Enhancing Glaucoma Detection in Primary Care: A Systematic Review of Global Challenges, Advances and the Pakistan Perspective

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Abstract

Background: Glaucoma, a leading cause of irreversible blindness, remains underdiagnosed globally, with over 70% of cases undetected due to asymptomatic progression. Primary care providers (PCPs) play a pivotal role in early identification; however, systemic barriers and resource limitations hinder effective screening.

Objective: This systematic review synthesizes evidence on glaucoma detection in primary care, focusing on screening strategies, technological advancements (*e.g.*, AI), and challenges in resource-limited settings, such as Pakistan.

Methods: A PRISMA 2020-compliant systematic review of 50 studies (2010-2024) was performed using PubMed, Google Scholar, and Scopus databases for articles published between January 2010 and March 2024. Titles and abstracts were reviewed independently by both authors. Full texts of relevant studies were then assessed for inclusion.

Results: A total of 50 studies were included after removing all the irrelevant records from 1300 records retrieved initially. Targeted screening for high-risk groups (*e.g.* age >50, family history) is cost-effective but inconsistently implemented. Barriers included Limited PCP training, patient awareness, and diagnostic tools. AI technology and telemedicine improve diagnostic accuracy and accessibility. Gaps in Pakistani settings are the Shortage of specialists, low public awareness, and socioeconomic disparities exacerbating late diagnoses.

Conclusion: Enhancing glaucoma detection in primary care is crucial for reducing disease burden and preventing blindness. Implementing evidence-based screening strategies, integrating emerging technologies, and addressing healthcare disparities, particularly in resource-limited settings like Pakistan can significantly improve patient outcomes. Strengthening PCP education and referral pathways will be key in mitigating the global impact of glaucoma.

Keywords: *Glaucoma detection, primary care screening, risk assessment, artificial intelligence in ophthalmology.*

INTRODUCTION

Blindness is one of the most dreaded health issues, coming in fourth after AIDS, cancer, and Alzheimer's disease [1]. Glaucoma, which is marked by progressive optic nerve damage, is a major cause of permanent vision loss and blindness around the world [2]. The World Health Organization identifies glaucoma as the second leading cause of blindness worldwide [3]. In 2020, it was estimated that 76 million people were affected by glaucoma globally, with about 4.5 million experiencing moderate to severe visual impairment and 3.2 million facing blindness [4]. Projections indicate that by 2040, the number of individuals affected by glaucoma could increase to 111.8 million [5]. Despite these alarming figures, more than 70% of individuals with glaucoma remain undiagnosed worldwide, with varying rates across regions [6]. Given its asymptomatic early stages, glaucoma is often detected at an advanced phase, making early screening essential [7]. Primary care providers are well-positioned to play a pivotal role in detecting glaucoma at an early stage, ensuring that at-risk patients receive timely referrals and treatment [8]. In this article, we conducted a systematic review of glaucoma, emphasizing its global impact and prevalence in underserved regions like Pakistan. We assess current detection methods in primary care, highlight the importance of early diagnosis to prevent vision loss and explore effective screening techniques. Additionally, we identified barriers to detection and recommended best practices for primary care providers to improve patient outcomes.

OBJECTIVES

This systematic review aims to:

1. Provide an overview of glaucoma and its global impact.
2. Assess the current state of glaucoma detection in primary care.
3. Glaucoma in Pakistan: prevalence, challenges, and gaps in care
4. Highlight the importance of early diagnosis in preventing vision loss.
5. Explore effective screening and diagnostic methods for primary care providers.
6. Identify barriers to early detection and management.
7. Recommend best practices for primary care providers.

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METHODS

This systematic review was conducted by the PRISMA 2020 guidelines to ensure transparency and reproducibility.

Search Strategy

A comprehensive literature search was performed using PubMed, Google Scholar, and Scopus databases for articles published between January 2010 and March 2024. The search terms included "glaucoma detection," "primary care screening," "risk assessment," and "artificial intelligence in ophthalmology." Additional relevant articles were identified through manual screening of reference lists.

