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Research Article

Application of optic coherence tomography as a screening in prevention and control of diabetic retinopathy

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Abstract

Background. Diabetes mellitus is a leading cause of death, disability, and adult blindness from diabetic retinopathy worldwide. Recent studies have provided a better understanding of the disease process and have opened new doors for prevention and treatment.

The **aim** of our study is to evaluate the effectiveness of the current screening methods for prevention and control of dia-betic retinopathy and to create a program for optimization.

Material and methods. We included 123 patients with type 1 and type 2 diabetes mellitus. Clinical characteristics of the population were collected from patients' files. The HbA1c level was measured.

Results. Among examined cohort group – 45% are with diabetes type 1 and 55% with diabetes type 2. In distribution by gender the prevalence is for males. The biggest part of the participants in our study is in the age group 45–66 years old. In 94% of the patients the duration of the disease is between 3–10 years. 22% of the pa-tients are with non-proliferative diabetic retinopathy (NPDR), 45% with proliferative diabetic retinopathy (PDR) and 33% with diabetic macular edema (DME).

Conclusion. Our opinion is that the current ophthalmologic devices, such as fundus cameras and OCT (multimodal imaging), should be incorporated in the process of screening for diabetic retinopathy due to the detailed information they provide and the short time to perform the procedure.

Keywords

screening, diabetic retinopathy, prevention, control

Introduction

Diabetes mellitus is a leading cause of death, disability and blindness worldwide (Kropp et al. 2023). According to the World Health Organization (WHO), currently 285 million people in the world suffer from diabetes, and it is predicted that by 2030 they will reach 439 million. According to the US Centers for Disease Control and Prevention, 18 million Americans have been diagnosed with diabetes, and 6.4 million have it but are undiagnosed. Diabetic retinopathy is a microvascular complication of diabetes mellitus (DM) type 1 and diabetes mellitus type 2, which develops in almost all patients 15 years after the diagnosis was made. In the last 20 years, diabetic retinopathy has become the leading cause of impaired vision in working age in developed countries - in 2% it leads to blindness, and in 10% it leads to severe visual deficit (VA below 0.1) (Kropp et al. 2023). Vision loss can be prevented with strict control and evaluation of the course of the disease. However, only half of diabetics receive even an annual eye exam. Nowadays, the terms "disease prevention and health promotion" have become very popular. The idea of prevention is clear – primary prevention means preventing the development of the disease, and secondary prevention means stopping the progression of the disease. "Promotion" means "the action of assisting, encouraging, supporting the growth or development of something" (Webster's 9th Dictionary, 1984). According to the WHO definition of April 7, 1948, health is defined as "a state of complete physical, mental and social well-being and not merely the absence of disease" - i.e. the term 'health' is a positive concept. In this sense and according to modern trends in public health, the connection between the positive concept and the idea of disease prevention is extraordinarily strong.

According to us, successful prevention depends on the following: knowledge about the disease, its development dynamics, identification of risk factors and groups, early detection and treatment, control organization, and the continuous evaluation of the development of the processes that have occurred.

Diabetic retinopathy (DR) is the most common complication of diabetes mellitus and is among the leading causes of blindness worldwide (Kropp et al. 2023). Recent studies have provided a better understanding of the disease process and opened new doors for prevention and treatment (Sikorski et al. 2013; Chakrobortyet al. 2021; Estaji et al. 2023). There are many effective therapeutic options if diabetic retinopathy is detected early, during the asymptomatic phase. For this reason, screening programs for the early detection of diabetic retinopathy are an essential part of diabetic care. Several basic screening models have been developed. In recent years, diabetes mellitus has been seen as a pandemic that causes many complications. Diabetes mellitus is considered the greatest disease of the XXI century, although it has been said: "What was HIV in the last 20 years of the XX century, will be the diabetes mellitus in the first 20 years of the XXI century." A big "credit" for this is the increasing number of type 2 diabetes.

