereditary.
· Primary Open-Angle Glaucoma
· Angle-Closure Glaucoma
· Normal-Tension Glaucoma
· Other Types of Glaucoma

Fig: 2 Red eye in Glaucoma patient
Fig: 3 Rainbow like halos around lights
The two main types are open-angle and angle-closure. These are marked by an increase of intraocular pressure (IOP), or pressure inside the eye.

**Open Angle Glaucoma (23)**
- Open-angle glaucoma, the most common form of glaucoma, accounting for at least 90% of all glaucoma cases:
  - Is caused by the slow clogging of the drainage canals, resulting in increased eye pressure.
  - Has a wide and open angle between the iris and cornea.
  - Develops slowly and is a lifelong condition.
  - Has symptoms and damage that are not noticed.

“Open-angle” means that the angle where the iris meets the cornea is as wide and open as it should be as shown in fig: 4. Open-angle glaucoma is also called primary or chronic glaucoma. It is the most common type of glaucoma, affecting about three million Americans.

**Angle-Closure Glaucoma (25, 26)**
- Angle-closure glaucoma, a less common form of glaucoma:
  - Is caused by blocked drainage canals, resulting in a sudden rise in intraocular pressure.
  - Has a closed or narrow angle between the iris and cornea.
  - Develops very quickly.
  - Has symptoms and damage that are usually very noticeable.
  - Demands immediate medical attention.

It is also called acute glaucoma or narrow-angle glaucoma. Unlike open-angle glaucoma, angle-closure glaucoma is a result of the angle between the iris and cornea closing as shown in fig: 5.

**Normal-Tension Glaucoma (NTG) (27)**
- Also called low-tension or normal-pressure glaucoma, in normal-tension glaucoma the optic nerve is damaged even though the pressure in the eye is not very high. Doctors do not know why some people’s optic nerves are damaged even though they have almost normal pressure levels.

Those at higher risk for this form of glaucoma are:
People with a family history of normal-tension glaucoma

People of Japanese ancestry (28)

People with a history of systemic heart disease such as irregular heart rhythm (29).

Normal-tension glaucoma (NTG), also known as low tension or normal pressure glaucoma, is a form of glaucoma in which damage occurs to the optic nerve without eye pressure exceeding the normal range. In general, a "normal" pressure range is between 12-22 mm Hg.

Childhood glaucoma — also referred to as congenital glaucoma, pediatric, or infantile glaucoma — occurs in babies and young children. It is usually diagnosed within the first year of life. This is a rare condition that may be inherited, caused by incorrect development of the eye’s drainage system before birth. This leads to increased intraocular pressure, which in turn damages the optic nerve.

Other Types of Glaucoma (30)
Variants of open-angle and angle-closure glaucoma include:
- Secondary Glaucoma
- Pigmentary Glaucoma
- Pseudoexfoliative Glaucoma
- Traumatic Glaucoma
- Neovascular Glaucoma
- Irido Corneal Endothelial Syndrome (ICE)

Secondary glaucoma refers to any form of glaucoma in which there is an identifiable cause of increased eye pressure, resulting in optic nerve damage and vision loss.

As with primary glaucoma, secondary glaucoma can be of the open-angle or angle-closure type and it can occur in one or both eyes. Secondary glaucoma may be caused by an eye injury, inflammation, certain drugs such as steroids and advanced cases of cataract or diabetes. The type of treatment will depend on the underlying cause, but usually includes medications, laser surgery, or conventional surgery.

Glaucoma develops in some patients with a condition called exfoliation syndrome. Also known as pseudoexfoliation, it is caused by the abnormal accumulation of protein in the drainage system and other structures of the eye. This is a type of open-angle glaucoma with unique characteristics and physical findings. It is more common in certain racial groups including people from Russia, the Nordic countries, Greeks, Mediterranean populations, Indians, and others.

A gene abnormality has recently been associated with this particular condition. As a group, patients with exfoliative glaucoma show higher pressures and faster disease progression than patients with classic primary open-angle glaucoma. The underlying cause is likely due to the abnormal protein and associated pigment blocking the outflow structures in the eye.

Patients with exfoliative glaucoma often have more episodes of high pressure, more fluctuations and higher peak pressures than patients with other types of glaucoma. Generally, this kind of glaucoma is more difficult to control with medical therapy. Patients with exfoliative glaucoma often require a more aggressive stepwise therapy and more often need laser, or incisional surgery. Often more frequent visits to their eye doctor are necessary to monitor for disease progression. Exfoliative glaucoma patients seem to respond well to treatment by laser trabeculoplasty, possibly because of the more pigmented meshwork and a higher concentration of enzymes in the meshwork, termed matrix metalloproteinases, that are activated by laser trabeculoplasty. Patients with this disorder respond well to most types of glaucoma surgery. However, whether or not they respond well to trabecular stent devices or the new generation of tubes to the suprachoroidal space remains to be seen.

