Objective Study of Eye Movement in Ophthalmic Practice

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Abstract: Various pathological conditions of a human eye cause disorders in oculomotor functions. An objective determination of the eye movement range is crucial for diagnosing and evaluating an effectiveness of ophthalmic disease treatment. To achieve this goal, we developed the computer appliance for obtaining digital images of the anterior eye segment. The latter were standardized by illuminance conditions and could be viewed on the tablet computer screen, archived, or else sent over the Internet to the data processing server. For each eye, the motion range was determined separately for eight meridians. As a result, the algorithms for estimating the range of eye movements in relation to the diagnosis of ophthalmic diseases were determined. The developed technique and computer appliance for objective identification of the eye movement range were used for the patients of various age groups. Automation and standardization of research process exhibited high diagnostic capabilities of the computer appliance: hence, it was recommended for use in medical establishments, research institutions, telemedicine centers, and expert commissions.

Keywords: Digital images of anterior eye segment, eye movement, diagnosis of ophthalmic diseases, telemedicine.

Introduction

Determining eye movement range is of great importance in ophthalmic practice [1]. Oculomotor function disorders occur when central nervous system and the muscle of the visual analyzer are affected [2]. This leads to appearance of various strabismus types, the main symptom of which is the displacement of the eyeball relative to the visual axis [3]. There are many options for eyeball displacement, both relative to the meridian, or related to the degree of displacement. Eye movements are delivered by six muscles, along with oculomotor, trochlear and abducens cranial nerves. Thus, various combinations of oculomotor disorders occur [4].

Currently, determination of the eye movement range is conducted by a somewhat subjective method. A doctor examines a patient and controls the range of eye movements from a central position to the right, left, up and down. When strabismus is present, the technique for determining the strabismus angle is used. The severity of strabismus is determined sensu Hirschberg in degrees by a magnitude of reflected light reflex displacement from the center of the pupil [5]. The method allows identifying strabismus angles from 10 to 45 degrees depending on location of the light reflex in relation to the pupil zone. A shift in the light reflex to the region of an iris, corneal limb us or sclera is possible [6, 7].

With advances of digital measurement methods in clinical practice, the development and implementation of objective methods and devices for determining the range of eye movements to diagnose and evaluate an effectiveness of treating ophthalmic diseases is becoming increasingly relevant. Thus, the objective of our study included development and investigation of diagnostic capabilities of the computer appliance for objective determination of eye movement range.

Materials and Methods

We developed the computer appliance to determine the range of eye movements based on the analysis of digital images of an anterior eye segment (Fig. 1). The appliance is multifunctional and can be used in any operating conditions, both in medical and diagnostic medical institutions, as well as during on-site consultations and emergency care. It has autonomous power supply and fully autonomous functioning, and is compact and portable. It is able to save the results and transmit them over the Internet. The hardware of the appliance is connected to the stand mounted on a table. The stand has an adjustable height. Used light-shielding nozzles allow eye examination without dimming the room. The kit includes a tablet computer to visualize resulting eye images for saving and transmitting the data.

Figure 1. Appearance of the computer appliance hardware for objective determination of the eye movement range

Digital images of an anterior eye segment were standardized by illuminance conditions. They could be viewed on the tablet computer screen, archived, or else sent via the Internet to the data processing server. For each eye, the eyeball motion range was determined separately for eight meridians: nasal, upper nasal, upper, upper temporal, temporal, lower temporal, lower, and lower nasal. Eye positions were recorded both in binocular mode and separately for each eye. The photo or video recording mode was used at a frequency of 30 frames per second. The received data was saved as a file that could be archived and sent over the Internet. The results could be analyzed manually by applying a measuring grid to the image of the anterior eye segment.

The research technique involved fixing the face of a subject in a light-shielding nozzle and subsequent examination. As reference points for the gaze, LED light sources were used, located along eight meridians. The research can be conducted both around the circumference and spontaneously, along any meridian.