The Optic Coherence Tomography (OCT) was first described in 1989 by scientists from Harvard University and Massachusetts Institute of Technology. In 1994 the technology was patented by Carl Zeiss Meditec, Inc (Dublin, California) and in 1996 the first OCT was commercially available. OCT is technology that allows the practitioner to obtain cross-sectional images of the retina by reconstruction of the scattered light. The principle of working of OCT is similar to ultrasound imaging but with a crucial difference: it's using light instead of sound – a low-coherence interferometry. The reconstruction of retinal layers is based on detection of the echo time delay and magnitude of backscattered light reflected (Fujimoto et al. 2023).

The first articles to describe the role of the OCT in the diagnosis of retinal diseases were published in 1993 (Swanson et al. 2013).

Since its initial stages, OCT has passed enormous steps towards perfection and has become more reliable in its informativeness and the quality of its images. The standard OCT provides only structural information about the morphology. Various OCT extensions have been developed in recent years to provide functional information, such as:

- Polarization-sensitive OCT (PS-OCT) (Boer et al. 2013)
- OCT-Angiography (OCT-A) with its different modalities: speckle variance OCT, amplitude decorrelation and phase-variance OCT (Chen at al. 2017)
- Multi-contrast Jones matrix OCT (JMT system) (Chen et al. 2022)

Many of the described techniques have been incorporated into deep-learning automated methods for assessment of diabetic retinopathy, based on artificial intelligence (Lu et al. 2021).

A full description of the principles of work of all these techniques is beyond the scope of this paper. Therefore, we restrict our focus to the standard OCT. In the last two decades the importance of OCT imaging grew enormously due to its fast acquisition, non-invasiveness, high quality, and detailed information. Numerous studies describe the practical and clinical advantages of OCT in diagnosis, follow-up, and evaluation of the treatment effect and evolution of diabetic retinopathy (Sikorski et al. 2013; Chakrobortyet al. 2021).

Aim and scope

As a standard in Bulgaria, every diabetic patient must be examined by an ophthalmologist once a year by examining of the ocular fundus and performing fluorescein angiography, the combination of the two remaining the gold standard for the evaluation of diabetic retinopathy to this day. Fluorescein angiography is broadly recognized as an important tool in the diagnosis and treatment of DR. However, it requires venipuncture, and reports of anaphylaxis and death related to contrast injections, although rare, have been documented. In addition, the technique is costly and time-consuming, requiring up to 10 min for framing acquisition.

The main purpose of the present study is to evaluate the effectiveness of the current model for the prevention and control of diabetic retinopathy in Bulgaria and to use the results to make a pilot project for incorporation of multimodal imaging techniques (fundus cameras, optic coherence tomography-angiography (OCT) to detect every early sign of DR and minimalize the health consequences for the population.

Materials and methods

The cohort consists of 123 patients with diabetes mellitus, who passed through our Ophthalmology Department for a period of two months.

They are subdivided into two groups of patients: the first group includes patients with DM type 1 and the second group - with DM type 2. A questionnaire was distributed to collect: demographic data (such as gender, age, whether they live in the capital or in the countryside, as well as duration of the disease) to evaluate the patients' accessibility to specialized medical care - whether they undergo regular ophthalmic control, or if they seek a specialist in eye diseases if complications of the disease have already occurred; if the patients' first visit to the eyecare practitioner is triggered by vision loss (e.a. possible complications that have already occurred). Our aim is to clarify the reasons that led to the delay in contact with an ophthalmologist.

All the patients included in this study underwent full ophthalmic examination:

- Best corrected visual acuity – examined with the Snellen chart
- Tonometry – IOP is measured with contactless "air-puff" tonometer (Nidek NT-530/510)
- Biomicroscopy – to evaluate the anterior segment of the eye for other pathology (such as blepharitis, dry eye, inflammatory diseases, corneal dystrophies and cataract)
- Fundobiomicroscopy with 90 D indirect lens in pharmacologically dilatated pupils – to evaluate the posterior segment of the eye and presence or absence of ophthalmoscopy signs of DR.

