ECRONICON OPEN ACCESS

EC OPHTHALMOLOGY
Research Article

Screening for Diabetic Retinopathy Using a Non-Mydriatic Fundus Chamber as Part of a Public Service in the Republic of Kazakhstan

Abdullina VR[1,2]* and Zhanibekuly E[3]

[1]National Educational Institution "Kazakhstan-Russian Medical University", Almaty, Republic of Kazakhstan

[2]Limited Liability Partnership "Lucy Clinic", Almaty, Republic of Kazakhstan

[3]EyeLab LLP, Nur-Sultan, Republic of Kazakhstan

***Corresponding Author:** Abdullina VR, Candidate of Medical Sciences, Senior Lecturer of the Kazakh-Russian Medical University, Department of Ophthalmology, The Kazakh-Russian Medical University, Republic of Kazakhstan.

Received: July 19, 2022; **Published:** August 24, 2022

Abstract

Relevance: Studies have shown that screening programs using digital retinal images, both with and without pupillary dilatation, can contribute to the early detection of diabetic retinopathy (DR). As an adequate replacement for seven-field photography, the use of a non-mydriatic fundus camera is proposed. To work out the method of remote screening for DR, EyeLab LLP developed a program with elements of artificial intelligence, which was the basis of our research.

Objective: To study the effectiveness of detecting DR in patients with type 1 and 2 diabetes when automating business processes for diagnosing DR based on fundus camera images using artificial intelligence technologies.

Materials and Methods: The study was conducted on the basis of the "City Polyclinic No. 14" (Almaty), where 145 patients with type 1 and type 2 diabetes were examined. Also, as part of the World Diabetes Day program on November 14, 2021, a screening campaign was held for children and adults with diabetes in the cities of Almaty and Nur-sultan. A total of 185 patients were examined, including 145 children. The patient's fundus was photographed using a non-mydriatic fundus camera and the ophthalmologist drew up a conclusion remotely using a program developed by EyeLab.

Results: Among the ophthalmic manifestations identified as a result of screening in patients with type 2 diabetes, the most common were complicated cataract (47.4%), DR in the non-proliferation stage (47.4%). DR in the preproliferation stage was found in 31.8% of patients, the proliferation stage in 12.1%. Diabetic macular edema was detected in 11.2% of patients. In patients with type 1 diabetes mellitus, DR in the preproliferation stage (62.1%) and DME (34.5%) were most common. Complicated cataract and proliferating DR were found in 31% of patients. Among the examined children of the city of Nur-sultan and Almaty, in most patients, no pathological changes in the organ of vision were found. As a result of screening, glaucoma and retinal tapetoretinal abiotrophy were detected for the first time in some patients. Vascular angiopathy occurred up to 27.3%, among the refractive errors, myopia was detected.

Conclusion: Thus, domestic software has been created that allows: 1) to provide services remotely 2) to apply artificial intelligence algorithms.

Keywords: *Screening; Diabetic Retinopathy; Diabetes Mellitus; Artificial Intelligence; Neural Networks*

Introduction

The number of patients with diabetes mellitus (DM) is currently steadily increasing both worldwide and in the Republic of Kazakhstan (RK). According to the World Bank, Kazakhstan ranks 119th in the world in terms of the prevalence of diabetes mellitus, which is 6.1%. According to the information system "National Register "Diabetes Mellitus" of the Ministry of Health of the Republic of Kazakhstan, the incidence of diabetes mellitus in the Republic of Kazakhstan increased by 12.1% in 2018 - 2020 [1-3].

According to the large-scale Russian epidemiological study NATION, in the Russian Federation, the true number of patients is more than 2 times higher than the number of detected ones. The danger lies in the fact that patients with an untimely diagnosis of diabetes will not be able to receive the necessary treatment at the optimal time [4,5].

Diabetic retinopathy (DR) is a chronic progressive disease affecting retinal microvessels that develops in patients with DM. DR is the leading cause of vision loss among the working population. A difficult problem in the diagnosis and treatment of DR is its asymptomatic progression. Treatment of this pathology, started in the early stages of the disease, is more effective than already at the proliferative stage (PDR) and with the development of clinically significant macular edema (CMDE). That is why early detection of DR is relevant for prescribing timely treatment and minimizing the complications of the disease, leading to blindness and low vision in the working population [6-9].

One of the most important methods for early detection of DR is screening, a diagnostic procedure performed in patients at risk (with an established diagnosis of DM) in order to identify retinal lesions that require additional examination and treatment. The screening program for the detection of various pathologies must meet a number of criteria:

1. Simplicity.
2. Accuracy and reproducibility.
3. Price.
4. High sensitivity and specificity [10].

To identify the displayed biomarkers, screening studies are often carried out [9-13].

However, on average, 40 to 60% of patients with DM do not undergo annual screening for DR. The reasons for not screening are numerous: the cost of screening; discomfort from pupil dilation and bright light needed for retinal examination; remoteness of the venue and the need to waste time [11,12].

Studies have shown that screening programs using digital retinal images, both with and without pupillary dilatation, can contribute to the early detection of DR. The most informative method for diagnosing and determining the severity of DR was the seven-field retinal stereophotography used in the ETDRS studies. Despite the high information content and reproducibility of this method, its use is not practical. This is due to the complexity, the need to have special equipment and qualified personnel, which requires significant financial costs. In addition, this procedure takes a lot of time for the patient. As an adequate replacement for seven-field photography, many other variants of retinal photography have been studied, differing mainly in the number and location of fields, as well as the viewing angle of digital cameras [13-16].

In recent years, there has been an increase in the development of information technologies and the gradual introduction of artificial intelligence of artificial neural networks in the diagnosis of pathology of the organ of vision [17-20].

Neural networks (NS - Neural Networks) are mathematical models that work on the principle of networks of nerve cells in an animal organism. Artificial NNs (INS) can be implemented in both programmable and hardware solutions [18].

