Using Neural Network for Remote Analysis of the Clinical State in Patients with Endocrine Ophthalmopathy

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Abstract: Currently, there is an increase in the number of patients with endocrine ophthalmopathy, due to deterioration of environmental situation, presence of iodine deficiency, consequences of man-made disasters, and hereditary factors. Endocrine ophthalmopathy is an interdisciplinary disease, equally related to endocrinology and ophthalmology. Endocrine ophthalmopathy is caused by pronounced functional changes in the organ of vision, leading to disability. For a long time, there was no methodology for early diagnostics and an algorithm for examining patients with early signs of endocrine ophthalmopathy using modern information technologies. The latter opened up new possibilities for diagnosing and monitoring the condition of patients with endocrine ophthalmopathy, including use of remote methods. It is very difficult to ensure effective interaction between specialists, since there is a shortage of equipment and professional personnel. The goal of this study was to develop and analyze an effectiveness of using a neural network for remote analysis of the clinical state in patients with endocrine ophthalmopathy. The authors have developed an algorithm for remote diagnosing and monitoring the condition of patients with endocrine ophthalmopathy. Key requirements for the development of the algorithm was the possibility of its remote use. In this regard, a specialized Internet service, *Intelligent Telemedicine System*, was created and adapted for patients with endocrine ophthalmopathy and physicians conducting treatment. The list of questions on the general condition of the subject and complaints about the organ of vision was taken from the World Health Organization (WHO) clinical guidelines and medical standards of care for endocrine ophthalmopathy.

Keywords: endocrine ophthalmopathy, telemedicine, remote monitoring.

Introduction

Endocrine ophthalmopathy is a multifactorial ailment, in which a primary lesion of the thyroid and subsequent changes in the organ of vision occur [1]. The negative impact of social factors on frequency of endocrine ophthalmopathy, in particular, chronic stress, sleep disorders, and smoking has been proven. The presence of concomitant endocrine diseases, such as diabetes, significantly worsens the course of endocrine ophthalmopathy. In women, the incidence of the disease is 2.1–3.3 times higher than in men [2]. At the same time, severe forms of this disorder in women occur 4–8 times more often than in men [3]. A very important social aspect is the increase in endocrine ophthalmopathy in children of different ages. This is primarily due to

a hereditary factor. Analysis of data among children and young adults under 18 years of age showed that, in 10 % of cases, a family history of endocrine ophthalmopathy was an important factor [4, 5].

The cause of decline in visual functions is optic neuropathy, which develops in 3–30 % of patients with endocrine ophthalmopathy, and in 70 % of patients with a decompensated stage of this disease. The cause of damage to the optic nerve is the compression effect of edematous retrobulbar fiber layer. There are also pronounced microcirculation changes in retinal capillaries.

Endocrine ophthalmopathy is an interdisciplinary disease, equally related to endocrinology and ophthalmology. It is very difficult to ensure effective interaction between specialists, since there is a shortage of equipment and professional personnel. Contemporary information technologies provide new opportunities for diagnosing and monitoring the condition of patients with endocrine ophthalmopathy, including use of remote sensing approaches [6]. The main tasks of a clinician are to identify symptoms of endocrine ophthalmopathy based on patient complaints. In this case, an assessment of both general health condition and organ of vision condition is necessary.

Analysis of patient complaints allows identifying the characteristic symptoms and determining the degree of the pathological process activity. Consistent with the guidelines by the European Thyroid Association, since 1989, the so-called Clinical Activity Score (CAS) has been used, according to which the degree of severity of endocrine ophthalmopathy is assessed by ten parameters: (1) pain in the orbit, (2) pain during eye movements, (3) edema of eyelids, (4) redness of eyelids, (5) condition of the conjunctiva, (6) chemosis, (7) edema of the lacrimal meatus, (8) increase in exophthalmos by more than 2 mm, (9) limitation of eye movement in any direction, (10) visual acuity decrease [10]. Equally important is the assessment of the general condition of the patient, since there are typical complaints and symptoms of this illness.