Additionally, to this classic and "basic" visit, to every patient was performed also:

- OCT and photo of the fundus, using TOPCON 3D OCT-2000 System, which was the first spectral domain (SD) OCT to combine a high resolution non-mydriatic fundus camera in a single device. Hard exudates, cotton wool spots and epiretinal membranes are characterized with specific hyper-reflectivity, whereas diabetic macular edema shows hyporeflectivity.

All the patients who had concomitant ocular disease (corneal dystrophy, non-neovascular glaucoma etc.) were excluded from the study.

Results

Only 37% of the patients are resident in a capital city, and the rest – in the province.

We also collected data about previous endocrinologic and ophthalmic visits, as well as treatment regimens (by the questionnaire mentioned in the "Materials and methods" section).

Table 1. Specifications of TOPCON 3D OCT-2000 System – credits to ©2014 Topcon Medical Systems, Inc.

Specifications	
Field Angle	45°
Working Distance	40.7 mm
Pupil Diameter	≥ 3.3 mm for Fundus image
Scanning Range	8.2 × 3.0 mm, 6.0 × 6.0 mm, 4.5 × 4.5 mm or 3.0 × 3.0 mm
A scan speed	27,000 A Scans/sec
Scan Depth	2.3 mm
Horizontal Resolution	20 µm
Longitudinal Resolution	5–6 µm
Fundus Observation	Near IR
Fundus Camera	Nikon D90 12.3 MP Color
Fixation	Adjustable internal matrix LCD and external fixation device
Diopter Scale Range	-13D to +12D (in fundus photography)
Light Source	Super luminescence diode (SLD) Wavelength 840 nm Half Bandwidth: 50 nm Output on cornea ≤ 0.65 mW
Automatic OCT Reference Focus	Vitreous and Choroid
Scan Patterns	3D, Cross*, Raster*, Line*, Radial*, Circle* (*available with oversampling, overlapping)
Power Supply	Source voltage : AC 100/110/120/220/230/240V 50–60Hz Power input : 200VA (normal), 400VA (max)
Dimensions	21.5" (W) × 21" (D) × 23.5" - 25" (H)
Weight	70 lbs
Retinal Layers Identified	Macula: ILM, IS/OS, RPE, Bruch's Membrane Glaucoma: RNFL

From the obtained results, represented in Table 2 it is clear that in the specific sample, patients with type 2 diabetes mellitus prevail over those with type 1 diabetes mellitus. The same trend has been reported on a global scale (Xu et al. 2018). There is also a distinction in the distribution by patient gender - there are more men than women (Xu et al. 2018). The average age of the patients is 62.3 years. Since the data is from a specialized eye clinic, the fact that a large part of the patients has an advanced form of the disease is somewhat justified - it is normal that at some point the severe pathology is collected in a highly specialized unit, if it is impossible to help elsewhere. However, the impressive number of diabetic patients, who visit an ophthalmologist once every few years - 76.42%, despite the recommendations for an annual examination, should not be overlooked. It could somehow be explained by a higher number of patients from the province (63%), where the accessibility to medical care is much more difficult. We further find perplexing the high fraction of patients who make a visit to an endocrinologist only every 2–3 years.

Diabetics with retinopathy have been divided into categories, according to the classification corresponding to morphological changes in the retina, which were found during examination. From the above results, it is clear that the majority of patients have complicated forms of diabetic retinopathy - PDR and DME. The pathology evaluation and classification system are based on both a conventional ophthalmic examination with biomicroscopy and indirect

Table 2. Represents the percentage values of the examined cohort, distributed by the type of Diabetes Mellitus (DM), respectively in Type 1 or Type 2 and the distribution of the cohort by sex.

Type DM	DM 1	DM 2
%	45.0%	55.0%
Sex	Male	Female
%	66.0%	34.0%

Table 3. Represents the age distribution in three different age groups, the duration of the disease and the stage of the disease (defined as Non-proliferative diabetic retinopathy – NPDR, Proliferative diabetic retinopathy – PDR, and diabetic macular edema – DME).

