

New visual field testing possibilities (a preliminary report)

V.P. ERICHEV¹, A.P. ERMOLAEV¹, A.A. ANTONOV¹, G.L. GRIGORYAN², J.V. KOSOVA¹

¹Research Institute of Eye Diseases, 11 A, B Rossolimo St., Moscow, Russian Federation, 119021; ²MOIDS Laboratory, Lomonosov Moscow State University, Leninskie gory 1, Moscow, Russian Federation, 119991

There are currently no portable mobile perimeters that allow visual field testing outside ophthalmologist's examination rooms. **Purpose** — to develop a mobile perimetry technique based on use of a virtual reality headset (VR). **Material and methods.** The study involved 26 patients (30 eyes) with II-III stage primary open-angle glaucoma (POAG) with compensated IOP. Perimetry was performed for each patient twice — on Humphrey analyzer (test 30-2, 76 points) and employing similar strategy on a perimeter integrated into VR headset (Total Vision, Russia). Visual field testing was performed with an interval of 1 hour to 3 days. The results were comparatively analyzed. **Results and Conclusion.** Patients have tolerated the examination well. Comparative analysis of preliminary perimetry results obtained with both methods showed high degree of identity, so the results were concluded to be comparable. By visually isolating the wearer, VR headset achieves elimination of distractions and stable light conditions for visual field testing. The headset-perimeter is compact, mobile, easily transportable, can be used in the work of visiting medical teams and for examination at home.

Keywords: perimetry, field of vision, virtual reality headset, medical on-site testing, portable perimeter, Humphrey analyzer.

Vestnik_Oftalmologii_2018-2_66EN

Glaucoma is one of the leading causes of irreversible blindness. According to WHO the number of patients with glaucoma in the world is constantly growing [1]. One of the dramatic features of the disease is that in a large part of cases the diagnosis of glaucoma occurs in the late stages, when there is already a significant and irreversible damage in the optic nerve [2,3]. On the eyes with glaucoma the peripheral vision deteriorates irreversibly and slowly while the acuity of central vision can remain high for a long time. For this reason, a large number of patients do not notice the progression of the disease. In many countries the number of cases of undiagnosed glaucoma can reach 80% [1]. The main condition for preventing blindness and preserving visual functions is early diagnosis of glaucoma and the timely beginning of treatment.

Primary diagnosis of glaucoma often occurs during occasional visits to an ophthalmologist when high intraocular pressure (IOP) is detected within the framework of a routine measurement. But this so-called “tonometric” glaucoma is often detected at advanced stages of the disease.

The leading methods in the diagnosis of glaucoma comprise optical visualization of the anterior and posterior segments of the eye, ophthalmotometry, perimetry and gonioscopy. In specialized clinics new high-tech diagnostic devices for morpho-functional evaluation of the optic nerve and retina state, such as optical coherence tomography (OCT), OCT angiography, scanning laser ophthalmoscopy [4-6] are becoming increasingly important. However the inaccessibility and high cost of these equipment as well as necessity in highly qualified specialists for interpreting the results leave these methods in real

medical practice as additional diagnostic examinations only.

In real medical practice, the main method for assessing the level of glaucoma lesion of the optic nerve is perimetry. Modern automatic perimeters have wide diagnostic capabilities and the number of strategies. The downside of these devices is lack of portability and mobility, so that the existing ones can be used in an office of an ophthalmologist only, which limits the possibility of their application in places that are far from medical centers.

Attempts to minimize the size of devices for perimetry have been made [7-9] but so far this has not produced significant practical results. A compact and mobile device for perimetry would allow to optimize the process of early diagnostics of glaucoma and monitoring the course of the disease for patients outside medical centers, as well as conduct a full-scale examination during doctor's visits to patients.

With the advent of modern digital technologies, attempts have been made to integrate the perimeter into virtual reality (VR) device [10-12].

