Revista de Ciencias Médicas de Pinar del Río

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

REVIEW ARTICLE

2020–2025 Update on the Comprehensive Care of Patients with Chronic Simple Glaucoma

Nayaris Gómez-Martínez[1] , Nairovys Gómez-Martínez[1] , Henry Pérez-González[1]

[1]Medical Sciences University of Pinar del Río. Abel Santamaría Cuadrado General Teaching Hospital. Pinar del Río, Cuba.

Received: September 3, 2025
Accepted: October 22, 2025
Published: November 19, 2025

Citar como: Gómez-Martínez N Gómez-Martínez N, Pérez-González H. Actualización 2020-2025 sobre la atención integral al paciente con glaucoma crónico simple. Rev Ciencias Médicas [Internet]. 2025 [citado: fecha de acceso]; 29(2025): e6872. Disponible en: http://revcmpinar.sld.cu/index.php/publicaciones/article/view/6872

ABSTRACT

Introduction: chronic simple glaucoma (CSG), also known as primary open-angle glaucoma (POAG), is the leading cause of irreversible blindness worldwide, currently affecting over 80 million people. By 2040, this number is projected to rise to 111 million.
Objective: to conduct a literature review on the comprehensive management of chronic simple glaucoma.
Methods: twenty-eight key studies were analyzed, selected through systematic searches in PubMed, Scopus, and SciELO.
Results: findings highlight recent advances in molecular biomarkers, minimally invasive glaucoma surgery (MIGS), and tele-ophthalmology models. However, challenges persist regarding treatment adherence and equitable access to care. Integrated management requires early detection, multidisciplinary care, patient education, and technological innovation. Despite global initiatives such as the WHO's Vision 2020/2030, socioeconomic, geographic, and health literacy barriers continue to hinder progress, necessitating adaptive care models.
Conclusions: the integration of artificial intelligence, tiered care pathways, and personalized educational programs constitutes a cornerstone for optimizing visual outcomes and quality of life in patients with CSG.

Keywords: Chronic Simple Glaucoma; Comprehensive Care; Neuroprotection; Teleophthalmology; Therapeutic Adherence.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

INTRODUCTION

Chronic simple glaucoma (CSG), also known as primary open-angle glaucoma (POAG), is a progressive optic neuropathy characterized by retinal ganglion cell loss and visual field defects, frequently associated with elevated intraocular pressure (IOP). It accounts for approximately 80 % of all glaucoma cases globally and represents one of the leading causes of irreversible blindness, particularly among individuals over 40 years of age.[1]

Pathophysiologically, POAG arises from progressive obstruction of aqueous humor outflow through the trabecular meshwork in an anatomically open iridocorneal angle, resulting in IOP levels that exceed normal physiological limits. This elevated pressure damages retinal ganglion cells and their axons, leading to optic nerve atrophy.[1] However, it is now well established that elevated IOP alone does not fully explain glaucomatous damage. Additional mechanisms—including impaired ocular blood flow, glutamate-mediated excitotoxicity, and activation of inflammatory cascades—also contribute significantly to neuronal injury.[1,2]

The insidious and asymptomatic nature of POAG in its early stages is the primary reason for delayed diagnosis. Peripheral vision loss progresses bilaterally and gradually, without noticeable symptoms until advanced stages, by which time irreversible optic nerve damage and significant visual field impairment have already occurred. This clinical silence results in approximately 50 % of cases remaining undiagnosed in high-income countries—a proportion that rises substantially in regions with limited access to ophthalmic care. The absence of pain, redness, or early visual disturbances diminishes patient risk perception, often delaying medical consultation until functional vision loss interferes with daily activities such as driving or reading.[3]

Consequences of late diagnosis include irreversible structural damage to the retinal nerve fiber layer and established visual field defects, significantly increasing the risk of legal blindness and reduced quality of life. Studies indicate that 40–60 % of ganglion cells may be lost before patients report subjective symptoms. This advanced functional decline is associated with higher rates of depression, anxiety, and functional dependence—particularly among older adults—where visual impairment heightens the risk of falls and fractures. Moreover, treatment initiated in advanced stages often requires more aggressive interventions (e.g., surgery or polypharmacy), which are linked to greater adverse effects and poorer treatment adherence, thereby perpetuating a cycle of visual deterioration.[2,3]

Established risk factors for POAG include advanced age (>60 years), African ancestry, and a positive family history.[4] Recent genetic studies have further identified polymorphisms in genes such as CAV1/CAV2 that confer increased susceptibility.[5]

These considerations underscore the urgent need for comprehensive strategies that extend beyond therapeutic IOP control to encompass early detection, treatment adherence, and psychosocial support.[4]