Thus, the use of artificial intelligence in screening for the detection of DR in patients with type 1 and 2 diabetes using fundus photography is relevant.

Purpose of the Study

The purpose of the study is to study the effectiveness of detecting DR in patients with type 1 and 2 diabetes when automating business processes for diagnosing DR based on fundus camera images using artificial intelligence technologies.

Materials and Methods

The main purpose of the System proposed by Eylab (Figure 1) is the formation of a new diagnostic workflow for detecting retinal pathology based on fundus camera images, which allows the ophthalmologist to remotely analyze fundus images as part of the provision of the state medical service "Fundus photography (1 eye)" (Figure 2).

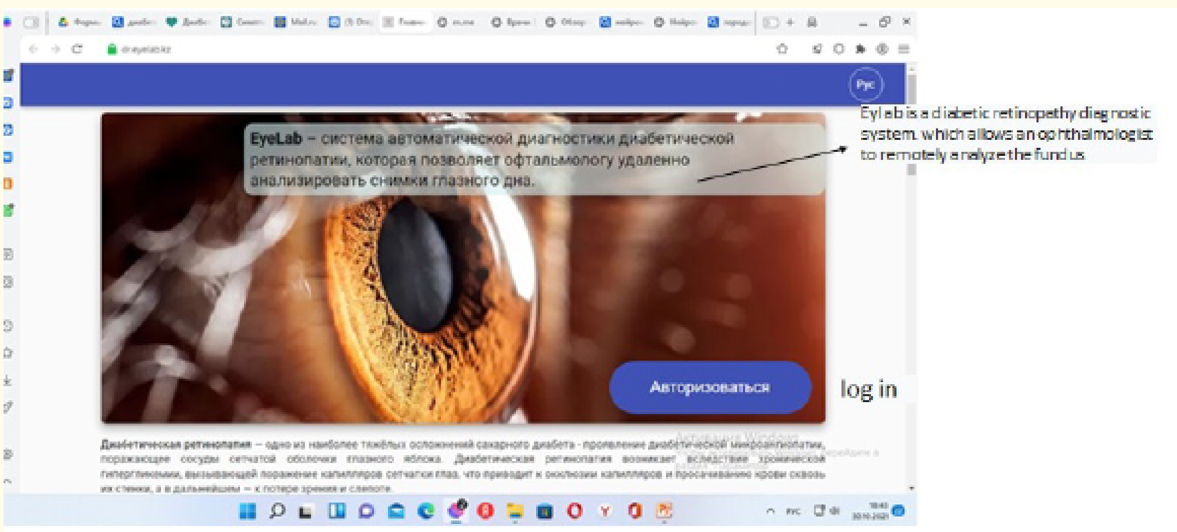

Figure 1: *Artificial intelligence system developed by Eylab employees.*

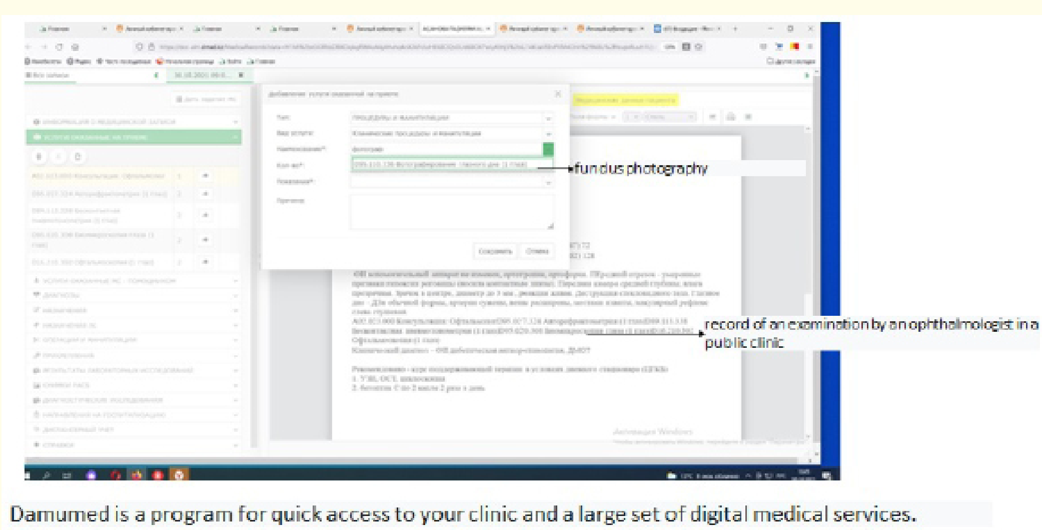

Figure 2: *Provision of medical services within the framework of the state.*

The system is based on an algorithm using neural networks (artificial intelligence) to detect and diagnose retinal pathologies by analyzing fundus photographs obtained using a fundus camera (Figure 3).