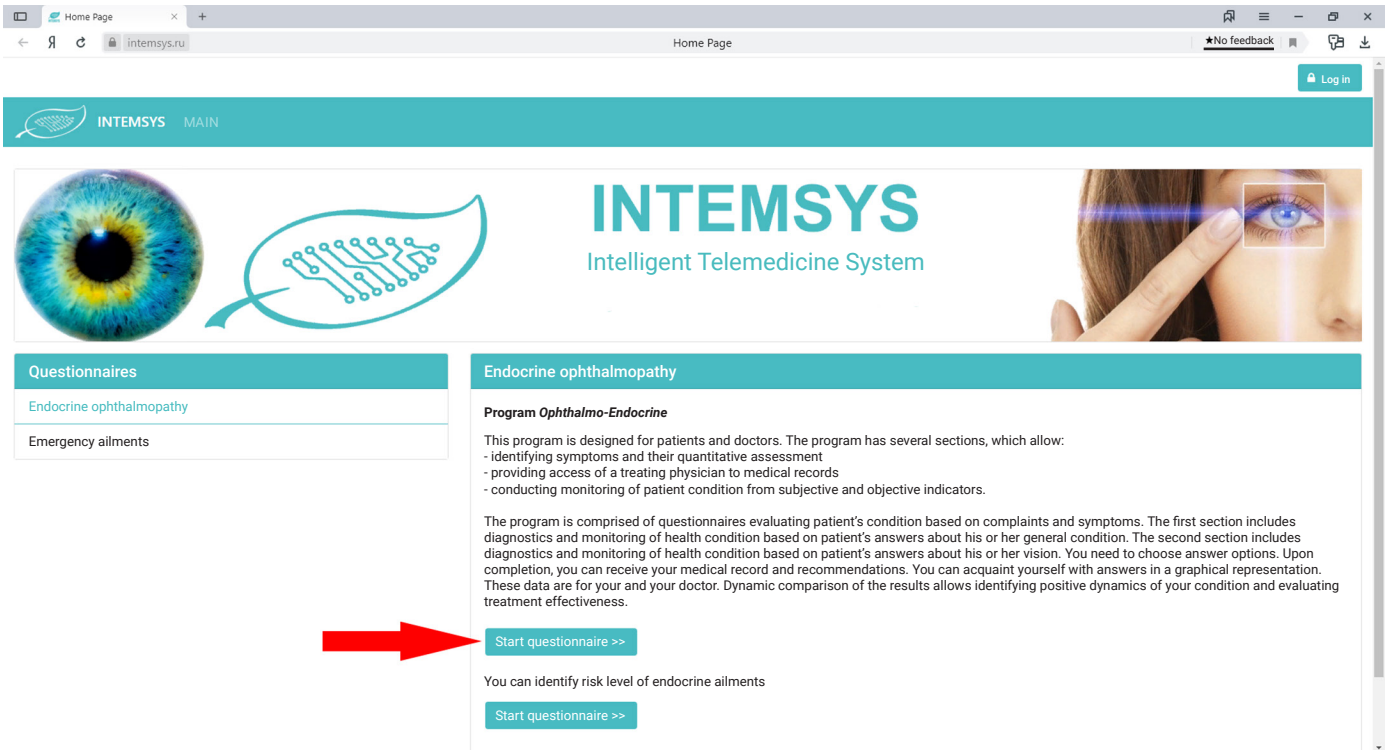
In clinical practice, the physician has limited ability to identify complaints and symptoms of endocrine ophthalmopathy. The attending physician does not always have sufficient time and knowledge to identify symptoms and analyze them. There is a vital need to create a methodology for remote detection of symptoms and a quantitative assessment of the results. In this regard, it is essential to create clinical systems using information technology.

Materials and Methods

The goal of our study was to develop and analyze the effectiveness of using a neural network for remote analysis of the clinical state in patients with endocrine ophthalmopathy. The authors have developed an algorithm for remote diagnosing and monitoring the condition of patients with endocrine ophthalmopathy. Main requirements for the development of the algorithm was the possibility of using it in a remote version for diagnostics and monitoring of the clinical state. Standard questionnaires, employed in clinical practice, were used as initial data. The list of questions on the general condition of the subject and complaints about the organ of vision was taken from the WHO clinical guidelines and medical standards of care for endocrine ophthalmopathy.

