Glaucoma: The stealthy thief of vision

Antara Choudhury

Department of Pharmacognosy & Phytochemistry, IKON Pharmacy College, Bidadi, Karnataka 562109, India

Email: antarapiya@gmail.com

Abstract

Glaucoma is like a stealthy cat burglar, it creeps up on you without warning. The optic nerve, which connects your eye to your brain, gets damaged by this eye condition. It is often associated with elevated intraocular pressure (IOP). It silently steals your peripheral vision as it progresses, leaving you blissfully unaware until it's too late. It is an important cause of irreversible blindness for people over 60 globally. This paper explores the pathophysiology of glaucoma, examines various treatment delivery systems, and discusses the policies aimed at managing and preventing this disease. Advancements in drug delivery systems and comprehensive public health strategies are crucial for mitigating the impact of glaucoma on populations worldwide.

Keywords: glaucoma, vision, blindness

1. Introduction

Glaucoma is a group of eye conditions that, if left untreated, can result in irreversible vision loss and possibly blindness due to gradual damage to the optic nerve. It is a major global health concern, affecting approximately 76 million people worldwide as of 2020, with projections indicating that this number could exceed 111 million by 2040 due to aging populations and increased life expectancy (1). Despite its prevalence, glaucoma is often referred to as the "silent thief of sight" because it typically progresses without noticeable symptoms until significant vision impairment occurs (2).

2. Risk factors for glaucoma

Elevated intraocular pressure (IOP) is the main cause of glaucoma, resulting from an imbalance between the production and drainage of aqueous humor—the fluid that maintains eye shape and nourishes ocular tissues as shown in Fig. 1 (2). Genetics, age, ethnicity, and medical history significantly contribute to the risk and progression of the disease (3).

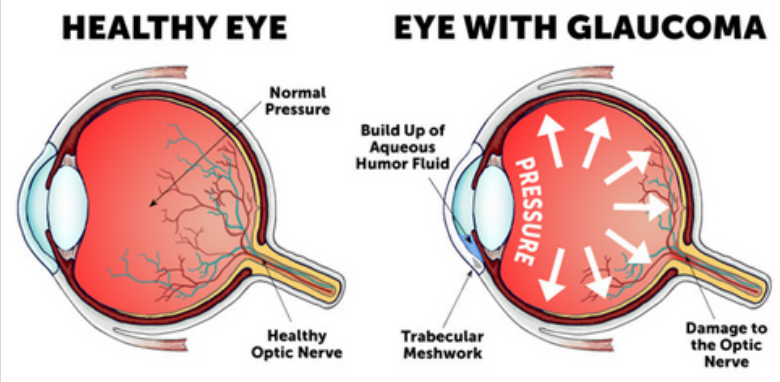

Figure 1. Glaucoma

3. Glaucoma types

The two most common types of glaucoma are angle-closure glaucoma (ACG) and primary open-angle glaucoma (POAG). POAG, the most common, is characterized by a gradual increase in IOP due to blocked drainage canals in the eye (3). In contrast, ACG occurs when the iris is too close to the drainage angle, potentially leading to a sudden obstruction of fluid outflow, rapid IOP elevation, and acute symptoms requiring immediate medical attention (4).

4. Mechanisms of optic nerve damage

Increased IOP is considered to be the main cause of optic nerve injury and a significant risk factor for glaucoma. The eye maintains its shape and proper function through the continuous production and drainage of aqueous humor, which provides nutrients and removes waste products. This liquid is formed by the ciliary body, flows through the pupil, and exits the eye via the Schlemm's canal. An imbalance between the production and drainage of aqueous humor causes elevated intraocular pressure (IOP) in glaucoma. This elevated pressure can mechanically compress the optic nerve head, resulting in axonal damage and loss of retinal ganglion cells (2).

The pathophysiology of glaucoma is also significantly influenced by vascular factors. Impaired blood flow to optic nerve head can contribute to its damage. Reduced perfusion pressure, vasospasm, and other vascular dysregulations can lead to ischemia and subsequent optic nerve damage (5).

At the molecular and cellular levels, several processes contribute to glaucomatous optic nerve damage:

- Oxidative stress: Reactive oxygen species (ROS) can accumulate due to increased oxidative stress, and these substances can harm lipids, proteins, and DNA among other components of cells. The loss of retinal ganglion cells may be worsened by this oxidative damage (6).
- Neuroinflammation: Chronic neuroinflammation has been implicated in glaucoma. Activated glial cells release inflammatory cytokines, exacerbating retinal ganglion cell damage (7).
- Apoptosis: Apoptosis, or programmed cell death, is a retinal ganglion cell loss mechanism in glaucoma. Elevated IOP and other stressors can activate apoptotic pathways, leading to the degeneration of these cells (8).