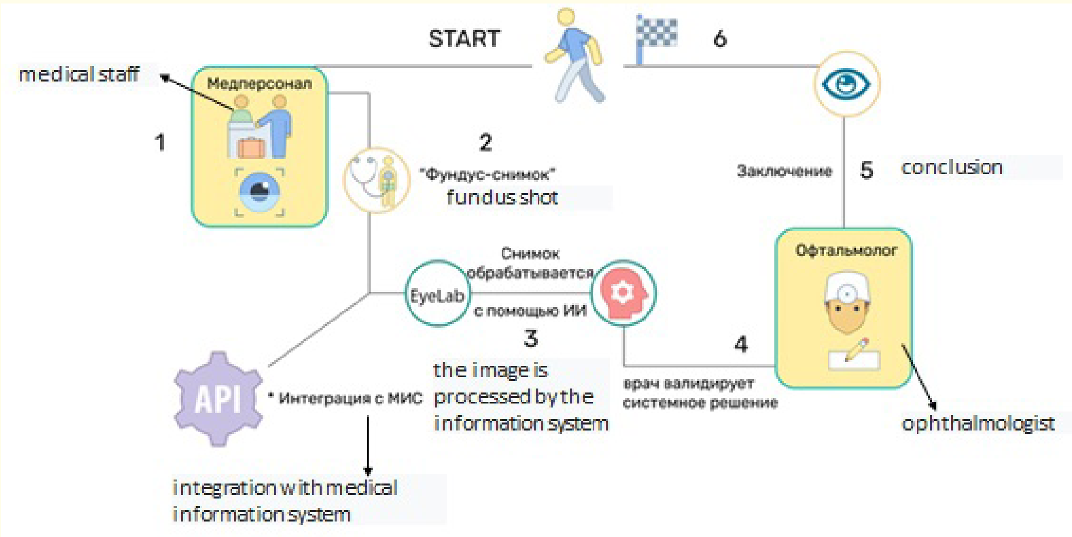

Figure 3: *Model of the system.*

Detection of lesions in fundus images using artificial intelligence helps to detect diabetic retinopathy at an early stage. The model of a convolutional neural network used to create an artificial intelligence neural network is shown in figure 4.

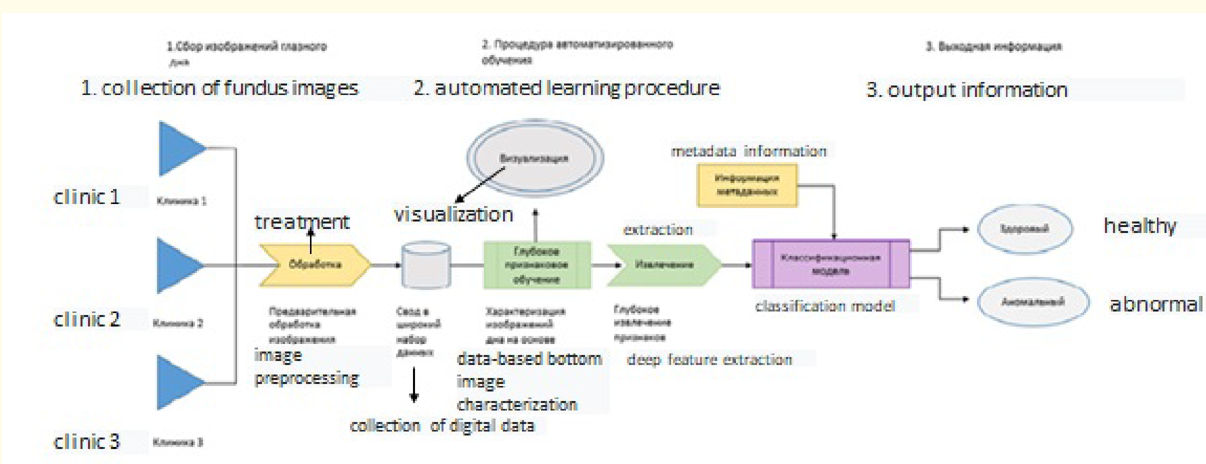

Figure 4: *Model of a convolutional neural network used to create an artificial intelligence neural network.*

The study was conducted on the basis of the State Enterprise on the REM "City Polyclinic No. 14" (Almaty). There were 145 patients with various ophthalmological manifestations of diabetes mellitus on the dispensary registration of the ophthalmologist of the State Clinical Hospital on the REM "City Polyclinic No. 14". 80% (116 people) were patients with type 2 diabetes, 20% (29 patients) - type 1. The age of the surveyed population is presented in table 1 and 2.

No.	Age	Men		Women	
		Abs numbers	%	Abs number	%
1	40-50 years old	13	25	14	22
2	51-60 years old	19	36	30	47
3	61-70 years old	16	31	15	23
4	71-80 years old	4	8	5	8
5	Total	52	100	64	100
			45		55

Table 1: *Adult population with type 2 diabetes.*

No.	Age	Men		Women	
		Abs numbers	%	Abs number	%
1	20-30 years old	9	56,2	9	69,2
2	30-40 years old	5	31,3	4	30,8
3	40-50 years old	2	12,5	-	-
	Total	16	55,2	13	44,8

Table 2: *Adult population with type 1 diabetes.*

As can be seen from table 1 and 2, the age of the surveyed population ranged from 20 to 72 years.

EYlab campaign employees, together with doctors from the Department of Ophthalmology of the KRMU, conducted a remote screening campaign for children and adults with diabetes in Almaty and Nur-Sultan. A total of 185 patients were examined, including 145 children (45 (31.03%) children in Almaty and 100 (68.97%) patients in Nur-sultan). Boys were 70 (48.27%) patients, girls - 75 (51.73%). Adults were 40 people, men were 15 (37.5%), women - 25 (62.5%). The age of the children ranged from 1 to 18 years. The age of the adult population ranged from 45 to 65 years. The number of patients by age is presented in table 3 and 4.

Age	Almaty				Nur-sultan				Total	
	Boys		Girls		Boys		Girls		Abs number	%
	Abs number	%	Abs number	%	Abs number	%	Abs number	%		
Up to 1 year	0	0	0	0	0	0	0	0	0	0
1-3	1	4,36	2	9,1	0	0	1	1,9	4	2,8
4-6	3	13,04	1	4,55	4	8,5	4	7,55	12	8,3
7-9	3	13,04	1	4,55	6	12,8	7	13,3	17	11,7
10-13	10	43,48	12	54,6	25	53,2	28	52,8	75	51,7
14-16	3	13,04	4	18,2	10	21,2	9	16,9	26	17,9
17-18	3	13,04	2	9,0	2	4,3	4	7,55	11	7,6
Total	23	51,1	22	48,9	47	47	53	53	145	100
				45					100	

Table 3: *The contingent of the surveyed child population (with type 1 diabetes mellitus) in the cities of Almaty and Nur-sultan by age.*

As can be seen from table 1, the largest number of children were examined at the age of 10-13 years (51.7%). The smallest number of children were examined at the age of 1 - 3 years (2.8%) (Figure 1).

