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Options for implementing electrical impedance tomography for diagnostics blood clots and bruises

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Abstract. The possibility of detecting and diagnosing bruises, blockages of veins or arteries and blood clots based on electroimpedance tomography is being considered. The advantages of electroimpedance tomography compared to other similar methods are substantiated. Physical principles are presented, implementation options for the electrical impedance tomography method are systematized; the basics of the clinical application of this diagnostic method including the capabilities of both classical and portable installation options are outlined.

Keywords: electroimpedance tomography, non-invasive diagnosis, bioimpedance, biological tissue, electrode

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Возможности применения электроимпедансной томографии для диагностики тромбов и гематом

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Аннотация. Рассмотрена возможность обнаружения и диагностики гематом, закупорок вен или артерий и тромбов на основе электроимпедансной томографии. Обоснованы преимущества электроимпедансной томографии по сравнению с другими аналогичными методами. Представлены физические принципы, систематизированы варианты реализации метода электроимпедансной томографии; Изложены основы клинического применения этого метода диагностики, включая возможности как классического, так и портативного варианта установки.

Ключевые слова: электроимпедансная томография, неинвазивная диагностика, биоимпеданс, биологическая ткань, электрод

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Introduction

The principle of the electroimpedance tomography (EIT) method is to supply an electric current or voltage through electrodes that are located on the body of the person being examined. Thanks to this method, the impedance distribution of human tissues is visualized. The method is based on measuring the potential difference between the electrodes and the electric currents flowing through the electrodes [1]. The method of electroimpedance tomography has a number of advantages over other similar diagnostic methods, which, first of all, include ultrasound (ultrasound), magnetic resonance imaging, as well as computed tomography. The EIT positive functional characteristics include the fact that the method has high resolution and is non-invasive [2]. In addition, the method is also promising in terms of technical and economic indicators, since it is characterized by low cost, the small weight and overall dimensions of the equipment allow it to be portable, which opens up prospects for real-time monitoring. Technical limitations of the EIT method are associated with the inability to reconstruct the image slice by slice, since a change in conductivity anywhere in the region affects the measurement results in various areas, and not just for a specific slice [3]. The possibility of developing wearable portable devices based on EIT expanded the prospects for using this tomography method, which is essentially a unique portable imaging method.

Options for implementing EIT in practice

EIT with time-stretched measurements is useful for monitoring changing physiological phenomena (for example, 24-hour monitoring after surgery), but it is only applicable in special cases where changes occur over time, such as ventilation and perfusion. In contrast, EIT with a varying frequency of the current or voltage probing signal influences various tissue impedance characteristics, allowing image reconstruction if it is necessary to make measurements in a shorter time frame. Various modifications of the EIT imaging method are summarized in Table.

When implementing a method based on impedance measurement, single measurements, which are used to restore the distribution of absolute impedance across the tissues of the human body are performed. Despite the theoretical elaboration, in practice a number of uncertainties, which include errors in the location and accuracy of the electrodes on the surface of biological tissues, as well as other sources of systematic errors lead to errors in image reconstruction. Possible directions for solving this drawback are widely discussed in a number of scientific papers [2–3].

The current supply can be implemented in different ways depending on the specific purpose. A modification of the method is possible, in which an electric current is supplied between two adjacent electrodes, and the voltage is recorded between all remaining pairs of adjacent electrodes. This is the most common method. In another variant, it is possible to supply the current with two electrodes located at an angle of 180° relative to each other. In this case, the measurement of the electric voltage is carried out in pairs between each of the electrodes and the reference electrode [5]. One of the most common ways of such an arrangement of electrodes is the method of electroimpedance tomography in the study of the brain. The diagonal or cross arrangement of the electrodes is due to the fact that one electrode is used to measure voltage as a reference, and the current is set alternately between different combinations of electrode pairs.

Further, the following approaches to the implementation of electrical impedance tomography in practice are considered:

- EIT in voltage mode consists of applying a given voltage to biological tissues through electrodes and measuring induced currents;
- EIT in current mode means supplying specified values of electric currents and measuring voltages generated on the human body surface.

Table

The effect of lens voltage on the structure size

Area of application	Measurements based on the modification of the EIT method	Measured parameter
Computer modeling of tissues bioimpedance distribution	Impedance measurement	Bioimpedance
Study of the processes dynamics occurring in the body	Measuring dynamically changing impedance	Time dependence of bioimpedance
Identification of various types of biological tissues	Measuring impedance with a changing frequency of the measuring signal	Frequency dependence of bioimpedance

The so-called trigonometric modification of the method of arranging electrodes is based on the supply of electric current to all electrodes simultaneously. In this case, the electrical voltage is measured relatively to the reference electrode. The specified implementation of the method involves performing multiple independent measurements, due to a significant reduction in the random component of the measurement error is achieved.