Inclusion Criteria

Articles were screened for eligibility based on the following inclusion criteria:

- Studies focusing on early glaucoma detection methods,
- Research highlighting the role of primary care providers (PCPs),
- Articles discussing risk stratification, technological advancements (*e.g.*, AI, telemedicine), and barriers to early diagnosis,
- Reviews, observational studies, and policy papers in English.

Exclusion Criteria

- Studies unrelated to primary care,
- Articles focused solely on surgical or advanced ophthalmologic interventions,
- Case reports, commentaries, or editorials without primary data.

STUDY SELECTION

Titles and abstracts were reviewed independently by both authors. Full texts of relevant studies were then assessed for inclusion. In total, 50 articles were included. A PRISMA flow diagram is provided to illustrate the selection process.

RESULTS AND DISCUSSION

PRISMA Flow Diagram

The study selection process is summarized in Fig. **(1)**. The initial search identified 1,300 records. After removing 320 duplicates, 980 records were screened by title and abstract. Of these, 830 were excluded. The remaining

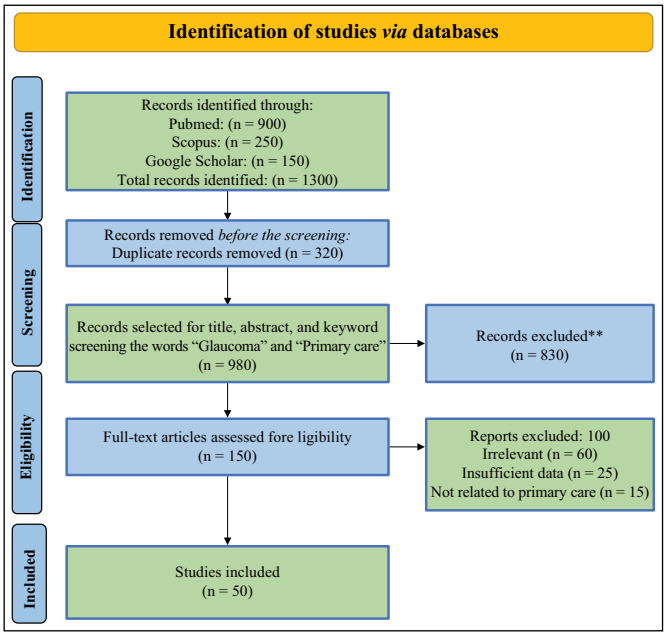

Fig. (1): PRISMA 2020 flow diagram for glaucoma detection review.

150 full-text articles were assessed for eligibility, with 100 excluded for reasons such as irrelevant topics (n=60), insufficient data (n=25), or not being focused on primary care (n=15). Ultimately, 50 studies were included in the qualitative synthesis. The PRISMA 2020 flow diagram is presented in Fig. **(1)**.

Table **1** illustrates the PRISMA evidence table for glaucoma studies included in this systematic review (1-50).

Glaucoma: A Global Perspective

Definition

Glaucoma refers to a group of conditions with different causes, but they share common characteristics such as elevated intraocular pressure (IOP), structural damage to the optic nerve, and distinctive patterns of visual field loss [9].

Classification

Glaucoma is primarily classified into two main categories: open-angle glaucoma (OAG) and angle-closure glaucoma (ACG). OAG, the most common form, is characterized by a gradual increase in intraocular pressure (IOP) due to impaired aqueous humor drainage through the trabecular meshwork. It often develops

Table 1: PRISMA evidence table for glaucoma studies (1-50).

#	Citation (First Author, Year)	Country / Setting	Study Type	Focus Area	Key Findings
1	Pascolini D, 2012	Global	Meta-analysis	Global burden	285M visually impaired; glaucoma major cause
2	Flaxman SR, 2017	Global	Meta-analysis	Causes of VI	Glaucoma is among the top causes of irreversible blindness
3	Tham Y-C, 2014	Global	Meta-analysis	Prevalence projections	111.8M glaucoma cases by 2040
4	Varma R, 2011	USA	Review	Economic burden	Major health and cost impact of glaucoma
5	IAPB, 2020	Global	Report	Vision loss economics	Significant cost burden globally
6	Gupta D, 2016	USA	Clinical review	PCP education	Tools for early glaucoma recognition