Another reason to know whether or not exfoliation is present is that these patients sometimes have increased difficulty with cataract surgery. The abnormal protein seen in this condition settles on and weakens the lens zonules which are suspensory fibers that hold the lens in place.
place. In most patients, the surgical technique can be modified to obtain a good outcome.

**Neovascular Glaucoma** is caused by the abnormal formation of new blood vessels on the and over the eye’s drainage channels. Neovascular glaucoma is always associated with other abnormalities, most often diabetes. It never occurs on its own. The new blood vessels block the eye’s fluid from exiting through the trabecular meshwork (the eye’s drainage canals), causing an increase in eye pressure.

**Pigmentary Glaucoma** occurs when the pigment granules that are in the back of the iris (the colored part of the eye) break into the clear fluid produced inside the eye. These tiny pigment granules flow toward the drainage canals in the eye and slowly clog them, causing eye pressure to rise.

**Traumatic Glaucoma** — Injury to the eye may cause traumatic glaucoma. This form of open-angle glaucoma can occur immediately after the injury or develop years later. It can be caused by blunt injuries that bruise the eye (called blunt trauma) or by injuries that penetrate the eye.

**Uveitic Glaucoma** — Uveitis is swelling and inflammation of the uvea, the middle layer of the eye. The uvea provides most of the blood supply to the retina. Increased eye pressure in uveitis can result from the inflammatory process itself or the medication (steroids) used to treat it.

**Pathophysiology:** Several large studies have shown that eye pressure is a major risk factor for optic nerve. In the front of the eye is a space called the anterior chamber. A clear fluid flows continuously in and out of the chamber and nourishes nearby tissues. The fluid leaves the chamber at the open angle where the cornea and iris meet. When the fluid reaches the angle, it flows through a spongy meshwork, like a drain, and leaves the eye (31).

In open-angle glaucoma, even though the drainage angle is “open,” the fluid passes too slowly through the meshwork drain. Since the fluid builds up, the pressure inside the eye rises to a level that may damage the optic nerve as shown in fig: 6. When the optic nerve is damaged from increased pressure, open-angle glaucoma—and vision loss—may result. That’s why controlling pressure inside the eye is important.

Another risk factor for optic nerve damage relates to blood pressure. Thus, it is important to also make sure that your blood pressure is at a proper level for your body by working with your medical doctor. Progress made in the past few years in medical research has allowed a new approach to the pathophysiology of glaucoma, by studying the pathologic process on a tissue, cellular, molecular and genetic level (32). Following factors are responsible for causing glaucoma

1. **Role of vascular factors:** Some studies have shown a link between ocular perfusion pressure and glaucoma, as it is known that glaucoma can progress despite low intraocular pressure. Progression in case of normal tension glaucoma has been associated with deficiencies in the mechanism of regulation of ocular circulation. Interestingly, reduction of blood flow was also observed in the nail-fold capillaries of fingers in glaucoma patients suggesting that the reduction of blood flow is not due to increased IOP or an epiphenomenon of glaucoma, but a global vascular dysregulation is involved in POAG especially in NTG cases.

Researchers have proved that the long term changes in retinal circulation can lead to glaucoma-like aspects of the optic disc, independent of intraocular pressure (33).

2. **Glaucoma and Neurodegenerative Disorders:** Recent findings, no longer consider glaucoma as an autonomous dysfunction, affecting a single population of cells—the retinal ganglion cell fibers. More and more data suggest that glaucoma should be integrated in the category of neurodegenerative diseases (24).

3. **Oxidative stress of the Retinal ganglion cell layer:** It has been proved that the death of retinal
ganglion cells in glaucoma occurs through apoptosis. It is thought that increased oxidative stress, due to high levels of free radicals, can induce apoptosis of retinal ganglion cells and is thus involved in the pathogenesis of glaucomatous optic neuropathy (25, 26).

4. Role of serotonin: Serotonin is a neurotransmitter synthesized in neurons and deposited in intracellular vesicles. Serotonin is present in high amounts in the iris-ciliary body complex and seems to play a part in regulating the flow of the aqueous humor.

Seven types of serotoninergic receptors have been identified (from 5-HT1 to 5-HT7). Stimulation of 5-HT7 leads to an increase of intraocular pressure, while stimulation of 5-HT1 leads to decrease in intraocular pressure (27).

Diagnosis
1. Visual field testing: During a routine eye exam, some eye doctors may want to determine through visual field testing the full horizontal and vertical range of what you are able to see peripherally as shown in fig: 7. This range is commonly referred to as “side vision.” Visual field tests assess the potential presence of blind spots (scotomas), which could indicate eye diseases (34).

2. Dilated eye exam: In this exam, drops are placed in your eyes to widen, or dilate, the pupils. Your eye care professional uses a special magnifying lens to examine your retina and optic nerve for signs of damage and other eye problems as shown in fig: 8. After the exam, your close-up vision may remain blurred for several hours (35).
3. **Tonometry**: It is the measurement of pressure inside the eye by using an instrument (right) called a tonometer as shown in fig: 9. Numbing drops may be applied to your eye for this test (36).