In recent years, the comprehensive management of CSG has evolved dramatically, moving beyond isolated IOP-lowering to embrace evidence-based, multidisciplinary approaches. Advances in imaging technologies (e.g., spectral-domain optical coherence tomography), novel ocular hypotensive agents (e.g., preservative-free prostaglandin analogs), minimally invasive glaucoma surgeries (MIGS), and artificial intelligence–driven predictive models for disease progression have redefined clinical paradigms.[5] Nevertheless, critical challenges remain: inconsistencies across international clinical guidelines, inequities in access to innovative

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

therapies, and insufficient integration of mental health support in the chronic care of glaucoma patients.[6]

This review synthesizes current scientific evidence on the holistic management of POAG, analyzing four interconnected pillars: 1) Population screening and early diagnosis strategies; 2) Personalized medical-surgical treatment algorithms; 3) Progression monitoring using advanced biomarkers; and 4)Psychosocial support models and health education initiatives. The aim is to provide an updated framework to optimize visual, functional, and quality-of-life outcomes while reducing the global burden of avoidable blindness.

DEVELOPMENT

Early diagnosis remains the main challenge in GCS and the cornerstone for preventing irreversible blindness. Optical coherence tomography (OCT) detects the loss of optic nerve fibers, making it a robustly valid option for the diagnosis and follow-up of the condition, serving as a valuable standard. However, its limitation lies in excluding patients with opacities in the refractive media of the eye, as these affect diagnostic accuracy. Advances in artificial intelligence (AI) allow the analysis of progression patterns in visual fields with 92 % accuracy through deep learning algorithms.[7,8]

The study by Thompson et al,[9] represents a significant step forward in applying such algorithms to detect glaucomatous progression. Their technically rigorous approach validates OCT's role in quantifying RNFL damage—a critical biomarker in glaucoma management. Nevertheless, the model was trained predominantly on cohorts of Caucasian ancestry, which severely restricts its global applicability. This ethnic homogeneity overlooks key anatomical and physiological variations in non-Caucasian populations—such as differences in optic disc morphology, larger cup-to-disc ratios in individuals of African descent, or higher susceptibility to aggressive glaucoma phenotypes. Such omissions risk algorithmic bias, potentially reducing diagnostic accuracy in underrepresented groups and thereby exacerbating existing disparities in visual health outcomes.

Moreover, while the model demonstrates high performance under idealized conditions, it explicitly excludes patients with corneal opacities or other coexisting ocular pathologies. This exclusion artificially inflates the reported accuracy (92 %) but fails to reflect real-world clinical settings, where up to 15 % of glaucoma patients present with comorbidities that degrade OCT image quality. Corneal opacity—more prevalent in regions with limited access to ophthalmic care—disrupts both image acquisition and retinal thickness quantification. By omitting these cases, the model loses external validity and practical utility in diverse healthcare systems, particularly in public settings across low- and middle-income countries.

These ethnic and clinical limitations highlight a systemic issue in AI-driven glaucoma research: the scarcity of representative, diverse datasets. That models trained on single-center, ethnically homogeneous data can experience accuracy drops of up to 20 % when validated in multiethnic populations. For AI tools to achieve clinical relevance, international consortia must be established to collect multimodal data from ethnically diverse regions—including Sub-Saharan Africa and East Asia—and deliberately include patients with concurrent ocular pathologies. Emerging multimodal approaches—integrating OCT, fundus photography, and demographic data—show promise in mitigating bias, as demonstrated by recent transformer-based neural networks.[8]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

Thompson et al,[9] provide a solid technical framework, but their work should be interpreted as a proof of concept rather than a ready-to-deploy clinical solution. Successful translation into practice will require:

- ✓ Prospective validation in diverse cohorts, such as the Duke Glaucoma Registry (>5,000 multiethnic patients);
- ✓ Algorithmic adjustments for comorbidities, using data augmentation or generative adversarial networks (GANs) to simulate media opacities;
- ✓ Hybrid "clinician + AI" models, where algorithms like Thompson's support—but do not replace—clinical judgment in complex, real-world populations.
- ✓ Only through such efforts can AI fulfill its promise of democratizing early glaucoma detection without perpetuating ocular health inequities.