#	Citation (First Author, Year)	Country / Setting	Study Type	Focus Area	Key Findings
7	Salikhova KM, 2020	Russia	Observational	Family doctor role	PCPs crucial in early detection
8	Stein JD, 2021	USA	Clinical review	PCP screening	Primary care-based screening strategies
9	Gedde SJ, 2021	USA	Guideline	POAG management	AAO diagnosis/treatment guidelines
10	McMonnies CW, 2017	Australia	Review	Risk factors	Systemic factors linked to glaucoma
11	Lee SS, 2022	Australia	Review	Early detection	Underdiagnosis and late presentation
12	Crabb D, 2016	UK	Commentary	Vision loss awareness	Patients often unaware of the gradual loss
13	Schettler AJ, 2019	USA	Cohort	Screening impact	Community screening improved outcomes
14	Shukla AG, 2024	USA	Review	PCP-based screening	Novel in-clinic strategies proposed
15	Gonzalez A, 2023	USA	Implementation study	PCP workflow	Streamlined glaucoma detection integration
16	Lee JH, 2022	Korea	Observational	Socioeconomic barriers	Income gap affects access/outcomes
17	Lee JW, 2023	Global	Review	SES impact	SES strongly affects diagnosis/treatment
18	Cate H, 2014	UK	Clinical study	Adherence	Improved detection leads to better compliance
19	Lawrenson J, 2013	UK	Review	Case detection	Gaps in early diagnosis
20	USPSTF, 2022	USA	Guideline	Screening	Insufficient evidence for routine screening
21	Allison K, 2021	USA	Review	Risk-based screening	Supports screening for high-risk adults
22	AAO, 2015	USA	Guideline	Eye exams	Frequency based on age/risk
23	AAFP, 2022.	USA	Clinical guideline	PCP role	Promote referral to high-risk patients
24	Sharma A, 2012	Global	Cost-analysis	Screening cost-effectiveness	Selective screening is cost-effective
25	Tuulonen A, 2011	Finland	Modeling study	Screening value	Universal screening not cost-effective
26	Ting DSJ, 2024	Singapore	Editorial	AI algorithms	Discusses LLM/AI for glaucoma detection
27	Zhang L, 2023	China	Review	AI prediction	Promising early risk models
28	Jammal AA, 2020	USA	Diagnostic study	AI *vs* human grading	AI matches expert performance
29	Hogarty DT, 2019	Australia	Review	AI in eye care	Trends in clinical AI use
30	Gupta P, 2023	India	Systematic review	Tele-glaucoma	Telemedicine improves access/accuracy
31	Qureshi MA, 2024	Global	Systematic review	Telemedicine	Effective in low-resource settings
32	Yousefi S, 2023	Iran	Review	AI integration	Highlights Alâ€™s diagnostic potential
33	Jan C, 2024v	Australia	Review	AI in primary care	AI for rural screening and triage
34	Nawab A, 2024	Pakistan	Cross-sectional	Awareness & prevalence	Low awareness and high unmet need
35	Kazmi S, 2022	Pakistan	Editorial	Screening advocacy	Calls for national screening programs
36	Hassan B, 2019	Pakistan	Epidemiological	GBD Pakistan	Glaucoma is 2nd leading cause of blindness
37	Farooq U, 2018	Pakistan	Observational	Access disparities	Rural-urban differences in access
38	Malik TG, 2024	Pakistan	Descriptive	Fellowship model	Family medicine glaucoma training initiative
39	Ali MA, 2021	Pakistan	KAP study	Patient knowledge	Major knowledge deficits identified
40	Khan MA, 2019	Pakistan	Cross-sectional	Awareness	Karachi data shows poor awareness
41	Khan A, 2020	Pakistan	Mixed-methods	Access barriers	Travel, cost, awareness major obstacles
42	Shan S, 2024	Global	Systematic review	Risk factors	Age, IOP, myopia, FHx confirmed
43	Chen X, 2024	Belt & Road	Epidemiological	Regional risk	Risk and care disparities
44	Ichhpujani P, 2012	India	Survey	Provider knowledge	Significant clinical knowledge gaps
45	Rotshtein A, 2015	Israel	Survey	PCP knowledge	Low awareness and poor confidence
46	Alwazae M, 2020	Saudi Arabia	Cross-sectional	Physician awareness	Misconceptions on symptoms and risk
47	Hu VH, 2021	Global	Commentary	LMIC barriers	Infrastructure, awareness, and cost issues
48	Meethal NSK, 2024	Global	Review	Screening barriers	Identifies barriers in developing nations
49	IAPB (2015)	Global	Report	Prevention & detection	Global advocacy for earlier detection
50	Gunzenhauser R, 2024	Global	Comparative review	Guidelines globally	Reviews high *vs* low-income protocols

