Electrodes Device for Impedance Diagnostics of the Blood Flow in the Ophthalmic Artery

Petr V. Luzhnov[1], Anna A. Kiseleva[1] and Elena N. Iomdina[2]
[1]Bauman Moscow State Technical University, Moscow, Russian Federation
[2]Moscow Helmholtz Research Institute of Eye Diseases, Moscow, Russian Federation

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Abstract: The paper presents new electrodes device for diagnostics of the eye blood filling based on the registration of rheographic signals. The methods of bipolar rheoophthalmography and tetrapolar transpalpebral rheoophthalmography are briefly discussed. The elastic tape is presented as electrodes device. All main parameters of new electrodes device are chosen. An electrodes system has been developed for recording the pulse blood filling of main large arteries near eye: ophthalmic artery, internal carotid artery, anterior cerebral artery and middle cerebral artery. The application of this technique was shown in the example. Calculations made in analyzing signals obtained from patients without an ophthalmopathology are presented, which show that eye blood filling in the ophthalmic artery was 30-42 % above, than at research of an eye by a technique transpalpebral rheoophthalmography.

1 INTRODUCTION

A comprehensive analysis of blood flow is necessary for obtaining complete information about the eye blood flow and forming effective diagnostic conclusions on this basis. Currently, for studying the blood flow in the eye arteries, the transpalpebral ultrasound method is known - ultrasound color mapping (Machekhin and Vlazneva, 2009; Kiseleva, 2004). In addition, contactless optical methods are known - optical coherence tomography, angiography (Kurysheva et al., 2017) and laser Doppler flowmetry (Kiseleva and Adzhemyan, 2015).

Electrical impedance methods are now known, including methods for obtaining the impedance distribution in a human body through non-invasive electrical sounding, calculations and reconstruction algorithms (Patterson, 2005). The rheography is the electrical impedance method for studying the pulse oscillations of the blood flow in the vessels of various organs and tissues which based on the graphic recording of changes in the total electrical resistance of tissues (Sokolova et al., 1977). In electrical impedance diagnostics the ophthalmoplethysmography and the rheoophthalmography are also known (Avetisov et al., 1967; Lazarenko et al., 1999; Lazarenko and Komarovskikh, 2004). Rheoophthalmography (ROG) is the method for assessing the state of the blood flow in the eye. ROG is a method for studying the pulse blood filling in the vessels of various organs and tissues, based on recording changes in the total electrical resistance of tissues. In the classical method of ROG registration, the electrodes are mounted directly on the surface of the eye near the lens. It leads to necessity of anesthesia for conducting diagnostic researches.

To solve the limitations of the classical technique, a new registration technique has been developed - the method of transpalpebral rheoophthalmography (TP ROG) (Luzhnov et al., 2015; Luzhnov et al., 2017; Luzhnov et al., 2018; Shamaev et al., 2018). In this version of the study, the electrodes for TP ROG are positioned on the closed upper eyelid. This method provides for applying the special device for positioning the electrodes during the research (Luzhnov et al., 2017). The method is designed for obtaining quantitative parameters of uveal ocular blood flow. The main disadvantage of this method and device for its implementation is the impossibility of simultaneous evaluation of the blood flow in the ophthalmic artery and cerebral arteries.

The rheography electrodes system proposed by K.K. Yarullin are used in the studying of the brain

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(Yarullin et al., 1980). This electrodes system allow to estimate the blood flow in the main cerebral arteries: the anterior cerebral, middle cerebral, posterior cerebral and vertebral arteries (Bodo, 2010). The main drawback of this method is the impossibility of registration the pulse volume of the ophthalmic artery.

The above-mentioned methods do not allow a comprehensive assessment of the blood flow in the eye vessels, due to the fact of examining the blood flow in each vessel separately. At the same time, with the help of the electrical impedance method, it is possible to evaluate the blood flow not only in the individual arteries, but also in the whole vascular system of the eye. The main task of this work is a development of a device for the integrated assessment of blood circulation in the vessels of the eye and in addition of the brain, namely in the ophthalmic artery, (from which all the vessels of the eye branch off), and in the vessels of the anterior brain, the anterior cerebral artery and middle cerebral artery.

2 MATERIALS AND METHODS

2.1 Problem Statement

The electrical impedance methods ROG and TP ROG require to placing electrodes (see the Figure 1) for estimating the pulse volume of blood in intraocular vessels.

Both of these methods survey blood vessels from the first area (see the Figure 2) in diagnostic procedures. The rheoencephalography method (Sokolova et al., 1977) allows to estimate the blood flow in the third area in the Figure 2.

The diagnosing, for example, of patients with glaucoma (Luzhnov et al., 2018), demands a blood flow definition in vessels from the second area. Electrodes systems for ROG or TP ROG do not approach for this purpose.