The purpose of this work was to develop a method for studying visual field using portable and mobile equipment for perimetry on the basis of VR device (p-VRD).

Material and methods

30 eyes of 26 volunteers with open-angle glaucoma (stages II-III) with compensated IOP ($P_o \leq 19$ mmHg)

Correspondence mail:
Ermolaev Aleksey Pavlovich
e-mail: ermolaeff127@yandex.ru



Fig.1. P-VRD, designed and developed by Total Vision (Russia) based on the virtual reality helmet.

a — p-VRD (front view); b — rear view (from the eyepiece side).

with antihypertensive drops or anti-glaucoma surgery) were studied. The state of visual field was examined using a pilot sample of a portable mobile device for perimetry, which was based of a specially designed modification of the VR device (p-VRD) (Patent of the Russian Federation No. 2634682, 2017).

A screen to present the light stimuli on classical spheroperimeters is in the form of a semi-spherical bowl. P-VRD for stimuli projecting uses liquid crystal display (LCD) and an optical system, which makes it possible to comfortably watch LCD at close range, even in presbyopia condition. To obtain a diagnostic task on a flat LCD of a p-VRD similar to those used for patients in spheroperimeter, it is necessary to transform the parameters of the light stimuli (their size, brightness and presentation zones), taking into account the distortion. The result of this recalculation is the formation of a “virtual sphere” on the p-VRD display, which ensures the adequacy of the results of perimetry tests, regardless of where they were conducted — on the spheroperimeter or flat LCD of the p-VRD. Work with the virtual sphere allowed to present the term “virtual perimetry” for a new kind of perimetry. The working prototype of the p-VRD was designed and developed by the company “Total Vision” (Russia). P-VRD is a modification of the virtual reality helmet VR-2 designed for training pilots and astronauts on training simulators (Fig. 1).

For the medical use of the p-VRD the original optical system was refined, the main design tasks for the im-

