

IC3 - What's New in Glaucoma Diagnostics:

A Comprehensive Clinical Update and Workflow Guide

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Learning Objectives

- Understand strengths and limitations of modern glaucoma diagnostic tools
- Apply a practical workflow for challenging glaucoma cases
- Interpret multimodal data including AI-assisted outputs

1. Introduction: The Shifting Diagnostic Paradigm

Glaucoma remains the leading cause of irreversible blindness globally, currently affecting approximately 80 million individuals, with the burden projected to rise exponentially due to ageing demographic profiles. The insidious nature of the disease, frequently characterised as the "silent thief of sight," stems from the pathophysiological reality that structural damage to the retinal ganglion cells (RGCs) and the retinal nerve fibre layer (RNFL) almost always precedes noticeable functional visual field loss. The traditional diagnostic and monitoring paradigm relied heavily on episodic, point-in-time intraocular pressure (IOP) measurements using Goldmann applanation tonometry and standard automated perimetry (SAP) to detect and quantify damage that had, unfortunately, already become irreversible.^[1]

Over the past decade, the contemporary diagnostic paradigm has undergone a profound, technologically driven transformation toward a proactive, highly personalised, and predictive model. This monumental shift is driven by a confluence of breakthroughs encompassing home-based continuous IOP monitoring, high-resolution structural and depth-resolved vascular imaging, objective electrophysiological testing, and the rapid integration of artificial intelligence (AI) and polygenic risk scores (PRS) into daily clinical decision-making. This exhaustive instructional report delineates the latest advancements in glaucoma diagnostics. It provides a rigorous, evidence-based analysis of their clinical utility, specific diagnostic advantages, inherent technical limitations, and the practical logistical steps required to seamlessly integrate these novel modalities into standard, high-volume clinical workflows.

2. Advances in IOP Measurement

The IOP remains the sole proven, modifiable risk factor for the development and progression of glaucomatous optic neuropathy. However, the standard clinical practice of capturing merely a momentary snapshot of a patient's IOP during standard office hours inherently ignores the complex, dynamic diurnal and nocturnal fluctuations that heavily influence disease progression.

2.1 The Limitations of Snapshot Tonometry

Standard office-hour measurements have been repeatedly shown to miss the peak diurnal IOP in a substantial majority of patients. The physiological reality is that IOP varies continuously from hour to hour and day to day, heavily influenced by circadian rhythms, systemic hemodynamics, and patient posture.^[2,3] The traditional reliance on single, daytime Goldmann Applanation Tonometry (GAT) measurements fosters a

dangerous false sense of security, particularly in patients classified as having normal-tension glaucoma or those whose disease continues to progress despite seemingly "controlled" clinic pressures. To accurately gauge the true biomechanical stress exerted on the optic nerve head, continuous or high-frequency remote monitoring is essential.

2.2 Home-Based Tonometry: The iCare HOME2 System

The advent of miniaturised rebound tonometry, specifically adapted for unsupervised patient self-use, has fundamentally altered the IOP monitoring landscape. The iCare HOME2 device represents the current vanguard of this technology, allowing patients to accurately measure their IOP across various times of the day and night. Utilising a lightweight magnetic probe that briefly decelerates against the cornea, the device requires no topical anaesthesia, eliminating the risk of corneal toxicity or patient discomfort associated with repetitive drop instillation. Crucially, unlike its predecessors, the iCare HOME2 can be used while the patient is in the supine position, allowing for accurate nocturnal profiling when IOP often reaches its circadian zenith due to episcleral venous pressure changes.^[2]

Clinical evaluations and cost-benefit analyses reveal that home tonometry identifies significantly different IOP parameters than clinic-based methods. In multiday monitoring studies, home tonometry recorded significantly higher maximum IOPs, lower minimum IOPs, and a vastly greater overall IOP range compared to clinical GAT. However, clinicians need to recognise that the coefficient of variation and the standard deviation of measurements are inherently higher in home settings. This is not indicative of device inaccuracy, but rather a reflection of the true, unmasked

physiological fluctuations that occur in real-world settings outside the controlled, artificially calming environment of the examination room.

