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Teleophthalmology in diabetic retinopathy screening: diagnostic performance, equity, and integration into the care pathway.

Teleophthalmology in Diabetic Retinopathy Screening: Diagnostic Performance, Equity, and Integration into the Care Pathway

Teleofthalmology in the database of diabetic retinopathy: diagnostic performance, equity and integration in the care pathway

John Neves de Medeiros

Ophthalmologist specializing in cornea, medical auditing, and management; trained in clinical research and experienced in teleophthalmology, regulation, and leadership in healthcare services.

Summary

Diabetic retinopathy is a potentially disabling microvascular complication, the impact of which depends on both the duration and control of diabetes and the timeliness of detection and treatment. This article critically analyzes teleophthalmology as a population screening strategy, with emphasis on diagnostic performance, image quality, referral flows, equity, data protection, and integration into primary care.

A structured narrative review of institutional documents and indexed studies was conducted, without primary data collection. The literature supports the use of validated digital retinography to identify individuals requiring specialized evaluation, but also demonstrates that technology alone does not constitute a screening program. Clinically relevant outcomes depend on coverage, periodic repetition, reliable classification, timely referral, and therapeutic capacity. It is concluded that teleophthalmology can expand access and rationalize resources when incorporated into a measurable, auditable, and person-centered care pathway.

Keywords: diabetic retinopathy; teleophthalmology; screening; eye health; primary care; equity.

Abstract

Diabetic retinopathy is a potentially disabling microvascular complication whose impact depends on diabetes duration and control as well as timely detection and treatment. This article critically examines teleophthalmology as a population-screening strategy, critically diagnostic performance, image quality, referral pathways, equity, data protection, and primary-care integration. A structured narrative review of institutional documents and indexed studies was conducted, with no primary data collection. Evidence supports validated digital retinal imaging to identify people specialist requiring assessment, but also shows that technology alone does not constitute a screening program. Clinically meaningful results depend on coverage, periodic recall, reliable grading, timely referral, and treatment capacity.

Teleophthalmology may expand access and improve resource allocation when embedded in a measurable, auditable, person-centered care pathway.

Keywords: diabetic retinopathy; teleophthalmology; screening; eye health; primary care; equity.

1. Introduction

Diabetes has reached global dimensions and poses a challenge to health systems that goes beyond...

Glycemic control. The 11th edition of the Diabetes Atlas from the International Diabetes Federation.

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It is estimated that hundreds of millions of adults are living with the disease and projects further growth. in the coming decades. The expansion in the number of people exposed increases the demand for prevention of renal, cardiovascular, neurological, and ocular complications. In the retina, Changes can evolve silently during a significant portion of the course, which makes It is inadequate to rely solely on spontaneous requests for care after the onset of symptoms.

The World Health Organization considers early detection and timely treatment essential to avoid irreversible vision loss from diabetic retinopathy. This statement displaces the debate from isolated examinations to the organization of programs capable of locating the population eligible, conduct assessments at appropriate intervals, recognize findings that require Reference and ensuring access to subsequent care. Screening does not equate to a a specific campaign; it is a longitudinal function of the system, with registration, summons, and control. of absentees and evaluation of results.

Teleophthalmology emerged as a possible architectural approach to separate unnecessary steps. The acquisition of images can occur in the same place or at the same time. The patient's territory, while the classification is performed by trained professionals or by Validated automated systems, with clinical supervision and explicit rules. This This configuration reduces unnecessary travel and preserves in-person consultations for people. with non-gradable images, referable disease, symptoms or other conditions that require Complete examination (WORLD HEALTH ORGANIZATION, 2020).

The usefulness of this architecture, however, cannot be presumed from the existence of a camera or algorithm. Diagnostic performance, operational quality and effect. populations belong to different levels of evaluation. The aim of this article is to integrate these levels and discuss how tracking programs can combine evidence, security, Equity and healthcare capacity without turning a triage tool into a replacement. improper ophthalmological judgment (WONG et al., 2018).

2 Methodology

A structured narrative review of an analytical-conceptual nature was conducted, guided by a Central question: what components determine the effectiveness and safety of Teleophthalmology applied to diabetic retinopathy screening? The review was not registered. It is a systematic approach and does not intend to estimate its own aggregate effect. Its purpose was to articulate

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diagnostic evidence, clinical recommendations, and tools for organizing systems of health in a model applicable to program analysis (FAR et al., 2022).