Age (years)	Under 45	45–66	Over 66
%	7.0%	56.0%	37.0%
Duration of the disease	**1–3 years**	**3–10 years**	**Over 10 years**
%	2.0%	94.0%	4.0%
Stage of the disease	**NPDR**	**PDR**	**DME**
%	22.0%	45.0%	33.0%

Table 4. Collected data about previous endocrinologic and ophthalmic visits.

How often does the patient go to an ophthalmologist?			
Ophthalmic visit	**1 time/year**	**Every 6 months**	**1 time every 2–3 years**
Number/ %	24/ 19.51%	5 / 4.06%	94 / 76.42%
Has the patient been treated by an ophthalmologist so far?			
YES	**58 / 47.15%**		
NO	65 / 52.84%		
How often does the patient go to an endocrinologist?			
Endocrinologist visit	**1 time/year**	**Every 6 months**	**1 time every 2–3 years**
Number/ %	43/ 34.95%	30 / 24.39%	50 / 40.65%

ophthalmoscopy without mydriasis, as well as an examination with a fundus camera for digital retinal images and optical coherence tomography.

The use of images from the device ensures high recognizability of lesions, including DME (thanks to OCT). Examination using this device showed high sensitivity and specificity - up to 95% comparable to indirect ophthalmoscopy, accepted as the gold standard.

The examination time (ophthalmic visit + fundus photography + OCT) was approximately 12+/-2 min per patient, depending on the transparency of the ocular tissues (cataract or cornea with opacities due to dystrophies, trauma or degenerations).

All that being said, the results presented above are disappointing. Although the study was conducted among patients initially admitted to a specialized ophthalmology unit, the tendency towards late diagnosis in advanced complications of the disease is clearly outlined. This is due to the lack of adequate screening programs, prophylaxis and prevention strategies and the lack of communication between specialists from different fields of medicine, since diabetes mellitus is a complex chronic disease requiring an interdisciplinary approach.

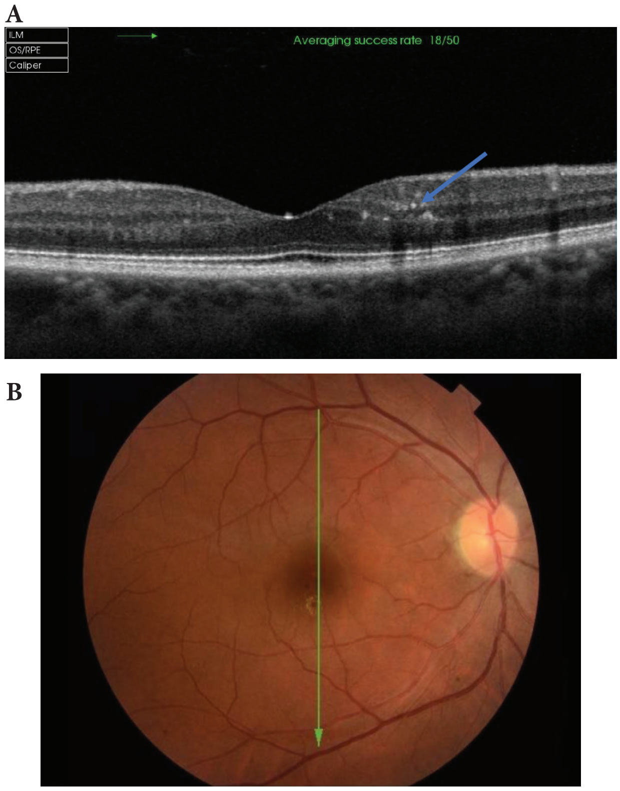

Figure 1. A. OCT scan – NPDR. An OCT scan of a patient with visual acuity 1.0, asymptomatic. On the OCT and fundus photography you can see the microaneurysms. OCT – hyperreflective foci – microaneurysms – blue arrow; **B**. Fundus photography – NPDR.

