

Remote Digital Technology for Diagnosing and Monitoring Eye Condition in COVID-19 Pandemic

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Abstract: We present the results of investigating the use of remote digital sensing technology for diagnostics and monitoring of the eye condition in patients in existing epidemiological situation. Restricted access to specialized medical care leads to an increase in the risks of the development and progression of many ailments. The optimal solution to existing problems lies in the development and implementation of remote digital sensing technology for diagnostic purposes and patient monitoring. We have developed an Internet service that included an automated system for analyzing complaints and symptoms of patients prior to seeing the doctor. The system permitted to identify the symptoms of emergency conditions and provide remote medical care. The hardware part has an original design, using the methods of computer analysis and diagnostic algorithms. We investigated the effectiveness of the developed method and areas of its potential application in existing epidemiological conditions.

Keywords: Telemedicine, diagnostics, health condition monitoring, eye, digital technology, coronavirus infection, epidemiological conditions.

Introduction

Currently, due to massive burden on the healthcare system, caused by the COVID-19 coronavirus pandemic, the ability to provide specialized medical care in various regions of the Russian Federation has sharply decreased [1]. The disproportion in the volume and quality of health care in large cities and rural districts is especially noticeable [2, 4]. In urban settings, there is a choice of a physician and a medical institution, along with necessary diagnostic equipment [3, 5]. In small towns and sparsely populated rural areas, there is an obvious shortage of specialty doctors and modern equipment, hence general practitioners prevail [6, 7]. The epidemiological status quo has significantly worsened the existing situation in provisioning specialized medical care. Doctors cannot carry out as many polyclinic appointments as they used to [8]. Many of them temporarily change their specialty during the pandemic. Even if the epidemiological situation improves, we cannot expect a quick recovery of the specialized care volume.

Another important feature of this problem is the availability of modern equipment at polyclinics. To a large extent, it does not meet the existing requirements. In these circumstances, it is necessary to change the system of specialized medical care via the introduction of digital

methods and modern information technologies [9, 10].

The goal of our research project was the development and implementation of remote digital sensing technology for diagnosing and monitoring the eye condition in the context of the coronavirus pandemic.

Materials and Methods

The problem under our study has organizational, methodological, informational and communication aspects. Specialized software must meet these complex needs. Interdisciplinary cooperation can provide an integrative software product. It should be specifically noted that obtained information can be used not only in ophthalmology, but also in other medical fields. It is known that changes in the eye are associated with many common diseases, in particular, of endocrine, neurological, pediatric, infectious, and gerontological nature.

Digital methods should provide maximum information content and versatility. Information content should be ensured *via* using standardized conditions for obtaining digital data and employing specialized data processing programs. Digital biomicroscopy of the anterior segment of the eye meets these requirements and is chosen as the major examination technique. The methodology for examining the eye should encompass all available diagnostic standards and algorithms, since they are used in the practice of doctors. Accordingly, the transition to remote digital technologies should not require any significant investment of time and money.

Digital biomicroscopy methods are based on the conventional technique, differing from it solely by the use of digital photo and video recording cameras and the transmission of information *via* the Internet. That is, the optical and lighting systems of digital biomicroscopy of the anterior segment of the eye do not differ from conventional systems. Control programs for lighting and optical units expand the possibilities due to the use of ultraviolet and infrared light ranges, along with monochromatic three-band (red, green, blue) light sources. This enhances the capabilities of digital biomicroscopy and creates clear advantages over traditional methods.