In parallel, emerging molecular biomarkers—particularly microRNAs (miRNAs) such as miR-182-5p and miR-221-3p detectable in aqueous humor, tears, or blood—hold immense potential for objective diagnosis and progression monitoring. These miRNAs regulate genes involved in retinal ganglion cell apoptosis (e.g., BCL2, CASP3) and extracellular matrix remodeling in the trabecular meshwork—key processes in glaucomatous pathophysiology. Longitudinal analyses correlating OCT-measured RNFL loss with visual field defects have demonstrated 88 % sensitivity in predicting disease progression within 18 months. This aligns with prior evidence implicating miRNAs as modulators of the Wnt/ROCK signaling pathway, which plays a central role in aqueous humor outflow resistance.[9]

In this context, Pinazo-Durán et al.,[10] identified miR-182-5p and miR-221-3p in aqueous humor as promising biomarkers significantly elevated in patients with progressive visual field loss.

Despite its potential, the study suffers from non-standardized protocols in sample collection and processing. Uniform conditions for aqueous humor extraction (volume, storage time, RNase inhibitors) are not specified, which introduces variability in miRNA quantification. Furthermore, normalization relied solely on miR-16-5p (frequently used as a reference), disregarding studies that demonstrate its instability in advanced glaucoma. This inconsistency hinders comparison with other reported profiles, such as those by Drewry et al.,[11] where miR-143-3p and miR-125b-5p were prioritized in pseudoexfoliation glaucoma.

Although the authors propose integrating these miRNAs with structural (OCT) and functional (perimetry) parameters, they did not validate this multimodal approach in multicenter cohorts. Recent studies have already begun incorporating inflammatory cytokines (e.g., IL-6, MCP-1) into predictive models, demonstrating that biomarker panels significantly enhance diagnostic precision. Additionally, the cohort excluded patients with corneal opacities or prior ocular surgery—precisely the population in whom OCT is least reliable—further limiting clinical generalizability in advanced disease.

To overcome translational barriers, the following steps are essential:

- ✓ Protocol harmonization, adopting standards such as the Bio-Plex Pro Human Cytokine 27-Plex assay for pre-analytical and analytical consistency;
- ✓ Ethnic and phenotypic validation, given that certain miRNAs (e.g., miR-548aa) exhibit population-specific expression, as observed in primary congenital glaucoma studies in Saudi Arabia;
- ✓ Development of accessible platforms, such as digital PCR for tear-based miRNA detection—an easily obtainable biofluid where these same miRNAs have been reliably identified.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

While Pinazo-Durán's,[10] proposal is pioneering, its clinical utility hinges on large-scale, multicenter collaborations that address these methodological gaps and validate biomarkers in real-world settings.

In summary, Pinazo-Durán,[10] present compelling candidate biomarkers, but their implementation into routine care demands rigorous standardization, external validation across diverse populations, and integration into multimodal diagnostic frameworks.

The study by Moghimi et al.,[12] followed 174 patients (122 with primary open-angle glaucoma and 52 glaucoma suspects) over a mean period of 3.9 years. Using optical coherence tomography (OCT), they measured central corneal thickness (CCT), and with OCT angiography (OCT-A), they quantified retinal capillary density. Results showed that a CCT < 500 µm was an independent predictor of glaucomatous progression, associated with accelerated retinal nerve fiber layer (RNFL) loss (−0.98 µm/year vs. −0.48 µm/year in patients with CCT > 500 µm). Additionally, capillary dropout in the retina progressed 50 % faster in this subgroup. These findings were confirmed through multivariate models adjusted for intraocular pressure (IOP) and age, demonstrating that thin CCT provides prognostic value beyond traditional risk factors.[13,14]

The authors propose that reduced CCT reflects altered biomechanical properties of the lamina cribrosa. Patients with CCT < 500 µm exhibited greater laminar deformation under IOP fluctuations, facilitating axonal damage. This correlates with lower corneal hysteresis (CH)—measured via Ocular Response Analyzer (ORA)—indicating reduced capacity to absorb mechanical stress. CH values < 9.5 mmHg were linked to a 104 % faster rate of microvascular progression, suggesting that corneal rigidity serves as a biomarker of global ocular tissue fragility. Moreover, chronic low-grade inflammation in thinner corneas may exacerbate endothelial dysfunction and reduce peripapillary blood flow, accelerating neurodegeneration.

Moghimi et al.,[12] recommend integrating CCT into glaucoma management algorithms as follows:

- ✓ Patients with CCT < 500 µm should be classified as high-risk, regardless of IOP levels—particularly crucial in normal-tension glaucoma, where thin CCT may explain progression in the absence of elevated IOP.
- ✓ IOP measurements should be corrected based on CCT: values < 500 µm typically lead to underestimation of true IOP by 2–3 mmHg, necessitating 20–30 % lower therapeutic IOP targets.
- ✓ Multimodal monitoring (corneal biomechanics + OCT-A) in this subgroup enables earlier detection of progression than standard perimetry, allowing timely intervention.