Age	Almaty				Nur-sultan				Total	
	Men		Women		Men		Women		Abs number	%
	Abs number	%	Abs number	%	Abs number	%	Abs number	%		
45-50	1	25	2	50	4	40	3	11,5	10	25
51-55	0	0	1	25	2	20	12	46,2	15	37,5
56-60	0	0	0	0	3	30	6	23,1	9	22,5
61-65	0	0	0	0	1	10	5	19,2	6	15
Total	1	25	3	75	10	27,8	26	72,2	40	100
				4					36	

Table 4: *The contingent of the surveyed adult population (with type 2 diabetes mellitus) in the cities of Almaty and Nur-sultan by age.*

As can be seen from table 4, the largest number of examined patients were aged 51 - 55 (37.5%) and 45 - 50 (25%) years.

Fundus photography was performed with a non-mydriatic manual fundus camera. The mobile version of the fundus camera made it possible to take pictures of the fundus in any position of the patient. Viewing Angle: 45 Degrees. Camera resolution: 1920x1080 pixels. Fundus lighting: two modes - white LED and infrared LED (Figure 5).

Figure 5: *Non-mydriatic manual fundus camera.*

After photographing, the obtained data were entered into the system. The ophthalmologist remotely logged in with his individual login and password to the patient examination log (Figure 6).

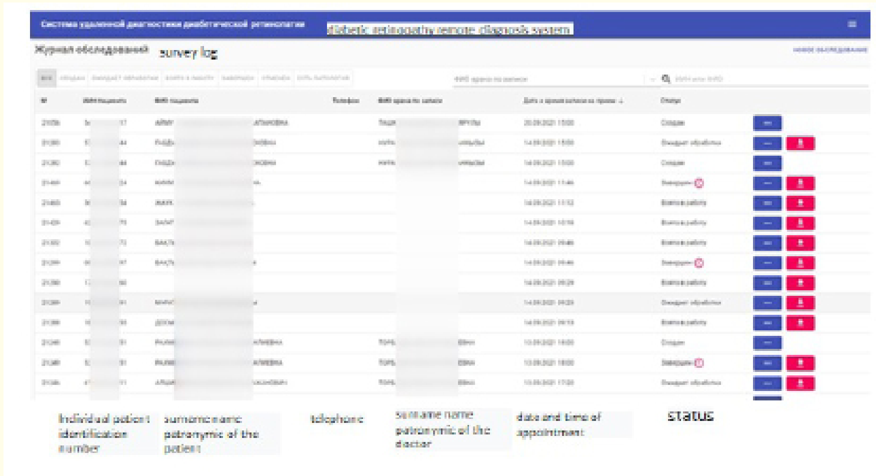

Figure 6: *Journal of examinations of patients.*

By pressing the red button of the opened panel, the doctor confirmed the beginning of the formation of the conclusion for this patient. Then a panel appeared in front of him with all the individual data of the patient and photographs of the fundus (Figure 7).

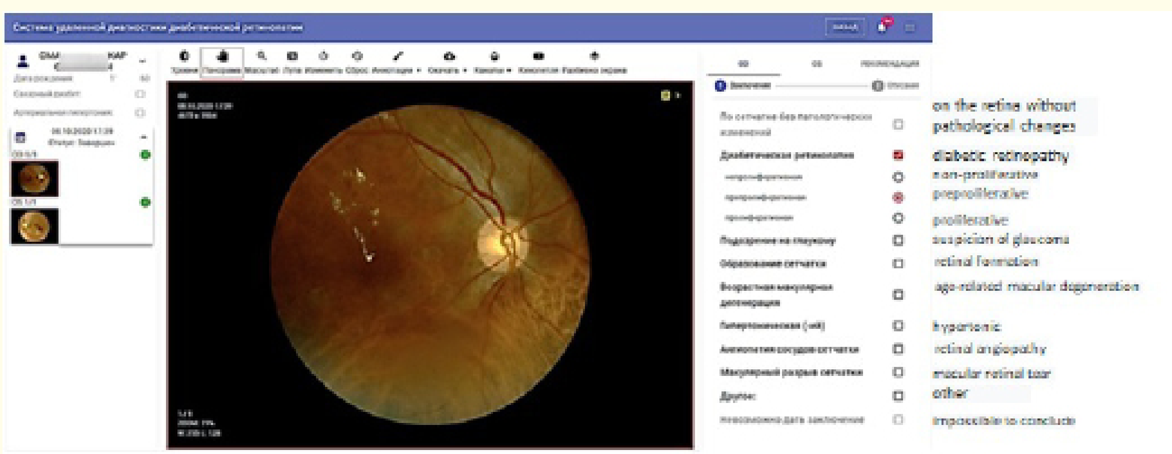

Figure 7: *Information data of the patient with photographs of the fundus.*

In the course of adjusting the program, the interface was improved (color filters were added (Figure 8), the software module was expanded in terms of increasing the possibility of description (Figure 9), a local zoom was added for a clearer examination of certain areas (Figure 10).