2.3 Emerging Contact and Non-Contact Modalities

Beyond the iCare HOME2, other modalities are streamlining clinical IOP capture.

The Tono-Vera tonometer, recently granted FDA clearance, features automated positioning systems that utilise biocompatible probes, showing strong correlation and agreement with Goldmann-correlated IOP measurements.

Looking further into the translational research pipeline, the ultimate frontier in IOP assessment involves continuous, telemetric smart contact lenses. These lenses, embedded with highly calibrated micro-sensors, provide 24-hour continuous surveillance of corneal strain, which acts as a physiological surrogate for IOP.

Recent material science iterations utilise highly biocompatible polydimethylsiloxane (PDMS) to maintain structural integrity under typical wear conditions. These lenses withstand the mechanical stress of folding, blinking, and stretching while keeping maximum sensor strain below 10%, thereby preserving their mechanical and electrical properties. While still largely in the advanced proof-of-concept phase, these devices offer an astonishing sensitivity of 1,121 ppm/mmHg. Furthermore, molecular sensors are being integrated into these lenses to detect abnormal tear molecule concentrations, offering dual biomechanical and biochemical glaucoma monitoring.^{[1-}

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Tonometer Modality	Clinical Setting	Advantages	Limitations
Goldmann Applanation (GAT)	In-Clinic	Gold standard, high precision, low recurring cost.	Snapshot data only, requires topical anaesthesia, highly subject to central corneal thickness (CCT) artefacts.
iCare HOME2	Home/Remote	Captures true diurnal/nocturnal spikes, requires no anaesthesia, and allows supine testing.	High upfront cost, requires patient dexterity, ~40% failure rate in totally unassisted self-use.
Tono-Vera	In-Clinic	Biocompatible probes, automated positioning, and strong GAT correlation.	Still limited to point-in-time clinical encounters.
Smart Contact Lenses	Continuous Wear	True 24-hour telemetry captures nocturnal peaks and potential molecular sensing.	Currently experimental, potential for ocular surface irritation and high developmental cost.

3. The Evolution of Perimetry: Standard and Virtual Reality Modalities

Visual field testing remains the absolute cornerstone for diagnosing functional glaucomatous damage and calculating the rate of disease progression.

3.1 Advancements in Standard Perimetry: The SITA Faster 24-2C Algorithm

To combat patient fatigue and optimise clinic throughput, the Swedish Interactive Thresholding Algorithm (SITA) has evolved continuously. The recent introduction of the 24-2C SITA Faster protocol represents a major workflow optimisation for the Humphrey Field Analyser (HFA). The "C" designation indicates the strategic inclusion of 10 centrally located test points, meticulously selected from the denser 10-2 testing pattern, which are appended to the standard 24-2 grid.^[6]

This hybrid pattern addresses a critical paradigm shift in our understanding of glaucoma: the macula, previously thought to be spared until late in the disease, is frequently involved in early glaucoma. The diagnostic utility of the 24-2C SITA Faster pattern is noninferior to standard protocols for detecting general macular damage in mild-to-moderate glaucoma.^[6] However, it is vital to note that while the 24-2C provides excellent screening capabilities, the dedicated 10-2 SITA Standard test may still be mathematically superior for detecting highly subtle, localised macular defects when analysing the pattern deviation (PD) plot. Therefore, the optimal clinical workflow utilises the 24-2C SITA Faster as the default baseline and routine monitoring tool, reserving the denser 10-2 test specifically for patients who demonstrate suspicious paracentral scotomas or isolated ganglion cell layer thinning on OCT.

3.2 Virtual Reality Perimetry (VRP): Democratising Visual Fields

The physical constraints of SAP—requiring a dedicated dark room, bulky equipment, and rigid patient posture at a chin rest—have severely limited the accessibility of visual field testing, particularly in bedbound, mobility-impaired, or rural populations. The integration of Head-Mounted Virtual Reality Perimeters (HVRP) directly addresses these fundamental bottlenecks.