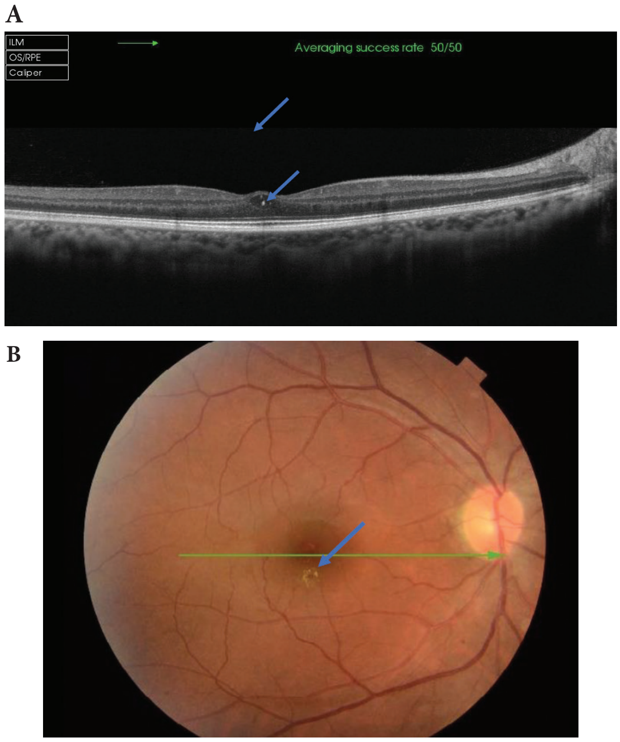

Figure 2. A. NPDR with macular cyst. OCT – macular cyst (blue arrow) in diabetic patient with visual acuity 0.8; **B.** Fundus photography – NPDR with macular cyst.

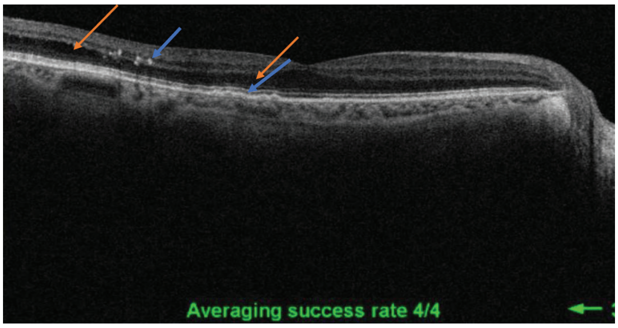

Figure 3. OCT – PDR. OCT scan of patient with PDR – microaneurysms (blue arrow) and mild intraretinal edema (orange arrow) are observed

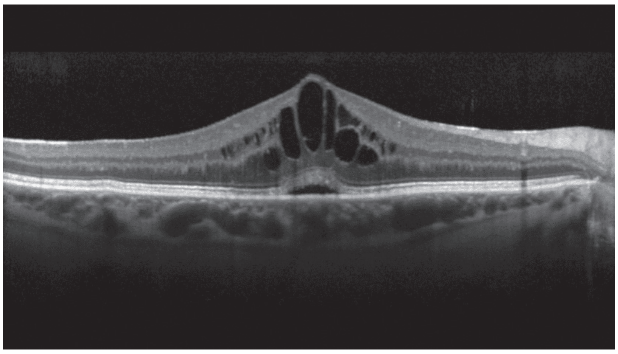

Figure 4. OCT – DME.

Dicussion

Screening is a systematic assessment of apparently healthy people at significant risk of developing a specific disease with medically preventable consequences (Yogesan et al. 2006). Screening is applied to a specific group of the population. Those who give a positive result during the screening are "screened out" and are referred for additional research (Ng et al. 2009; Yongdong et al. 2010). Diabetic retinopathy has few, if any, symptoms until the advanced stages of the disease occur, until the development of macular edema.