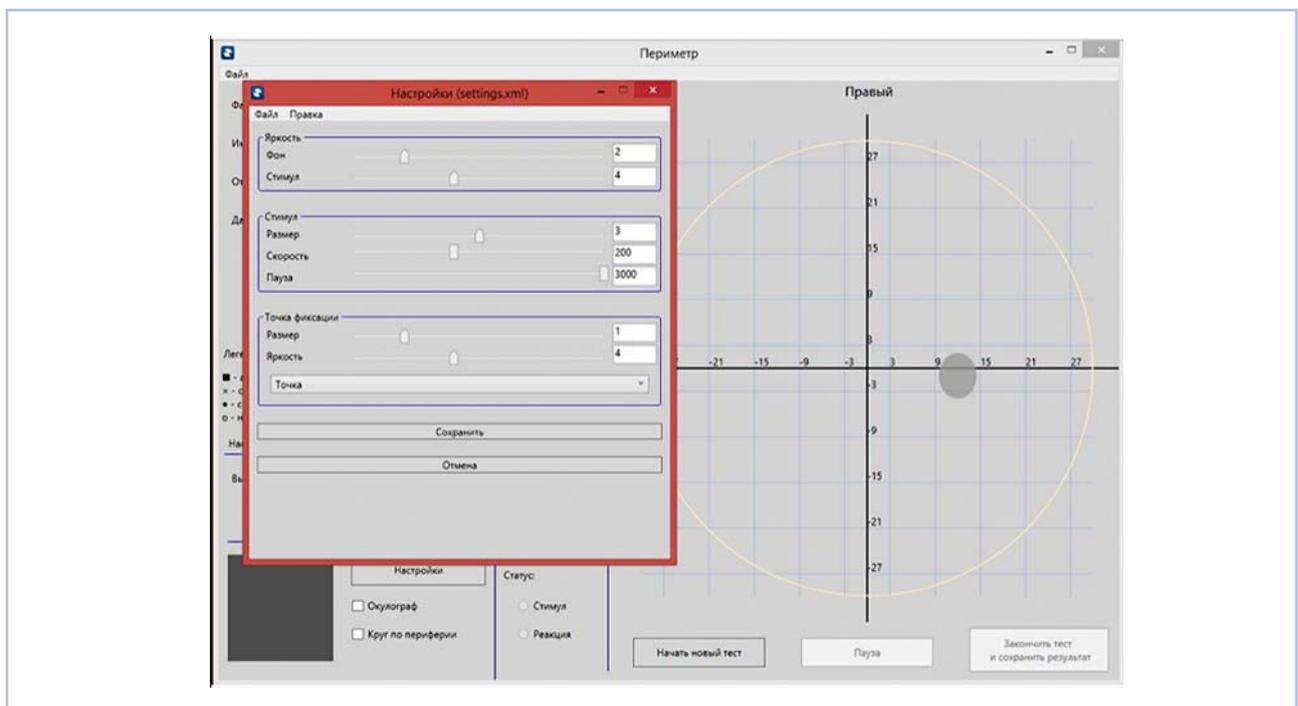


Fig.2. The screen interface for researcher allows to observe the process of examination and the patient’s answers on-line (an additional window for setting the perimetry parameters has been opened).

provement of ergonomics were defined. The special software for perimetry with a “friendly” interface was created, which allows to change the setting before the examination and to monitor the process of examination in online mode (Fig. 2) on the researcher’s computer.

Each patient was examined twice at intervals of 1 hour to 3 days between studies: 1-st time using the p-VRD, the 2-nd similarly using the Humphrey visual field analyzer (HFA) (which was considered a control group). With the use of the p-VRD, screening of the visual field was performed in the range up to 30° from the fixation point (total — 60°). As a strategy for examining the work of the screening program (test scheme 30-2) presented in the HFA was selected with stimuli presentation in 76 points, with a 6° interval between points along the vertical and horizontal axes (Fig. 3).

The brightness of the background luminescence of the LCD corresponded to 31.5 asb. At the request of the researcher the main parameters of the testing program could be changed. The following parameters were set by default: the background color is white (on the RGB scale — R255G255B255), the fixation point of the eye corresponded to size III according to Goldman (color R255G204B0). A random order of presentation of light stimuli is chosen. The duration of each stimulus was 200 ms, the pause between stimuli was 3 s., the stimulus size corresponded to size III for the Goldman perimetry (0.43 angular degrees).

In the ongoing screening study an algorithm of random presentation of stimuli and a 3-zone strategy was used. The stimulus of supra-threshold luminance is initially presented. In case the patient does not respond, after a while, after presentation of some stimuli in other points, the program repeats the stimulus at the same point with the same brightness. If this again turns out to be unnoticed, the brightest signal is sent to this point. If the first or second (similar in parameters) stimulus re-

ceived a positive response, the program fixes this as the *absence of scotoma*. In case there was no response to the supra-threshold stimulus, but the patient responded to a bright stimulus, the program registers this as the presence of *relative scotoma*. If the answer is absent for all three stimuli, the program fixes the result as *absolute scotoma*.

The study was conducted in accordance with the decision of the local ethical committee of the Research Institute for Eye Diseases of the Russian Academy of Sciences of September 19, 2017.

The course of the examination (Fig. 4). LCDs for both eyes in the p-VRD are physically isolated. During the examination each eye sees only its part of the screen. There is no need to close the pair eye with an occluder. (In this case, the patient has the illusion that he sees the p-VRD display with both eyes.) Since the display constantly works in the background illumination mode simultaneously in front of both eyes, it ensures the maintenance of a constant level of dark adaptation, which allows to obtain more objective results.