Documents from the World Health Organization and the International Diabetes Association were prioritized. The Federation and the American Academy of Ophthalmology, in addition to systematic reviews and studies. indexed in PubMed. The search terms included diabetic retinopathy, teleophthalmology, teleretinal screening, diagnostic accuracy, artificial intelligence, referral, cost-effectiveness and equity. The selection prioritized sources with methodological description, persistent identifier and Direct relationship with tracking or organizing the care pathway.

The synthesis was organized into six dimensions: disease burden and prevention; design of program; diagnostic performance; care flow; equity and patient experience; Governance, quality, and artificial intelligence. Sensitivity and specificity were... interpreted in light of the population, the reference standard, the imaging protocol, and the The treatment given to non-gradeable tests. Results from one piece of equipment were not extrapolated. algorithm or environment for different contexts without reservation (WORLD HEALTH) ORGANIZATION, 2022).

As limitations, the revision is subject to the interpretative selection inherent in the narrative method and to... Heterogeneity of studies. Technologies, classifications, and regulations evolve. quickly, and local effectiveness depends on prevalence, human resources, connectivity and therapeutic capacity. Therefore, the propositions presented should be understood as Design and evaluation principles, not as a self-sufficient clinical protocol or recommendation. individual (AMERICAN ACADEMY OF OPHTHALMOLOGY, 2025).

3. Disease burden, preventive window, and purpose of screening.

Wong et al. (2018), in international recommendations for eye care related to diabetes, they emphasize that the organization of screening should consider the start date, frequency, Severity and referral flow. Diabetic retinopathy results from microvascular changes. related to cumulative metabolic exposure, but the risk is not uniform: duration of Diabetes, glycemic and blood pressure control, pregnancy, kidney disease, and other factors modify the probability of appearance or progression. This heterogeneity justifies intervals and Priorities defined by guidelines and clinical risk, rather than an undifferentiated logic.

Digital fundus photography is a detection tool, not a representation. Complete ophthalmological examination. Guidelines from the American Academy of Ophthalmology.

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They acknowledge that validated digital imaging can be effective in tracking, while
in which they preserve the dilated examination as a comprehensive clinical reference. This distinction is
Essentially: the teletriage system determines if there is evidence that requires referral, repeat screening, or...
Further evaluation; it should not be presented as a universal exclusion of eye disease.
The population benefit depends on the chain that links invitation, examination, and intervention.
High sensitivity loses its value if patients classified as referable do not arrive.
to the specialist. Similarly, expanding acquisition without considering laser, intravitreal therapy,
Surgery or follow-up care may only move the queue. The analysis should include coverage.
Effectiveness and time to care, not just the number of images taken (WORLD HEALTH)
ORGANIZATION, 2020).
Mature programs define the target population based on reliable clinical registries and
They establish recall mechanisms. The absence of tracking in a cycle requires
To produce action, because non-participation tends to concentrate within groups with barriers.
social factors and a higher risk of delayed outcomes. Therefore, monitoring for missed appointments and losses to follow-up is...
part of the quality and not peripheral administrative activity (INTERNATIONAL DIABETES
FEDERATION, 2025).
The ethical purpose of contact tracing is to reduce avoidable harm. This requires a balance between
detection, false positives, false negatives, reference overload and opportunity
Therapeutic technology should be evaluated by how it modifies this balance in context.
Real. A responsible program sets clear limits for the patient and maintains channels for evaluation.
In-person evaluation is recommended when there is low vision, acute symptoms, clinical uncertainty, or inadequate imaging.
(WONG et al., 2018).

4. Operational architecture and acquisition quality

The World Health Organization's guide for integrating eye care into healthcare systems
The World Health Organization (WHO, 2022) recommends that technologies be incorporated into healthcare pathways.
defined, with monitoring and accountability. In teleophthalmology, the most
Typically, it is asynchronous: minimal clinical images and information are captured at a single point in time.
Care is taken and forwarded for further classification. This method favors scale, but its
Success depends on standardized protocols, unambiguous identification, correct laterality,
adequate retinal fields, transmission security, and maximum time frame for issuing the report.
Image quality is a clinical variable. Media opacities, small pupil, technique

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Insufficient or inadequate equipment may render the examination ungradeable. Excluding these [examples]
Images from analyses tend to produce more favorable estimates than those observed in...
operation. Therefore, the non-graduation rate should be presented as its own indicator and
linked to a repeat procedure or in-person examination, never treated as a negative result.
(FAR et al., 2022).

The training of pickup artists combines technical expertise and communication skills. Positioning, focus,
Lighting and field selection influence readability, while clear explanations enhance it.
Cooperation and trust. Sample audits, individual feedback, and periodic calibration.
They reduce variability. When acquisition occurs in primary care, the team also
needs to recognize situations that require direct referral, without waiting for routine procedures.
screening (WONG et al., 2018).