Devices such as the C3 Field Analyzer (an indigenous Indian innovation developed by Alfaleus in collaboration with Aravind Eye Hospital), VisuALL, and the Radius perimeter offer fully portable, lightweight testing environments that can be deployed in standard waiting rooms, at the patient's bedside, or in remote telemedicine satellite clinics. Because the VR headset operates as a closed system, it completely isolates the eye from ambient light, eliminating the need for a darkened examination room. Patients overwhelmingly prefer VRP over SAP, reporting greater comfort due to the absence of a chin rest and the elimination of the heavy eye patch used for monocular occlusion. However, clinicians must approach VRP data with an understanding of its limitations. In advanced disease stages, VR systems occasionally underestimate the exact depth and absolute scotoma boundaries of the visual field loss.^[7]

3.2.1 Web-Based and Portable Perimetry: The Melbourne Rapid Field (MRF)

Expanding the umbrella of highly portable digital perimetry is the Melbourne Rapid Field (MRF) system. The MRF is a device-independent, web-browser-based online perimetry platform that can function on laptops, desktops, or tablets with digital screens, including offline capabilities for remote areas.

Clinical validations comparing the MRF to the clinical gold standard HFA 24-2 SITA Standard demonstrate a strong correlation in mean deviation (MD) and pattern standard deviation (PSD). Test-retest repeatability is comparable to HFA, and the MRF yields significantly shorter test durations alongside lower false-positive rates. This makes MRF a highly reliable, cost-effective, and clinically valid tool for screening of glaucoma patients in underprivileged areas.^[8]

Ultimately, VRP and digital modalities like MRF should not be viewed as wholesale replacements for SAP in advanced disease management. Instead, they are powerful, highly accessible adjuncts that vastly expand screening capabilities into the community, serve as excellent triage tools, and significantly reduce the bottleneck of visual field machines in high-volume tertiary care centres.

Feature	Standard Automated Perimetry (HFA)	Virtual Reality Perimetry (VRP) & MRF
Patient Posture	Fixed, chin-rest required, highly fatiguing	Flexible, can be performed seated or supine
Testing Environment	A dedicated dark room is required	Ambient light independent (closed headset system)
Disease Staging Accuracy	Gold standard across all severity stages	Excellent for screening/mild disease; statistical variance in severe stages
Portability & Cost	Static, bulky equipment, high maintenance	Highly portable, telemedicine compatible, and lower hardware footprint

4. Structural and Vascular Imaging: OCT and OCTA

Optical Coherence Tomography (OCT) is arguably the most indispensable imaging modality in the modern glaucoma clinic. By providing high-resolution, cross-sectional images of the retina, it allows for the objective, quantitative assessment of RNFL, the macular ganglion cell-inner plexiform layer (GCIPL), and the optic nerve head (ONH) morphology. However, conventional structural OCT suffers from specific technical

limitations. The advent of Optical Coherence Tomography Angiography (OCTA) has seamlessly merged structural imaging with functional microvascular assessment, propelling glaucoma diagnostics into an entirely new dimension.

4.1 The "Floor Effect" and Myopic Confounders in Structural OCT

A major, inherent limitation of structural OCT is the recognised "floor effect." As glaucomatous damage progresses to severe stages, the RNFL thins until it reaches a residual basement level composed primarily of non-neural glial tissue and blood vessels. Once the RNFL reaches this minimum measurement threshold (40-50 microns), structural OCT becomes virtually blind to further axonal loss, rendering it useless for detecting ongoing disease progression in patients with advanced visual field deficits.^[9]

Additionally, diagnosing glaucoma in highly myopic eyes presents a pervasive clinical challenge. The extreme axial length in high myopia causes disc torsion, severe peripapillary atrophy, and scleral stretching. These anatomical alterations confound standard OCT segmentation algorithms, leading to high rates of false positives (so-called "red disease") and making it exceedingly difficult to differentiate true glaucomatous optic neuropathy from benign myopic stretching.^[9]