We developed the computer program working according to the following steps. First, the name and the date of birth of a study subject needs to be entered in specific fields. Next, an investigator could choose the examination methodology (the sequence of presenting light sources to a subject). An algorithm has been developed to assess the degree of an eyeball displacement in degrees and in millimeters. Each millimeter of displacement from the optical center of the cornea corresponds to 7–8 degrees of strabismus, or 15 prism diopters. The correct eyeball position is determined based on the analysis of digital images of major reference points: locations of the corneal limb us and corneal apex.

Our original program provides an examination of the position of both eyes simultaneously (Fig. 2). For subsequent data processing, a file with eye examination data is loaded into the program. The data remain in the program memory and provide its ability to dynamically compare the measurement results. The data is transmitted over wireless Wi-Fi channels.

Results

Our original method and computer appliance for objective determination of eye movement range were tested on 82 patients, ranging 6–82 years of age. After viewing the training video for the patient about the examination procedure, eye movement range was determined. Since the technique

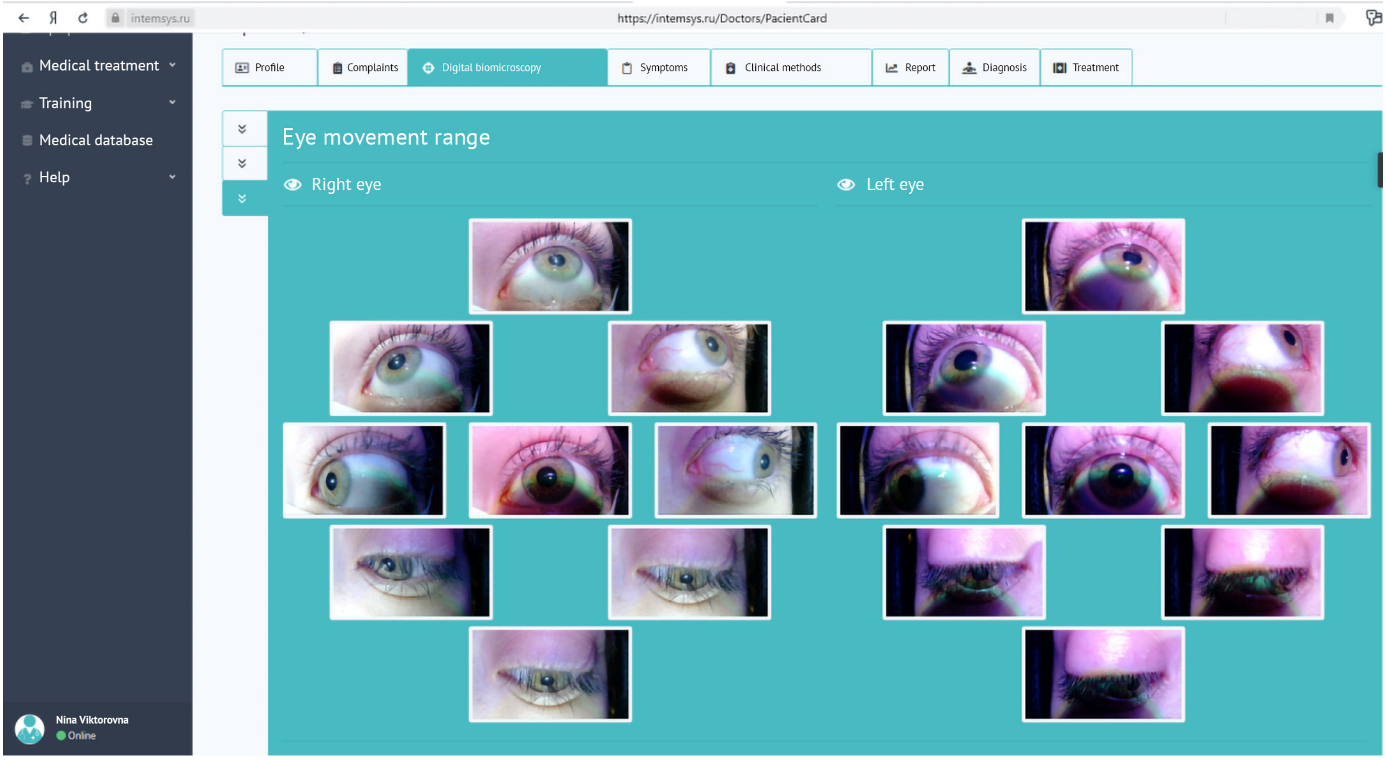

Figure 2. **The program for determining eye movement range**

was non-contact and pain-free, it was implemented successfully in all age groups. It arose interest among children; they perceived it as a game. The illuminance level during the examination did not cause blinding and discomfort in patients. The research methodology was feasible both in stationary and on-site conditions. Alternatively, the possibility of using it for telemedicine purposes hould be noted. The results were transmitted as a file to the data processing server.