The so-called trigonometric modification of the electrodes arrangement method is based on supplying an electric current simultaneously to all electrodes. In this case, the electrical voltage is measured relative to the reference electrode. The specified implementation of the method implies the performance of multiple independent measurements, thereby achieving a significant reduction in the random component of the measurement error [6–9].

The frequency of the flowing current depends on the bioimpedance and dielectric constant of the analyzed biological tissue. The standard frequency at which measurements are performed is 50 kHz, but some devices analyze several frequencies (10 Hz–10 MHz) to improve image quality and analyze various tissues. However, frequencies above 1 MHz are complex, primarily due to parasitic impedances that distort signals; thus, special high-performance circuit components and data acquisition modules are required [9–10].

Due to the fact that the conductivity of the human body has different numerical values in different areas, in addition, the measurement of conductivity is not always possible due to the technical capabilities of electrical impedance tomography, it is advisable to use the EIT to diagnose clots and bruises in the extremities and abdominal cavity, limbs, neck and head. Blood clots and bruises have reduced conductivity, unlike whole blood, as they are formed due to clots of blood components, lipids and proteins. To detect their accumulation or presence in a specific desired area, it is required to conduct an EIT under normal conditions, introduce a marker into the circulatory system in the form of a sodium chloride solution to improve blood conduction and re-examine the EIT [11–12].

We assume that the best EIT application is the diagnosis of pulmonary thromboembolism. There are several factors associated with it. Firstly, the belt of injecting-diagnostic electrodes can be positioned quite well precisely on the chest, where, in fact, the lungs and the small circulatory circle are located. This arrangement of the electrodes contributes both to the tight mechanical fixation of the electrodes and to the location of the electrodes at a distance from each other. Due to it, the mutual influence of the electrodes on each other is minimized and the parasitic capacitive component of measuring the potential difference on paired electrodes is minimized. Secondly, since pulmonary thromboembolism is caused by blood clots that form more often in the large veins of the lower extremities or pelvis, it is necessary to monitor changes in blood flow to the lower extremities, which can be done using the rheography method in tandem with an EIT. In addition, the flow of blood fluid by rheography can be measured between the upper extremities in order to already deal with hemodynamic characteristics during the EIT.

There are various methods for determining the hemodynamic parameters of the circulatory system. The most common are the stroke volume of the heart (SVH) according to the Kubichek, Tishchenko method and now patented by the domestic specialist Zabolotskikh I.B.

According to the latest method, the stroke volume of the heart in patients without heart defects is determined according to the following expression:

$$US = \left(90.97 + 0.54 \cdot PD - 0.57 \cdot AD - 0.61 \cdot V\right) \cdot k.$$

To calculate the stroke volume of patients with heart disease, the expression is used:

$$US = \left(90.97 + 0.54 \cdot PD - 0.57 \cdot AD - 0.61 \cdot B\right) / k,$$

where *US* is the stroke volume of the heart, *PD* is pulse pressure, *AD* is diastolic pressure, *V* is age in years, *k* is the entered coefficient depending on the patient.age.

To calculate the blood volume per minute (VB), the following formula was used:

$$\text{VB} = \text{UOS} \cdot \text{FS} / 1000,$$

where UOS is the stroke volume of the heart, FS is the heart rate.

Pulse pressure is the difference between systolic and diastolic blood pressure, which can be determined using a tonometer using a hydrojet [13, 14].

Thus, it is possible to make an entire system based on rheography, EIT and tonometer, monitoring the hemodynamic parameters of a person and in monitoring mode (for example, during the day) determine a person's predisposition to thromboly in the early stages.

Conclusions

When implementing electroimpedance tomography, the bioimpedance distribution is analyzed based on the measurement of electric current and potential difference at the electrodes. The solution of the specified problem of reconstruction of the impedance distribution is nonlinear. In contrast, in the case of X-ray computed tomography, photons travel along rectilinear trajectories. In the case of EIT, the current depends on the bioimpedance values in different parts of the object. This imposes limitations on the task of image reconstruction using electroimpedance tomography. To increase the EIT modeling accuracy, it is necessary to take into account the anatomically realistic geometry of the body, heterogeneity, filling of living tissues with blood and other fluids, and the flow rate of fluids in the body.

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