The main difference from existing methods is the possibility of remote use: in such setup, the

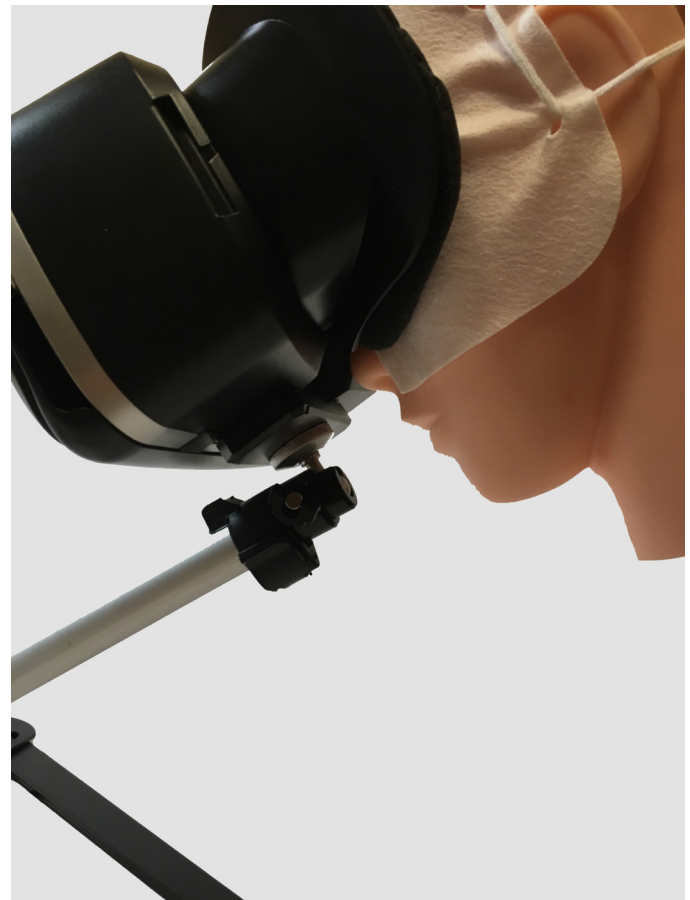


Figure 1. Appearance of assembled computer appliance

hardware is placed anywhere, while the consulting physician examines the patient and carries out diagnostics from another location. The lack of physical contact with a doctor is an advantage for a patient in conditions of the coronavirus pandemic. The obtained digital images can be in the format of individual images or video recordings, they can also be archived or included in the medical information bases. If necessary, the doctor can carry out a visual examination of the anterior segment of the eye in a traditional form, followed by archiving. He has the opportunity to view the results of the patient's survey in electronic form, and the survey is filled out as a questionnaire *via* the Internet. We have implemented a voice communication channel with a patient as well.

Thus, the optimal solution is to use the methodology and principles of medical examination by means of conventional methods, supplemented by the use of modern technologies. The software part is designed for the functioning of the hardware part and