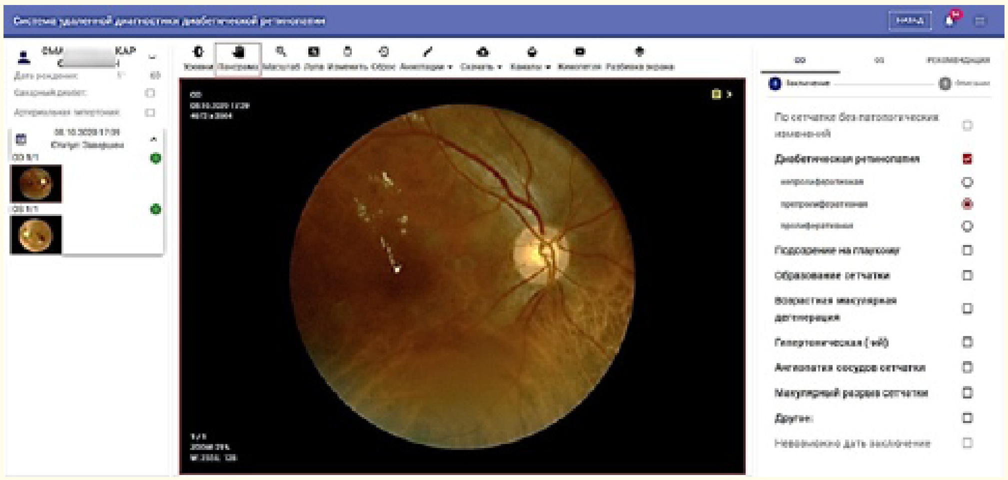

Figure 8: *Color filters when looking at photographs of the fundus.*

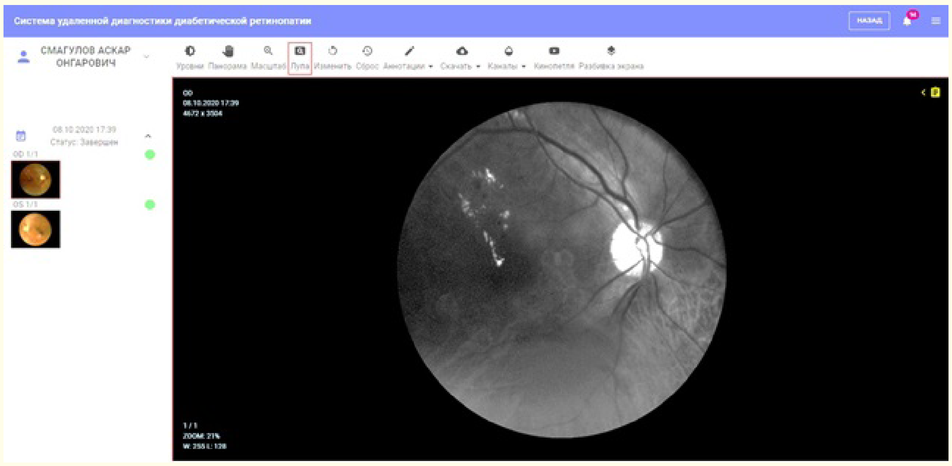

Figure 9: *Extension of the software module when describing the fundus.*

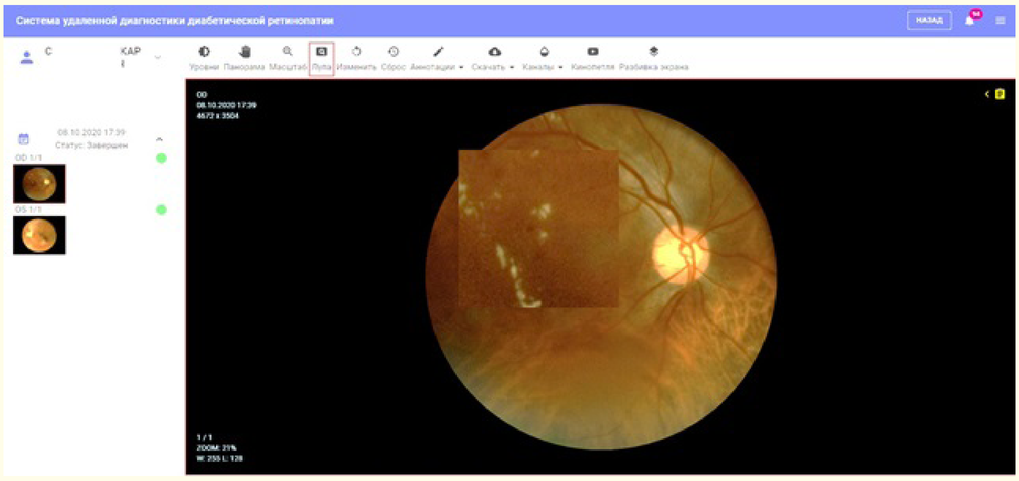

Figure 10: *Adding local magnification for a clearer view of certain areas.*

The results of the examination were stored in the form of a summary table containing individual patient data, conclusion, recommendations and photographs of the fundus (Figure 11).

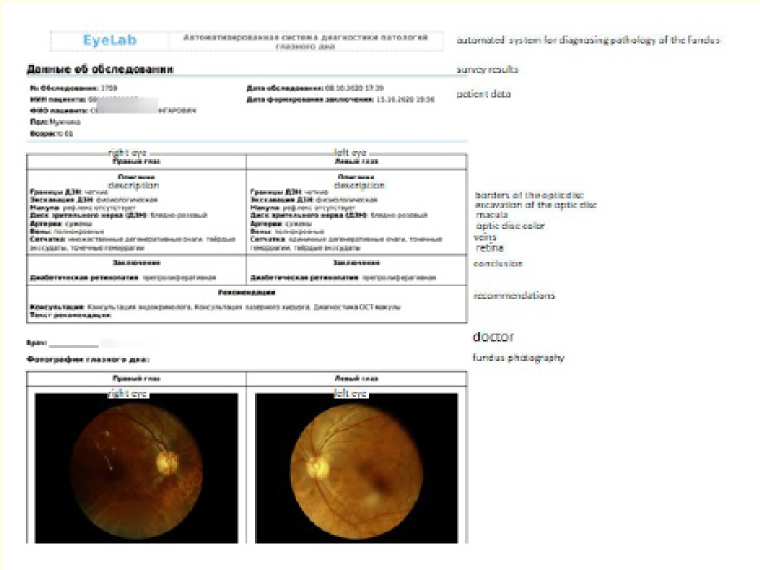

Figure 11: *Conclusion containing the results of screening.*

Also, the obtained data were prepared for the further formation of a register of patients with diabetic retinopathy in the Republic of Kazakhstan.