Since use of the computer appliance for objective determination of the eye movement range is automated, it does not require special training of specialists. It can be employed in clinical practices of other specialty physicians, such as neurologists. The ability to transfer data via the Internet to a user's mail or data processing server ensures the possibility of remote examination and interpretation of the results.

The software was used in diagnosing strabismus of various etiologies. In addition to displacement magnitude from the horizontal meridian, it was possible to determine the presence of a vertical component, impaired adduction and abduction functions. In terms of diagnostics, the state of ophthalmoplegia was especially notable: paralysis of several or all of the ocular muscles innervated by the oculomotor, trochlear and abducens cranial nerves.

The computer program was used in diagnosing and monitoring the condition with oculomotor pathology and showed the possibility of the diagnostic process objectification, a comparative data analysis in dynamics, both in a single patient and in relation to the average age-specific norm. The most informative was the graphical option for comparing medical examination data. Digitalization and, accordingly, objectification of the data obtained in the course of the clinical examination, may significantly increase diagnostic efficiency in patients with oculomotor disorders of various etiologies.

Discussion

Our original method and computer appliance for objective determination of the eye movement ranges can be used in any age group of patients, including children. Before the study, a patient watches an information video about how it will happen. The study per se is safe and non-contact, it uses disposable wipes to ensure individual hygiene.

