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DİABETİK RETİNOPATİYA SKRİNİNQİNİN TƏKMİLLƏŞDİRİLMƏSİNDƏ SÜNİ İNTELLEKTİN İSTİFADƏSİ

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XÜLASƏ

Məqsəd – diabetik retinopatiyanın və onun simptomlarının aşkarlanmasında "Retina AI" süni intellekt sisteminin diaqnostik effektivliyini qiymətləndirmək.

Material və metodlar
Tədqiqat 2025-ci ilin birinci rübü ərzində Sırdərya vilayətinin mərkəzi çoxprofilli poliklinikalarının bazasında aparılmışdır. Tədqiqata xəstəlik müddəti 5 il və daha çox olan, müəyyən edilmiş şəkərli diabet diaqnozu olan (1-ci və ya 2-ci tip) 250 pasiyent ardıcıl şəkildə daxil edilmişdir.

Nəticələr
“Retina AI” sistemi ilkin tibbi yardım həkimləri ilə müqayisədə statistik cəhətdən daha yüksək həssaslıq (94,7% - ə qarşı 72,8%) və dəqiqlik (93,5% - ə qarşı 77,5%) nümayiş etdirmişdir. Spesifiklik göstəricisindəki fərq də həmçinin statistik əhəmiyyət kəsb etmişdir (91,3% - ə qarşı 85,0%). “Retina AI” sisteminin mütəxəssislərlə Kappa uyğunluq nisbəti 0,88 təşkil etmişdir ki, bu da "çox yaxşı" uyğunluq göstəricisidir.

Yekun
"Retina AI" süni intellekt sistemi Sırdərya vilayətindəki pasiyentlər arasında diabetik retinopatiyanın skrininqində yüksək effektivliyini sübut edərək, əsas diaqnostik dəqiqlik göstəricilərinə görə ilkin tibbi yardım həkimlərinin qiymətləndirməsini geridə qoymuşdur.

Açar sözlər: *diabetik retinopatiya, süni intellekt, diaqnostika, skrininq, sinir şəbəkələri*

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IMPROVING DIABETIC RETINOPATHY SCREENING USING ARTIFICIAL INTELLIGENCE TECHNOLOGY

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SUMMARY

Purpose – to evaluate the diagnostic effectiveness of the “Retina AI” artificial intelligence system in detecting of diabetic retinopathy (DR) and its symptoms.

Material and methods
The study was conducted on the basis of the central multidisciplinary polyclinics of the Syrdarya region during the 1st quarter of 2025. The study consistently included 250 patients with an established diagnosis of diabetes mellitus (DM) (type 1 or type 2 diabetes), the duration of the disease is ≥ 5 years.

Results
The “Retina AI” system demonstrated statistically significantly higher sensitivity (94.7% vs 72.8%) and accuracy (93.5% vs 77.5%) compared to primary care physicians. The difference in specificity also reached statistical significance (91.3% vs 85.0%). The Kappa coefficient of agreement of the Retina AI system with experts was 0.88, which indicates a "very good" agreement.

Conclusion
The “Retina AI” artificial intelligence system has proven to be highly effective in screening DR among patients in the Syrdarya region, surpassing the assessment of primary care physicians in terms of basic diagnostic accuracy.

Key words: *diabetic retinopathy, artificial intelligence, diagnostics, screening, neural networks*

Diabetic retinopathy (DR) is rightfully recognized in modern clinical practice as one of the most characteristic microvascular complications of diabetes mellitus. This pathology is a chronic, progressive process that affects precapillary arterioles, capillaries and retinal venules, which ultimately leads to their occlusion, increased permeability and the development of sensorineural tissue ischemia. The pathogenesis of DR is multicomponent and includes chronic hyperglycemia, activation of the polyol pathway, accumulation of final glycation products, oxidative stress, and inflammation, which together induce a cascade of pathological changes in microcirculation levels [1, 2].

The main feature of DR that determines its high socio-medical importance is that it is the main reason for the irreversible loss of vision in the working-age population on a global scale. This makes DR a serious socio-economic burden for health systems and society from a purely medical problem. Loss of vision in active-aged patients leads to a sharp decrease in quality of life, loss of professional training, disability and, as a result, significant direct and indirect economic losses.