At an early stage of endocrine ophthalmopathy, there are nonspecific complaints of both general nature and eye condition. Quite often, the first symptoms are a feeling of dryness, unstable conjunctival hyperemia, lacrimation, and photophobia. In some cases, intermittent double vision (diplopia), and swelling of the eyelids (mainly in the morning) are among early complaints. The degree of edema of the eyelids varies during the day, the maximum – in the morning, during the day – decreases. At the early stages of the disease, there may be no obvious displacement of the eyeball, that is, exophthalmos. At the next stages, an eyeball displacement gradually develops, along with impaired eye mobility. Endocrine ophthalmopathy can be unilateral and bilateral. On average, endocrine ophthalmopathy appears in the second eye within three years. In this regard, a specialized Internet service, *Intelligent Telemedicine System*, was developed, adapted both for patients with endocrine ophthalmopathy and for doctors performing treatment. One of the main sections of the site is the questionnaire. The nature of the questions and the answer options reflect the content and quantitative characteristics of the symptoms.

The questions are distributed among two sets, the first one devoted to collection of data on general condition of the patient, while the second dedicated to the organ of vision state. Taking into account



gender and age characteristics, there are three options for children and adults, while section 2 has options for women and men. This is due to the nature of the complaints and gender differences in the clinical picture of the ailment. Questions about complaints are structured, set out in the sequence of their presence and chronology of occurrence. The novelty of our approach is that we proposed a quantitative assessment of the patient condition in the form of a questionnaire indicating the severity of symptoms. The patient is asked to choose the option of the presence or absence of a particular symptom. In case of a positive answer, the patient chooses an option of weak, medium, or strong manifestation of symptoms. The questions are pooled into groups, first of all, according to the general condition, then according to ophthalmic manifestations.

Questions:

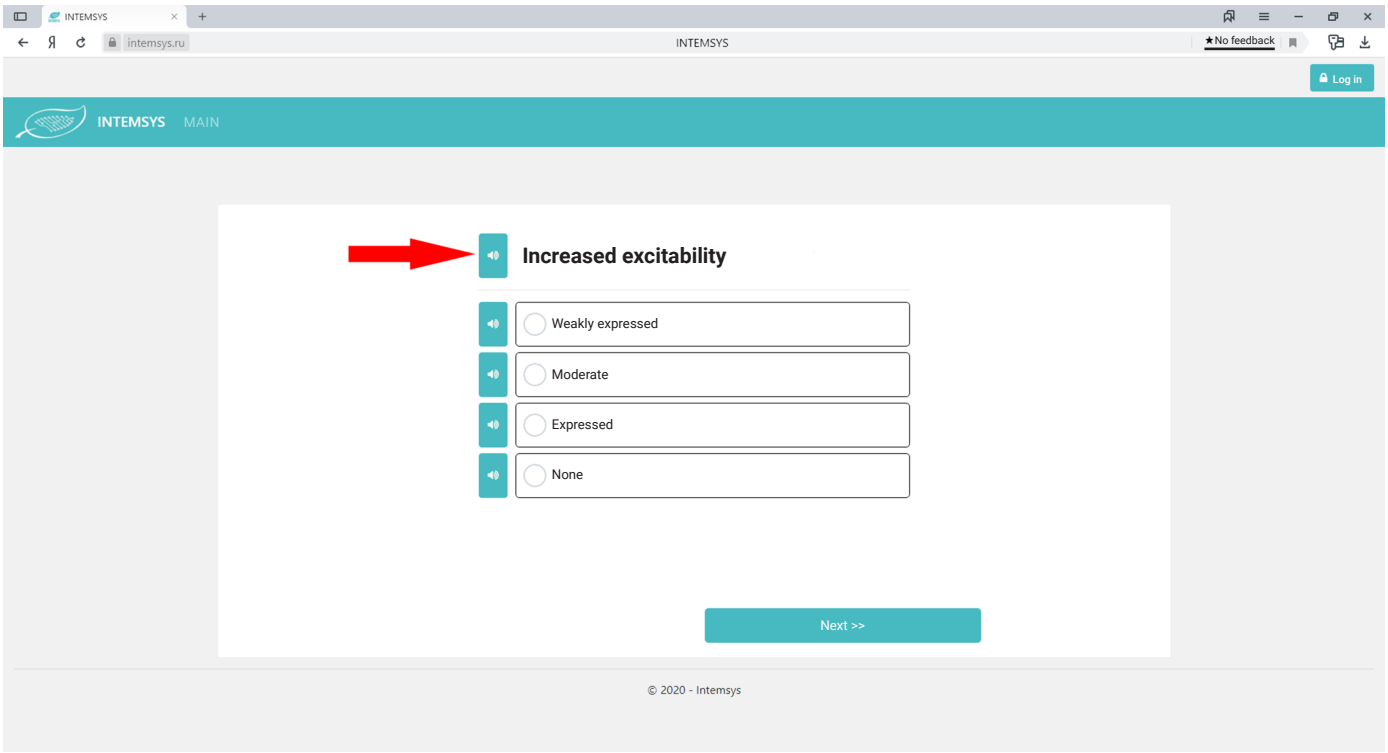
1 – Increased excitability
2 – Emotional lability
3 – Crying
4 – Anxiety
5 – Sleep disorder
6 – Fussiness
7 – Impaired attention
8 – Weakness
9 – Sweating
10 – Irregular heartbeat
11 – Body tremors
12 – Weight loss
13 – Frequent stools
14 – Disruption of the menstrual cycle
15 – Potency disorder
16 – Muscle weakness.