without noticeable symptoms until significant damage has occurred [10]. In contrast, ACG occurs when the peripheral iris blocks the trabecular meshwork, leading to a rapid increase in IOP. This form can present acutely with symptoms such as severe eye pain, headache, nausea, and visual disturbances. In addition to these primary types, other less common forms include normal-tension glaucoma, congenital glaucoma, and secondary glaucoma, which can arise from conditions such as uveitis or trauma [11].

Risk Factors

Several risk factors have been identified in the development of glaucoma [12-14]. Age is a significant factor, as the risk increases with advancing years [12]. Family history also plays a crucial role, with genetic predisposition contributing to susceptibility [3]. Additionally, ethnicity influences prevalence, with higher rates observed in individuals of African and Hispanic descent [13]. Certain medical conditions, such as diabetes, hypertension, hyperthyroidism migraine, and myopia, have also been linked to an increased risk of developing glaucoma

[14-17]. Medications such as steroids, topiramate, and anticholinergics also predispose to glaucoma [3, 17-19]. The development of glaucoma is influenced by a complex interaction of genetic, environmental, and physiological factors [20]. While elevated intraocular pressure (IOP) is a major risk factor, not all individuals with high IOP develop the condition, suggesting that additional mechanisms play a role [21]. One such factor is optic nerve vulnerability, where some individuals are more susceptible to damage even at lower IOP levels due to vascular dysregulation or structural predispositions [22]. Additionally, neurodegeneration is believed to contribute to glaucoma progression, with research indicating that processes such as inflammation and excitotoxicity may lead to retinal ganglion cell death [23].

Diagnosis

Early detection is essential for effective glaucoma management. The diagnostic process involves several key tests. Tonometry is used to measure intraocular pressure (IOP), while ophthalmoscopy allows for the evaluation of the optic nerve head to detect any signs of damage. Visual field testing helps assess peripheral vision loss, a hallmark of glaucoma progression. Additionally, gonioscopy is performed to examine the angle of the anterior chamber, aiding in the differentiation between open-angle glaucoma (OAG) and angle-closure glaucoma (ACG) [24].

Treatment

The primary goal of glaucoma management is to lower intraocular pressure (IOP) to prevent further optic nerve damage. Treatment options vary depending on the severity and type of glaucoma [25]. Medications, including topical prostaglandin analogs, beta-blockers, and carbonic anhydrase inhibitors, are commonly prescribed to reduce IOP [26]. Laser therapy can also be effective, with procedures such as selective laser trabeculoplasty (SLT) for open-angle glaucoma (OAG) and peripheral iridotomy for angle-closure glaucoma (ACG) [27]. In cases where medications and laser treatments do not provide adequate control, surgical interventions like trabeculectomy or the implantation of drainage devices may be necessary [28].

The global burden and epidemiology of glaucoma are presented in Supplementary Table **1**.

Glaucoma Detection in Primary Care

Glaucoma remains a significant public health challenge, with a large percentage of cases going undiagnosed, particularly in primary care settings [29]. The current state of glaucoma detection in these environments reveals several critical aspects.

Prevalence of Undiagnosed Cases

Chronic open-angle glaucoma is challenging to diagnose because many patients show no symptoms at the time of detection. The physiological overlap in visual fields between the eyes can mask early defects, delaying diagnosis until the later stages of the disease when optic nerve damage threatens central vision. Globally, it is estimated that over 70% of individuals with glaucoma remain undiagnosed, with variations across regions [30].