Epidemiological data clearly show the extent of the impending "epidemic" of DR. According to current international research, the risk of developing DR is directly related to the duration of the underlying disease. For more than 10 years, the prevalence of diabetic retinopathy in patients with diabetes reaches 60–80% according to various estimates [3, 4]. Given the steady growth of DM worldwide, specifically type 2 diabetes, these figures predict avalanche-like growth of vision-threatening retinopathy (VTR) cases in the next decades. Such a prognosis requires immediate revision of existing ones and the development of new, more effective strategies for diagnosing and monitoring this complication.

One of the most serious problems in managing patients with DR is the asymptomatic development of pathology in the early, pre-clinical stages. The patient may not have any subjective vision disorder until the development of macular edema or the progression of the disease to the proliferative stage, when the damage to the retina becomes noticeable and often irreversible. It is this "mute" stage of the disease that creates a significant gap between the onset of the pathological process and its clinical detection.

In this regard, the issue of timely started treatment is of particular importance. Modern methods of steroid-containing DR therapy for panretinal laser coagulation, intravitreal injections of vascular endothelial growth factor inhibitors (anti-VEGF) or stopping macular swelling, and surgical interventions-vitrectomy, for the treatment of severe complications of the proliferative stage, efficacy in preventing high permanent vision loss in most cases [5]. However, their success directly depends on the stage at which treatment began. The faster the changes are detected, the softer, more effective and cheaper the therapeutic measures will be.

The above clearly demonstrates the high importance of developing, implementing and supporting effective screening programs, the main purpose of which is the active early detection of retinal pathology in patients with diabetes, even before they develop severe symptoms. Systematic screening allows to transfer attention from palliative care at the stage of advanced complications to a preventive strategy aimed at maintaining visual functions.

Nevertheless, the organization of DR mass, population-based screening faces a number of significant organizational, personnel, and economic challenges. These difficulties are especially acute in areas with limited health resources, which include not only developing countries, but also remote rural areas with developed countries. The main barriers to timely diagnosis:

- Lack of qualified ophthalmologists with specialized knowledge in diabetic retinopathy. This deficiency is observed globally, but its effects are most harmful in low-income regions.

- Uneven distribution of medical personnel, their concentration in large regional or capital medical centers, is called "medical deserts" in rural areas.

- The physical and economic non-availability of specialized ophthalmic care for a large part of the population living in remote areas. The costs of transportation, accommodation and medical care itself remain an insurmountable obstacle for many patients.

- High cost and limited availability of traditional fundus documentation and research methods such as mydriasis fundus cameras or fluorescent angiography. In addition, these methods require trained personnel (optometrists, medical professionals) to obtain quality images.

Together, these factors cause a vicious cycle in which patients who need regular monitoring cannot use it, leading to severe, preventable consequences such as late diagnosis and blindness.

Against this background, the revolutionary prospects for overcoming existing obstacles are revealed by artificial intelligence (AI) technologies, in particular, the machine learning division – deep learning algorithms (Deep Learning). In recent years, these technologies have demonstrated impressive potential in automated analysis of complex medical images, including fundus photographic data. Convolutional neural networks (CNN) have been trained in a broad set of data set by ophthalmologists, showing the ability to automatically detect and quantify DR signs – from microaneurysms and hemorrhages to macular edema and neovascularization. Many validation studies conducted under controlled conditions show that the diagnostic accuracy of the best AI systems in a DR-detection task (requiring a specialist referral) is comparable and in some respects superior to the assessment of experienced ophthalmologists [6 - 11]. This technological breakthrough provides real prospects for the creation of cost-effective, extensible and highly efficient screening models. The main idea is to assign the task of primary analysis of the fundus image to automated AI systems that can work day and night with constant and repetitive quality. This is especially true for areas with a sharp shortage of qualified ophthalmologists, where the AI system can act as a "breeding force", eliminate patients without pathology and draw the attention of human doctors to complex and recommendations. Thus, AI offers not only an alternative, but also a new paradigm for organizing eye care for DM.