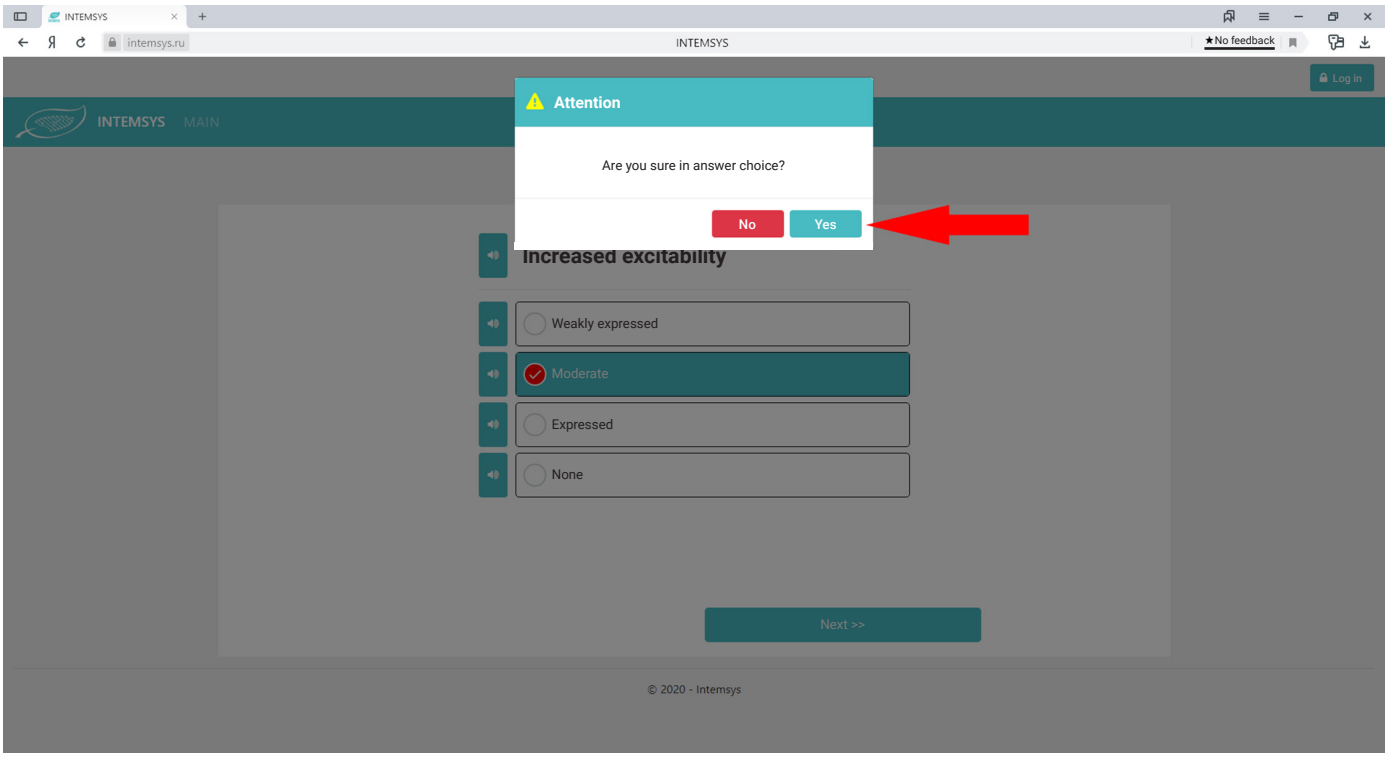
Answers:

- Weakly expressed
- Moderate
- Expressed
- None.

