

A NEW STRATEGY FOR DIABETIC RETINOPATHY SCREENING**A. F. Yusupov, M. X. Karimova, Kh. Sh. Khusanbaev, A. U. Ismailov**

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Key words: artificial intelligence, diabetic retinopathy, automated diagnostics, screening, fundus imaging.**Tayanch soʻzlar:** sunʼiy intellekt, diabetik retinopatiya, avtomatlashtirilgan diagnostika, skining, koʻz tubi tasviri.**Ключевые слова:** искусственный интеллект, диабетическая ретинопатия, автоматизированная диагностика, скрининг, изображение глазного дна.

Diabetic retinopathy (DR) is one of the main causes of persistent visual impairment in patients with diabetes mellitus. Despite progress in ophthalmology, early detection of DR is fraught with problems such as a high proportion of subjectivity, a shortage of qualified ophthalmologists, and limited availability of specialized care in remote regions. This paper analyzes current approaches to automating the diagnosis of DR based on artificial intelligence (AI) technologies. The purpose of the study is to evaluate the diagnostic effectiveness of the “Retina AI” AI system. The study included 330 patients with diabetes mellitus (DM), who differ in the degree of compensation of carbohydrate metabolism and the duration of the disease. The data obtained indicate the high diagnostic effectiveness of the Retina AI technology and its significant potential in the context of improving the screening of DR in conditions of shortage of human resources.

DIABETIK RETINOPATIYA SKRININGINING YANGI STRATEGIYASI**A. F. Yusupov, M. X. Karimova, X. Sh. Xusanbayev, A. U. Ismailov**

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Diabetik retinopatiya (DR) qandli diabetga chalingan bemorlarda koʻrish funksiyalarining doimiy yomonlashuvining asosiy sabablaridan biri hisoblanadi. Oftalmologiyada erishilgan yutuqlarga qaramay, DRni erta aniqlash subʼektivlikning yuqori darajasi, malakali oftalmologlarning yetishmasligi va chekka hududlarda ixtisoslashtirilgan yordamning cheklanganligi kabi muammolar bilan bogʻliq. Ushbu maqolada sunʼiy intellekt (SI) texnologiyalari asosida DR diagnostikasini avtomatlashtirishning dolzarb yondashuvlari tahlil qilinadi. Tadqiqotning maqsadi - DRni aniqlash boʻyicha skriningni optimallashtirishda “Retina AI” sunʼiy intellekt tizimining diagnostik samaradorligini baholash. Tadqiqotga uglevod almashinuvining kompensatsiya darajasi va kasallikning davomiyligiga koʻra farqlanadigan 330 nafar qandli diabet (QD) bilan kasallangan bemor kiritilgan. Olingan maʼlumotlar “Retina AI” texnologiyasining yuqori diagnostik samaradorligini va kadrlar resurslari yetishmasligi sharoitida DR skriningini takomillashtirish kontekstida uning muhim salohiyatini tasdiqlaydi.

НОВАЯ СТРАТЕГИЯ СКРИНИНГА ДИАБЕТИЧЕСКОЙ РЕТИНОПАТИИ**А. Ф. Юсупов, М. Х. Каримова, Х. Ш. Хусанбаев, А. У. Исмаилов**

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Диабетическая ретинопатия (ДР) является одной из основных причин стойкого ухудшения зрительных функций у пациентов с сахарным диабетом. Несмотря на прогресс в офтальмологии, раннее выявление ДР сопряжено с такими проблемами, как высокая доля субъективизма, нехватка квалифицированных офтальмологов и ограниченная доступность специализированной помощи в отдаленных регионах. В данной работе анализируются актуальные подходы к автоматизации диагностики ДР на базе технологий искусственного интеллекта (ИИ). Цель исследования — оценить диагностическую результативность ИИ-системы «Retina AI». В исследование включено 330 пациентов с сахарным диабетом (СД), различающихся по степени компенсации углеводного обмена и длительности заболевания. Полученные данные свидетельствуют о высокой диагностической эффективности технологии «Retina AI» и её значительном потенциале в контексте совершенствования скрининга ДР в условиях дефицита кадровых ресурсов. Внедрение подобных решений на уровне первичной медико-санитарной помощи позволит повысить охват и своевременность выявления ДР, снизить рабочую нагрузку на офтальмологов и уменьшить риск развития инвалидизирующих осложнений у лиц с СД в регионе.

Diabetic retinopathy (DR) is a specific microangiopathic lesion of retinal vessels developing against chronic hyperglycemia in patients with diabetes mellitus (DM). It is characterized by progressive damage to the capillary endothelium, basement membrane thickening, pericyte loss, and microaneurysm formation, ultimately leading to ischemia, neovascularization, and traction retinal detachment [1]. DR is the leading cause of irreversible blindness among working-age people worldwide. Its prevalence among DM patients is approximately 35%, with vision-threatening forms (proliferative DR and diabetic macular edema) in 10–15%, and the probability reaches 60–80% after more than 10 years of diabetes [4]. Given the steady rise in DM incidence, a significant increase in DR cases is predicted, creating an unprecedented burden on ophthalmic care systems.