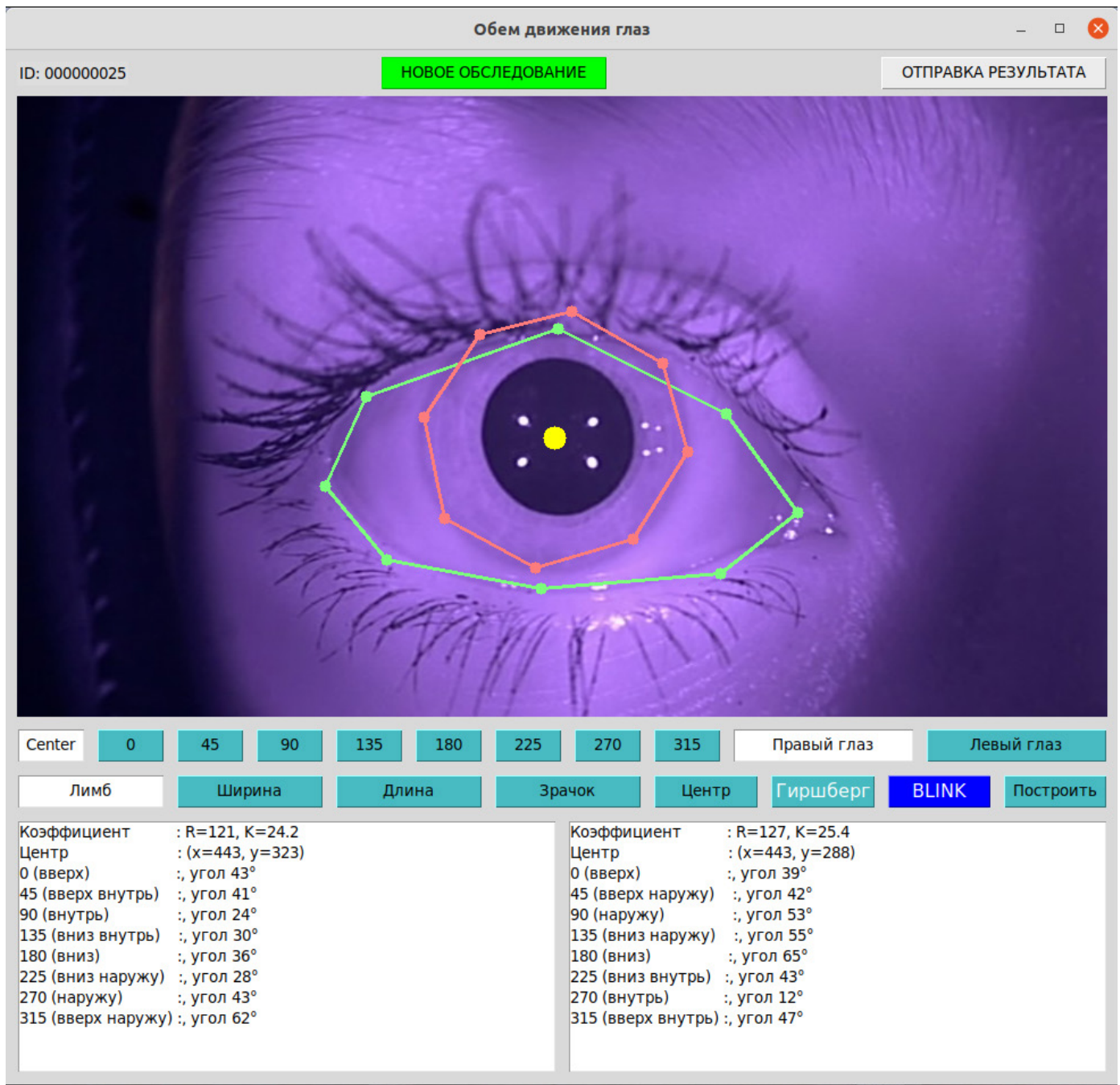


Figure 2. Presentation of the remote patient examination process

provides service and diagnostic capabilities of digital methods.

The developed computer appliance (hardware and software complex) for digital biomicroscopy of the eye can be used at any medical and diagnostic institutions, including its remote use. It provides a complete clinical examination for the organ of vision.

For the first time, the possibility of remote digital analysis of the following indicators has been implemented:

- parameters of the width of the palpebral fissure,
- frequency of blinking movements,
- condition of the mucous membrane of the eye,

Medical report

Patient' complaints
Moderate excitability. Emotional lability is expressed. Crying is weakly expressed. Anxiety: none. Sleep disorder is moderate. Fussiness is expressed. Impaired attention is weakly expressed. Weakness: none. Sweating is expressed. Heartbeat disorder is moderate. Body tremors are weakly expressed. Weight loss: none. Frequent stools are expressed. Disruption of the menstrual cycle is moderate. Potency disorder is expressed. Muscle weakness is weakly expressed. Bulging eye is expressed. Sudden pain behind the eye is moderate. Pain with eye movement: none. Redness of eyelids is moderate. Redness of conjunctiva is weakly expressed. Swelling of eyelids: none. Edema of the mucous membrane of the eye is expressed. Feeling dry: moderate. Rare blinking is expressed. Inconsistent double vision (diplopia) is weakly expressed. Intermittent edema of the eyelids is expressed.

Diagram of patient condition

Diagnosis:
You are suspected to have endocrine ophthalmopathy.

Date: 06.22.2020
INTEMSYS

Recommendations

Description:
You are required to undergo medical investigation ASAP and get consulted by the specialist.