The goal of treatment is to prevent further loss of vision, not to restore what has already been lost. Because diabetic retinopathy in its early stages is asymptomatic, screening is important to detect the disease, when it is still treatable and the consequences - minimized. After that, regular follow-up examinations are necessary to monitor the progression of the disease and to catch the moment to start treatment. The benefits of screening, early detection of diabetic retinopathy and timely treatment reduce the social and economic losses of reduced vision and blindness. Optical coherence tomography could visualizes minimal changes in the inner and outer retina. Early detection of changes in the macula and peripheral retina allows individualization of the therapeutic approach. Accurate early diagnosis indicates the place of intravitreal pharmacology, lasers (photocoagulation, subthreshold therapy and surgical interventions.

Diabetic retinopathy perfectly satisfies the screening criteria:

1. There is significant morbidity
2. It has a high frequency in the population
3. There are clearly defined diagnostic criteria
4. Treatment is cost-effective: the benefits of treatment outweigh the losses from reduced vision
5. Treatment has more benefits if it is started earlier (still in the asymptomatic phase).
6. Valid and cost-effective imaging techniques

Validity is measured by sensitivity (the ability of the test to correctly identify the disease) and specificity (the ability of the test to correctly identify the absence of the sought pathology). A good screening method has high sensitivity and high specificity.

Different screening models for diabetic retinopathy have been developed - direct or indirect ophthalmoscopy, with or without mydriasis, color or monochrome photography, video recording, digital photography.

In the past, screening for diabetic retinopathy was performed by fundoscopy with mydriasis. Subsequently, screening also began to be carried out through fundus cameras, and this type of screening became a practice in a number of countries - the USA, Australia, Singapore, some countries of Western Europe and Great Britain (Yogesan et al. 2006; Ngoh et al. 2010; Ng et al. 2009; Liesenfeld et al. 2000; Chun et al. 2007). A new screening approach gaining increasing interest among researchers is video-based retinal imaging technology (Luzio et al. 2004). Each retinal video is 15–20 seconds long and represents a continuous recording from the optic nerve to the macula and temporal fields. It is performed using a simple fundus camera that has video recording as an option. The implementation technique is simple and can be performed by personnel with little experience (Taylor et al. 2007). Several studies have been conducted to evaluate the effectiveness of this new screening method and to compare it with the gold standard fundoscopy. The most extensive data in this regard was provided by the screening performed at the Royal Perth Hospital, Western Australia (Glasson et al. 2018). Patients in the Australian study were matched in terms of their demographics, eye and endocrinological history, disease duration, comorbidities (arterial hypertension, hyperlipemia, macro- and microvascular complications of diabetes mellitus), harmful habits. After mild mydriasis, all 100 patients underwent three sets of tests:

1. Three-dimensional 30 photos of the retina (optic nerve, macula, temporal lobes).
2. Color retinal videos
3. Examination with a biomicroscope and 78D lens for indirect ophthalmoscopy

Photographs and videos were taken by trained personnel, and their assessment and control examination with a biomicroscope – by two independent ophthalmologists. As a technical problem, the Australian study only reported that the resulting videos were very large in size, making them difficult to use routinely. The study shows that the new video imaging technique is a potential alternative to the gold standard biomicroscope and fundoscopy screening. Diagnostic specificity and sensitivity are over 90% for both images and video and 100% for advanced sight-threatening diabetic retinopathy. The efficiency of the video recording was reanalyzed by Kappa-statistics and was above 0.8 for lesions such as microaneurysms, hemorrhages, soft and hard exudates, neovascularizations, hemophthalmias, etc. The problem of the large size of records can be solved by converting. The study shows that the recordings have high sensitivity, specificity and short conversion time. Technical impossibility of execution for photos is 7%, and for video - 7.5%. The study did not provide data for a cost-effectiveness assessment.

The methodology allows to save the time of specialists, to track the development of the disease in real time. The video technique has been found to allow viewing of a larger area in a shorter period of time compared to standard fundus photography. Video technology does not offer a three-dimensional view of the retina, which is a disadvantage of DME.