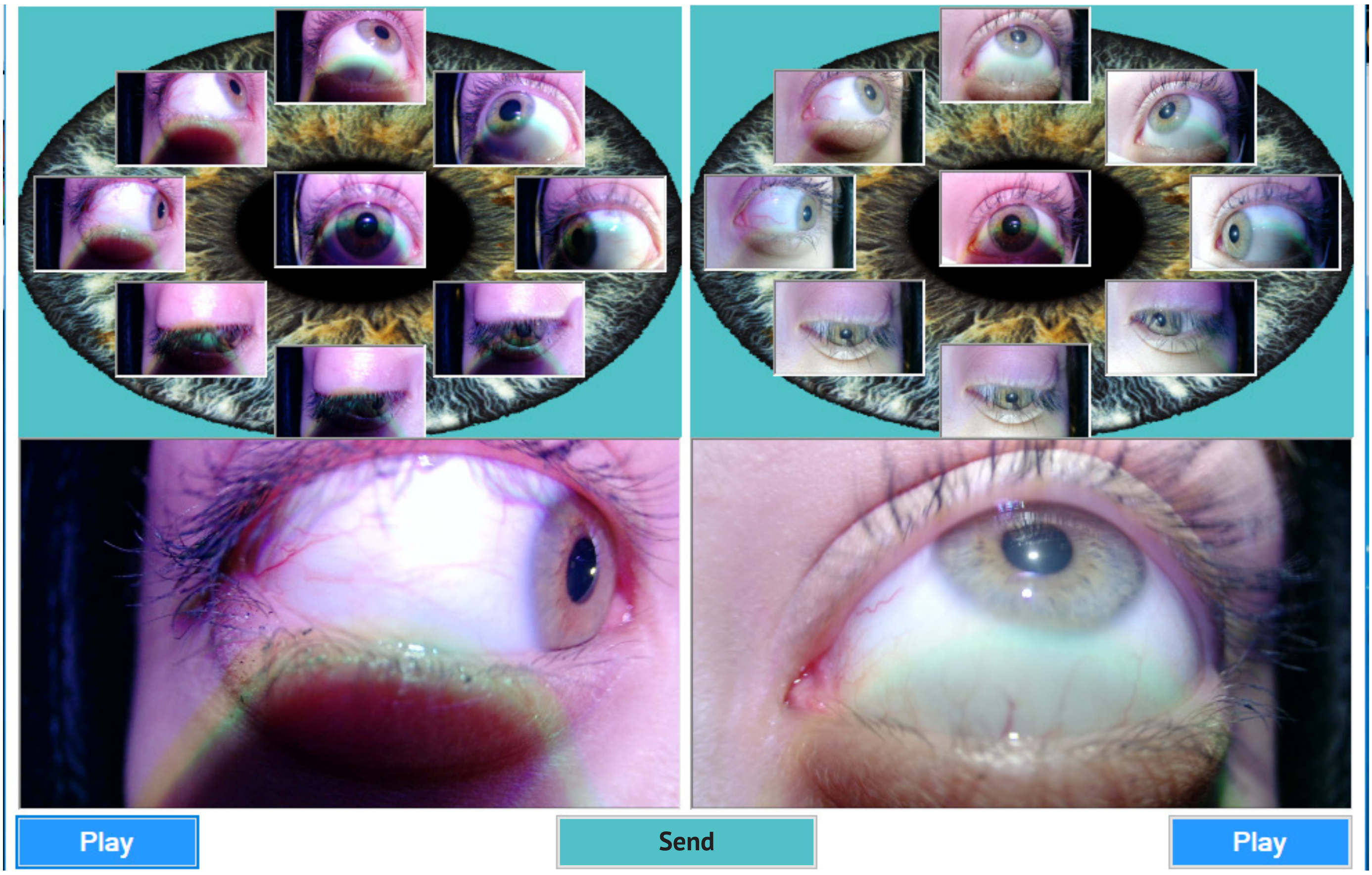

Figure 3. Program interface for objective identification of eye movement range

There are several modes for determining the ranges of eye movements. The automated mode uses a program of sequential presentation of stimuli along eight meridians. It is also possible to use the mode of free generation of the stimulus location, which provides improved diagnostic accuracy. The program has a mode of the stimulus re-presentation in order to compare the results in case of suspected error.

The results can be archived and used to evaluate the treatment effectiveness by comparing the outcomes of eye examination in dynamics via associating the graphs of the eye movement range boundaries. Functioning of the computer appliance fulfills the needs for telemedicine examinations. The software implements an ability to transmit data over the Internet via an integrated wireless transmitter. The software and hardware comply with the requirements for telemedicine equipment [4,8].

It should also be noted the lack of close analogues of the computer appliance and the experience of using this type of equipment in ophthalmic practice. A field examination option of using the computer appliance is of great importance for non-transportable patients and persons with disabilities.

Conclusion

The proposed methodology for studying the range of eye movements is objective, based on methods of digital analysis of the anterior eye segment images. The computer appliance for studying the range of eye movements is intended for use, and is used, in diagnostic and evaluation of the effectiveness of various disease treatment. The functionality of computer appliance is adapted for clinical and outpatient conditions, as well as for field examinations and remote diagnostics. Automation and standardization of the research process provides high diagnostic capabilities for use by other specialty physicians rather than ophthalmologists alone. Development of a novel equipment using digital methods and Internet information channels opens up fundamentally new opportunities, both in medical science and clinical practice: it can be used at diagnostic, treatment and prevention institutions, as well as by expert commissions, telemedicine, and research centers.

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