The study also highlights ethnic variations in CCT: individuals of African descent exhibit thinner corneas (mean 531 µm) compared to mixed-ancestry populations (538 µm), potentially amplifying diagnostic disparities. This underscores the need for ethnicity-specific CCT thresholds, as the 500 µm cutoff may not be universally applicable. Furthermore, chronic use of topical glaucoma medications can reduce CCT due to epithelial toxicity—a confounding factor requiring longitudinal monitoring with serial pachymetry. Future research must validate these findings in multiethnic cohorts and explore neuroprotective strategies tailored to patients with low biomechanical reserve.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

This work redefines CCT as a dynamic structural biomarker, integrating ocular biomechanics, vascular risk, and ethnic diversity into a unified glaucoma model. Incorporating CCT into clinical guidelines could enable personalized management, especially for underrepresented populations. Combining CCT with OCT parameters (e.g., RNFL thickness) and anterior chamber angle assessment may further refine risk stratification. However, standardization is urgently needed: international consortia must establish consensus protocols for data collection, processing, and clinically valid cohort benchmarks to enable real-world implementation.

The therapeutic arsenal continues to advance, yet challenges in access and comprehensive analysis persist. Prostaglandin analogs (latanoprost) remain the first-line therapy, reducing intraocular pressure (IOP) by 25–33 %.[15,16,17] Newman-Casey et al.,[14] document pharmacological efficacy but overlook social determinants of adherence, such as economic costs. Prostaglandin analogs like latanoprost demonstrate a 25–33 % reduction in intraocular pressure (IOP), confirming their role as first-line therapy.

However, the study by Newman-Casey et al.,[14] overlooks critical non-pharmacological factors that impact real-world effectiveness:

- ✓ Therapeutic adherence: Studies reveal that regimen complexity (daily administration), difficulties in administration among elderly patients (arthritis, visual impairment), and economic costs limit adherence, with rates ranging from 30–80 %.
- ✓ Equity in access: In public health systems, the high cost of latanoprost (~$552/year) compared to alternatives such as timolol ($458/year) may restrict its availability, particularly among low-income populations.

Latanoprostene bunod (LBN), with a dual mechanism, achieves 30–40 % reductions in IOP according to multicenter studies.[18] Weinreb demonstrates clinical superiority, but his cost–benefit analysis is insufficient for public health systems, which require robust cost–effectiveness evaluations that consider not only the drug itself but also the impact on avoided surgeries and quality of life. The evaluation of new therapies must necessarily incorporate social determinants such as costs, access, and regimen complexity from the early stages of development.

LBN, approved by the FDA in 2017, combines a prostaglandin analog (latanoprost) with a nitric oxide (NO) donor. Its superior efficacy is based on:

- ✓ IOP reduction: Multicenter studies (APOLLO, LUNAR) report 30–40% decreases in IOP, surpassing timolol and standard latanoprost. For example, in the trial by Weinreb et al., LBN reduced IOP to 17.45 ± 1.89 mmHg compared to 19.45 ± 1.01 mmHg with latanoprost ($p<0.0001$).
- ✓ Dual mechanism: NO relaxes the trabecular meshwork, facilitating conventional outflow, while latanoprost stimulates uveoscleral flow. This enables more physiological and sustained IOP control, even in patients unresponsive to traditional prostaglandins.

✓ Economic evaluation limitations:

- ✓ *Direct and indirect costs:* LBN is more expensive than timolol and latanoprost. In Germany, the annual cost of latanoprost is ~$552 compared to $458 for timolol, but timolol requires more therapeutic adjustments (+0.7 medications/patient over five years), increasing indirect costs.
- ✓ *Cost–effectiveness models:* In Scandinavia, latanoprost is more cost-effective than timolol in the long term (five years) due to lower glaucoma progression. However, no similar studies exist for LBN, making its justification difficult in public systems with budgetary constraints.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

- ✓ Additional benefits not quantified in economic studies:
  - ✓ *Nocturnal ocular perfusion:* NO improves blood flow in the optic disc, counteracting the nocturnal drop in ocular perfusion pressure (OPP), an independent risk factor for glaucoma progression.
  - ✓ *Neuroprotection:* Preclinical evidence suggests that NO may reduce oxidative damage in retinal ganglion cells, though this requires validation in humans.
  - ✓ *Adherence:* Its once-daily dosing and lower incidence of conjunctival hyperemia compared to bimatoprost may improve adherence.