A widely used method was utilized - the "UK-Screening Center - Digital Retinal Photography". With it, stereoscopic photographs are taken in seven fields - this is a screening method with high accuracy, thanks to which the scales for the classification of diabetic retinopathy were developed. It is this method that is used as the gold standard and for comparison with other methods. Seven 30°, three 60°, or nine overlapping 45° photographs must be taken to satisfy ETDRS requirements. Despite the high accuracy of this screening method, there are numerous logistical problems. All this is difficult to implement due to the large number of patients in screening programs and the need for specially trained personnel, collection and storage of large numbers of photographs and their reading by highly qualified personnel. In addition, the need for pupil dilation takes additional time (Conlin et al. 2006; Schneider et al. 2005; Cummings et al. 2001; Rotvold et al. 2003).

Non-stereoscopic photographic screening is logistically easier than stereoscopic photography and is a relevant convenience as a modus operandi (Stillman et al. 2004). By definition, DME is retinal thickening that cannot be detected with non-stereoscopic photography. Visual acuity is another easy method to assess macular status. The presence of microaneurysms, hemorrhages, hard exudates near the macula is accepted as an indicator of DME. Non-stereoscopic photography has reasonably good sensitivity for the boundaries of diabetic retinopathy, similar to that of ETDRS-accepted seven-field stereoscopic photography, and moderate sensitivity for detecting intermediate degrees of DME. Excluding the poor validity in the detection of DME, non-stereoscopic photography is considered a good screening method (Gomez-Ulla et al. 2008).

Non-stereoscopic photography can be performed without mydriasis (pupil dilation), which facilitates the screening method and saves time. From this point of view, non-stereoscopic photography has an indisputable advantage, as well as better patient cooperation, but there are also disadvantages: reduced image quality, lower sensitivity, as well as a significant amount of unusable photos (mainly due to cataract), which can to be avoided when dilating the pupil.

There is an active discussion about the minimum photos and the field they should cover. The most essential part is the presence of a field covering the macula, the accepted minimum being 45° horizontally and 40° vertically. A single image of the macula may be sufficient, but a larger number of images covers more of the retina (better coverage) and increases the sensitivity of the test. Severe macular pathology is often associated with more advanced lesions in the nasal parts of the retina. Therefore, in some screening models there is a mandatory requirement for a photograph of an area of the nasal retina (Gomez-Ulla et al. 2008; Boucher et al. 2008).

Shooting a single field has its advantages - lower demands on the technical contractor, no need to dilate the pupil, reduced shooting time, more reading time, better cost-effectiveness. However, capturing only one field has not gained wide popularity in practice. In the United Kingdom, digital cameras that do not require a midrash (Minimum Camera Specification) have been proposed for implementation.

OCT-angiography (OCT-A) has become a "must" in the follow-up of diabetic patients, because it is not invasive and is informative enough, compared to the classic fluorescein angiography (FA). It is not the first line choice for the screening program, since it's a slower exam than fundus photography and the structural OCT (in standard cases, they are believed effective and informative enough).

Our proposal for fast and effective screening method, like described above – is based on the structural OCT and a fundus photography at 45° - it provides sufficient information and has advantages of fast acquisition even in non-mydriatic pupils and high quality of images compared to the previously described screening programs. Compared to the standard funduscopy, OCT in combination with fundus photography is much more objective, since the interpretation of a single scan or photo of the fundus depends less on personal abilities and subjective factors from the examiner. We consider OCT with fundus photo extremely useful because it gives us more detailed information compared to funduscopy alone and gives us the opportunity to detect a minimal lesion, even if the visual acuity is 100%. Compared to the fluorescein angiography the screening method proposed in this research is non-invasive and with higher amount of effectiveness, due to the short screening time and the high-quality information that is acquired.

According to literature data, the prevalence of NPDR is 50.3%, of PDR 9.9% and 39.7% is the prevalence of DME (Xu et al. 2018).

In our study the distribution is completely different – the fraction of all three groups with PDR is higher – in first position with 45%. We believe that this tendency is explained by the setting of the study – it was performed in a highly specialized ophthalmic center, where more complicated cases usually happen.

Conclusion

There is an active debate about screening methods and also about its frequency. There is no single standard in world practice. Screening once a year is accepted in most countries.