Genetic factors also contribute to the susceptibility and progression of glaucoma. Mutations in genes such as MYOC (myocilin) and OPTN (optineurin) have been linked to primary open-angle glaucoma (POAG). These genetic mutations can affect the trabecular meshwork's function and other cellular processes, increasing the risk of developing glaucoma (9,10).

5. Treatment

Early detection and ongoing therapy are essential for effectively managing glaucoma to protect optic nerves and maintain vision. Treatment strategies typically focus on reducing IOP through medications, laser therapies, or surgical interventions (11). However, adherence to treatment regimens remains a significant challenge, underscoring the need for developments in drug delivery systems to enhance efficiency and patient compliance (12).

6. Drug delivery systems

Selecting the drug delivery system ensures medication efficacy, improves patient adherence, and minimizes side effects. Various drug delivery systems used in the treatment of glaucoma:

- Topical eye drops: The most widely used technique for delivering glaucoma medications. These drops contain drugs like beta-blockers, prostaglandin analogs, alpha agonists, and carbonic anhydrase inhibitors, which either increase aqueous humor outflow or decrease its production (2).
- Sustained release systems: Sustained-release systems aim to improve adherence by reducing the frequency of drug administration. These include inserts, implants, and injectable formulations that provide a controlled release of medication over an extended period (13).
- Nanotechnology-based delivery systems: Encapsulation of drugs in nanoparticles or liposomes can improve drug stability and penetration (20).
- Gene therapy: Gene therapy presents a promising long-term treatment for glaucoma by targeting the underlying genetic causes or enhancing the production of protective proteins (13).
- Drug-eluting contact lenses: These contact lenses offer a novel method for sustained drug delivery directly to the eye surface. Lenses are impregnated with glaucoma medication, which is gradually released into the tear film (13).
- Iontophoresis: Iontophoresis is a non-invasive method that uses a low electrical current to enhance drug penetration into ocular tissues. An electrode is placed on the eye, and a small electric current drives the drug into the cornea and anterior chamber. Thus, enhancing drug delivery and reducing dosing frequency (20).

7. Education and awareness

Glaucoma is often symptomless in its early stages, which leads to delayed diagnosis and treatment. Many individuals remain unaware of their condition until significant vision loss occurs. By educating people on the importance of regular eye examinations, particularly for those who are more vulnerable—such as older adults, those with a family history of glaucoma, and members of specific ethnic groups—public education campaigns aim to bridge this knowledge gap (14).

- Public health campaigns: Public health campaigns can make glaucoma more widely known by using a variety of media platforms, such as print materials, social media, radio, and television (15).
- Symptom recognition: While early-stage glaucoma is often asymptomatic, education programs inform the public about potential symptoms of advanced disease, such as peripheral vision loss, halos around lights, and eye pain, prompting timely medical consultation (2).
- Regular screening and early detection: Emphasizing the importance of regular eye examinations, particularly for high-risk groups, is a cornerstone of glaucoma education. Early detection through comprehensive eye exams, including IOP measurement and optic nerve assessment, can prevent significant vision loss (16).
- Community outreach programs: Collaborating with community organizations, healthcare providers can conduct educational workshops, free screening events, and informational sessions to increase awareness at the grassroots level (17).
- Healthcare provider education: Educating primary care physicians, optometrists, and other healthcare professionals about the importance of glaucoma screening and referral processes ensures that patients receive timely and appropriate care (14).
- Patient education materials: Providing patients with brochures, videos, and websites containing detailed information about glaucoma, its management, and the importance of adherence to treatment regimens enhances their understanding and engagement in their care (16).

8. Support for research and innovation

Public policies support research into the causes, prevention, and treatment of glaucoma. Funding for scientific research is crucial for developing new diagnostic tools, and treatments, and understanding the genetic and environmental factors contributing to the disease. Notable among these is the "Trilab" initiative, a collaboration among three tertiary centers in Southern India (L.V. Prasad Eye Institute, Sankara Nethralaya, and Aravind Eye Care Systems), aimed at studying the pathogenesis and progression of primary angle-closure glaucoma (PACG) using advanced "omics" technologies (18). This collaborative effort highlights the need for more substantial and sustained funding to support comprehensive research and large-scale clinical trials.

9. Global initiatives and collaborations

International collaborations and initiatives play a significant role in shaping public policy on glaucoma. Organizations like the International Agency for the Prevention of Blindness (IAPB) work with governments, health professionals, and non-profits to develop and implement strategies to combat glaucoma globally. The WHO's Global Action Plan for the Prevention of Avoidable Blindness and Visual Impairment 2014-2019 outlines specific targets for reducing blindness from glaucoma and other eye diseases through enhanced health systems, better data collection, and increased awareness (19).