Purpose - to evaluate the diagnostic effectiveness of the “Retina AI” artificial intelligence system in detecting DR and its symptoms through digital fundus photographs as part of the screening pilot project in the Syrdarya region and compare its accuracy with the assessment of primary care ophthalmologists.

Material and methods

The study was carried out on the basis of the Central polyclinics of the districts of Boyovut, Okoltin, Sardoba and the city of Gulistan in Syrdarya region in the 1st quarter of 2025. The study included 250 patients diagnosed with DM (type 1 or type 2 diabetes), with a duration of the disease $\geq$ 5 years. Exception criteria: opaque optical medium (high density cataracts, hemophthalmos), impossibility of high-quality imaging of the fundus. All patients were given a dual digital color photograph of the central area of the retina (30–50 degrees) with midriasis on the Optomed Aurora IQ retinal camera. The images were stored in digital format.

Image analysis: digital images were anonymized and sent for evaluation by primary care ophthalmologists. Doctors classified each image as "missing DR", "non-proliferative DR" (NPDR: mild, moderate, severe), "proliferative DR" (PDR) or "maculopathy" (clinically significant macular edema) and noted the presence/absence of underlying symptoms (microaneurysms, hemorrhages, hard exudates, soft exudates (cotton patches), intraretinal microvascular disorders (IRMA),