Regarding the cost-effectiveness of screening, the concept of evaluation based on “cost per sight year saved” is widely accepted. The financial resources invested in screening are repeatedly justified and exceed the costs that would lead to the loss of vision in the working population.

The size of the diabetes epidemic, socio-economic, cultural and geographical features, lack of health education, limited health resources and poor communication between individual health institutions and specialists contribute to the lack of adequate care for diabetic patients. Access to health care is the determinant of the organization of the health system in the respective country and is directly related to its socio-economic situation. Also important are duration of diabetes, metabolic control after diagnosis, screening for retinal pathology, access to early treatment.

In Australia, a significant difference in disease severity and access to health care between urban and rural patients has been demonstrated.

As a complex, chronic, and until complications occur - asymptomatic disease, medical intervention in diabetic retinopathy is often delayed, especially in the absence of a developed screening program. Barriers to the patient’s access to medical care can be divided into the following groups:

1. Psychological/behavioural
2. Psychosocial
3. Comorbidity
4. Economic
5. Educational

Digital photographic screening for diabetic retinopathy combined with optical coherence tomography (in a device combining a fundus camera and OCT) is a cost-effective and sensitive method for early recognition of retinal pathology, because they provide the medical practitioner a detailed information, they are fast to perform, noninvasive and sensitive (Schneider et al. 2005; Cummings et al. 2001). The technical part – capturing a retinal image – can be performed not only by ophthalmologists, but also by specially trained non-medical personnel – such as optometrists. However, this does not negate the need for the classic variant of this screening model, the images to be read by a specialist ophthalmologist. The development of detailed systems for automatic analysis would save time and personnel resources. From the literature review and the study conducted among 123 patients with diabetes mellitus (in which both classical methods - ophthalmoscopy and modern - fundus photography, OCT) were used for the diagnosis and staging of diabetic retinopathy, we can draw the following conclusions:

1. Diabetic retinopathy is a disease that requires an interdisciplinary approach - with a good collaboration between endocrinologists and ophthalmologists, the results in the fight against it would be much better.
2. Diabetic retinopathy remains an asymptomatic disease until complications occur - this is why it is important to develop reliable screening programs for the population at risk so that treatment can be initiated in the early, reversible phases. Currently, worldwide, the trend is toward late diagnosis.
3. Access to health care and in particular to specialized medical care is important.
4. The health culture of the population and the socio-economic situation in the country are also of key importance. Due to the pandemic nature of diabetes mellitus and the increase in cases of macro and microvascular complications, a resource should be allocated to health education.
5. Since at the present time diabetes mellitus and diabetic retinopathy are well studied in their pathogenetic course and the morphological and functional changes are classified, it is easy to work on the established scales for assessing the severity of the disease. Thus, when developing screening programs, patients falling into one or another group can be treated according to a protocol approved for the respective condition.
6. Due to the lack of sufficient specialists - ophthalmologists worldwide, digital screening is gaining more and more popularity, the technical part of which can be performed by non-medical specialists trained for the purpose. Combined with the automated analysis systems being developed, they unite around a promising future in the face of telemedicine. There is controversy in the literature regarding the cost-effectiveness of digital screening, but given the increasing morbidity and shortage of medical professionals, more and more consideration should be given in this direction.

Ethics approval and consent to participate

1. Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the (Eye Clinic ZRENIETO, Sofia, Bulgaria) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was reviewed by the Ethical Committee of University First Multiprofile Hospital for Active Treatment “Sveti Yoan Krastitel” – Sofia, Bulgaria. The study was approved by the Ethic Committee. Approval code: Y057/2022. Approval date: 10.01.2022
2. Consent to participate: Informed consent was obtained from all individual participants included in the study.
3. Consent to publish – All the four authors declare their consent to publish the research

4. Availability of data and materials: The collected data (demographic and medical information about the patients, their dossiers and videos of the performed surgeries) used to support the findings of this study are available from the corresponding author upon request.
5. Competing interests: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.
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7. Authors' contribution – All the authors have contributed equally to the research.

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