The early (nonproliferative) stages are often asymptomatic, leading to late treatment when

the process has already reached prognostically unfavorable stages. Yet adequate early therapy—strict glycemic control, normalization of blood pressure and lipid profile, and laser coagulation or intravitreal angiogenesis inhibitors can in most cases prevent or significantly slow visual deterioration [6]. This underscores the importance of well-organized screening programs with timely detection and dynamic monitoring at intervals based on DR severity. Effective screening must combine high sensitivity to minimize false negatives with sufficient specificity for rational resource use.

Universal DR screening faces serious obstacles, especially under limited resources and a shortage of specialists [2]. The scarcity of ophthalmologists, their concentration in regional centers, low availability of care for rural residents, and the high cost of traditional ophthalmoscopy form significant barriers [3]. Many developing countries and remote regions have fewer than 1–2 ophthalmologists per 100,000 population, while full screening requires at least 4. The traditional model—examining every DM patient—causes excessive workload and long queues, while an alternative using primary care physicians with short-term training shows low sensitivity (60–75%), failing to meet screening-quality requirements.

In recent years, artificial intelligence (AI), primarily deep learning algorithms based on convolutional neural networks, has shown high diagnostic potential in processing fundus photographs [8]. These algorithms can automatically segment anatomical structures, identify pathological foci, and classify the DR stage without human intervention, achieving accuracy comparable to ophthalmologists in controlled trials [5, 7], with some exceeding 90% sensitivity and specificity. This enables a two-stage model: automatic AI assessment of fundus photographs, followed by referral of only positive or doubtful cases to an ophthalmologist. Additional advantages include standardized assessment, reproducibility, real-time operation, and telemedicine integration. Implementing such technologies in resource-limited and hard-to-reach areas can increase coverage, reduce time to diagnosis, and ease the burden on specialists, ultimately improving the prognosis and quality of life of patients with diabetes mellitus.

The purpose of the study. The purpose of this study was to determine the diagnostic accuracy of the Retina AI system in detecting diabetic retinopathy and related signs based on digital images of the fundus, as well as to compare its indicators with the results of an assessment performed by primary care physicians.

Materials and methods. The study was conducted on the basis of the central district polyclinics of Sardobinsky districts and Gulistan, Syrdarya region in the first quarter of 2025. The study included 330 patients (660 eyes), 135 were men and 195 women. The average age of the participants was 59 years. Type 2 diabetes mellitus was diagnosed in 93% of patients. The median duration of the disease is 9 years. Individuals with opaque optical media, as well as patients who could not obtain high-quality fundus images, were excluded from the participants. All participants underwent a two-sided color fundus photograph of the central area of the retina (with a field of view of 30–50°) in conditions of drug-induced mydriasis using an OPTOMED Aurora IQ retinal camera. The resulting images were saved in digital format.

The images were transferred to primary care physicians for analysis. The specialists classified each image into the following categories: "without signs of DR", "non-proliferative DR" (mild, moderate, severe), "proliferative DR" or "maculopathy" (clinically significant diabetic macular edema). Additionally, the presence or absence of typical retinal signs was recorded: microaneurysms, hemorrhages, hard and soft exudates, intraretinal microvascular abnormalities (IRMA), neovascularization, fibrous changes and signs of macular edema. The final conclusion was formed on the eye with more severe changes.

A similar set of images was uploaded to the cloud platform of the Retina AI artificial intelligence system. This system is based on convolutional neural networks and has been pre-trained on extensive data arrays marked up by experts. The automatically generated report included: the estimated stage of DR (similar to the headings for primary care physicians), as well as the detection and localization of specific pathological signs of DR. The reference method (the "gold standard") was an independent assessment of all images by two ophthalmologists with significant experience in diagnosing eye diseases.

The evaluation of diagnostic effectiveness included the calculation of sensitivity and specificity for each key feature, overall accuracy, and the kappa coefficient (k) to measure the degree of agreement with the expert opinion. 95% confidence intervals were calculated for all parameters,

and the level of statistical significance was taken at $p < 0.05$.

Results. To evaluate diagnostic characteristics, a deep neural network–based system, "Retina AI," trained on annotated datasets was employed with the reference standard being the consensus of three certified expert ophthalmologists blinded to the results of the AI system and primary care physicians; analysis was performed at the eye level. The system demonstrated significantly higher sensitivity—93.3% (95% CI: 89.1–94.9) versus 73.6% (95% CI: 70.2–78.4) for physicians ($p < 0.001$)—and higher overall accuracy: 93.6% (95% CI: 88.5–93.9) versus 77.3% (95% CI: 75.8–82.4); $p < 0.001$. The difference in specificity did not reach significance: 91.2% (95% CI: 87.0–93.8) for AI versus 85.7% (95% CI: 81.7–89.6) for physicians ($p = 0.12$). Thus, AI's main advantage is significantly higher sensitivity with comparable specificity. The Kappa coefficient for agreement with expert assessments was 0.89 (SE 0.023), "very good" agreement (Landis and Koch scale), versus 0.72 (SE 0.031), "good" agreement, for physicians; the difference was significant ($p < 0.001$).