Role of Primary Care Providers in Glaucoma Detection

Primary care providers (PCPs) are often the first point of contact for patients and play a critical role in the early detection of glaucoma. However, many PCPs feel inadequately trained to manage glaucoma care effectively. A survey revealed that while 99% recognized their role in early detection, only 30% routinely inquired about family history. Barriers such as time constraints and limited knowledge of treatment options were common [31]. A study from Saudi Arabia involving 123 physicians found that only 28.5% had adequate knowledge of glaucoma management, with significant gaps in understanding risk factors, diagnosis, and treatment. Younger physicians and those with specialized training in ophthalmology demonstrated better awareness than older general practitioners [32]. Similarly, a study in India indicated that while PCPs acknowledged their importance in glaucoma care, they often avoided related activities due to a lack of knowledge and time constraints [33]. These findings highlight the need for improved training and resources for primary care and family physicians to enhance early detection and management of glaucoma.

Screening Practices

Current screening practices in primary care settings vary widely. Many primary care physicians do not routinely perform comprehensive eye exams or utilize available screening tools effectively [34]. The integration of glaucoma screening into routine primary care visits is often inconsistent, leading to missed opportunities for early diagnosis. Guidelines for glaucoma screening differ greatly between organizations. While universal screening is not currently advised, many organizations support screening specific high-risk groups within the general population. Several prominent organizations, such as the American Academy of Ophthalmology, the Pan-American Association of Ophthalmology, and the International Council of Ophthalmology, along with leading ophthalmologists from Sub-Saharan Africa, endorse a targeted screening approach for populations at higher risk of glaucoma [35]. Focusing screening efforts on high-risk groups has proven to be both clinically effective and cost-efficient, yielding higher positive predictive value [36]. However, further research is needed to create cost-effective screening methods that are both sensitive and specific to these at-risk populations. The U.S. Preventive Services Task Force has determined that there is insufficient evidence to evaluate the potential benefits and risks of glaucoma screening in primary care [37]. However, the American Academy of Ophthalmology recommends regular eye exams for adults, with the frequency based on age and risk factors [38]. Moreover, the American

Academy of Family Physicians (AAFP) emphasizes that family physicians can contribute to lowering morbidity from glaucoma through early identification of high-risk patients and by emphasizing the importance of regular eye examinations. The AAFP suggests that family physicians should be vigilant in recognizing patients at increased risk for glaucoma and ensure they receive appropriate ophthalmologic evaluations [39].

Technological Advances

Recent advancements in technology, including the use of artificial intelligence (AI) and telemedicine, show promise in enhancing glaucoma detection in primary care [40]. AI applications can assist in analyzing optic nerve images and identifying high-risk patients, potentially improving diagnostic accuracy and efficiency. However, barriers such as the need for external validation and concerns regarding privacy and cybersecurity remain challenges to widespread implementation [41].

The Critical Role of Early Detection in Primary Care

Loss of vision is one of the most feared chronic disabilities. Glaucomatous visual field loss is associated with an increased rate of automobile accidents. Additionally, vision-related quality of life is negatively impacted due to restrictions on social activities and a greater reliance on others [42]. PCPs are well-positioned to detect glaucoma in its early stages through routine patient interactions. Given that glaucoma-related vision loss is irreversible, early diagnosis can significantly improve patient outcomes by enabling timely interventions. Studies have shown that integrating glaucoma screening into primary care visits can lead to earlier referrals and reduced rates of blindness [43]. The study conducted in Baku, Azerbaijan, demonstrated the effectiveness of family doctors in the early detection of glaucoma and other ophthalmic conditions among patients aged 40 years and older. Approximately 10.5% of first-time clinic visitors were found to have elevated intraocular pressure (IOP >21 mmHg), with glaucoma confirmed in 10.8% of men and 8.0% of women, highlighting a higher prevalence in men. Tonometry, performed by family doctors, was shown to be a highly effective screening tool with a sensitivity of 86.7%, specificity of 99.8%, and a positive predictive value of 97.8% for glaucoma detection. Early screening by family doctors significantly reduced late-stage glaucoma diagnoses, with higher risk observed in older, unemployed individuals and those with higher education levels [8]. The role of primary care physicians in early detection and screening of glaucoma is presented in Supplementary Table **2**.