The research results were subjected to static processing using the Excel program.

Research Results

Among the ophthalmic manifestations identified as a result of screening in patients with type 2 diabetes, the most common were complicated cataract (47.4%), DR in the non-proliferation stage (47.4%). DR in the preproliferation stage was found in 31.8% of patients, the proliferation stage in 12.1%. Diabetic macular edema was detected in 11.2% of patients (Figure 12).

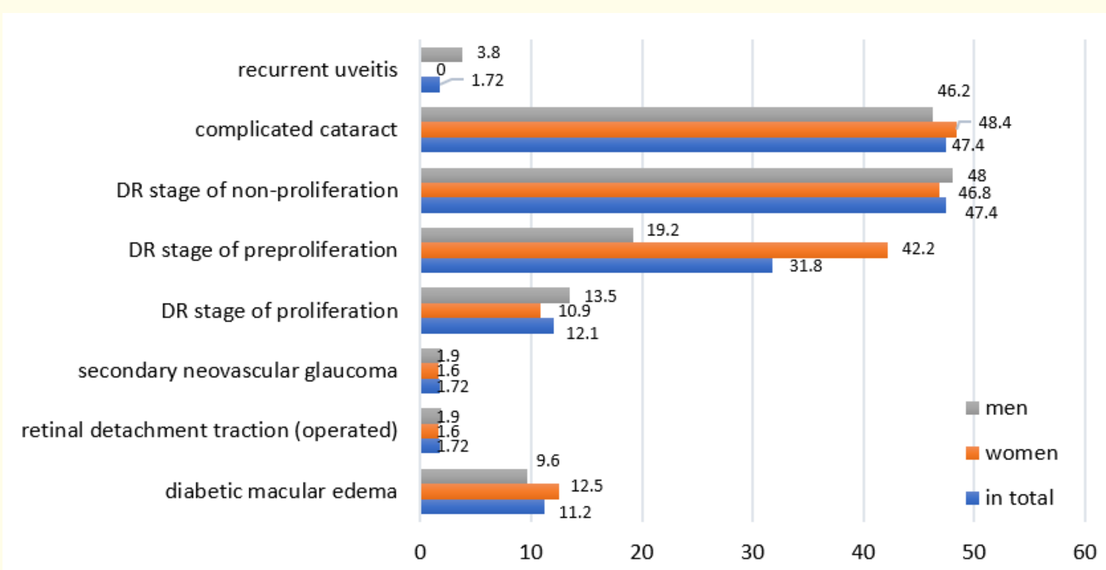

Figure 12: *The structure of ophthalmic manifestations in patients with type 2 diabetes.*

In patients with type 1 diabetes mellitus, DR in the preproliferation stage (62.1%) and DME (34.5%) were most common. Complicated cataract was found in 31%, and proliferating DR was also found in 31% of patients (Figure 13).

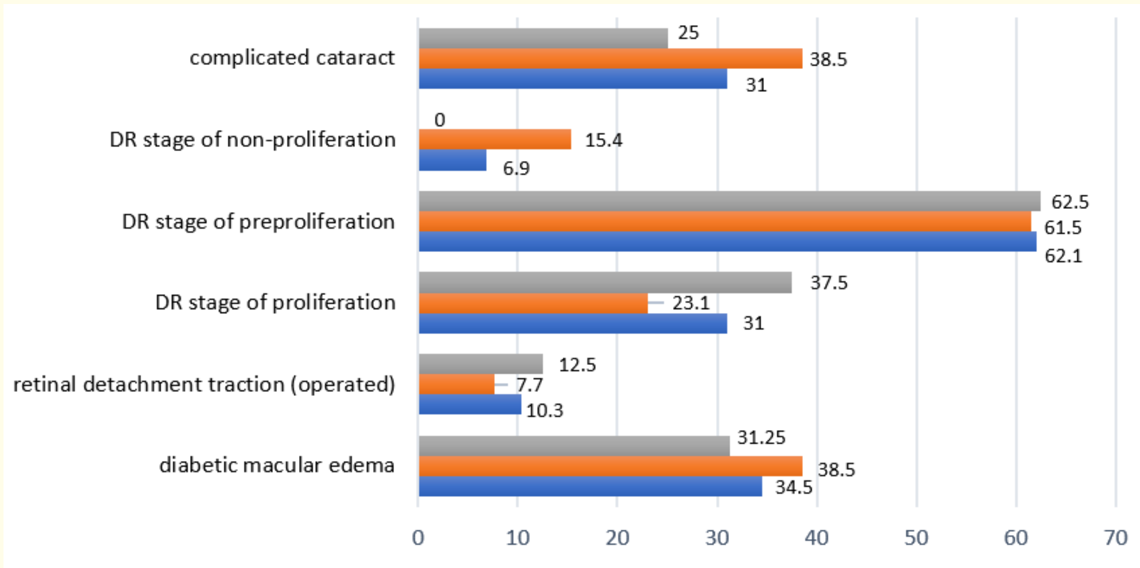

Figure 13: *The structure of ophthalmic manifestations in patients with type 1 diabetes.*

Among the examined children of the city of Nur-sultan and Almaty, in most patients, no pathological changes in the organ of vision were found. As a result of screening, glaucoma and retinal tapetoretinal abiotrophy were detected for the first time in some patients. Vascular angiopathy occurred up to 27.3%, among the refractive errors, myopia was detected (Figure 14 and 15).