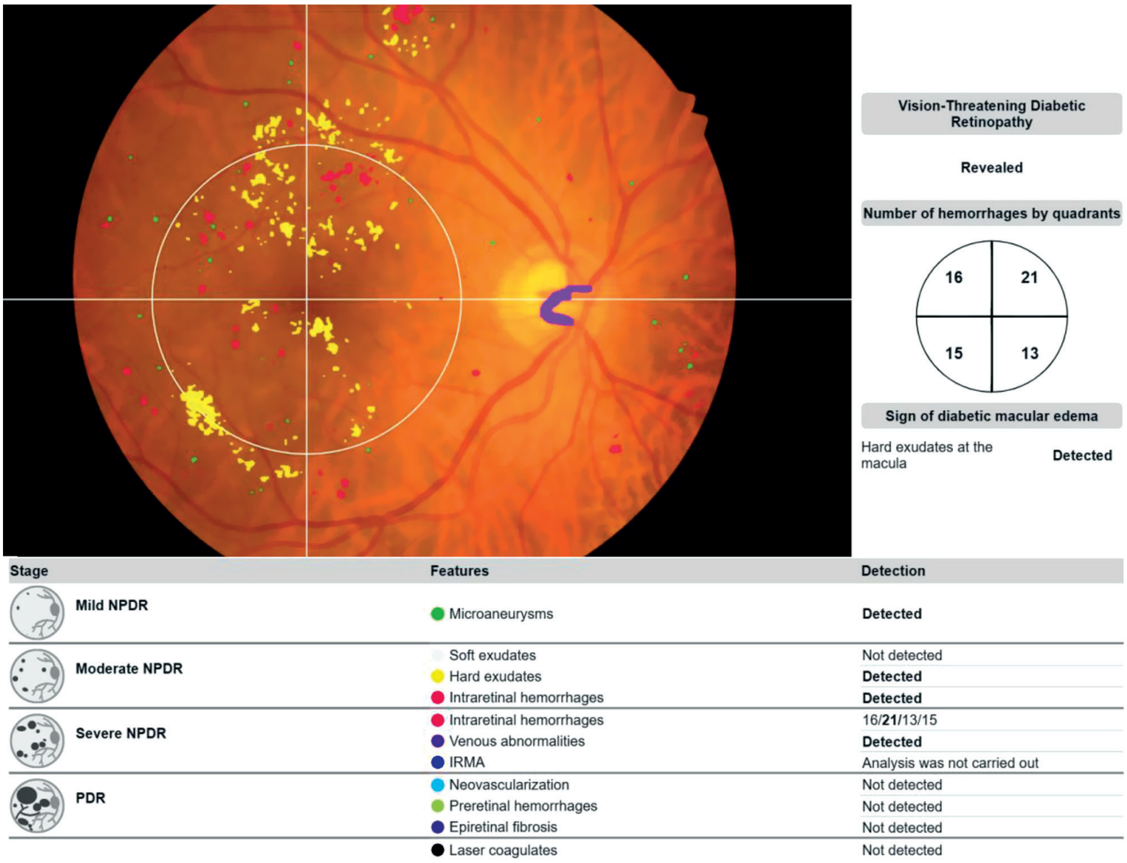

Figure 1. *Report of fundus image analysis by "Retina AI" system.*

neovascularization, fibrosis, signs of macular edema). The worst vision score was used for the final evaluation. The same anonymized images were uploaded to the "Retina AI" system cloud platform. A system based on a convolutional neural network architecture pre-trained in a wide data set with expert comments automatically generated a report. The report included: binary classification ("it is recommended to consult an ophthalmologist" / "pathology is not identified"), evaluation of the DR stage (similar to the classification of primary ophthalmologists), identification and localization of specific pathological features of DR (Figure 1). All figures were independently evaluated by two certified ophthalmologists with extensive experience in the diagnosis of eye diseases operating at the scientific and practical medical center of the Republican Specialized Scientific and Practical Medical Center for Eye Microsurgery. Experts used the same criteria as primary care ophthalmologists to classify DR and assess symptoms. Their imprisonment was regarded as the "gold standard".

Efficiency assessment: sensitivity and specificity for each key feature (microaneurysms, hemorrhages, exudate, macular edema, neovascularization, etc.), accuracy, Kappa coefficient for assessing consent with specialists (k). Confidence interval and significance level were calculated.

Results

250 patients (500 eyes) were examined, including 106 men and 144 women. The median age was 57 ± 1.27 years. 92.7% of patients were diagnosed with Type 2 diabetes. The average duration of DM is 12 ± 2.68 years.

According to Table 1, the "Retina AI" system showed statistically much higher sensitivity (72.8% versus 94.7%, $p < 0.001$) and accuracy (77.5% versus 93.5%, $p < 0.001$) compared to primary care physicians. The difference in specificity was also statistically significant (85.0% versus 91.3%, $p < 0.005$). The compliance of the "Retina AI" system with specialists had a kappa coefficient of 0.88, which indicates a "very good" compatibility. The agreement coefficient of Kapp between primary care ophthalmologists and specialists was 0.65, which corresponds to a "good" agreement. The difference between AI and ophthalmologists was statistically significant ($p < 0.001$)

In addition to assessing the overall diagnostic effectiveness of binary classification, a detailed analysis of the ability of the "Retina AI" artificial intelligence system to detect individual pathological signs of diabetic retinopathy in comparison with the conclusions of primary care ophthalmologists was carried out. The "gold standard" was adopted by two certified ophthalmologists by consensus.

The "Retina AI" system showed statistically significant higher sensitivity in detecting all major signs of DR. The most obvious advantage of the algorithm was noted when early microangiopathic changes were detected. Thus, sensitivity in detecting microaneurysms is 96.2% (95% CI: 91.5 – 98.5) versus 68.5% (95% CI: 60.1 – 76.0) in primary care ophthalmologists ($p < 0.001$). A similar advantage was noted for detection of hemorrhages: 94.8% (95% CI: 89.7 – 97.7) and 71.2% (95% CI: 62.8 – 78.6) ($p < 0.001$), respectively. These findings are consistent with the results of international studies, in which deep learning algorithms show remarkable efficacy in determining small and large number of changes in the fundus that are often overlooked in routine clinical examinations in the context of mass screening.

"Retina AI" system's sensitivity for solid exudates reached 92.5% (95% CI: 86.8 – 96.1) compared with 73.9% (95% CI: 65.7 – 80.9) for ophthalmologists. The algorithm's ability to reliably identify signs indicating the development of retinopathy and retinal ischemia is of particular clinical significance. Sensitivity in detecting cotton-like foci (indicating blockage of precapillary arterioles) was 89.1% (95% CI: 81.5 – 94.2), 23.8% points higher than primary care ophthalmologists (65.3%; 95% CI: 55.2 – 74.3).