4.2 The Role of OCTA in Glaucoma Diagnostics

The OCTA utilises the intrinsic motion contrast of circulating erythrocytes to generate depth-resolved, high-resolution maps of the retinal and choroidal microvasculature, entirely without the need for invasive, anaphylaxis-prone intravenous fluorescein dye. In the context of glaucoma management, the primary quantitative parameter evaluated is Vessel Density (VD) or Capillary Density, which is analysed in distinct anatomical slabs.^[10]

The clinical protocol for OCTA in glaucoma focuses on three primary regions:

1. **Superficial Peripapillary Region:** Imaged from the internal limiting membrane (ILM) to the RNFL, allowing for the assessment of the radial peripapillary capillaries, which are highly susceptible to glaucomatous damage.
2. **Choroidal Vasculature:** Examining the parapapillary choroidal region, specifically looking for deep microvascular dropout within the lamina cribrosa and surrounding peripapillary sclera.
3. **Superficial Macular Vasculature:** Imaged from the ILM to the inner plexiform layer (IPL), correlating precisely with the metabolic supply to the dense macular ganglion cell populations.

4.2.1 Pre-Perimetric Detection and Progression Prediction

Glaucomatous damage is not solely a mechanical phenomenon of axon compression; it involves a complex, intertwined pathogenesis of mechanical stress and microvascular ischemia. Studies conclusively demonstrate that a reduction in superficial peripapillary vessel density can be detected significantly earlier than measurable RNFL or GCIPL thinning.^[10] Furthermore, OCTA serves as a powerful predictive biomarker. Baseline scans revealing focal sectorial capillary drop-out (particularly deep choroidal microvascular drop-out) and generalised lower peripapillary vessel density are highly predictive of subsequent, future RNFL thinning and the clinical appearance of disc haemorrhages.

4.3 Protocols, Reproducibility, and Artefact Management

Implementing OCTA into routine clinical practice requires stringent adherence to quality control and image interpretation protocols. The intravisit and intervisit reproducibility of OCTA vessel density parameters is generally excellent when images are acquired perfectly.^[11-13]

However, this reproducibility is heavily contingent upon signal strength index (SSI) and scan quality. Clinicians cannot blindly trust automated numerical outputs; they must manually scrutinise en face OCTA B-scans for pervasive artefacts that can artificially depress vessel density scores. Common artefacts include:

- **Segmentation Errors:** Improper automated delineation of the ILM or RPE layers in pathologically altered eyes, leading to the algorithm analysing the wrong anatomical slab.
- **Motion and Blink Artefacts:** Micro-saccades and blinks create horizontal banding or disjointed, fractured vessels across the scan.
- **Projection Artefacts:** Highly reflective superficial vessels cast moving shadows onto deeper retinal layers, tricking the software into mimicking deep vascular flow where none exists.
- **Z-offset Errors:** Resulting from poor focus or patient movement along the Z-axis.

For longitudinal progression monitoring via trend-based analysis, using the same commercial device is an absolute necessity. Vessel density segmentation algorithms and normative databases vary wildly between manufacturers (e.g., Zeiss AngioPlex, Optovue AngioVue, Heidelberg Spectralis), and their numerical outputs are not interchangeable under any circumstances.^[11-13]

5. Electrophysiology (ERG) in Early Functional Detection

While structural OCT measures physical tissue thickness and standard perimetry measures subjective visual perception, a critical, intermediate physiological state exists: RGC dysfunction. During the earliest stages of glaucoma, before RGCs undergo irreversible apoptosis and physical thinning occurs, they enter a phase of metabolic compromise where they are poorly functional but still viable. Because preserving and restoring cellular function is only possible during this reversible dysfunction phase, ERG provides a vital, objective window into early disease that neither OCT nor perimetry can access.^[14]