The classification can be performed by ophthalmologists, certified readers, or systems.
Automated within the validated scope. Each arrangement requires competency criteria, double
Reading or arbitration according to risk. The severity scale should be linked to conduct.
unequivocal operational steps: periodic return, image repetition, forwarding
Scheduled or urgent evaluation. Diagnostic categories without defined consequence not
organize care (AMERICAN ACADEMY OF OPHTHALMOLOGY, 2025).

Interoperability prevents teleophthalmology from becoming an isolated image bank.
Results, quality, recommendations, and confirmation of receipt should be integrated into the...
medical records and diabetes registration. The design needs to allow tracking of each person from the beginning.
Eligibility extends to the conclusion of the referral process. This traceability makes it possible to distinguish
Technological failure of access failure and guiding continuous improvement (WORLD HEALTH)
ORGANIZATION, 2022).

5. Diagnostic performance and responsible interpretation

Sensitivity expresses the proportion of people with the condition identified by the test;
Specificity, the proportion of those without the condition that are correctly classified. In screening,
Both are important, but their operational weight varies. Missing referable disease can delay treatment.
treatment, while low specificity increases consultations and anxiety. Predictive values
They also depend on prevalence, which is why the performance observed in a service
specialized care should not be automatically transferred to primary care (FAR et al.,
2022).

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The systematic review by Far and colleagues, published in 2022, compiled 28 articles. For any diabetic retinopathy, estimated sensitivity of 0.91 and specificity of 0.88; for for referable disease, 0.88 and 0.86, respectively. The authors classified the certainty as Low for any retinopathy and moderate for referable disease. These results support teletriage is possible, but the wide intervals and heterogeneity make it difficult to interpret the results. averages as a guarantee for any implementation (WONG et al., 2018).

The reference standard modifies the conclusion. Clinical examination, stereoscopic photography and Optical coherence tomography responds to different aspects, especially in the evaluation of macular edema. Exclusively photographic protocols may use surrogate markers or Forward this information when there is suspicion. The documentation needs to state what the system detects. which level is referable and which findings remain outside its scope (AMERICAN ACADEMY OF OPHTHALMOLOGY, 2025).

Patient-by-patient and eye-by-eye analysis also yields distinct measurements. A population-based program usually the decision is made for the person based on the eye with the greater severity, but Storage should preserve laterality. Incidental changes — such as signs of Glaucoma, macular degeneration, or vascular occlusions—require prior planning, as they can... to be visible without the system having been validated to track them (FAR et al., 2022).

Performance should be monitored after deployment. Negative test samples may to be re-evaluated, referred cases can be compared to in-person diagnoses and Changes to the camera, software, or population should trigger a new verification. This cycle Transform validation into a continuous process. Security doesn't stem solely from the initial result. from a study, but from the ability to identify degradation and correct the system (WONG et al., 2018).

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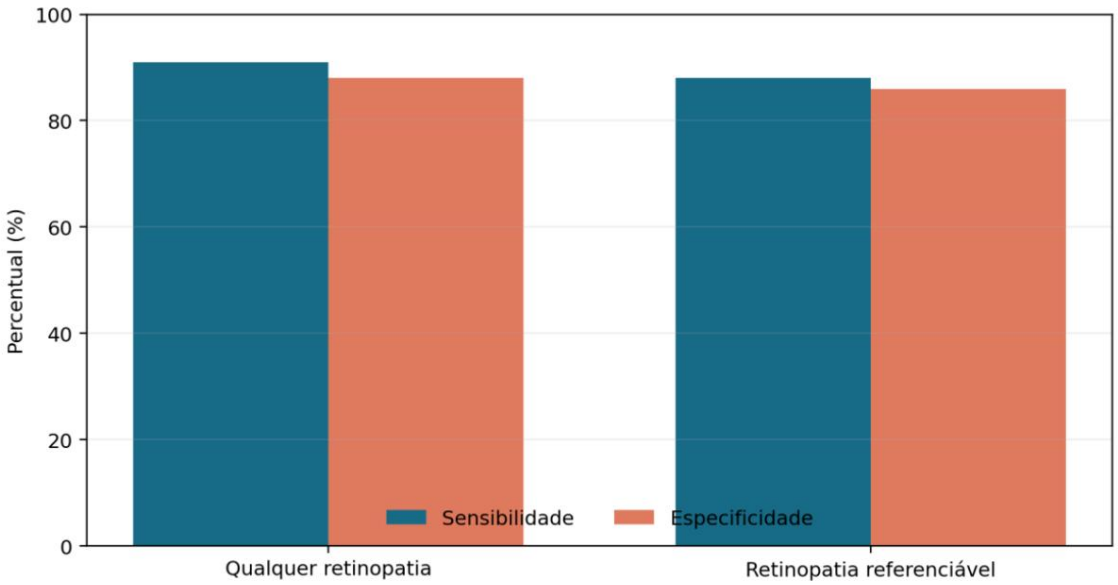