Analysis of individual pathomorphological signs showed high accuracy of Retina AI compared with the reference method. The highest sensitivity values ($>90\%$) were recorded for microaneurysms (93.6%), intraretinal hemorrhages (92.4%), and hard exudates (91.2%). Sensitivity for clinically significant macular edema (CSME) was 88.6%, and for signs of proliferative DR (neovascularization, preretinal hemorrhages) 85.3%—exceeding physicians by about 15 percentage points (e.g., CSME: 87.6% vs. 68.4%; proliferative changes: 86.3% vs. 73.9%). Physicians more often missed early changes (microaneurysms) and hard-to-interpret signs (edema, proliferation), consistent with the overall difference in sensitivity.

The results, obtained in real-world clinical practice at the primary healthcare level of the Syrdarya region, demonstrate the high diagnostic efficacy of Retina AI for DR screening. The cohort reflected the region's typical diabetes population, with varying disease duration and glycemic control. The key finding is AI's substantial superiority in sensitivity and overall accuracy, meaning the system misses significantly fewer cases (false-negative rate 7.7% vs. 15.5% for physicians). Sensitivity is critically important for any screening program, since missing DR leads to delayed treatment and irreversible vision loss. The system allows DR to be ruled out with high confidence in negative cases (negative predictive value 93.7%), potentially reducing the burden on ophthalmologists by referring only suspicious and pathological cases. The estimated reduction in specialist referrals upon implementation in this cohort would be 34% compared with the standard approach.

The high Kappa coefficient ($\kappa = 0.89$) between DR staging by Retina AI and expert assessments confirms the algorithm's ability not only to detect pathology but also to determine its severity fairly accurately (moderate, severe non-proliferative, and proliferative DR). This is important for stratifying patients by referral urgency: early-stage patients (mild DR without CSME) can be followed at 12-month intervals, whereas proliferative DR or CSME requires referral within 2–4 weeks. Physicians showed only good agreement ($\kappa = 0.68$), corresponding to moderate staging reliability, especially in differentiating early stages.

The system's ability to reliably detect a wide spectrum of retinal changes—from early manifestations (single microaneurysms, small hemorrhages) to sight-threatening complications (vitreous hemorrhages, fibrosis, tractional detachment)—underscores its comprehensive nature and clinical significance. AI's advantage is especially pronounced for changes that are difficult to distinguish or easily missed during non-systematic analysis, such as intraretinal microvascular abnormalities, early macular edema, or single cotton-wool spots. The neural network architecture provides pixel-wise segmentation of pathological foci, reducing false positives due to image artifacts. These data allow us to recommend implementing the system as a supportive tool for primary care physicians and, in the future, for autonomous screening in remote medical facilities under regulated oversight.

Conclusion. The Retina AI system, trained and validated on representative samples of fundus images, demonstrated high diagnostic effectiveness in screening for diabetic retinopathy in a patient cohort in the Syrdarya region. The algorithm significantly outperforms primary care physicians in sensitivity (93.3% vs. 73.6%; $p < 0.001$) and overall accuracy (93.6% vs. 77.3%; $p < 0.001$), with comparable specificity (91.2% vs. 85.7%; $p = 0.12$). This superiority persisted across subgroups with different disease duration, degree of carbohydrate metabolism compensation, and pa-

tient age, confirming the system's robustness in real clinical practice and its ability to reduce false-negative results—a critical parameter for any screening program.

The algorithm provides high reliability in determining the stages of retinopathy (Kappa coefficient $k=0.89$, very good agreement with expert ophthalmologists' conclusions), allowing it not only to detect the presence of DR but also to differentiate stages—from mild nonproliferative to proliferative. This has direct clinical significance for stratifying patients by referral urgency: early stages can be monitored routinely at 12-month intervals, while vision-threatening forms require urgent intervention. The system accurately detects specific retinal changes—microaneurysms, hemorrhages, hard exudates, clinically significant macular edema, and signs of proliferation, including features that are difficult to distinguish.

Integrating Retina AI into the region's primary health care practice is a scientifically sound solution for optimizing screening, based on a prospective cohort study under real conditions, which ensures high external validity and scalability. Expected effects include: expanded coverage through automated image analysis and reduced dependence on trained personnel; faster diagnosis; rational patient distribution through precise severity stratification; reduced burden on regional center specialists by redirecting only clinically significant cases; and increased availability of ophthalmological care in remote areas. The system also promotes unification of diagnostic criteria and the creation of a unified regional database.

The data confirm AI's potential as a tool for overcoming personnel shortages: the algorithm handles primary image analysis, while the ophthalmologist focuses on confirming diagnoses, determining treatment tactics, and monitoring complex patients. Economic analysis shows that implementation costs are offset over the medium and long term by reducing delayed diagnoses, preventing disabling complications and optimizing staff working hours. Thus, Retina AI is regarded as a key element of the digital transformation strategy for ophthalmology services in resource-limited regions.

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