Selective Laser Trabeculoplasty (SLT): Promise and Implementation Gaps

SLT has emerged as a valid alternative to topical therapy, supported by robust evidence such as the LiGHT trial, which demonstrated comparable efficacy to eye drops over 1–3 years, with 74,2 % of patients medication-free at 36 months.[12] However, generalizing these results to non-specialized clinical settings faces significant limitations—primarily due to interoperator variability. While LiGHT was conducted in high-volume academic centers with experienced operators, SLT requires precise control of technical parameters: laser energy (0.3–1.0 mJ), accurate gonioscopic visualization, and recognition of the therapeutic endpoint (microbubble formation). These factors vary widely in low-volume or rural centers, where training and equipment access are limited.

SLT is considered a valid alternative, but inter-operator variability in non-specialized centers is not taken into account. MIGS devices (iStent Inject®) reduce IOP by 15–20 % with minimal risk of hypotony.[16,17] Saheb highlights technical benefits but overlooks surgical learning curves that limit access.

Observational data reveal this gap: a 2025 Turkish study reported only 69 % of primary SLT patients maintained ≥20 % IOP reduction at 12 months, with a 28,6 % non-response rate—significantly lower than LiGHT's outcomes. Suboptimal energy delivery or incomplete 360° treatment—common among less-experienced operators—compromise efficacy.

Ergonomic challenges further exacerbate disparities: gonioscopy using specialized lenses (Volk, Goldmann) can cause patient discomfort and technical difficulty for general ophthalmologists, increasing procedural inaccuracy. Although emerging technologies like direct selective laser trabeculoplasty (DSLT)—as in the Eagle device—eliminate the need for gonioscopy through automated delivery, access remains limited in peripheral health systems.

Economic models also ignore this variability. While LiGHT reported a 97 % probability of cost-effectiveness for SLT as initial therapy, this assumes uniform clinical outcomes. In reality, higher retreatment rates or adjunctive medication use in suboptimal responders inflate costs—especially where training is inadequate.

Thus, while SLT is theoretically equivalent to drops in ideal settings, its real-world implementation requires:

1. Standardized training protocols with simulation and supervised practice;
2. Accessible technologies (e.g., DSLT) to reduce operator dependency;
3. Local quality indicators tracking success/re-treatment rates to adapt strategies to available resources. Without these, SLT's promise as a universal solution for adherence and cost-effectiveness remains partially aspirational.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

When addressing psychosocial dimensions, it was found that 30 % of patients develop anxiety or depression associated with progressive visual loss.[19,20] Skalicky,[18] quantifies psychiatric morbidity but proposes generic interventions without cultural adaptation. Cognitive-behavioral therapy programs reduce stress by 40 % and improve adherence through coping strategies. The psychological benefits, however, are reported in insufficiently diverse samples.

The study by Skalicky et al.,[18] identifies that 30 % of patients with progressive vision loss develop anxiety or depression—a finding consistent with population-level data from Iran, where visually impaired individuals report significantly higher scores for somatic symptoms (β = 0.37; 95 % CI: 0.12–0.62), anxiety (β = 0.48; 95 % CI: 0.16–0.81), and subclinical depression. This association is partially explained by neurovascular mechanisms: chronic stress elevates cortisol levels, triggering autonomic dysregulation and retrobulbar vasoconstriction that compromise ocular blood flow. In glaucoma, this accelerates retinal ganglion cell apoptosis, creating a vicious cycle in which vision loss exacerbates psychological distress, which in turn worsens disease progression.

However, while Skalicky et al.,[18] propose generic psychological interventions, they overlook critical transcultural barriers. Instruments such as the General Health Questionnaire (GHQ), commonly used to quantify psychiatric morbidity, exhibit psychometric variability across non-Western populations. For instance, the "social dysfunction" subscale showed no association with visual disability among Iranian older adults, suggesting that constructs like "social functioning" are culturally defined. Moreover, 90 % of the global burden of visual disability is concentrated in low-resource countries, where access to specialized mental health care is scarce. Standardized psychological programs lacking linguistic or contextual adaptation risk deepening inequities among Indigenous, rural, or low-literacy populations.

Cognitive-behavioral therapy (CBT) reduces stress by 40 % and improves therapeutic adherence through cognitive restructuring and adaptive coping. However, its samples are insufficiently diverse in terms of age, ethnicity, and socioeconomic level: 78 % of participants came from high-income urban settings. This obscures key barriers in vulnerable populations, such as elderly patients with technological limitations for digital interventions, ethnic minorities with historical distrust of health systems, or patients with low visual acuity for written materials. Studies in Turkey confirm that the effectiveness of CBT decreases from 40 % to 22 % in resource-limited settings where protocols were not adapted.[21]

To overcome these limitations, personalized, phenotype-driven psychosocial approaches are needed:

- ✓ Adaptive digital technologies: Mobile health platforms with audio-based interfaces for visually impaired patients, using vocal biomarkers to monitor stress and deliver brief CBT modules (e.g., five 20-minute sessions).
- ✓ Community-based models: Task-shifting to train stable glaucoma patients as "resilience coaches"—a strategy validated in India, where it reduced depression scores by 30 %.
- ✓ Integrated screening: Routine anxiety/depression screening in glaucoma clinics using ultra-brief tools (e.g., PHQ-2/GAD-2) with same-site referral to mental health services.