5.1 Steady-State Pattern ERG (ssPERG) and Photopic Negative Response (PhNR)

Clinical electrophysiology in glaucoma relies primarily on specific waveforms that isolate inner retinal activity. The steady-state Pattern ERG (ssPERG) utilises a reversing checkerboard stimulus to directly reflect the bioelectrical activity of the inner retina, predominantly targeting the RGCs. Recent analytical advancements have vastly simplified the extraction of these microvolt signals, demonstrating conclusively that ssPERG amplitude deficits precede structural OCT RNFL thinning by a significant temporal margin.^[14]

Additionally, the Photopic Negative Response (PhNR) of the full-field ERG—a slow negative wave following the b-wave—is another highly specific indicator of global RGC function. Reductions in the amplitude of the PhNR correlate strongly with the degree of functional visual impairment in glaucoma, offering an entirely objective measure that is completely independent of the patient's cognitive focus, motor response, or fatigue levels, which frequently confound perimetric results.

5.2 Handheld ERG Devices and Clinical Viability

Historically, ERG was strictly confined to tertiary academic research laboratories.

The testing process was arduous, requiring mydriasis, topical anaesthesia, the placement of uncomfortable corneal electrodes, and reliance on bulky signal amplifiers. This made routine clinical application impossible.

The commercialisation of handheld, highly portable ERG devices has successfully democratised functional electrophysiology. Devices such as the FDA-cleared RETeval system (developed by LKC Technologies) utilise proprietary sensor strips placed on the skin below the lower eyelid. These devices operate seamlessly without the need for pupillary dilation, assessing retinal amplitude responses to sinusoidal flicker stimuli at specific frequencies (between 30 and 50 Hz) that target the OFF visual pathways known to be highly susceptible in early glaucoma.

6. Artificial Intelligence in Glaucoma Clinics

Artificial Intelligence (AI)—encompassing the disciplines of machine learning (ML), deep learning (DL), and advanced large language models (LLMs)—is no longer a theoretical research concept. It is actively revolutionising the entire continuum of glaucoma care, from community-based mass screening to the precise prognostication of surgical outcomes.

6.1 Deep Learning in Diagnostic Image Analysis

Deep learning convolutional neural networks (CNNs) have consistently demonstrated the capacity to match, and often surpass, human expert graders in analysing two-dimensional fundus photographs for signs of glaucomatous optic neuropathy.^[15] In the Indian healthcare context, the deployment of "offline AI" is particularly transformative. The Medios AI-Glaucoma software, integrated directly

into a smartphone-based fundus camera (the Remidio Fundus-on-Phone), operates entirely without an internet connection. Deployed in rural satellite vision centres associated with the Aravind Eye Care System, this offline AI acts as a highly effective, automated triage tool. It analyses 42-degree disc-centric fundus images on the spot, accurately flagging suspect discs for subsequent telemedicine review by tertiary glaucoma specialists. This elegantly overcomes the severe infrastructural bottleneck of poor or absent internet connectivity in rural India, enabling high-fidelity screening at the absolute grassroots level.^[16]

6.2 Multimodal AI and Progression Prediction

The primary limitation of early-generation AI was its unimodal nature—it analysed only a fundus photo or only an OCT scan. The current vanguard of diagnostic software is multimodal AI, which intelligently concatenates structured numerical data (IOP curves, patient demographics), functional threshold data (visual fields), and diverse structural imaging arrays (OCT thickness maps, OCTA vessel density slabs).^[17]

These sophisticated models utilise advanced architectures such as hybrid Vision Transformers (ViT) and Capsule Networks (CapsNet). By dynamically cross-referencing these varied data streams, multimodal AI facilitates the highly coveted shift in glaucoma management from reactive treatment to proactive intervention. By tracking minute, mathematically complex sub-clinical longitudinal changes across all imaging modalities simultaneously, these AI models can accurately predict the trajectory of visual field decay months, or even years, before a scotoma becomes clinically apparent on an HFA printout.^[17]

