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Commentary
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Artificial Intelligence in Early Detection of Diabetic Retinopathy

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Dear Editor,

Diabetic retinopathy (DR) represents a growing and largely preventable cause of blindness among working-age adults worldwide. It is the leading cause of vision loss in this population, with 103 million people currently affected and prevalence projected to reach 160 million by 2045[1]. The diabetes epidemic is expanding faster than our healthcare systems can accommodate. Although detection at the non-proliferative stage enables effective interventions such as laser photocoagulation and optimized glycemic control, a substantial proportion of patients in resource-limited settings continue to miss routine eye examinations, leaving them vulnerable to irreversible visual impairment.

Conventional screening approaches, including dilated fundus examination and digital fundus photography, are failing to scale with this growing burden. Diagnostic tools such as optical coherence tomography and standardized grading systems (ICDR and ETDRS) provide detailed clinical pictures but require specialist expertise that remains globally scarce. The resulting bottleneck is unsustainable: a worldwide shortage of ophthalmologists, compounded by the time-intensive and inherently subjective nature of manual image grading, creates systemic gaps in which early lesions, including microaneurysms and subtle hemorrhages, are frequently missed. Autonomous AI-based systems integrated into primary care represent a compelling solution to overcome these structural barriers.

Artificial intelligence (AI), and convolutional neural networks in particular, have substantially advanced early detection of DR through automated analysis of retinal fundus images. In a landmark study using curated retinal fundus datasets, a deep learning model achieved 97.5% sensitivity and 93.4% specificity for detecting referable DR[2]; however, real-world performance across diverse settings, imaging devices, and patient populations is typically lower[3]. The FDA-approved IDx-DR system demonstrated 87.2% sensitivity and 90.7% specificity for identifying more-than-mild DR in primary care settings among patients with

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gradable images, enabling autonomous screening without immediate specialist input[4]. These systems rapidly detect microaneurysms, intraretinal hemorrhages, and hard exudates while integrating with existing fundus camera infrastructure, ensuring consistent, reproducible image grading, reducing diagnostic delays, and facilitating earlier referral of moderate-to-severe cases.

Despite this promise, AI-based DR screening faces important limitations. Model performance is heavily dependent on the quality and diversity of training data, and generalizability across different patient populations and imaging devices remains inconsistent. Image quality issues, including motion blur and suboptimal illumination, further compromise diagnostic reliability. Perhaps most critically, steep implementation costs, infrastructure requirements, and limited technological access pose significant barriers in low-resource settings, where the burden of DR is disproportionately concentrated[3].

Addressing these challenges will require future AI development centered on scalability, equity, and clinical trustworthiness. Large-scale, multi-centric clinical trials enrolling diverse populations are essential to validate generalizability. Integrated diagnostic platforms capable of simultaneously evaluating DR, glaucoma, and macular pathologies will optimize clinical workflow efficiency. Federated learning offers a particularly promising framework, enabling collaborative model training across institutions without transferring sensitive patient data, thereby producing robust AI tools while fully safeguarding privacy. Explainability mechanisms, such as gradient-weighted attention maps, will be critical to building clinician trust, and structured training programs must communicate both AI capabilities and its inherent limitations.

In low-resource settings specifically, future priorities must center on affordability and accessibility. Offline AI systems, edge computing architectures, and smartphone-based fundus imaging represent viable approaches that substantially reduce dependency on cloud infrastructure and high-speed internet[5]. These technologies hold significant potential to extend equitable DR screening to populations currently beyond the reach of conventional ophthalmologic services.

In conclusion, AI offers a transformative opportunity to close the global DR screening gap. Realizing these potential demands not only technical refinement, but deliberate policy investment, rigorous validation across diverse populations, and deployment strategies designed with equity at their core.

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