Figure 1 – Aggregate performance of retinal teletriage

Source: compiled by the author with data from Far et al. (2022). Values expressed in

Percentage; the certainty of the evidence and heterogeneity should be considered.

6. Referral, treatment and continuity of care

The Preferred Practice Standard of the American Academy of Ophthalmology (2025) recognizes the usefulness of validated digital images in tracking, while preserving the need for Referral and clinical evaluation based on findings. Teleophthalmology creates value when It differentiates who can remain in periodic monitoring from who needs evaluation. specialized. For this, the report must be understandable, contain a degree of urgency, and reach a conclusion. who can act. The care pathway should assign responsibility for communication, for scheduling and confirmation of attendance.

The time between triage and consultation should reflect severity and risk. Suspected illness. Proliferative conditions, macular edema, or significant visual impairment cannot compete for the same waiting list as... Subtle changes. Prioritization protocols reduce risk, but need to be monitored. based on actual capacity. When the referenced volume exceeds the supply, the program must revise. criteria, expand resources or reorganize schedules without relaxing safety standards (WORLD HEALTH ORGANIZATION, 2022).

Primary care occupies a central position because it monitors diabetes, blood pressure, and blood function. Renal function and therapeutic adherence. The ocular outcome may reinforce education and systemic control. While clinical data qualify the interpretation of the image, integration does not mean...

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Transferring specialized responsibilities to the generalist, but organizing communication.
bidirectional and complementary decisions (WONG et al., 2018).
Loss to follow-up requires active case finding proportionate to the risk. Barriers may include
Transportation, work, language, cost, limited understanding, or fear of treatment. Register.
Simply stating "did not attend" hides modifiable causes. Patient navigation, reminders and
Scheduling before leaving the triage point are organizational interventions that can
to be as crucial as the accuracy of the equipment (AMERICAN ACADEMY OF
Ophthalmology, 2025).
Final outcomes should include preserved vision, timely treatment, and experience.
Appropriate. Test counts are indicators of output, not benefit. An assessment
Complete care relates to coverage, quality, referral, attendance, treatment, and outcome.
functional. This chain allows you to locate bottlenecks and avoids attributing effects to the camera that depend
of the entire system (WORLD HEALTH ORGANIZATION, 2022).

7. Fairness, acceptability and data protection

The proximity of the exam can reduce travel and indirect costs, benefiting people.
in remote areas or areas with limited mobility. However, deployment can reproduce
Inequalities will not depend on connectivity, documentation, or digital literacy.
available to all. Equity should be tested by comparing coverage, not graduation, and
loss of follow-up by territory and socially relevant groups, with protection against uses
discriminatory (NAKAYAMA et al., 2023).
Acceptability depends on trust. The patient needs to know why the images are...
What information is needed to understand how to proceed, including who will analyze the samples, when you will receive the results, and what to do if you experience symptoms.
Consent and information must be compatible with the cultural and linguistic context.
Operational convenience does not replace the right to understand limits and alternatives.
(WORLD HEALTH ORGANIZATION, 2022).
Eye data is health data and requires access control, encryption, and record keeping.
Events and retention policy. Contracts with suppliers should define responsibilities.
Location of processing, secondary use, and incident response. Image banks.
Tools aimed at algorithmic improvement require a specific ethical and legal foundation, with governance.
that goes beyond the acceptance of generic terms (FAR et al., 2022).
The review by Nakayama et al. (2023) on artificial intelligence applied to telemedicine for

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Diabetic retinopathy draws attention to implementation, equity, and differences between populations. Systems trained on specific equipment and groups may exhibit Performance decline in other scenarios. Evaluate subgroups, non-gradable images and Distribution changes are part of the validation process. Human supervision should be designed to... in accordance with the risk and the system's ability to recognize when it cannot decide. Equity also involves the distribution of specialized resources. By reducing consultations... For routine screening, teleophthalmology can free up ophthalmologists for complex cases; However, cost savings should not result in indiscriminate capacity reduction. The purpose It is about using skills at the appropriate level and expanding effective access, while preserving pathways. in-person services for those who need them (WORLD HEALTH ORGANIZATION, 2022).

