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ASSESSMENT OF BLOOD CIRCULATION DISORDERS IN BIOLOGICAL TISSUE USING THE ELECTRICAL CONDUCTIVITY METHOD

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Анотація. *Встановлено, що при одночасному вимірюванні зміни імпедансу в двох однакових ділянках кінцівок постійна часу іонізації є критерійним параметром для вивчення розвитку ішемії. Розвиток синдрому реперфузії у досліджуваних біологічних об'єктах спостерігається при порушенні перфузії протягом більше ніж 1 години, а порушення перфузії протягом більше ніж 2,5 годин призводить до незворотних змін властивостей біологічної тканини.*

Ключові слова: електрична провідність, кровообіг, біологічна тканина, множинні травми різного ступеня тяжкості.

Abstract.*It has been established that when measuring the impedance change in two identical areas of the limbs simultaneously, the ionization time constant is a criterion parameter in studying the development of ischemia. The development of reperfusion syndrome, for the studied biological objects, is observed when perfusion is disrupted for more than 1 hour, and perfusion disruption for more than 2.5 hours leads to irreversible changes in the properties of BT.*

Keywords:electrical conductivity, blood circulation, biological tissue, multiple injuries of varying severity.

Introduction

The primary cause of death in polytraumas of varying severity remains blood loss. Circulatory disorders are also associated with a number of diseases, such as arterial and venous hyperemia (hyperemia), ischemia, blood stasis, thrombosis, disseminated intravascular coagulation (DIC) syndrome, embolism, infarction, bleeding and hemorrhage, diabetes mellitus, and others [1,7]. Currently, the incidence of circulatory disorders is 1.5% of cases per 10,000 people per year. Limb injuries resulting from industrial and household activities, in particular, when received in a combat zone, remain the main cause of lethal consequences and injuries among people of working age, especially during military operations.

Circulatory disorders lead to the development of necrosis, paranecrosis, which precedes necrobiosis. Acidosis occurs in the tissues, hyperkalemia develops [1,2]. Figure 1 presents the consequences of acute limb ischemia (diabetic foot).

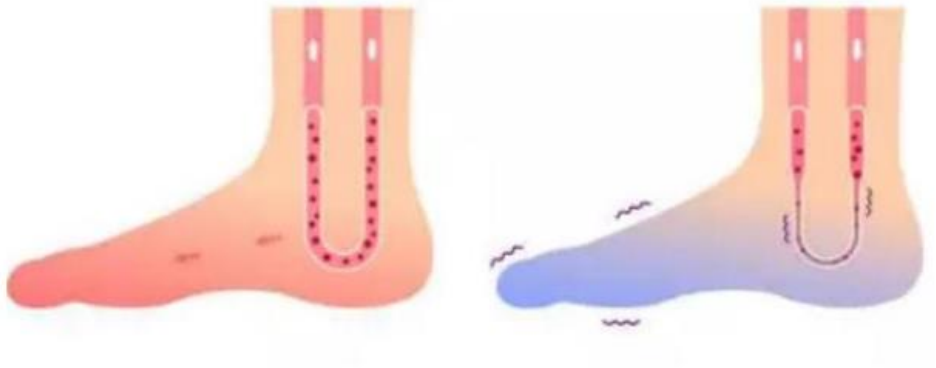


Figure 1 – Consequence of acute limb ischemia (diabetic foot)

Timely diagnosis of tissue microcirculation disorders by optoelectronic devices allows to detect tissue necrosis formation at the initial stage, allows not only to predict the development of the disease, but also to adjust the course of therapeutic treatment at the early stages of development, thereby postponing surgical treatment and disability of the patient. In the case of stopping bleeding with a hemostatic tourniquet - to establish the remaining time before removing the applied hemostatic tourniquet [1,2,3].

The main methods for diagnosing the development of biological tissue ischemia (BT) during inpatient examination are: differential diagnosis, photoplethysmography, ultrasound duplex scanning of the vessels of the lower extremities, computed tomography angiography and magnetic resonance angiography, digital subtraction angiography [2,4]. The methods require complex and expensive equipment, are intended for clarifying the diagnosis and extent of the disease, are not cheap and require a certain amount of time for

diagnosis. It should be noted that the use of changes in the electrical conductivity of BT in the transition period of ionization as an informative diagnostic criterion parameter has not been sufficiently studied in known scientific sources [5,6].

MATHEMATICAL MODEL

The mathematical model of resistance change has the form;

$$Z = R_1 + R_2(1 - e^{-\frac{t}{\tau_1}}) \quad (1)$$

Where is the time constant of the ionization process for biological tissue without an applied tourniquet.$\tau_1 = C \cdot R_2$

To study the effect of the distance between the electrodes on the sensitivity of the change in BT impedance for invasive measurement, the data presented in Table 1 were obtained.

Table 1. Results of the study of the change in impedance over time depending on the distance between the needle electrodes

s	0 kOm	10 kOm	20 kOm	30 kOm	40 kOm	50 kOm	60 kOm	70 kOm	80 kOm	90 kOm	100 kOm	110 kOm	120 kOm
L=10mm	1.30	2.78	3.76	4.32	4.85	5.17	5.37	5.46	5.6	5.7	5.71	5.72	5.73
L=30mm	1.65	3.16	4.10	4.65	5.16	5.42	5.67	5.86	5.99	6.13	6.34	6.34	6.42
L=50mm	1.90	3.49	4.33	4.92	5.25	5.60	5.93	6.13	6.25	6.45	6.58	6.65	6.65

RESEARCH RESULTS

Fig. 2 presents graphs of the change in BT impedance in the transition period depending on the distance L between the needle electrodes, which were obtained experimentally. The studied biological object after completion of the studieswas not injured.