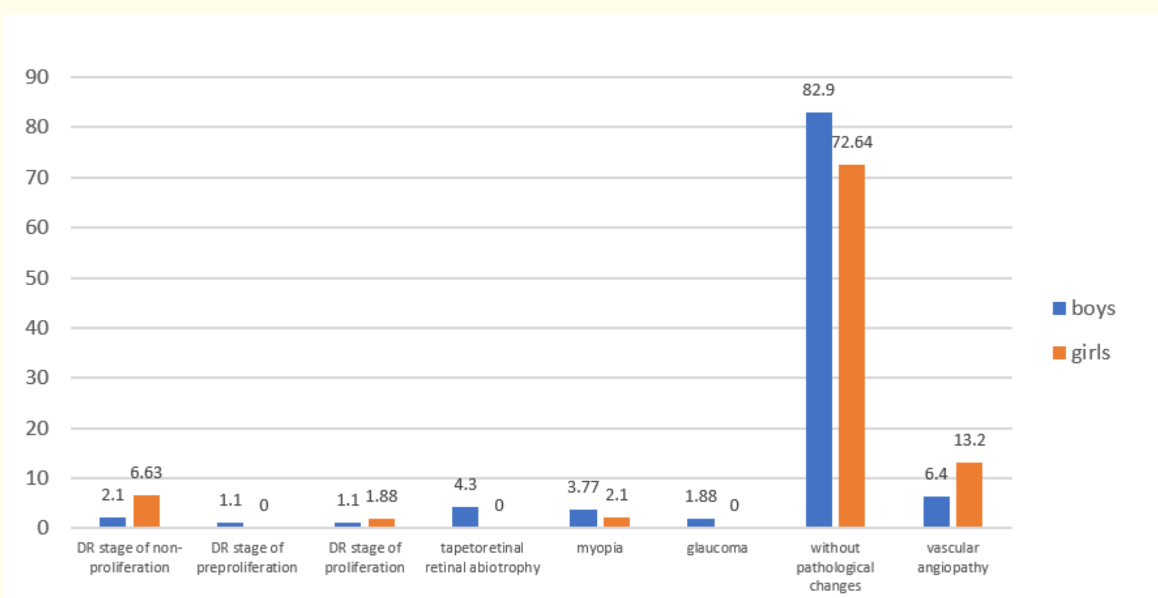

Figure 14: *The structure of the revealed pathology on the part of the organ of vision in children suffering from type 1 diabetes mellitus in Nur-sultan.*

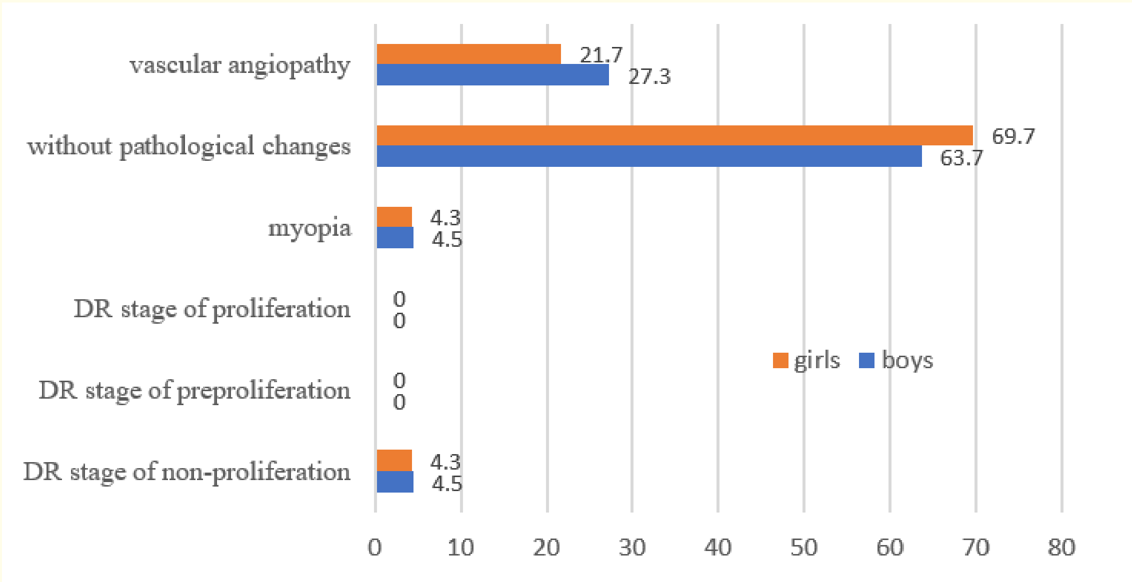

***Figure 15:** The structure of the revealed pathology on the part of the organ of vision in children with type 1 diabetes mellitus in Almaty.*

The structure of the revealed pathology on the part of the organ of vision in adults suffering from type 2 diabetes mellitus in the cities of Almaty and Nur-sultan is presented in table 5.

No.	Nosology	Total	
		Abs	%
1	Vascular angiopathy	12	30
2	No pathological changes	14	35
3	DR non-proliferation stage	4	10
4	DR st preproliferation	8	20
5	DR st proliferation	2	5
	Number of patients	40	100

***Table 5:** The structure of the revealed pathology on the part of the organ of vision in adults suffering from type 2 diabetes mellitus in Almaty and Nur-sultan.*

As can be seen from table 5, among the examined adult patients, DR in the preproliferation stage occurred in 20%, and DR in the proliferation stage in 5% of patients.

When forming and concluding, the system contained the following recommendations: examination by an ophthalmologist (frequency of examination), additional examination methods (OST angiography, ultrasound, EFI), consultation of other specialists (neuropathologist, nephrologist, etc).