The examination protocol. The patient is conveniently placed on a chair and instructed on the operation of the device and the necessary actions, until a complete understanding of what he should do is reached. A diagnostic program is run on computer, and the p-VRD display starts to glow in the background. The p-VRD is fixed on the patient’s head so that it does not cause discomfort. In doing so, the doctor must ensure that the helmet does not hang under its own weight, and the display of the device would be perpendicular to the patient’s line of gaze directed forward, since the skewed helmet may cause a false sickle-shaped scotoma in the lower part of the visual field. The patient is asked to keep the gaze of the examining eye on the fixation point in the center of the screen to maintain the position of the eye for the entire duration of the study. A feedback button, which he must push when he sees the stimulus is in his hand, just as it is done with other automatic devices for perimetry.

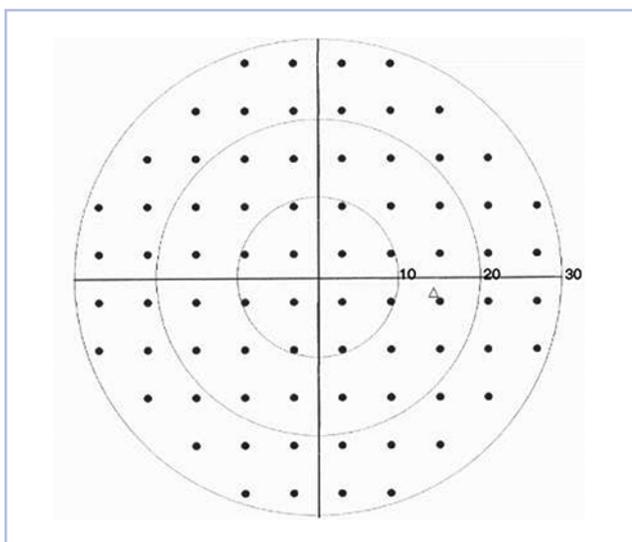


Fig.3. Pattern test for the right eye (similar to 30-2, HFA).



Fig.4. P-VRD in the examination process.