Ophthalmic manifestations:

17 – Bulging eye (or two)
18 – Sudden pain behind the eye
19 – Pain with eye movement
20 – Redness of eyelids
21 – Redness of conjunctiva
22 – Swelling of eyelids
23 – Edema of the mucous membrane of the eye
24 – Feeling dry
25 – Rare blinking
26 – Inconsistent double vision (in the morning)
27 – Intermittent edema of the eyelids (in the morning).

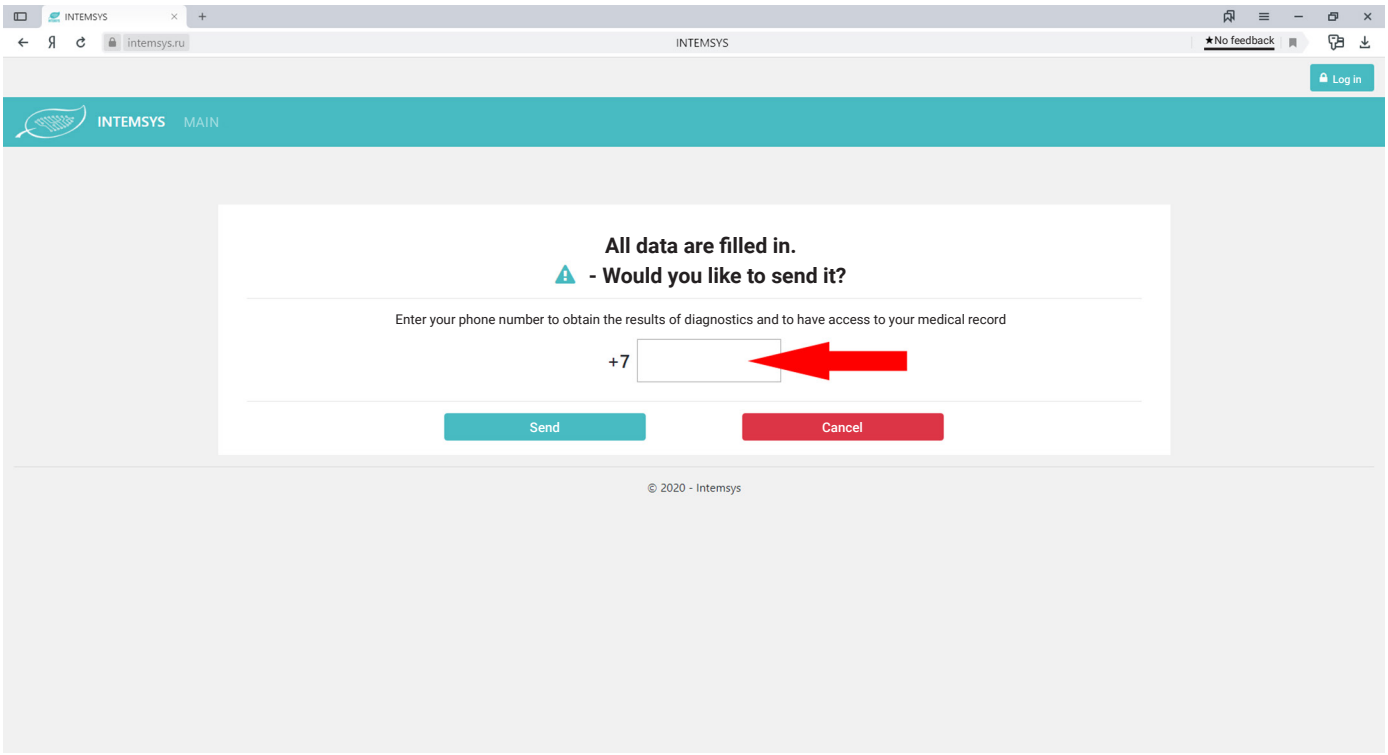


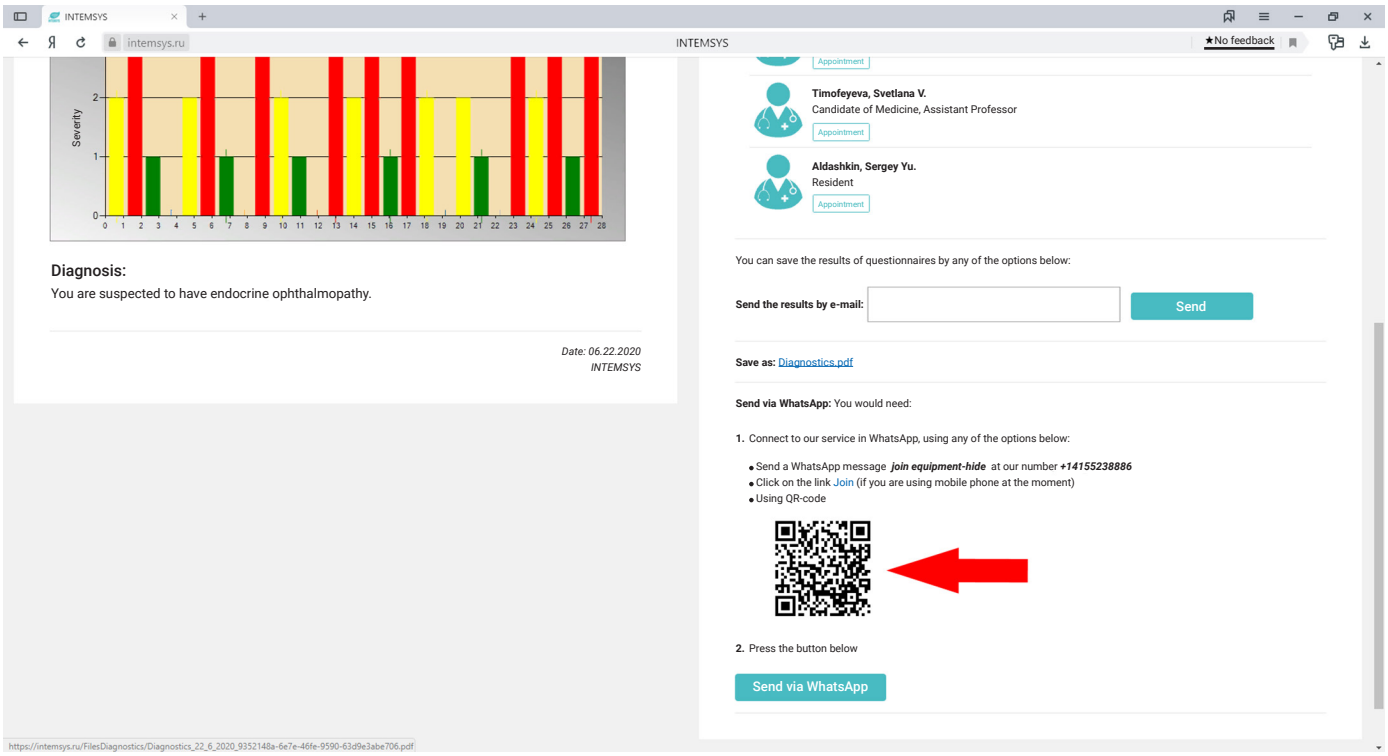


Answers:

- Weakly expressed
- Moderate
- Expressed
- None.