Thus, screening made it possible to identify not only ophthalmic signs of DM, but also concomitant general and eye diseases. This technique, using artificial intelligence, allows diagnosing and monitoring diabetic changes in the organ of vision remotely and efficiently. Among the identified ophthalmic pathologies in patients with type 2 diabetes, complicated cataracts were relatively more common (46.2%), in patients with type 1 diabetes, changes in the retina (DME - 31.25%, PPDR - 62.5%, PDR - 37.5%).

Discussion

The introduction of the System for Remote Diagnosis of Diabetic Retinopathy allows solving many problems both on the part of patients and healthcare institutions. One of the most acute problems is the understaffing of institutions with ophthalmologists capable of examining and diagnosing DR and the inability to track the history of the disease - historical images are not saved. Such problems are present not only in districts and regions, but also in regional centers. Undoubtedly, the system has a number of advantages in the form of high economic efficiency with early detection of signs of DR, reducing the burden on medical personnel, reducing labor intensity and increasing the accuracy and reliability of the examination.

Thus, domestic software has been created that allows: 1) to provide services remotely 2) to apply artificial intelligence algorithms.

Conclusions

1. The main purpose of the System is the formation of a new diagnostic workflow for diagnosing retinal pathologies based on fundus camera images, which allows an ophthalmologist to remotely analyze fundus images as part of the provision of the medical service "Fundus photography (1 eye)".

2. The system is based on an algorithm using neural networks (artificial intelligence) to detect and diagnose retinal pathologies by analyzing fundus photoimages obtained using a fundus camera, which will increase the efficiency of doctors conducting examinations. This will save financial resources, reduce the waiting time for an appointment with an ophthalmologist, and also solve the problem of the lack of a sufficient number of qualified specialists.

3. Through the introduction of the system in public clinics, universal coverage of the population for screening for diabetic retinopathy will be ensured.

4. In the future, the software will increase the accuracy of the diagnosis, eliminating the "human factor".

Conflict of Interest

The authors declare the absence of obvious and potential conflicts of interest related to the content of this article.

Financing Support

The work was done on the initiative of the authors without attracting funding.

Author's Contribution

Abdullina VR: Collection and processing of materials. Analysis of the received data, writing the text.

Zhanibekuly E: Concept and design of the study.

Bibliography

1. Guidelines for managing diabetes based on the International Diabetes Federation (IDF) Diabetes Atlas 9th edition (2019).
2. Akanov ZhA. What the study "The Burden of Diabetes in the Republic of Kazakhstan" showed.
3. Seydinova ASh., *et al*. "Epidemiology of diabetes mellitus in the world and the Republic of Kazakhstan (review article)". *Bulletin of KazNMU* 1 (2018): 250-253.
4. Zhernakova YuB., *et al*. "The prevalence of diabetes mellitus in the population of patients with arterial hypertension. According to the ESSE-RF study". *Systemic Hypertension* 15.1 (2018): 56-62.
5. Dedov I., *et al*. "Prevalence of type 2 diabetes mellitus (T2DM) in the adult Russian population (NATION study)". *Diabetes Research and Clinical Practice* 115 (2016): 90-95.
6. Cheung N., *et al*. "Diabetic Retinopathy". *Lancet* 376.9735 (2010): 124-146.
7. Sinclair SH and Delvecchio C. "The internist's role in managing diabetic retinopathy: screening for early detection". *Cleveland Clinic Journal of Medicine* 71.2 (2004): 151-159.
8. Abdullina V.R., *et al*. "Refractive anomalies in children with type 1 diabetes". *Medicine and Ecology* 4.97 (2020): 59-64.
9. Bikbov MM., *et al*. "Influence of refraction and axial length of the eye on the development and progression of diabetic retinopathy". *Clinical Ophthalmology* 21.4 (2021): 205-209.
10. Abdullina VR and Stepanova IS. "The results of the use of functional research methods in children with type 1 diabetes mellitus depending on the level of glycated hemoglobin". *RMJ Clinical Ophthalmology* 22.2 (2022): 99-102.
11. Pyadushkina EA., *et al*. "Foreign recommendations for the early detection of chronic non-communicable diseases: the experience of the UK and the USA". Medical technologies. Evaluation and Choice 3.25 (2016): 20-33.
12. Miroshnichenko II and Ptitsina SN. "Biomarkers in modern biomedical practice". *Biomedical Chemistry* 55.4 (2009): 425-440.
13. Budzinskaya MV., *et al*. "Biomarkers in diabetic retinopathy". *Diabetes Mellitus* 23.1 (2020): 88-94.
14. Abramoff MD., *et al*. "Automated analysis of retinal images for detection of referable diabetic retinopathy". *JAMA Ophthalmology* 131.3 (2013): 351-357.
15. Early Treatment Diabetic Retinopathy Study Research Group. "Fundus photographic risk factors for progression of diabetic retinopathy. ETDRS report number 12". *Ophthalmology* 98.5 (1991): 823-833.
16. Stefansson E., *et al*. "Screening and prevention of diabetic blindness". *Acta Ophthalmologica Scandinavica* 78.4 (2000): 374-385.
17. Sergeev YuA., *et al*. "The use of neural networks in medicine. Comparison of methods of neural network and group analysis of pathologies". *Scientific and Educational Journal for Students and Teachers* 9 (2021): 1-9.
18. Andreeva EA. "Optimal control of dynamic systems". Tver. TVGU (2016):144.
19. Vyucheyskaya MV., *et al*. "Neural network technologies in the diagnosis of diseases". M.: Journal of Medical and Biological Research (2018): 284-294.
20. Katalevskaya EA., *et al*. "Prospects for the use of artificial intelligence in the diagnosis and treatment of retinal diseases". *BC Clinical ophthalmology* 22 (2022): 36-43.

Volume 13 Issue 9 September 2022