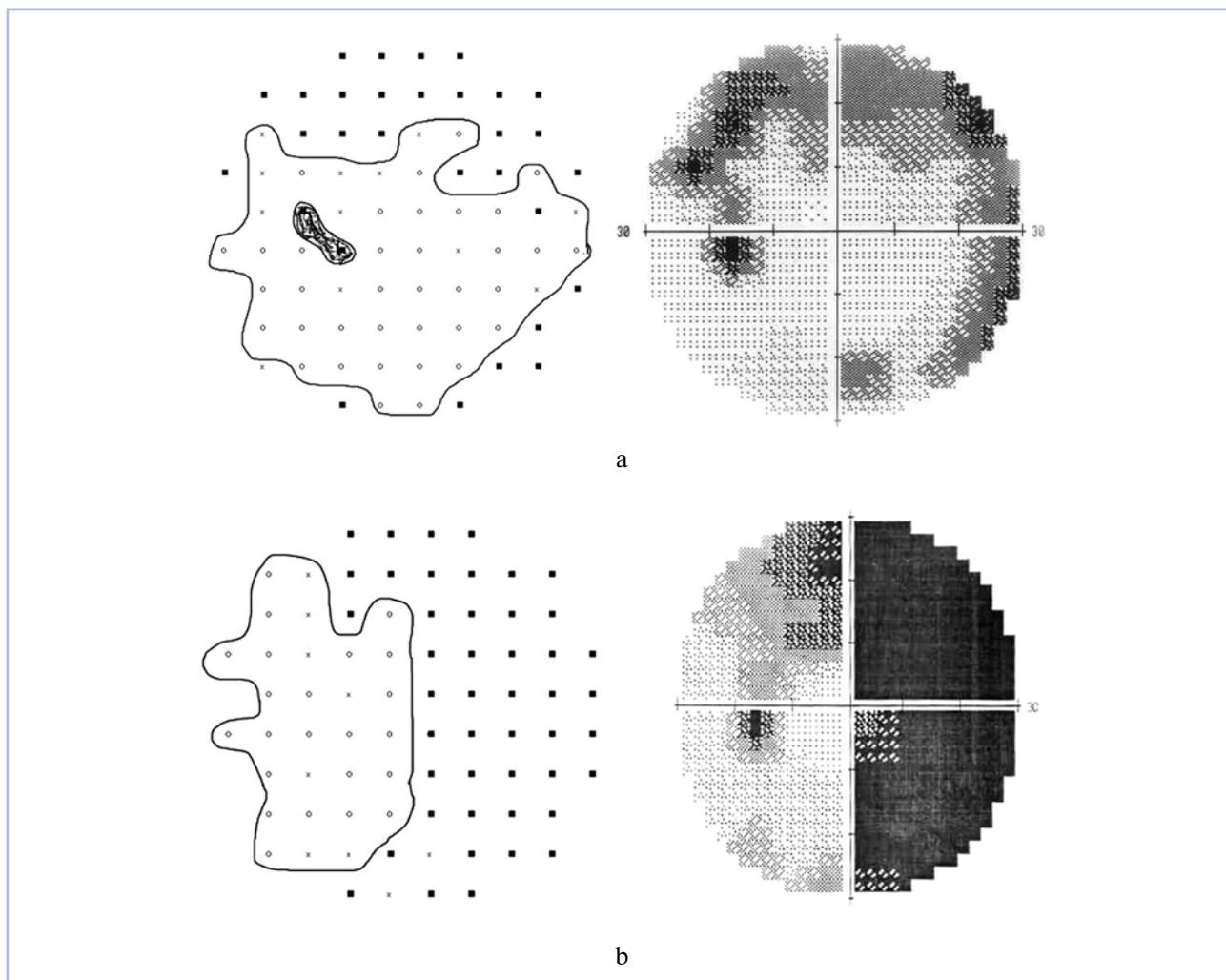


Fig.5. Results of perimetry in the study of the same eye.

a — data of the screening perimetry performed with p-VRD; b — threshold perimetry, carried out according to the program 30-2 with the use of the Humphrey analyzer (HFA). Hemianopsia from the nasal side, relative scotoma in the zone of Bjerrum.

To control the correct direction of eye gaze the principle of Heijl-Krakau is used. (A false light stimulus is periodically fed into the zone of the blind spot. In case of positive responses to false stimuli, deviation of the line of sight is indicated. This allows to understand the reliability of the results.) A summary of positive responses to false stimuli is reflected on the screen of researcher's computer on-line, and can be posted on the printout.

A comparative evaluation of results obtained with the use of p-VRD for test 30-2 and the results for the same patients using the HFA was performed (Fig. 5).

Results and discussion

All patients tolerated the examination well. The symptoms of claustrophobia were not detected. The duration of the examination (if the patient saw all the stimuli at the first projection and the program did not need to

repeat them) is about 4.5 minutes per eye. In the presence of defects in the visual field, if there was a need for repetition of stimuli, the study time could last up to 8-9 minutes. The results of the screening perimetry are stored in the database and simultaneously printed out (see Fig. 5).

We consider the results of our study as preliminary, since further work is needed to improve not only the technique of examination but also the hardware and software.

A comparative visual analysis of the results of the visual functions examinations obtained with the help of the Humphrey analyzer in the 30-2 screening test and the results of perimetry obtained p-VRD with the same test showed a high degree of identity of the patterns of defined scotoms.

This allows us to draw preliminary conclusion about the comparability of the results of the studies obtained

with both devices. Nevertheless, this work is of a pilot nature and further research is needed on a statistically significant sample.

In the course of assessment of results of the study with p-VRD, new technical targets were identified: it is necessary to achieve a careful fit of the rubber pad of the helmet to the face to prevent extraneous light penetration, since the slightest light reflection distracts the patient; to improve the sanitary characteristics of the gasket, to ensure efficient ventilation of the space under the helmet to prevent fogging of the optical system; to refine the control of gaze line direction and also to improve the ergonomics of the p-VRD in order to create the necessary level of comfort for the patient.