Timely detection of complications that threaten vision is essential to prevent permanent loss of vision. The "Retina AI" system showed high efficacy in detecting clinically significant macular edema – 87.3% (95% CI: 78.5 – 93.2) versus 62.7% (95% CI: 51.9-72.4) in primary care ophthalmologists. The superiority of the algorithm in identifying signs of the proliferative phase of DR was equally important. Sensitivity was 85.3% (95% CI: 74.6 – 92.4) when neovascularization of the optic disc and/or retina was detected, compared to 58.8% (95% CI: 46.2 – 70.5) in the primary care group ($p < 0.001$). This parameter is key to timely prescribing panretinal laser coagulation and preventing serious complications such as hemophthalmos and tractional retinal detachment.

It should be noted that such high sensitivity was achieved without damage to the specificity. For all the pathological signs listed above, the specificity of the "Retina AI"

Table 1. *Diagnostic effectiveness of the binary classification of DR*

Parameter	*Primary care ophthalmologists*	*"Retina AI" system*	*p-value*
Sensitivity	72.8% (64.9% - 79.6%)	94.7% (89.2% - 97.8%)	< 0.001
Specificity	85.0% (76.4% - 91.4%)	91.3% (83.8% - 96.0%)	< 0.005
Accuracy	77,5% (71.1% - 83.1%)	93,5% (89.0% - 96.6%)	< 0.001

artificial intelligence system was preserved at very high level (from 93.5% for severe exudates to 99.5% for neovascularization), which minimizes false positive results.

Discussion

The findings are fully consistent with the results of major international validation studies such as the work of Gulshan et al. (2016), which demonstrate that modern algorithms based on convolutional neural networks not only achieve, but also exceed in sensitivity the level of training of primary care physicians in the diagnosis of others [12]. The high productivity demonstrated by "Retina AI" in actual primary care practice confirms its willingness to be widely used as a highly effective mass screening tool capable of reliably detecting the full spectrum of pathological changes in patients. The results of this study, carried out in the actual practice of primary care in the Syrdarya region, show the high diagnostic efficiency of the "Retina AI" artificial intelligence system in diabetic retinopathy screening. The presence/absence of other objects is important in the binary classification of sensitivity (94.7% vs. 72.8%) and overall accuracy (93.5% vs. 77.5%). This means that the AI system will miss significantly fewer cases, which is an important parameter for the screening program. The AI system allows the elimination of DR with high confidence in patients with negative outcomes, which reduces the unnecessary burden on ophthalmologists.

The high Kappa coefficient (k=0.88) between the classification of dr stages by the "Retina AI" system and the conclusions of ophthalmologists confirms the ability of the algorithm not only to determine the presence of pathology, but also to accurately determine its severity, which is important for the stratification of patients.in accordance with the relevance of treatment and urgency of referral to a specialist.

The system's ability to reliably detect a variety of pathological changes from early retinal signs (microaneurysms) to visual-threatening complications (neovascularization, macular edema) emphasizes its complexity and clinical significance. The advantage of AI is especially evident in determining changes that are almost imperceptible or easily overlooked.

Conclusion

The "Retina AI" artificial intelligence system has proven its high effectiveness in diabetic retinopathy screening among patients in the Syrdarya region and has significantly exceeded the assessment of primary care ophthalmologists in terms of basic diagnostic accuracy.

The algorithm demonstrates high accuracy both in binary classification of the presence of DR, in determining its stage, and in determining specific pathological changes in the retina.

The introduction of "Retina AI" technology into the primary medical and sanitary care system of the Syrdarya region seems to be a very promising and rational solution for optimizing the screening of people. This increases the coverage and timely execution of the detection of DR, optimizes the flow of patients sent to the ophthalmologist by accurate stratification in terms of the degree of severity, reduces the load on specialized ophthalmologists in the regional center and increases the availability of eye care for the population in remote areas of the region.

The results of the study confirm the potential of AI technologies as an effective tool for overcoming resource limitations in the organization of specialized medical care in regions with a shortage of personnel, such as the Syrdarya region.

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