Choose the doctor:

- Bolotova, Nina V.**
Department Chair, Doctor of Medicine, Professor
- Filina, Natalya Yu.**
Doctor of Medicine, Associate Professor
- Raigorodskaya, Nadezhda Yu.**
Doctor of Medicine, Associate Professor
- Timofeyeva, Svetlana V.**
Candidate of Medicine, Assistant Professor
- Aldashkin, Sergey Yu.**
Resident

You can save the results of questionnaires by any of the options below:

Send the results by e-mail:

Save as: [Diagnostics.pdf](#)

Figure 3. Report on the examination results and its transmission to the patient's e-mail address

- cornea condition,
- range of eyeball motion,
- and pupillary responses.

All obtained results have a digital version and are saved in the form of diagrams and reports, necessary for diagnostic purposes and for making medical decisions.

The device for digital biomicroscopy of the anterior segment of the eye is self-contained and uses its own built-in batteries. It is possible to transfer data both through wired and wireless channels *via* the Internet. The service part is automated as much as possible and does not require any additional personnel training. For information support of the process of diagnosing and monitoring the patient condition, the Internet resource was created on intelligent telemedicine systems, available at: <https://intemsys.ru/>. The site contains the sections of surveys that identify the symptoms of various ailments, their analysis, as well as an ability to make an appointment with a doctor, and a capability of transferring primary data to the consulting physician.

Results

The developed computer appliance and information support is used at several medical institutions – in particular, at the Department of Endocrinology of the Saratov State Medical University, the equipment and software were tested for six months. Currently, the experience of clinical use of this computer appliance encompasses over 200 patients with a variety of illnesses. The most common reasons for seeking medical attention are emergencies, which include inflammation processes, vascular disorders and a glaucoma attack. It is especially important that there is the possibility of providing emergency care virtually at the time of the patient's request. This is crucial for glaucoma, when the time factor is decisive, since irreversible loss of vision is possible within a few hours.

The second most common reason for seeking medical attention involves oculomotor disorders, which is more typical in neurological diseases. These include variants of strabismus, along with other eye movement pathologies. The third most common reason includes patients with endocrine pathology, including ophthalmopathy. This is a group of patients that requires the integration of both

ophthalmologists and endocrinologists. Based on the analysis of this group of patients, it was found that early diagnosis of endocrine disorders is possible, primarily, in the category of youths under 16 years of age.

The age, at which examination with the use of a computer appliance is possible, is 3–5 years old. Since the proposed technique is noninvasive and painless, children accept it well. Based on the survey results, a report was generated, in which all medical investigation results were presented. They can be used both for diagnostic purposes and for monitoring the patient's condition, since the data undergo statistical analyses.

The state of the eye is determined by the method of digital biomicroscopy and the capacity of eye movements.

Discussion

Currently, telemedicine consultations provide video communication with patients. The use of basic diagnostic methods, in particular, such as biomicroscopy of the anterior segment of the eye, is impossible in this case and insufficient for adequate diagnosis and monitoring of the patient's condition. It is necessary to use hardware to obtain digital information – first

of all, high resolution images of the eye and surrounding tissues for subsequent analysis. Previously, research was carried out in this area (Bakutkin V. V et al., 2019). A prerequisite for collecting digital data is their ability to be used in the further diagnostic process. Not only should they have information content, but be presented in photo and video recordings, standardized in terms of lighting parameters and conditions (Court J. H., Austin MW, 2015). It is also necessary for digital biomicroscopy of the anterior segment of the eye to be integrated into existing information and communication systems.

Conclusion

Integration of digital technologies with diagnostic and monitoring methods in medical practice is the most promising course in contemporary conditions. The emergence of epidemiological factors requires quick and effective solutions. Solutions in the form of a computer appliance of digital biomicroscopy and the corresponding information support were proposed to provide remote diagnostics and monitoring in patients with various diseases. The proposed solutions were based on the most effective methodology for applying digital methods and communication devices. Active introduction of these methods and their use would ensure an increase in the quality and volume of medical care.

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