6.3 Large Language Models (LLMs) and Ethical Governance

Large Language Models are now being deeply integrated into electronic medical records (EMRs) to serve as advanced Clinical Decision Support Systems (CDSS). These LLMs synthesise decades of unstructured, free-text patient notes, cross-reference them instantaneously with current clinical guidelines, and propose personalised, evidence-based treatment escalation pathways. Furthermore, conversational AI chatbots are being deployed to provide localised, patient-facing education. These systems can send dynamic, automated reminders for drop adherence based on the patient's specific behavioural patterns and visit history, directly addressing the chronic, vision-threatening issue of medication non-compliance.^[18,19]

However, the rapid integration of AI is fraught with regulatory and ethical friction. Algorithmic bias is a paramount concern; models trained predominantly on Caucasian or East Asian European datasets frequently demonstrate unacceptable diagnostic inaccuracies when deployed in diverse South Asian populations due to variations in normative disc morphology. Compliance with strict emerging regulatory frameworks, such as the FDA's Good Machine Learning Practice (GMLP) and the EU AI Act, demands the use of "explainable AI" (XAI). In an XAI system, the software does not function as a "black box"; rather, it generates heatmaps or saliency maps that explicitly highlight the specific anatomical regions of the optic nerve that led to its diagnostic conclusion, allowing the clinician to verify the machine's logic.

Additionally, to protect patient privacy while building robust datasets, Federated Learning (FL) architectures (such as FedProx) are gaining immense traction. Federated Learning allows multiple institutions across India and the globe to collaboratively train a shared AI model without ever moving or sharing the underlying

raw patient data, thereby ensuring absolute data privacy while achieving diagnostic accuracies upwards of 93%.^[20]

AI Architecture / Application	Primary Function	Clinical Benefit	Current Limitations
Offline CNNs (Medios AI)	Fundus image analysis	Grassroots screening without internet dependency	Limited to 2D structural analysis
Multimodal Vision Transformers	Data fusion (OCT, VF, IOP)	Predicts disease progression trajectory	Requires massive, pristine datasets for training
Federated Learning Networks	Multi-centre AI training	Maximises accuracy (93%+) while ensuring strict data privacy	High computational and infrastructural overhead
LLMs as CDSS	EMR synthesis and logic	Personalised treatment pathways, adherence tracking	Risk of algorithmic hallucination or biased training

7. Genetics and Polygenic Risk Scores in Glaucoma Screening

The underlying genetic architecture of glaucoma is exceptionally complex, comprising a vast spectrum of both rare genetic variants with immense effect sizes (Mendelian inheritance patterns) and highly common variants with minute individual effect sizes (polygenic traits). Integrating genetic profiling into clinical practice provides the ultimate tool for personalised risk stratification.^[21]

7.1 High-Penetrance Genes vs. PRS

Historically, genetic testing in ophthalmology was strictly reserved for cases of early-onset, juvenile, or primary congenital glaucoma. In these scenarios, the disease is driven by high-penetrance mutations in specific, identifiable genes such as *MYOC* (myocilin), *CYP1B1*, and *ASB10*. While mutations in these specific loci almost guarantee the development of severe glaucoma, they account for an exceedingly minute fraction of the overall global primary open-angle glaucoma (POAG) population.^[21]

For the vast majority of patients suffering from adult-onset POAG, their lifetime disease risk is not determined by a single broken gene, but by the cumulative, weighted effect of hundreds or thousands of subtle genetic variations spread across the genome. This aggregate genetic burden is quantified using a PRS. An individual's PRS allows for highly granular, personalised risk stratification long before the disease manifests structurally.^[21]

For example, a patient flagged as a "glaucoma suspect" based solely on family history, but who possesses a PRS resting in the lowest genetic decile, has an extraordinarily low likelihood (approximately 2%) of requiring actual treatment initiation within a three-year window. Knowing this verified low genetic risk allows the clinician to safely and confidently reduce the frequency of surveillance appointments, alleviating immense psychological burden on the patient and significantly reducing resource strain on the healthcare system. Identifying a high PRS at baseline justifies a highly aggressive, early-intervention surgical approach.