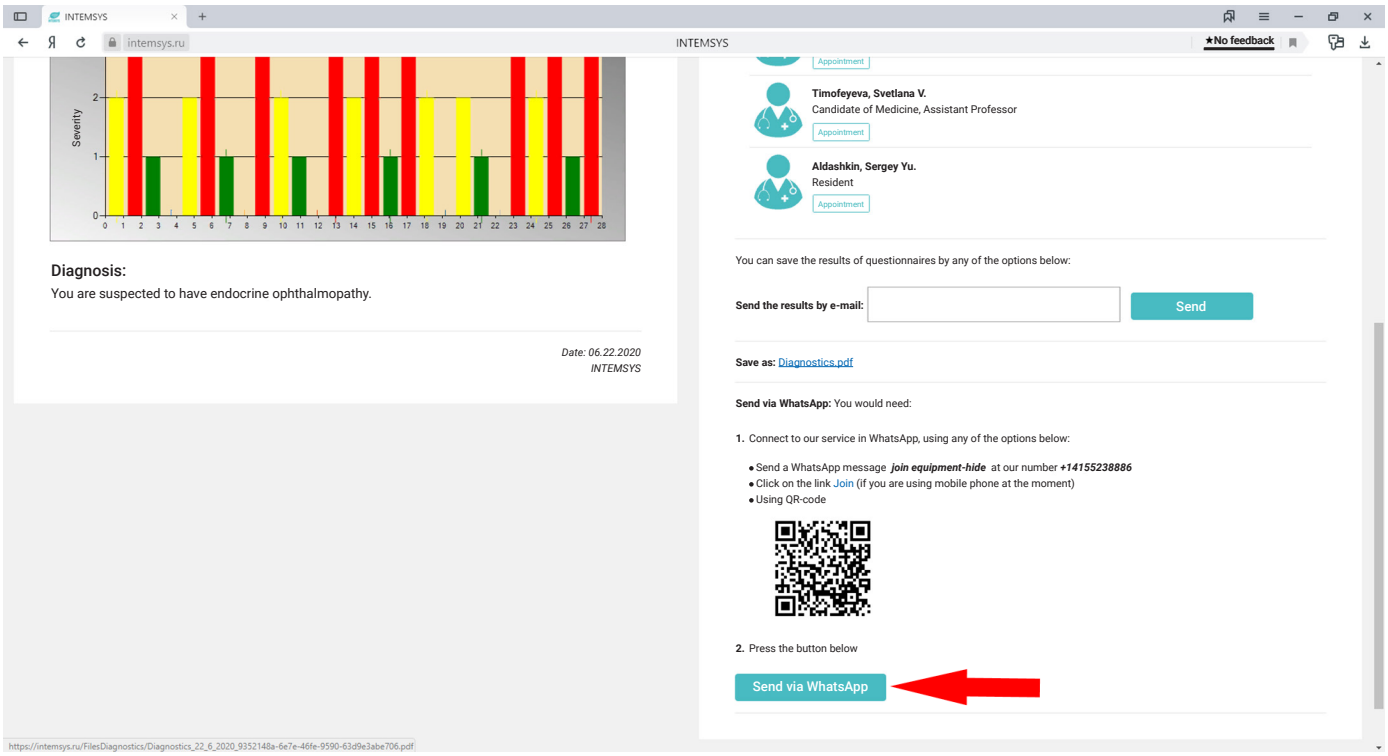
The patient has the opportunity to assess his or her condition and to correctly answer the questions. In order to avoid accidental and erroneous answers, the patient must confirm every completed section. There is an opportunity to increase the font size for people with poor eyesight. It is also possible to listen