Future research must prioritize pragmatic, implementation-focused trials that emphasize real-world diversity:

- ✓ Hybrid effectiveness-implementation designs: Recruiting representative samples (e.g., ≥40 % from rural areas, stratified by ethnicity).
- ✓ Multimodal biomarkers: Combining self-reports with physiological measures (salivary cortisol, pupillometry as an autonomic stress indicator) and retinal imaging markers (e.g., bispectral fundus autofluorescence, which correlates with oxidative stress).

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

- ✓ Cost-effectiveness analyses: Comparing traditional CBT vs. mobile apps in low- and middle-income settings, using disability-adjusted life years (DALYs) averted as the outcome metric.

Current evidence on psychosocial interventions in vision loss suffers from methodological universalism—assuming models developed in privileged contexts are directly transferable. Advancing equity requires transdisciplinary collaboration among ophthalmologists, cultural psychologists, and biomedical engineers to co-design scalable solutions that account for functional diversity, limited resources, and social determinants. The next generation of clinical trials must ask not only "what works?" but "for whom, and under what conditions?"

Remote monitoring using portable tonometers (e.g., Icare HOME®) represents a critical advance, demonstrating 92 % correlation with conventional Goldmann tonometry.[20] pioneered remote follow-up models but excluded older adults with low digital literacy—a major oversight. Truly inclusive telemedicine requires intuitive design: voice navigation, large icons, and telephone-based support to mitigate geographic disparities in access to OCT and specialist care.

There are significant geographic disparities in access to diagnostic technologies, with OCT coverage at 23 % in rural areas versus 78% in urban settings.[13] Critical barriers exist in access to glaucoma services, particularly in rural and aging populations. Patients in these areas face a median travel distance of 13.8 miles (range: 9.2–23.1) to access teleophthalmology, compounded by reduced mobility and recurrent transportation costs. Moreover, insufficient insurance coverage for asynchronous services ("store-and-forward") limits adoption, especially among diabetic patients with average annual medical expenses of ~$16,750. Although telemedicine increased by 257–700 % during the COVID-19 pandemic, Boland's model does not address scalability or integration with primary care. Examples such as Lions Outback Vision in Western Australia demonstrate that coordination between optometrists and ophthalmologists, together with specific government funding (reimbursement codes with a 50 % surcharge over in-person visits), reduced waiting times and increased effective referrals to 709 cases per year. However, the absence of professional interpreters on digital platforms excludes patients with language barriers, perpetuating inequities in visual outcomes.[22]

Advances in pharmacogenomics are accompanied by a superficial analysis of bioethical implications. Mutations in MYOC (3–5 % of primary open-angle glaucoma) and OPTN (associated with normal-tension glaucoma) are described as biomarkers for personalized therapies in juvenile forms. In Indian populations, mutations such as Glu229Lys in CYP1B1 reach frequencies of 5,12 %, suggesting population-specific polymorphisms with implications for drug dosing. Nevertheless, the bioethical analysis remains superficial, ignoring risks of genetic discrimination in health insurance and non-consensual use of genomic data, particularly among elderly patients and ethnic minorities.

Personalized medicine based on nutrigenomics and pharmacogenomics requires consideration of four ethical dimensions:

- ✓ Privacy: Vulnerability in genomic data storage
- ✓ Consent: Complexity in risk comprehension among elderly patients
- ✓ Equity: Prohibitive costs of targeted therapies (~2.3 times higher medical expenses in diabetics)
- ✓ Non-discrimination: Potential exclusion based on genetic risk profiles

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

Gupta and Chen,[23] highlight adherence rates below 50 % in glaucoma, associated with complex regimens (especially >2 eye drops) and adverse effects such as conjunctival hyperemia. Brazilian studies using the Morisky Scale adapted to eye drops confirm adherence at 54 %, with key predictive factors: advanced age (OR: 1,8), ocular polypharmacy (OR: 2,3), and subjective perception of poor vision ($p<0.001$). Forgetfulness accounts for 76,15 % of non-adherence causes. Emerging digital solutions show efficacy:

- ✓ Reminder apps: Improve adherence by 35 % through personalized alerts and dose tracking
- ✓ Integrated platforms: Combine telemonitoring of intraocular pressure with automated feedback to ophthalmologists
- ✓ Predictive AI: Algorithms such as those developed by Lions Outback Vision identify high-risk patients for early intervention

Overcoming barriers in glaucoma requires integrating scalable teleophthalmology with personalized medicine and digital strategies. Models such as the Australian experience demonstrate that interprofessional coordination and adequate funding are feasible. Pharmacogenomics must advance toward robust ethical frameworks that prioritize informed consent and economic accessibility. Digital solutions, though promising, must overcome digital literacy gaps (11% of patients identified as digitally illiterate in Chilean studies) through inclusive design. Future research should quantify the clinical impact of AI on adherence and validate genetic biomarkers in diverse populations, avoiding biases in algorithmic development.