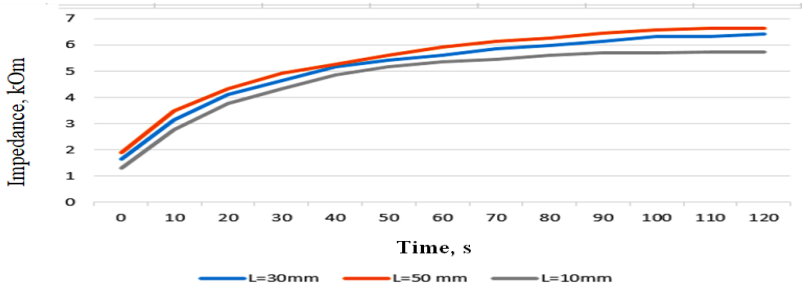


Figure 2 – Dependence of the change in impedance R=f(t), depending on the distance between the electrodes L=1 cm, L=3 cm and L=5 cm. (L=1см - graph of resistance change at a distance between electrodes of 1 centimeter, L=3cv - graph of resistance change at a distance between electrodes of 3 centimeters, L=5 см - graph of resistance change at a distance between electrodes of 5 centimeters)

Fig. 3 shows a graph of changes in BT impedance depending on the time of circulatory arrest.

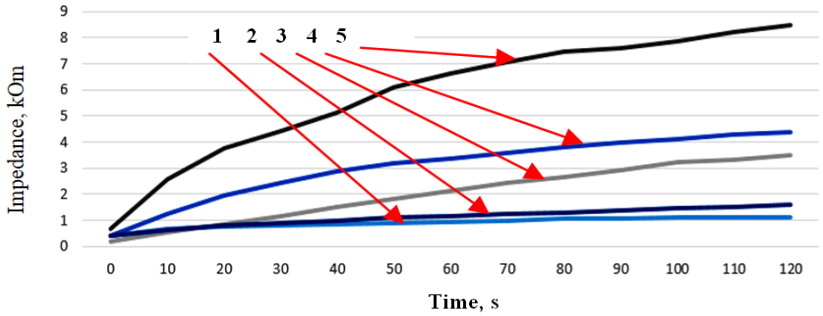


Figure 3 – Graph of tissue resistance change depending on the time of tourniquet application (R/kOm (without tourniquet) - graph of BT impedance change without applying a tourniquet, R/kOm (0,5 taim) - graph of BT impedance change with a 0.5 time harness applied, R/kOm (1.1taim) - graph of BT impedance change with a 1.2-time harness applied, R/kOm (2,5 taim) - graph of BT impedance change with a 2.5-time harness applied, R/kOm(3,0 taim) - graph of BT impedance change with a 3.0 time harness applied

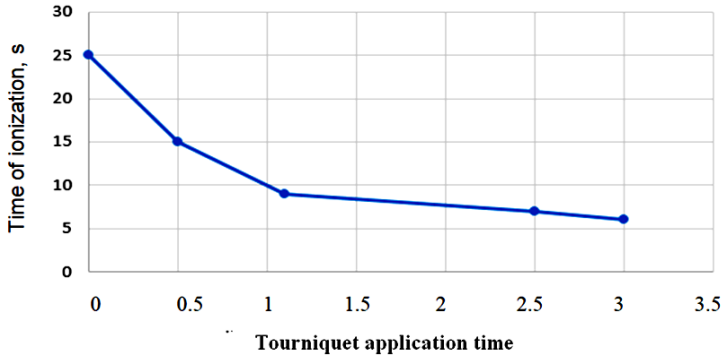


Figure 4 - Graph of the change in the ionization time constant depending on the time of the applied tourniquet

Fig. 4 shows a graph of the change in the ionization time constant depending on the time of the applied tourniquet. The obtained dependence confirms that changes in the ionization time constant can be one of the diagnostic criteria for changes in the BT property.

CONCLUSION

It should be noted that the changes in the coefficient k according to the exponential law in the transitional process confirm the viability of the biological tissue, which allows avoiding the perfusion syndrome after removing the hemostatic jute. Changes in the coefficient of relative electrical resistance k according to the linear law, in the transitional process, are due to irreversible processes of cell death. Deviation of the coefficient of relative electrical resistance k by (5-8)%, from the unit value, diagnoses the initial process of impaired blood perfusion and the development of ischemic tissue disease. The development of reperfusion syndrome, for the studied biological objects, is observed when perfusion is impaired for more than 1 hour, and perfusion is impaired for more than 2.5 hours leads to irreversible changes in the BT properties. It was also established that when simultaneously measuring the change in impedance in two identical areas of the limbs, the ionization time constant is a criterion parameter in the study of the development of ischemia.

The development of rapid diagnostic methods, in particular photometric methods for assessing tissue microcirculation disorders, based on data obtained in transient ionization processes of biological tissue, requires further research together with the results of changes in tissue properties obtained through biopsy, which will allow developing methods for predicting the development of ischemia, determining the time for surgical intervention, and adjusting the course of drug treatment.

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