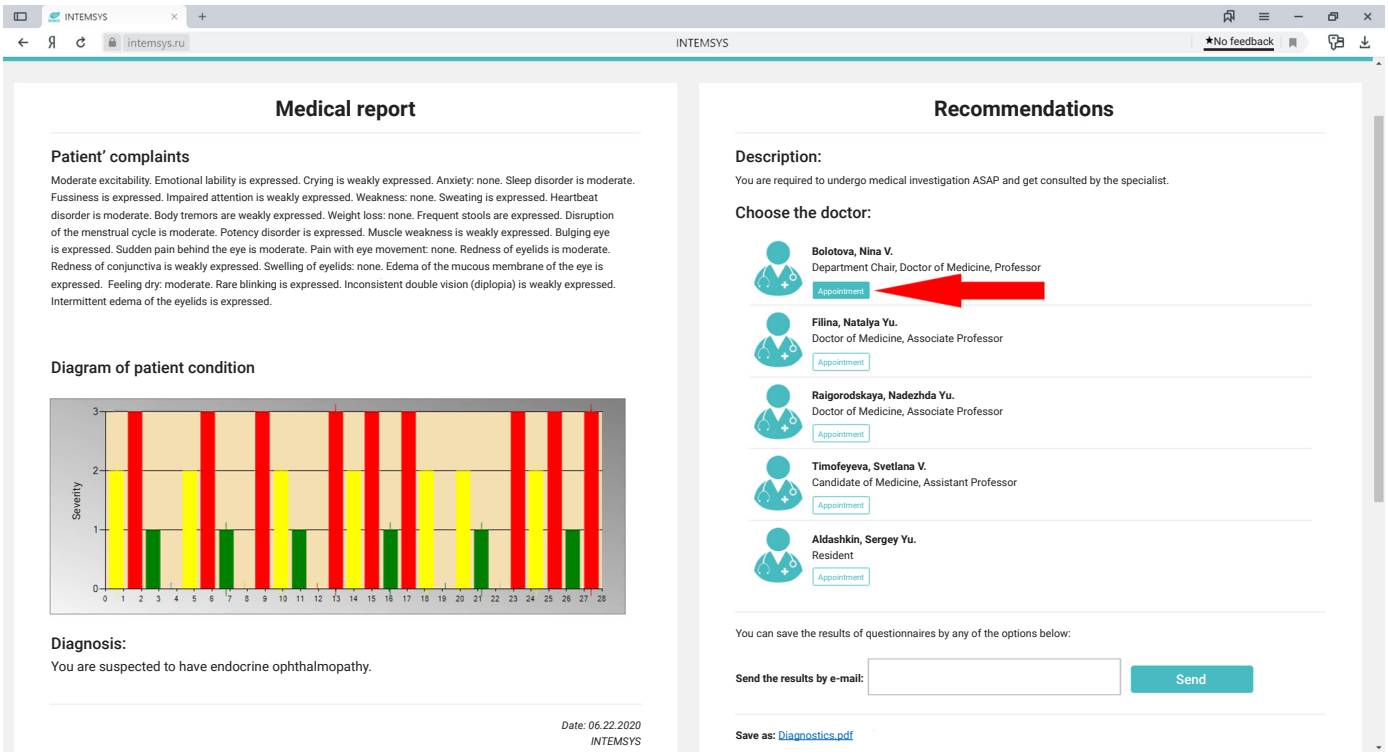




to questions if the patient needs it. After all replies, confirmation of their correctness is required prior to sending them to the data processing server.

Further, the automated data processing on the website and generation of a report for the patient and the doctor are carried out. The report looks like a version of the medical report, which indicates the complaints and their degree of severity in traditional form used in anamnesis. We propose a graphical form of the report, which indicates both the presence of complaints and the degree of their severity. This





form is more convenient for a doctor and a patient in terms of comparing medical indicators over time.

After analyzing the complaints, a medical report is formed, which determines the presence of characteristic symptoms and their combination to determine the presence of endocrine ophthalmopathy. The symptom complex includes both general symptoms and local, ophthalmic manifestations. It is especially important that there is a quantitative assessment of symptom severity. This allows tracking their dynamics and monitoring the patient's

condition. What is very important, a patient can monitor his or her condition, based on own sensations, on a daily basis, and, if the condition worsens, inform the doctor about it. Algorithms for assessing the patient condition make it possible to quantify the nature of dynamic changes in the clinical course of the disease.

Results

If, after examination, the patient reveals symptoms of endocrine ophthalmopathy, then a conclusion is generated about the need to seek specialized help and make an appointment with a doctor. The patient arranges the appointment with a doctor remotely. In this case, the existing complaints and the result of their analysis are sent to the doctor prior to the appointment. A patient account is created, and the most convenient time for a doctor's consultation is determined. It should be noted that, in the current practice of medical consultations, there is no possibility of a comparative analysis of clinical symptoms, especially for monitoring, due to the large number of clinical features. The doctor does not have time and data recording methods for this purpose. The proposed scheme provides the necessary level of data processing and their subsequent analysis. This methodology delivers remote monitoring of the patient's condition, since data can be transmitted over the Internet.

Conclusion

Information technologies, primarily those associated with digital data processing, led to the emergence and active development of new fields in medical practice. In recent years, examination methods were actively introduced into the practice of medical organizations, which made it possible to optimize the diagnostic process and obtain a verified diagnosis [7, 8]. Telemedicine methods seem to be the most promising in this regard, especially in the context of pandemics. They enable distance provisioning of medical care at a distance and is based on the transmission of medical information using telecommunication technologies [9].

The use of telemedicine is especially relevant for regions with remoteness of human settlements from large medical centers, where there is a problem of the quality and availability of medical care provided to the population [10, 11]. It is in remote areas and in understaffed hospitals that telemedicine technologies can effectively provide diagnostics, consultations, and medical care to patients, for whom timely intervention is critical.

Use of telemedicine technologies increases the availability of high-quality medical care to patients regardless of their location, significantly expands the possibilities for implementing human rights to receive it, and reduces the cost of providing medical services, where distance is a critical factor. At the same time, the development of information systems for contacting a doctor, based on artificial intelligence, is under way. There are very few completed projects in this area in the world. The presented results are one of the components of a comprehensive program for using neural networks in diagnosing and monitoring the condition of patients with endocrine ophthalmopathy. The program is offered on the information portal **intemsys.ru**.

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