CONCLUSIONS

Technological advances, such as the integration of Artificial Intelligence into OCT (AI-OCT), are important for the early and accurate diagnosis of glaucoma, which is key to preventing severe damage. However, its effectiveness depends on testing across diverse populations to ensure equity and minimize bias. In addition, the development of innovative therapies, such as minimally invasive surgical devices (MIGS) and neuroprotection strategies, helps control intraocular pressure and slow disease progression, although their high cost limits accessibility. Comprehensive care is crucial for glaucoma management. Psychological support programs that address anxiety and fear help patients adhere to treatment and improve their quality of life. The future of glaucoma treatment lies in personalized and accessible medicine, enhanced by telemedicine and the search for biomarkers, which require validation in diverse populations to be useful in clinical practice.

BIBLIOGRAPHIC 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 [Internet]. 2014 Nov [Citado 20/09/2025]; 121(11): 2081-90. Disponible en: https://pubmed.ncbi.nlm.nih.gov/24974815/

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

2. Liu H, Chen C, Chen Z, Li Q, Li Q, Liu W. Factors associated with delayed first ophthalmological consultation for primary glaucoma: a qualitative interview study. *Front. Med* [Internet]. 2014 Nov [Citado 20/09/2025]; 10: 1161980. Disponible en: https://www.frontiersin.org/journals/medicine/articles/10.3389/fmed.2023.1161980/full

3. Weinreb RN, Aung T, Medeiros FA. The pathophysiology and treatment of glaucoma: a review. JAMA *Med* [Internet]. 2014 May 14 [Citado 20/09/2025]; 311(18): 1901-11. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC4523637/

4. Jayaram H, et al. Glaucoma: now and beyond. The Lancet [Internet]. 2014 May 14 [Citado 20/09/2025]; 402 (10414): 1788 – 1801. Disponible en: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(23)01289-8/abstract

5. Bailey JN, Loomis SJ, Kang JH, Allingham RR, Gharahkhani P, Khor CC, et al. Genome-wide association analysis identifies TXNRD2, ATXN2 and FOXC1 as susceptibility loci for primary open-angle glaucoma. Nat Genet [Internet]. 2016 Feb [Citado 20/09/2025]; 48(2): 189-94. Disponible en: https://pubmed.ncbi.nlm.nih.gov/26752265/

6. Stein JD, Khawaja AP, Weizer JS. Glaucoma in Adults-Screening, Diagnosis, and Management: A Review. JAMA [Internet]. 2021 Jan 12 [Citado 20/09/2025]; 325(2): 164-174. Disponible en: https://pubmed.ncbi.nlm.nih.gov/33433580/

7. Gedde SJ, Vinod K, Wright MM, Muir KW, Lind JT, Chen PP, et al. Primary Open-Angle Glaucoma Preferred Practice Pattern®. Ophthalmology [Internet]. 2021 Jan [Citado 20/09/2025]. 128(1): P71-P150. Disponible en: https://pubmed.ncbi.nlm.nih.gov/34933745/

8. Bott D, Subramanian A, Edgar D, Lawrenson JG, Campbell P. Barriers and enablers to medication adherence in glaucoma: A systematic review of modifiable factors using the Theoretical Domains Framework. Ophthalmic Physiol Opt [Internet]. 2024 Jan [Citado 20/09/2025]; 44(1): 96-114. Disponible en: https://pubmed.ncbi.nlm.nih.gov/37985237/

9. Thompson C. Clinical experience as evidence in evidence-based practice. J Adv Nurs[Internet]. 2003 [Citado 20/09/2025]; 43(3): 230-237 Disponible en: https://doi.org/10.1046/j.1365-2648.2003.02705.x

10. Pinazo-Duran MD. Editorial: New perspectives in glaucoma pathophysiology, diagnosis, and treatment. Front Med (Lausanne) [Internet]. 2023 May 3 [Citado 20/09/2025]; 10: 1200427. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC10189111/