4. **Pachymetry**: It is the measurement of the thickness of your cornea. Your eye care professional applies a numbing drop to your eye and uses an ultrasonic wave instrument to measure the thickness of your cornea (36).

5. **Gonioscopy**: It is performed to make sure the aqueous humor (or “aqueous”) can drain freely from the eye. In gonioscopy, special lenses are used with a biomicroscope to enable your eye doctor to see the structure inside the eye (called the drainage angle) that controls the outflow of aqueous and thereby affects intraocular pressure. Ultrasound biomicroscopy is another technique that may be used to evaluate the drainage angle (37).

**Treatment**: Treatment can involve glaucoma surgery, lasers or medication, depending on the severity. Eye drops with medication aimed at lowering IOP usually are tried first to control glaucoma. Because glaucoma often is painless, people may become careless about strict use of eye drops that can control eye pressure and help prevent permanent eye damage.

**Medicines**

Medicines, in the form of eye drops or pills, are the most common early treatment for glaucoma. Taken regularly, these eye drops lower eye pressure. Some medicines cause the eye to make less fluid. Others lower pressure by helping fluid drain from the eye (38).

**Surgery**

**Laser trabeculoplasty**

Laser trabeculoplasty helps fluid drain out of the eye.

Before the surgery, numbing drops are applied to your eye. As you sit facing the laser machine, your doctor holds a special lens to your eye. 

**Table: 2 Drugs for the treatment of Open Angle Glaucoma** (39)

<table>
<thead>
<tr>
<th>OPEN ANGLE GLAUCOMA</th>
<th>TIMOLOL</th>
<th>BETAXOLOL</th>
<th>LEVOBUNOLOL</th>
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<tbody>
<tr>
<td>β ADRENERGIC BLOCKERS</td>
<td>BETA sympathetics</td>
<td></td>
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<tr>
<td>β ADRENERGIC AGONISTS</td>
<td>DIPIVEFRINE</td>
<td>APRACLONIDINE</td>
<td>BRIMONIDINE</td>
</tr>
<tr>
<td>PROSTAGLANDIN</td>
<td>LATANOPROST</td>
<td></td>
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<tr>
<td>ANALOGUES</td>
<td>TRAVOPROST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARBONIC ANHYDRASE INHIBITORS</td>
<td>ACETAZOLAMIDE</td>
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</table>

**Table: 3 Drugs for the treatment of Angle Closure Glaucoma** (40)

<table>
<thead>
<tr>
<th>ANGLE CLOSURE GLAUCOMA</th>
<th>HYPERTONIC MANNITOL</th>
<th>ACETAZOLAMIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIOTICS and TOPICAL β BLOCKERS</td>
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</table>

**Fig: 10** Conventional surgery makes new opening Sometimes after conventional surgery, your vision may not be as good as it was before conventional surgery. Conventional surgery can cause side effects, including cataract, problems with the cornea, inflammation, infection inside the eye, or low eye pressure problems (42).
A high-intensity beam of light is aimed through the lens and reflected onto the meshwork inside your eye. You may see flashes of bright green or red light. The laser makes several evenly spaced burns that stretch the drainage holes in the meshwork. This allows the fluid to drain better.

**Conventional surgery**

Conventional surgery makes a new opening for the fluid to leave the eye. Conventional surgery, called trabeculectomy, is performed in an operating room. Before the surgery, you are given medicine to help you relax. The doctor makes small injections around the eye to numb it. A small piece of tissue is removed to create a new channel for the fluid to drain from the eye as shown in fig.10. This fluid will drain between the eye tissue layers and create a blister-like “filtration bleb.” Conventional surgery is about 60 to 80 percent effective at lowering eye pressure. If the new drainage opening narrows, a second operation may be needed.

**Prevention**

Researchers in the U.K. found that higher levels of physical exercise appear to provide a long-term benefit of reducing the incidence of low ocular perfusion pressure (OPP), an important risk factor for glaucoma. OPP is a mathematical value that is calculated using a person’s intraocular pressure and his or her blood pressure. The results showed that study participants who engaged in moderate physical exercise approximately 15 years prior to the study had a 25 percent reduced risk of low OPP that could lead to glaucoma.

“It appears that OPP is largely determined by cardiovascular fitness,” said study author Paul J. Foster, MD, PhD, of the University College London Institute of Ophthalmology.

“We cannot comment on the cause, but there is certainly an association between a sedentary lifestyle and factors which increase glaucoma risk.”

Maintaining an active lifestyle appears to be an effective way for people to reduce their risk of glaucoma and many other serious health problems.

**Discussion and Conclusion**

Glaucoma is a common eye disease that is usually associated with an elevated intraocular pressure. Treatment options for patients with glaucoma include medications, laser therapy, and incisional surgery. The risks and benefits of each type of treatment must be carefully considered to maximize the treatment’s benefits while minimizing adverse effects.

**References**


Seema et al


