ARTIFICIAL INTELLIGENCE IN SCREENING AND EARLY DIAGNOSIS OF GLAUCOMA AND DIABETIC RETINOPIA: A SYSTEMATIC REVIEW AND META-ANALYSIS FOR 2020-2025

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Abstract: *Glaucoma and diabetic retinopathy (DR) remain among the leading causes of blindness worldwide. Early detection of these diseases is crucial for preserving vision; however, traditional screening methods require substantial resources and specialist time.*

Objective: *To systematically analyze and evaluate the diagnostic accuracy of artificial intelligence (AI) algorithms in detecting glaucoma and DR based on scientific publications from 2020 to 2025.*

Methodology: *More than 50 clinical studies retrieved from PubMed, Scopus, and Web of Science databases were included in a meta-analysis. Particular attention was given to the use of Deep Learning and Convolutional Neural Networks (CNNs) for the analysis of fundus images (retinal photographs).*

Results: *The analysis demonstrated that modern AI models achieve 94–97% sensitivity in detecting diabetic retinopathy and 91–95% specificity in glaucoma diagnosis. Novel algorithms developed between 2023 and 2025 have proven capable not only of identifying the presence of disease but also of determining its progression stages at a level comparable to human specialists.*

Keywords: *Artificial intelligence, glaucoma, diabetic retinopathy, screening, early diagnosis, deep learning, systematic review, meta-analysis, ophthalmology.*

INTRODUCTION

Analysis of ophthalmological studies conducted between 2020 and 2025 indicates that artificial intelligence systems have evolved from simple image recognition to multimodal analysis. Currently, glaucoma and diabetic retinopathy detection is no longer limited to color fundus photographs; there is a growing trend toward synchronizing optical coherence tomography (OCT) data with patients' general clinical indicators.

In particular, the emergence of Foundation Models has significantly enhanced the self-learning capabilities of algorithms. This advancement has helped overcome difficulties previously encountered in identifying rare clinical cases. Systematic reviews confirm that AI not only detects the presence of disease but also predicts the progression of pathology by analyzing microscopic alterations within retinal layers.

Moreover, the development of Explainable AI has addressed the issue of trust between physicians and intelligent systems. Algorithms now highlight specific pathological areas of the fundus—such as microaneurysms or exudates—through visual heatmaps. This minimizes errors associated with human fatigue and decreased attention during screening.

Integration of neural networks into mobile platforms also enables high-tech diagnostics in regions with limited access to ophthalmological care. Meta-analysis findings indicate that implementing AI in primary healthcare screening systems is one of the most effective and economically feasible strategies for preventing blindness.

Glaucoma and diabetic retinopathy continue to be major causes of blindness globally. Traditional screening methods require significant time and highly qualified specialists. AI technologies provide a revolutionary solution by accelerating processes and improving diagnostic accuracy

Deep Learning: Automated analysis of fundus images.

Convolutional Neural Networks (CNNs): Detection of microscopic changes such as microaneurysms and exudates.

Multimodal analysis: Simultaneous evaluation of fundus images, OCT scans, and general clinical indicators

Diabetic Retinopathy: Detection accuracy reaches 94–97% sensitivity.

Glaucoma: Diagnostic accuracy reaches 91–95% specificity.

Early diagnosis: New algorithms can predict not only the presence of disease but also its stage of progression

Glaucoma is often referred to as the "silent thief of sight" because it progresses asymptomatically for a long time. AI systems rely on the following indicators:

Cup-to-Disc Ratio: AI algorithms measure optic nerve disc excavation with an accuracy of up to 0.01 mm.

OCT-Angiography integration: Recent studies show that AI-based analysis of retinal capillary microvasculature enables prediction of glaucoma several years before visual field loss occurs.

Previously, one of the major challenges of AI in medicine was the "black box" effect, meaning that systems could not explain the reasoning behind their conclusions.

Heatmaps: Modern software visually marks pathological regions of the fundus image, allowing physicians to verify and confirm AI conclusions.

Automatic Segmentation in Diabetic Retinopathy (DR)

Microaneurysms: Small dilations of retinal capillaries—one of the earliest signs of DR.

Hemorrhages: AI detects and quantifies dot-and-blot hemorrhages faster and more accurately than the human eye.

Hard and soft exudates: Identification of lipid deposits and cotton-wool spots determines disease severity (proliferative or non-proliferative).

Fundus Photography: High-resolution color imaging of the retina.

Segmentation: Automatic separation of pathological elements (blood, edema, scarring) by AI.

False Positive/Negative Rates: Error rates have currently been reduced to below 5%.

Combined and Systemic Diagnostics

Glaucoma + DR: Patients often present with both diabetes and elevated intraocular pressure. AI can assess the severity of both conditions in a single scan.

Other pathologies: Studies demonstrate that AI analysis of fundus images can detect early signs of hypertension, Alzheimer's disease, and even myocardial infarction risk.

Research in 2025 indicates that AI can identify not only ocular diseases but also systemic changes in the body based on retinal images:

● Vessel Tortuosity: Measurement of microvascular curvature, indicating increased vascular resistance in early diabetes.

● Arteriovenous (A/V) Ratio: Calculation of arterial and venous diameter differences to predict hypertension or stroke risk with up to 90% accuracy.

● Neurodegenerative markers: Thinning of retinal nerve fiber layers enables early detection of Alzheimer's and Parkinson's diseases during ophthalmic examination

Multimodal AI by 2026

Multimodal integration: AI simultaneously analyzes fundus images, OCT scans, and patient anamnesis (blood pressure, glucose levels).

Foveal Avascular Zone (FAZ): Automatic measurement of enlargement in the macular avascular zone, a key indicator of reduced visual acuity.

Conclusion

Research conducted between 2020 and 2025 confirms that artificial intelligence has become a reliable assistant to physicians in the early detection of glaucoma and diabetic retinopathy. Modern algorithms analyze pathological signs with a level of precision beyond human visual capability and significantly accelerate the diagnostic process.

Widespread implementation of these technologies in medical practice will elevate mass screening quality to a new level and serve as a key factor in blindness prevention.

Meta-analyses and studies from 2020–2026 lead to the following final conclusions:

Diagnostic accuracy and efficiency: Modern deep learning algorithms achieve 94–98% sensitivity in DR detection, significantly reducing human-factor-related errors.

New biomarkers for early detection: AI systems identify microscopic vascular tortuosity, topographic deformation of the optic nerve disc, and thinning of the neuroretinal rim—allowing glaucoma prediction years before visual field loss.

Medical and economic efficiency: Automated AI-based screening systems reduce physicians' workload by 50–70% and decrease social and economic costs associated with advanced-stage disease by 5–6 times.

Systematic triage: Explainable AI technologies improve diagnostic transparency by highlighting pathological areas via heatmaps, enabling rapid identification of patients requiring urgent care during mass screening.

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