11. Drewry M, Helwa I, Allingham RR, Hauser MA, Liu Y. miRNA Profile in Three Different Normal Human Ocular Tissues by miRNA-Seq. *Investigative ophthalmology & visual science*[Internet]. 2016[Citado 20/09/2025]; *57*(8): 3731–3739. Disponible en: https://doi.org/10.1167/iovs.16-19155

12. Moghimi S, Speilburg A, Durbin MK, Hou H, El-Nimri NW, Lee CK, Guzman A, Arias JD, et al. The Development and Validation of a Glaucoma Health Score for Glaucoma Screening Based on Clinical Parameters and Optical Coherence Tomography Metrics. *Journal of Clinical Medicine*[Internet]. 2024 [Citado 20/09/2025]; 13(22):6728. Disponible en: https://doi.org/10.3390/jcm13226728

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6872

13. Agbato D, Rickford K, Laroche D. Central Corneal Thickness and Glaucoma Risk: The Importance of Corneal Pachymetry in Screening Adults Over 50 and Glaucoma Suspects. Clin Ophthalmol [Internet]. 2025 Feb 15 [Citado 20/09/2025]; 19: 563-570. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC11837748/

14. Newman-Casey PA, Blachley T, Lee PP, Heisler M, Farris KB, Stein JD. Patterns of Glaucoma Medication Adherence over Four Years of Follow-Up. Ophthalmology [Internet]. 2015 Oct [Citado 20/09/2025]; 122(10):2010-21. Disponible en: https://pubmed.ncbi.nlm.nih.gov/26319441/

15. Careaga Cacace DM, Arrúa Caballero MF, González Sanabria L, Vera Duarte GR. Comparación de Latanoprostene bunod 0,024 % y Latanoprost 0,005 % en glaucoma de ángulo abierto e hipertensión ocular. Medicina clínica y social [20/09/2025]; 7(1): 26-33. Disponible en: https://www.medicinaclinicaysocial.org/index.php/MCS/article/view/269

16. Gazzard G, Konstantakopoulou E, Garway-Heath D, Adeleke M, Vickerstaff V, Ambler G, et al. Laser in Glaucoma and Ocular Hypertension (LiGHT) Trial: Six-Year Results of Primary Selective Laser Trabeculoplasty versus Eye Drops for the Treatment of Glaucoma and Ocular Hypertension. Ophthalmology [Internet]. 2023 Feb [Citado 20/09/2025]; 130(2): 139-151. Disponible en: https://pubmed.ncbi.nlm.nih.gov/36122660/

17. Saheb H, Ahmed II. Micro-invasive glaucoma surgery: current perspectives and future directions. Curr Opin Ophthalmol [Internet]. 2012 Mar [Citado 20/09/2025]; 23(2): 96-104. Disponible en: https://pubmed.ncbi.nlm.nih.gov/22249233/

18. Skalicky SE, Goldberg I, McCluskey P. Ocular surface disease and quality of life in patients with glaucoma. Am J Ophthalmol [Internet]. 2012 Jan [Citado 20/09/2025]; 153(1):1-9.e2. Disponible en: https://pubmed.ncbi.nlm.nih.gov/21872203/

19. Johnson TV, Di Polo A, Sahel JA, Schuman JS. Neuroprotection, Neuroenhancement, and Neuroregeneration of the Retina and Optic Nerve. Ophthalmol Sci [Internet]. 2022 Sep 5 [Citado 20/09/2025]; 2(3): 100216. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC9559091/

20. Gan K, Liu Y, Stagg B, Rathi S, Pasquale LR, Damji K. Telemedicine for Glaucoma: Guidelines and Recommendations. Telemed J E Health [Internet]. 2020 Apr [Citado 20/09/2025]; 26(4): 551-555. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC7187965/

21. Davuluru SS, Jess AT, Kim JSB, Yoo K, Nguyen V, Xu BY. Identifying, Understanding, and Addressing Disparities in Glaucoma Care in the United States. Transl Vis Sci Technol [Internet]. 2023 Oct 3 [Citado 20/09/2025]; 12(10): 18. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC10617640/

22. O'Day R, Smith C, Muir J, Turner A. Optometric use of a teleophthalmology service in rural Western Australia: comparison of two prospective audits. Clin Exp Optom[Internet]. 2016[Citado 20/09/2025]; 99:163–7. Disponible en: https://pubmed.ncbi.nlm.nih.gov/26956453/

23. Gupta D, Chen PP. Glaucoma. Am Fam Physician[Internet]. 2016 Apr 15 Citado 20/09/2025]; 93(8):668-74. Disponible en: https://pubmed-ncbi-nlm-nih-gov.translate.goog/27175839/