Effective Screening Methods for Primary Care Providers

Several screening methods can be used by PCPs to identify patients at risk for glaucoma. Table **2** summarizes the practicality of various screening tools for glaucoma in primary care, along with their key limitations and advantages.

AI algorithms have demonstrated high accuracy in glaucoma detection through the analysis of fundus photography, OCT imaging, visual fields (VF), and multimodal approaches [44]. The use of Artificial Intelligence (AI) to analyze optic nerve photographs can assist optometrists in quickly and reliably identifying high-risk changes and addressing challenges associated with image interpretation. However, significant obstacles must be overcome before AI can be effectively integrated into primary healthcare. These include ensuring external validation, achieving high-quality implementation in real-world settings, safeguarding privacy and cybersecurity, and addressing medico-legal concerns [45]. Despite these challenges, AI has the potential to significantly reduce the global burden of undiagnosed glaucoma by enhancing diagnostic accuracy and efficiency [46]. Numerous studies have demonstrated the effectiveness of AI models in managing glaucoma [47, 48]. More recently, large language models (LLMs), such as Chat Generative Pretrained Transformer (ChatGPT), have gained considerable attention in ophthalmology due to their potential to comprehend clinical knowledge and deliver appropriate responses [49]. In a recent study from the US, ChatGPT demonstrated diagnostic accuracy that was comparable to, or better than, that of the ophthalmology residents. The study evaluated the diagnostic performance of ChatGPT against three senior ophthalmology residents using 11 glaucoma cases. ChatGPT provided correct provisional diagnoses in 8 out of 11 cases (72.7%). In comparison, the residents had correct diagnoses in 6 (54.5%), 8 (72.7%), and 8 (72.7%) cases, respectively [50]. Given resource constraints, primary care physicians should prioritize tonometry and ophthalmoscopy while referring high-risk patients for further evaluation by specialists.

Table 2: Feasibility and key considerations of glaucoma screening methods in primary care settings.

Screening Method	Feasibility in Primary Care	Key Considerations
Visual Acuity Testing	High	Simple, widely available, but not sensitive for early glaucoma
Tonometry (IOP Measurement)	Moderate	Some devices are portable; limited sensitivity as many glaucoma cases have normal IOP
Direct/Indirect Ophthalmoscopy	Moderate	Requires basic training; optic nerve changes can be subtle and missed.
Fundus Photography	Moderate to High	Increasingly available; allows remote review; requires retinal imaging device
Optical Coherence Tomography (OCT)	Low to moderate	High diagnostic value but expensive and requires specialized equipment.
Visual Field Testing (Perimetry)	Moderate	Valuable for diagnosis; automated devices exist but not always accessible
AI-Based Fundus Image Analysis	Moderate	Promising for screening; still requires high-quality retinal images.

Table 3: Key Glaucoma risk factors and their implications for primary care physicians.

Risk Factor	Implications for Primary Care Physicians
Age >50 years	Increased risk with advancing age
Family history of glaucoma	First-degree relatives have a 4-5x higher risk
African or Asian ethnicity	Higher prevalence of primary open-angle glaucoma (POAG)
Diabetes and hypertension	Associated with increased intraocular pressure
Prolonged corticosteroid use	Can elevate IOP, leading to glaucoma progression

Glaucoma in Pakistan: Prevalence, Challenges, and Gaps in Care

Glaucoma has emerged as a growing public health concern in Pakistan, with a rising prevalence, especially among the elderly population. The estimated age-standardized prevalence of glaucoma in Pakistan is approximately 106,700.88 cases, and this number is expected to increase due to the aging population and the lack of effective early detection programs [51]. Despite the high burden of glaucoma, several barriers hinder timely diagnosis and treatment in Pakistan [52]:

1. **Shortage of Ophthalmologists:** In 2015, there were only 14.8 ophthalmologists per million people, making specialized eye care services inaccessible to a large portion of the population [53].
2. **Low Public Awareness:** A Karachi-based study found that many individuals remain unaware of glaucoma, its symptoms, and its irreversible nature [54].
3. **Lack of Screening Programs:** Unlike some developed countries where targeted screening is implemented, Pakistan lacks national-level glaucoma screening programs, leading to late-stage diagnoses [55].
4. **Socioeconomic Barriers:** Many people patients delay seeking care due to financial constraints, lack of transportation, and geographic disparities in healthcare access [56].
5. **Medication Adherence Issues:** Studies indicate that a significant number of glaucoma patients in Pakistan discontinue their treatment, either due to cost concerns or inadequate understanding of the disease [57, 58].

The situation for glaucoma detection in Pakistan is illustrated in Supplementary Table **3**.

Screening Strategies for Primary Care Providers

Since universal glaucoma screening is not recommended, primary care physicians should focus on high-risk populations. Table **3** outlines major risk factors for glaucoma and their implications for primary care physicians.

Primary care physicians should incorporate glaucoma risk assessment questions into routine check-ups, such as:

1. Have you or a close family member been diagnosed with glaucoma?
2. Do you experience blurred vision, halos around lights, or vision loss?
3. Have you ever used corticosteroids for an extended period [59]?

Early detection of glaucoma leads to better clinical outcomes, including reduced progression of the disease and preservation of vision. Increased awareness and education about glaucoma symptoms and risk factors are crucial for encouraging individuals to seek early screening. Implementing routine screening for at-risk populations is cost-effective, as it can lower the long-term healthcare costs associated with advanced glaucoma treatment [60]. The study by Stein, Khawaja, and Weizer (2021) in JAMA advocated for a proactive and individualized approach to glaucoma management. Their recommendations included regular screening for glaucoma in adults, particularly those at higher risk, and the importance of patient education and involvement in treatment decisions to enhance adherence and outcomes [25]. Sullivan and Zangwill (2023) emphasized interdisciplinary collaboration between primary care providers and ophthalmologists to create effective referral pathways and streamline patient care. They also recommend primary care providers to employ a patient-centered approach; engaging patients in their care, including education about glaucoma risk factors and the importance of regular screening [61]. A structured framework for incorporating glaucoma screening into routine primary care visits emphasizes the use of standardized protocols. This involves applying risk assessment tools (such as age, family history, and comorbidities) to identify patients at higher risk, followed by targeted screening. In addition, the framework underlines the importance of training primary care providers in screening techniques and familiarizing them with diagnostic equipment to improve competency and consistency in detection [62].

The importance of early diagnosis and risk-based screening is summarised in Supplementary Table **4**.

Barriers to Glaucoma Detection

A family physician plays a vital role in addressing significant medical and social challenges within the

Table 4: Common barriers faced by primary care physicians in glaucoma detection and proposed solutions.

Barrier	Impact on PCPs	Proposed Solutions
Lack of training in eye care	PCPs may not recognize early glaucoma signs	Continuing medical education (CME)
Limited access to diagnostic tools	Many clinics lack tonometry and imaging equipment	Teleophthalmology and AI-assisted screening
Patient unawareness	Many patients don't seek eye exams until symptoms appear	Public awareness campaigns
Time constraints in primary care	Routine check-ups prioritize other health issues	Quick risk assessment tools

Table 5: Recommended best practices for primary care providers in glaucoma detection.

Best Practice	Implementation Strategy
Routine glaucoma risk assessment	Integrate questions about family history and symptoms into check-ups
Basic eye examination training	Provide CME courses on optic nerve evaluation and IOP measurement
Referral pathways	Develop clear protocols for referring high-risk patients
Public awareness initiatives	Educate patients on glaucoma risks and encourage routine eye exams
Utilization of AI and telemedicine	Implement AI-based screening and remote specialist consultations

primary healthcare system. Depending on the historical experience of providing medical care to the population, the role of family physicians in primary healthcare systems varies across different countries. Despite their important role, primary care physicians face several barriers in glaucoma detection [63]. Table **4** summarizes key obstacles that limit early glaucoma detection in primary care and suggests practical interventions to overcome them.