Along with this it is important to note the indisputable value of the perimeter, based on the VRD:

1. P-VRD isolates the patient from the visual sensations of the surrounding space. This helps him to concentrate attention only on what is projected on the screen. This helps to eliminate distractions and increase the effectiveness of the study.

2. Constant background illumination for both eyes support the condition for maintaining a constant level of dark adaptation.

3. The mobility and compactness of the p-VRD allows it to be easy transported and quickly brought into service which makes it promising to use out of hospital and in doctor's home visits.

4. The ability to encode the received information into an electronic protocol allows the use of p-VRD in telemedicine, confidentially sending diagnostic information for decryption and archiving to a remote consultation center.

Conclusion

P-VRD is a convenient mobile device for early diagnosis of glaucoma. The results of the screening perimetry obtained with the help of p-VRD, are comparable with the perimetry data obtained using the Humphrey visual field analyzer.

In the long term the device can be used for clinical examinations out of hospital, for telemedicine and for an ophthalmologist's home visits.

The authors declare that there are no conflicts of interest.

REFERENCES

1. Egorov E.A., Astakhov Yu.S., Eriчев V.P. Natsional'noye rukovodstvo po glaukome: dlya praktikuyushchikh vrachev — M.: GEOTAR — Media, 2015. (In Russ.).
2. Libman Ye.S. Epidemiologicheskiye kharakteristiki glaukomy/. Libman E.S., Chumayeva E.A., Yel'kina Ya.E. HRT Klub Rossii: sb. nauch. st.— Moscow, 2006;75-78 (In Russ.).
3. Libman E.S. Morbidity and disability in glaucoma in Russia. Need for rehabilitation. E.S./ Libman, E.V. Shakhova, Chumaeva E.A. VII Congress of Ophthalmologists of Russia: theses. reports, part 2.—Moscow, 2000. (In Russ.).
4. Volkov V.V, Zhuravlev A.I. Disk of the optic nerve in glaucoma. *Oftal'mologicheskii zhurnal*. 1982; 5: 272-276 (In Russ.).
5. Jarulla-zade Ch.D., Gasanova L.A. Informativeness of optical coherence tomography (OCT) in early diagnosis of glaucoma of the twin eye. *Oftal'mologiya*. 2010; 3: 53-55 (In Russ.).
6. Egorov E.A, Obruch B.V Skaniruyushchaya lazernaya polyarimetriya. *Oftal'mologiya*. Natsional'noe rukovodstvo pod red. Avetisova S.E., Egorova E.A.- M.:GEOTAR-Media. 2008: 155-158. (In Russ.).
7. Patent RF na izobretenie №2376926/ 17.06.2008. Fokin V.P, Balalin S.V, Bogdanov V.N. Ustroystvo dlya issledovaniya polya zreniya. (In Russ.).
8. Patent RF na izobretenie №2420223/ 06.03.2009. Betin V.N. Ustroystvo dlya issledovaniya polya zreniya. (In Russ.).
9. Patent RF na izobretenie №2409306/ 29.10.2009. Dvoretsov A.M, Smol'ey A.M, Sysoev S.S, Firsov E.E. Ustroystvo dlya issledovaniya polya zreniya. (In Russ.).
10. Patent USA №5737060/ 7.04.1998 Kasha Jr. Visual field perimetry using virtual reality glasses.
11. Tsapakis S., Papaconstantinou D., Andreanos K., Moschos M., Brouzas D. Visual field examination method using virtual reality glasses compared with the Humphrey perimeter. *Clin Ophthalmol*. 2017;11:1431–1443. <https://doi.org/10.2147/OPHTH.S131160>
12. Wroblewski D., Francis B., Sadun A., Vakili G., Chopra V. Testing of Visual Field with Virtual Reality Goggles in Manual and Visual Grasp Modes. Hindawi Publishing Corporation BioMed Research International. 2014. <https://doi.org/10.1155/2014/206082>