7.2 The Genetic Testing Landscape in India

The widespread availability and decreasing cost of Next-Generation Sequencing (NGS) have made genetic screening commercially viable for the general Indian

population. Advanced molecular diagnostics laboratories, such as MedGenome (which operates extensive networks across Kerala and massive national hubs) and Strand Life Sciences, now offer highly targeted NGS panels specifically engineered for glaucoma-associated genes.

7.3 Implementing Clinical Genetic Counselling

The integration of genetics into the glaucoma clinic cannot be treated as a simple blood test; it requires a structured, tiered model of implementation. Clinicians must perform rigorous initial risk identification and triage, prioritising early-onset, strongly familial, or syndromic cases as high-priority candidates for genetic referral.^[21,22]

Crucially, comprehensive pre-test and post-test genetic counselling is absolutely mandatory. The clinician must possess the skills to manage patient anxiety and clearly articulate the probabilistic, non-deterministic nature of a Polygenic Risk Score. Furthermore, identifying a high-penetrance mutation demands the ethical responsibility of organising systemic cascade testing for all at-risk, first-degree relatives, fundamentally shifting the practice from treating the individual to screening the extended family unit.^[21]

8. Overcoming Clinical Workflow Challenges in the Digital Era

The rapid, simultaneous influx of these diverse, high-density diagnostic technologies—cloud-connected home tonometry, highly portable VR perimetry, massive structural and vascular OCTA datasets, predictive AI algorithms, and complex genetic profiles—creates an unprecedented logistical challenge regarding data synthesis and clinic workflow.

8.1. Economic and Resource Allocation in India: While technologies like the iCare HOME2 and VR Perimeters are clinically invaluable, their capital expenditure is non-

trivial. In the Indian demographic, where a substantial portion of healthcare remains out-of-pocket, balancing these high costs with clinical utility involves highly selective, intelligent deployment. Indigenous VR Perimetry should be utilised heavily for mass rural screening and community outreach to maximise impact per rupee spent. Conversely, expensive home tonometry rentals and advanced OCTA imaging should be strictly reserved for complex, diagnostic-dilemma cases—such as patients exhibiting definitive structural progression despite seemingly tightly controlled clinic IOPs, or those requiring differentiation between myopic stretching and true glaucomatous neuropathy.

9. Synthesis and Clinical Integration

The landscape of glaucoma diagnostics has irrevocably shifted from a morphology-centric, reactive approach to a multi-dimensional, data-driven, and highly proactive science. The modern ophthalmologist can no longer rely on singular metrics; they must now act as a sophisticated synthesiser of diverse, continuous data streams. This requires correlating the deep vascular metrics of Swept-Source OCTA and the functional electrophysiological distress signals of the ssPERG with the predictive foresight provided by Polygenic Risk Scores and Multimodal Artificial Intelligence.

By strategically integrating home-based IOP monitoring and Virtual Reality perimetry, the rigid boundary of the physical clinic expands directly into the patient's daily life, capturing the true, unmasked pathophysiological nuances of the disease. While infrastructural and workflow challenges persist—particularly concerning data interoperability, EMR integration, and the mitigation of algorithmic bias—these innovations collectively enable a highly personalised standard of care. This transition not only promises to preserve the delicate retinal ganglion cells long before

irreversible blindness occurs, but also optimises the deployment of critical healthcare resources, ensuring that aggressive therapeutic and surgical interventions are targeted precisely when and where they are needed most.

Key Clinical Takeaways

- IOP is dynamic; clinic measurements may miss peaks
- 24-2C SITA Faster improves detection of central defects with shorter test time
 - useful in early diagnosis of glaucoma
- VR perimetry and AI tools enable screening in low-resource settings
- OCTA may reveal vascular compromise beyond RNFL thickness limits
- ERG can detect early RGC dysfunction before structural loss
- Genetic testing is selective, not universal—use it for early-onset, familial, or atypical glaucoma, and interpret PRS only alongside clinical findings.

Conflicts of Interest: None

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