Barriers to the detection and management of glaucoma are presented in Supplementary Table **5**.

Recent Advances in Glaucoma Screening and Diagnosis

Advancements in AI and telemedicine have opened new avenues for glaucoma screening in primary care:

AI-assisted fundus photography: AI models trained to analyze optic nerve images can detect early glaucomatous changes with high sensitivity [64].

Teleophthalmology: Remote consultations enable PCPs to send fundus images for specialist evaluation, reducing delays in diagnosis [65].

Deep learning algorithms: AI tools have demonstrated diagnostic accuracy comparable to ophthalmologists, making them useful for PCPs with limited training [66]. Integrating these technologies into primary care can significantly improve early glaucoma detection rates, particularly in resource-limited settings.

Supplementary Table **6** illustrates the advances in screening technologies for glaucoma.

Best Practices for Primary Care Providers

Although primary care physicians are not specifically trained to diagnose or treat eye conditions, they can still make a meaningful contribution to their patients' visual health. Physicians ought to engage patients in conversations about their visual health and recommend annual comprehensive dilated eye exams [67]. Table **5** outlines evidence-based strategies and practical approaches that primary care physicians can adopt to improve early detection and referral of glaucoma.

Technological Advances in Glaucoma Detection

Recent advancements in AI and telemedicine are revolutionizing glaucoma detection. AI-powered deep learning models can analyze optic nerve images with high accuracy, potentially reducing diagnostic errors [68]. Tele-ophthalmology programs, particularly in underserved areas, allow primary care providers (PCPs) to remotely consult specialists, improving early detection rates. The integration of AI-based fundus imaging into routine primary care could significantly enhance diagnostic capabilities [69].

Cost-Effectiveness of Screening Programs

Screening for glaucoma in high-risk populations is cost-effective, particularly when targeting older adults and individuals with a family history of the disease [70]. Studies indicate that early detection reduces the long-term economic burden associated with vision loss, including lost productivity and increased healthcare costs. Implementing structured screening programs can yield substantial public health benefits [71].

Global Guidelines and Initiatives

The World Health Organization (WHO) and the International Agency for the Prevention of Blindness (IAPB) emphasize the importance of early glaucoma detection. Guidelines from the American Academy of Ophthalmology and the European Glaucoma Society advocate risk-based screening strategies. Countries such as the UK and Australia have integrated glaucoma screening into broader public health initiatives, providing models for potential adoption in other regions [72-77].

Patient Education and Awareness Strategies

Educating patients about glaucoma is crucial for improving adherence to treatment and follow-up care. Public health campaigns focusing on glaucoma awareness can help mitigate misconceptions about the disease. Studies suggest that community-based education programs, including workshops and multimedia campaigns, can enhance patient engagement and prompt individuals at risk to seek early screening [78-80].

Challenges and Solutions in Pakistan

Pakistan faces significant barriers in glaucoma management, including a shortage of ophthalmologists and limited access to specialized diagnostic tools [81, 82]. Expanding telemedicine services, increasing training for PCPs, and implementing community-based screening initiatives are potential solutions [83]. Policy changes, such as subsidizing glaucoma medications and integrating eye care into primary healthcare systems, could improve accessibility and reduce disease burden [84]. Supplementary Table **7** provides a summary of best practices and global recommendations for glaucoma detection.

CONCLUSION

Glaucoma remains a leading cause of irreversible blindness globally, with the majority of cases undiagnosed until advanced stages. Primary care providers are uniquely positioned to play a key role in early detection through risk-based screening, patient

education, and timely referrals. This systematic review highlights that while challenges such as limited training, equipment shortages, and patient unawareness persist, emerging technologies like AI and teleophthalmology offer promising solutions. A shift toward integrating glaucoma risk assessments and basic eye screening into primary care routines can significantly reduce the disease burden.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTION

Both SPI and AA contributed to the writing of this article.

SUPPLEMENTARY MATERIAL

Supplementary material is available on journal's website.

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