8 Indicators, governance and sustainability

The monitoring framework proposed by the World Health Organization (2022) links Indicators for the implementation of integrated and person-centered eye care. In this From this perspective, governance begins with explicit objectives and defined authority. Those responsible... Clinical, operational, technological, and data protection professionals must understand their roles. Inclusion criteria, grading scales, deadlines, and exceptions must be documented. and subject to review; the absence of someone responsible for a critical step often appears as A silent loss between outcome and care.

A balanced panel may include eligible population, coverage during the period, rate of attendance, non-gradable images, time until reading, referenced proportion, time up to consultation, appointment with a specialist, diagnostic confirmation, and timely treatment. Indicators should be stratified by territory and risk. Isolated volume targets may to encourage quick and low-quality acquisitions (KIRKIZLAR et al., 2013).

Economic sustainability requires analysis of the entire system. Costs include equipment, Maintenance, personnel, connectivity, reading, integration, and on-site case assessment. Inadequate or positive. Benefits may result from avoided displacements, better use from the specialist and prevention of visual loss. Cost-effectiveness studies are sensitive to volume, prevalence, adherence, and distance; therefore, local decisions need to test scenarios. (WONG et al., 2018).

Compensation models should recognize acquisition, classification, coordination, and... tracking, avoiding fragmented incentives. If only the capture is remunerated, nobody

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assumes the conclusion of the referral. If the referral generates revenue without control of
With such specificity, there may be excessive queries. Contracts and metrics need to align.
Payment for quality and continuity (WORLD HEALTH ORGANIZATION, 2022).
The program's maturity is evident in its ability to learn. Review meetings, analysis of
incidents, performance comparison and participation of frontline teams
They transform data into change. Teleophthalmology is not a project that ends after installation; it is
a clinical service that requires technical maintenance, scientific updating, and accountability.
(KIRKIZLAR et al., 2013).

Conclusion

Teleophthalmology offers a plausible organizational response to the mismatch between...
The growth of diabetes and the ability to screen in person. Its main merit is
To bring detection closer to the territory and reserve specialized assessment for those who present a risk,
Inadequate image or clinical need. This merit, however, depends on design.
care is provided and does not automatically result from technology (FAR et al., 2022).
The literature demonstrates good overall performance of teletriage for diabetic retinopathy.
including referable disease. Estimates should be interpreted with their respective
intervals, levels of certainty, and differences between protocols. Each implementation needs to prove...
quality with the equipment, the population, the readers and the infrastructure effectively used.
(WORLD HEALTH ORGANIZATION, 2022).
Non-gradable images are a decision category, not a reassuring result.
Monitoring them, reducing their causes, and offering in-person testing protect people in whom
Opacities or technical limitations prevent evaluation. The same principle applies to
Symptoms and findings outside the scope: teletriage does not replace comprehensive consultation when this is the case.
It is indicated (NAKAYAMA et al., 2023).
Effective population response requires continuity. Registration, recruitment, acquisition, reading,
Communication, referral, attendance, and treatment form a chain; a break in
Any link reduces the benefit. Production indicators should be accompanied by measures.
of time, quality and outcome (AMERICAN ACADEMY OF OPHTHALMOLOGY, 2025).
Equity cannot be presumed based on geographical proximity. Programs need
to demonstrate that vulnerable groups achieve coverage, receive results, and complete the program.
Referrals. Language, transportation, income, literacy, and connectivity barriers should be addressed.

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to be treated as design features, not as individual flaws (FAR et al., 2022).

Artificial intelligence can support classification and scaling, but it increases the obligation to validate. Representativeness, monitoring performance change, and preserving oversight. Transparency. Regarding scope, uncertainty, and data usage, trust is a requirement. The decision to automate must... to be clinical and organizational, not just technological (WORLD HEALTH ORGANIZATION, 2022).

Sustainability depends on therapeutic capacity and coherent funding. Increasing the Detection without offering subsequent care can worsen queues and frustration. Planning must estimate referenced demand, adjust resources, and also remunerate the coordination that transforms results into action (NAKAYAMA et al., 2023).

It is concluded that teleophthalmology is best understood as a component of a broader field. integrated and person-centered. When governed by evidence, indicators and Clinical responsibility can broaden access and contribute to preventing avoidable vision loss. When reduced to capturing images, it runs the risk of producing careless volume. (AMERICAN ACADEMY OF OPHTHALMOLOGY, 2025).

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