Therefore the special electrodes device has been developed in our work. A distinctive feature is the possibility of conducting a comprehensive analysis of the blood flow in the ophthalmic artery and the vessels of the anterior part of the brain for further diagnosing, including early hemodynamic disorders in eye diseases and evaluating the effectiveness of their therapy. It is achieved through using sixteen electrodes system, positioned in accordance with the anatomical location of the analyzed vessels parts (internal carotid artery, anterior cerebral artery, middle cerebral artery and ophthalmic artery).

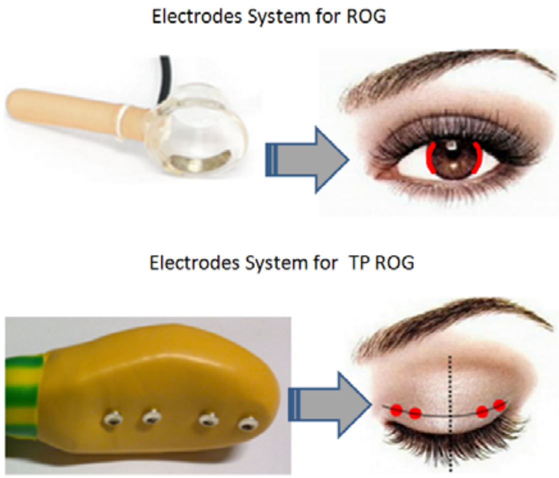

Figure 1: The electrodes systems for ROG and TP ROG.

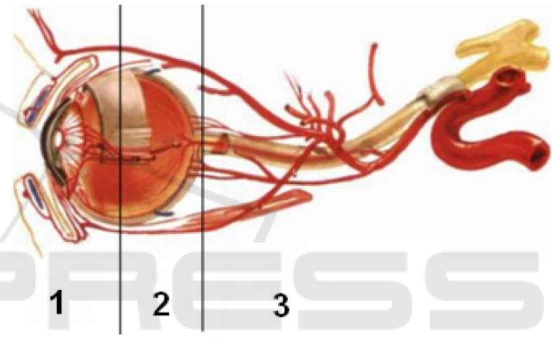

Figure 2: The areas of ocular blood vessels.

2.2 Electrodes Device

The device is an elastic tape with holes for further accommodation of 16 electrodes. 12 holes are located on the tape itself, and 4 holes are on 4 plates attached to the tape and protruding beyond tape’s borders. The tape has a pair of Velcro fasteners. They are providing, if necessary, the length changing of the tape.

A schematic picture of the device is shown at the Figure 3.

On the Figure 3 are shown:

1 – The elastic tape with a hexagonal hole in the center;

2 – Velcro fasteners at the borders of the tape, separated by a notch in the tape;

3 – The plates with holes for the electrodes protruding beyond tape’s borders;

4 – The holes for electrodes.

Velcro fasteners (at the borders of the tape) provide, if necessary, changing in the length of the tape in accordance with the anthropometric data of the patient's head and the necessary level for pressing the device to the patient's head. A pair of Velcro fasteners is located on the left and right ends of the tape. Structurally they are separated from each other by a notch in the tape, preferably 10.0 ± 1.0 mm wide. It allows to adjust the tension of the tape separately along its upper and lower edges, also for avoiding warping tape while fixing it on the patient’s head.

As a result, the perimeter of the tape in the buttoned state can vary in the range of 550-600 mm and can be chosen individually for each patient. The distance can be 20.0 ± 2.0 mm between the holes of the electrodes. The attachment points of the outside electrodes on the left and right sides of the tape (four electrodes on each side) are used for registration the pulse volume of the internal carotid artery, the anterior cerebral artery and the middle cerebral artery.

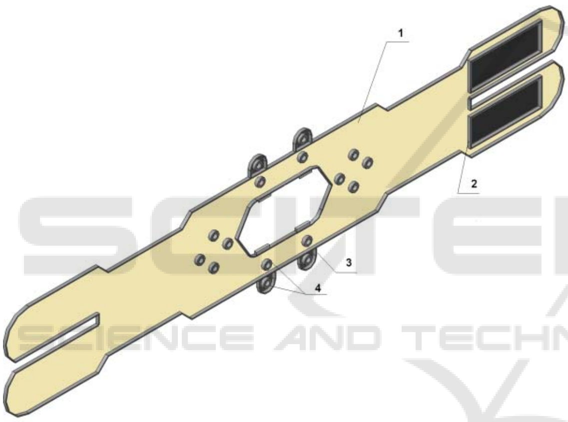

Figure 3: The elastic tape as electrodes device.