10. Conclusion

Glaucoma is a complex and multifaceted disease that poses a significant threat to vision worldwide. Early diagnosis and effective management are crucial to prevent irreversible damage to the optic nerve and subsequent vision loss. Advancements in understanding the pathophysiology of glaucoma have led to the development of various treatment options, including pharmacological therapies, laser treatments, and surgical interventions. However, issues with patient adherence and side effects highlight the need for improved drug delivery systems. Innovations in drug delivery systems, such as sustained-release formulations, nanotechnology-based carriers, gene therapy, drug-eluting contact lenses, and iontophoresis, show promise in addressing these challenges. These advanced delivery systems aim to enhance drug bioavailability, reduce dosing frequency, improve patient adherence, and minimize side effects, thereby optimizing the management of glaucoma. Government policies that support research funding, subsidize treatments, and implement public health initiatives can impact the management of glaucoma at a population level. The future of glaucoma management lies in personalized and precision medicine, leveraging advanced drug delivery systems, and robust public health policies to reduce the burden of this potentially blinding disease. Collaborative efforts among researchers, clinicians, policymakers, and patients are vital to advancing glaucoma care and improving outcomes for those affected by this condition.

References

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology. 2014;121(11):2081-2090.
2. Weinreb RN, Aung T, Medeiros FA. The pathophysiology and treatment of glaucoma: a review. JAMA. 2014;311(18):1901-1911.
3. Kwon YH, Fingert JH, Kuehn MH, Alward WLM. Primary open-angle glaucoma. The New England Journal of Medicine. 2009;360(11):1113-1124.
4. Friedman DS, He M. Anterior chamber angle assessment techniques. Survey of Ophthalmology. 2008;53(3):250-273.
5. Flammer J, Orgul S, Costa VP, Orzalesi N, Krieglstein GK, Serra LM, Renard JP. The impact of ocular blood flow in glaucoma. Progress in Retinal and Eye Research. 2002;21(4):359-393.
6. Tezel G, Wax MB. The immune system and glaucoma. Current Opinion in Ophthalmology. 2002;15(2):80-84.
7. Tezel G, Wax MB. The immune system and glaucoma. Current Opinion in Ophthalmology. 2004;15(2):80-84.
8. Kuehn MH, Fingert JH, Alward WLM. Early molecular events in glaucoma: wilderness of promises. Investigative Ophthalmology & Visual Science. 2005;46(1):114-125.
9. Stone EM, Fingert JH, Alward WLM, Nguyen TD, Polansky JR, Sunden SL, Sheffield VC. Identification of a gene that causes primary open angle glaucoma. Science. 1997;275(5300):668-670.
10. Rezaie T, Child A, Hitchings R, Brice G, Miller L, Coca-Prados M, Sarfarazi M. Adult-onset primary open-angle glaucoma caused by mutations in optineurin. Science. 2002;295(5557):1077-1079.
11. Weinreb RN, Aung T, Medeiros FA. The pathophysiology and treatment of glaucoma: a review. JAMA. 2014;311(18):1901-1911.
12. Newman-Casey PA, Blachley T, Lee PP, Heisler M, Stein JD. Patterns of glaucoma medication adherence over four years of follow-up. Ophthalmology. 2015;122(10):2010-2021.
13. Mansoor S, Shafique A. Advances in drug delivery for the treatment of glaucoma. Drug Development and Industrial Pharmacy. 2021;47(1):1-10.
14. American Academy of Ophthalmology. Glaucoma: What You Should Know. 2020. Retrieved from https://www.aao.org/eye-health/diseases/what-is-glaucoma
15. Kass MA, Heuer DK, Higginbotham EJ, Johnson CA, Keltner JL, Miller JP, Gordon MO. The Ocular Hypertension Treatment Study: a randomized trial determines that topical ocular hypotensive medication delays or prevents the onset of primary open-angle glaucoma. Archives of Ophthalmology. 2002;120(6):701-713.
16. Foster PJ, Buhrmann R. The definition and classification of glaucoma in prevalence surveys. British Journal of Ophthalmology. 2002;86(2):238-242.
17. Glaucoma Research Foundation. Glaucoma Information. 2020. Retrieved from https://www.glaucoma.org/glaucoma/
18. https://glaucomatoday.com/articles/2013-jan-feb/glaucoma-care-in-india
19. World Health Organization. Action plan for the prevention of avoidable blindness and visual impairment 2014-2019. 2013. Retrieved from https://apps.who.int/iris/handle/10665/178253
20. Faiq MA, Dada R. Nanotechnology in the treatment of glaucoma: a review on applications and novel approaches. Journal of Drug Targeting. 2019;27(5-6):558-571.