The holes for mounting the electrodes can have a diameter of Ø7.0 ± 0.7 mm. Each hole for mounting the electrode can be equipped with an insulating stopper, which allows to mount reusable metal electrodes.

Four plates (pos.3 in the Figure 3), made, for example, of ABS plastic (acrylonitrile butadiene styrene), are fixed on the tape. The location of the plates in the device is selected in accordance with the anatomical location of the ophthalmic artery. Each plate can be located at a distance of 25.0 ± 2.5 mm from the horizontal symmetry axis of the tape. Each plate has two holes for fixing the electrodes. One of the holes is taken out of the tape’s borders, and the other coincides with the corresponding hole in the tape.

The mounting holes for the electrodes preferably have a diameter of Ø7.0 ± 0.7 mm. Each hole of the electrode can be equipped with an insulating stopper in the case of mounting reusable metal electrodes.

2.3 Using in Clinical Practice

The device is used as follows: a device with electrodes located in it, fixed on an elastic tape and its plates, is mounted on the patient's head in the periorbital region (on the closed eye). The location of the plates is determined in accordance with the patient's nasal bone - the plates should be placed at a distance of 15 ± 3 mm from the nasal septum. Further, fixation on the patient's head is carried out with the help of Velcro elastic tape. After that, the device is ready for operation and further connection to the device of recording electrical impedance signals.

While using the device, it is possible to simultaneously obtain quantitative parameters of the blood flow in the ophthalmic artery and the blood flow in the vessels of the anterior part of the brain.

An example of the electrodes positioning scheme is shown at the Figure 4. This example shows use of the device for studying the left hemisphere of the brain. The scheme for studying the right hemisphere is symmetric relative to the sagittal plane.

In our research, TP ROG signals were analyzed in a group of patients without an ophthalmopathology. In total, four pairs of records with duration of two minutes each were analyzed. Each pair contained TP ROG signal (as in the Figure 1) and ROG signal from new electrodes device (as shown in the Figure 4).

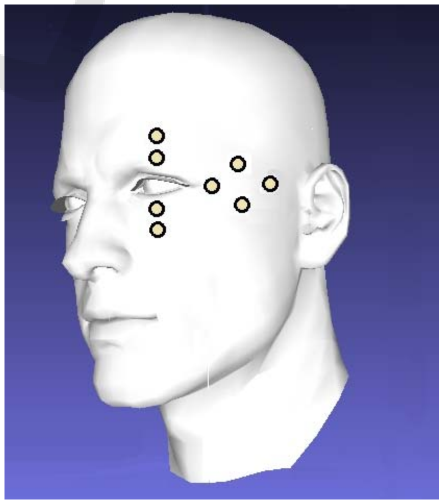

Figure 4: The registration of impedance signals for studying the left hemisphere of the brain.

This study was performed in accordance with the Declaration of Helsinki and was approved by the Local Committee of Biomedical Ethics of the Moscow Helmholtz Research Institute of Eye Diseases. A written informed consent was obtained from all participants.

3 RESULTS

The example of typical TP ROG signal, which is recorded in the 29 years old patient without an ophthalmopathology, is shown in the Figure 5. TP ROG signal shows blood flow pulse oscillations. Base impedance (BI) reflects blood filling level of eyes tissues.

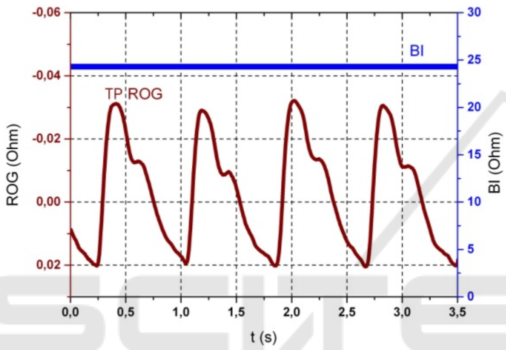

Figure 5: The example of TP ROG signal.

The results of using our electrodes device with such an arrangement of a tape with electrodes showed compliance with theoretical calculations which were obtained on the basis of a mathematical model (Shamaev et al., 2017) for TP ROG.

Value of BI parameter at blood flow research in the ophthalmic artery was 30-42 % above, than at research of an eye by a technique TP ROG. This result coincides with a theoretical estimation which gives increase of a base impedance parameter in this case.

4 CONCLUSIONS

The constructed device provides the ability for conducting multichannel electrical impedance studies in ophthalmology, with simultaneous assessment of blood flow in the orbital artery without contact with the eye surface, as well as in the vessels of the anterior part of the brain, which can have great importance in clinical practice - for the diagnosis of eye diseases and control the effectiveness of their treatment.

CONFLICT OF INTEREST

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