The electrical impedance method of the muscle blood supply determination in damaged intervertebral discs area.

A.A. Blinov[1;2], S.I. Shchookin[1]
1 BMSTU/Biomedical Engineering Department, Moscow, Russian Federation
2 Federal State Institution «Research and State Institute of Medical Devices»/Roszdravnadzor, Moscow, Russian Federation
Contact: AndrewBlinowjr@yandex.ru

Introduction

Electrical impedance techniques of the blood supply measurements allow estimate the changes of tissue blood supply in the region of interest. The blood supply of back muscles in the damaged spinal area is changing by reason of the distribution of the load on the extensor muscles of the back[3,4]. This changes are confirmed by MRI images of patients with damaged intervertebral discs. Measuring changes in the blood supply to this area allows to assume the possibility of localization of damaged intervertebral discs[1].
Determination of damaged intervertebral discs at an early stage will allow doctors to focus the attention on damaged area, before the emergence of pain in the patient..

Materials and Methods

Today there are a number of methods to determine the location of the damaged intervertebral discs. These include MRI and X-ray. X-ray diagnostic method does not allow a high enough level to determine the location of the damaged intervertebral discs, as well as adversely affect the patient's body. MRI method is more accurate, but its low availability is not to diagnose patients in preventive mode, before the treatment with an existing pain [2-4].On the basis of these facts it is necessary to consider a new method of localization of the arrangement of damaged intervertebral discs.

By passing an alternating current through the biological tissue there is an active and capacitive resistance, their sum - is a complex impedance. The resistance is caused by the ion-conducting tissue, capacitance - the formation of the electrical double layer at the interface of different structures.

$$Z = \frac{R}{\sqrt{1+(2fRC)^2}}, \qquad (1)$$

Where Z - impedance module, R - active resistance of the tissue, f - frequency of the current, C -capacity. The activities of organs and tissues of a living organism is accompanied by changes in volume and internal environment. The vascular network of blood moving therein (having a good electrical conductivity) rapidly changes its volume after every systole, whereas other tissues or no change in volume or change slightly. The study MRI scans, suffering from diseases of the intervertebral discs revealed the presence of increasing the diameter of the lumen of blood vessels feeding the damaged intervertebral disc. This change is due to the fact that muscular skeleton in the art assumes the load, which can not cope with a damaged intervertebral disc, which leads to the need to increase the power of this portion of the back muscles extensor. [2]

To determine the diagnostic capabilities pathology of intervertebral discs, has been developed model, which allows to determine the presence of changes in the specific resistance of biological tissue, associated with changes in muscle blood supply to the affected area.

In the course of determining the change in the blood supply to the muscles of the extensor muscles, a two-layer analytical model for determining the resistance of biological tissue was considered. The biological layer, such as skin tissue, adipose tissue, connective tissue, belonged to the first layer in this model. The second layer included muscle tissue and blood (Figure 1)

During the simulation, the following parameters were considered:

ρ1 is the resistivity of the first layer, which was varied from 4 to 20 Ω * m in steps of 2 Ω * m;

ρ2 is the resistivity of the second layer, which was varied from 1 to 10 Ω * m in steps of 1 Ω * m;

h1-thickness of the first layer equal to 8 mm, the data were obtained from the MRI;

a-half the distance between the current electrodes, which was 30 mm;

b-half the distance between the current electrodes, which was equal to 15 mm.

The distances between the electrodes were chosen based on the ratio at which the distance between the potential electrodes should be at least 3 times the depth of the object of interest.

The resistance value of the biological object was determined by the following formula:

$$R_{MN} = \frac{\rho_1}{2\pi} * [\frac{4b}{a^2 - b^2} + 4\sum_{n=1}^{\infty} K^n * \left\{ \frac{1}{\sqrt{(a-b)^2 + (2nh_1)^2}} - \frac{1}{\sqrt{(a+b)^2 + (2nh_1)^2}} \right\}] \qquad (2)$$

$$K = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}, \qquad (3)$$

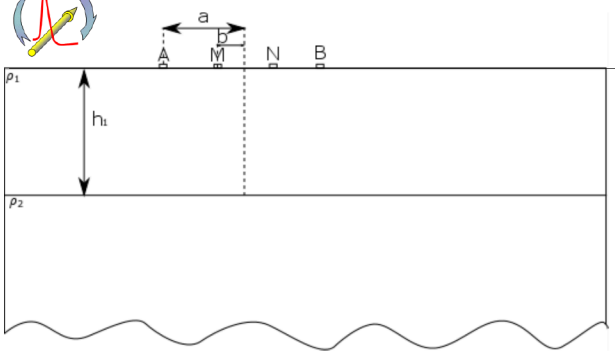

Figure 1: The construction of flat two layer model.

During the simulation, the following results were obtained:

Table 1: Change in impedance depending on the resistivity characteristics used in modeling mΩ

	ρ1,Ω* m	4	6	8	10
ρ2,Ω* m					
1		12,2	21,3	41,4	68,5
2		23,6	33,5	53,8	80,3
3		35,0	45,5	65,8	91,8
4		38,6	55,3	77,7	103,0
5		54,4	71,7	89,3	113,9
6		69,1	87,8	100,6	124,6
7		70,1	103,6	111,8	134,9
8		85,6	119,0	122,7	145,0
9		101,0	134,2	133,4	154,9
10		160,9	191,9	143,9	164,6

These results were compared with the value of the base impedance measured during the experiment on a healthy volunteer, which was 58.2 Ω. Based on the results obtained, the values of the equivalent resistivity for the fat layer were chosen and for the muscle tissue they were ρ1 eq = 6 Ω * m; ρ2eq = 4 Ω * m;

After determining the value of the equivalent resistance of biological tissue, a simulation was made of the determination of the change in the value of the pulse impedance in the region of the extensor muscles of the back caused by the impact release.

Terms of the model were as follows: calculates the change of the resistivity changing blood supply to the 100 g. of muscle tissue. These calculations were made on the basis of, that, as a result of pathological processes, the vessel, sourcing the muscular tissue in damaged region is enlarged twice, which leads to a change in blood filling by a factor of 1.5.[1]

$$\rho = \frac{S*R_{T+B}}{l}, \qquad (4)$$

Where RT+B - resistance muscle with blood, l - length of the muscle area, S - surface area of the muscle area.

It has been estimated resistivity change of muscle tissue with blood during systole and diastole. This change was about

Δρ = 0,4%; What is the translation of the resistance gave contribution of about 25 mΩ.

The model system has being designed, and are considered the optimal parameters of electrodes assembly, applicable for the diagnosis of the studied pathology (Figure 2).

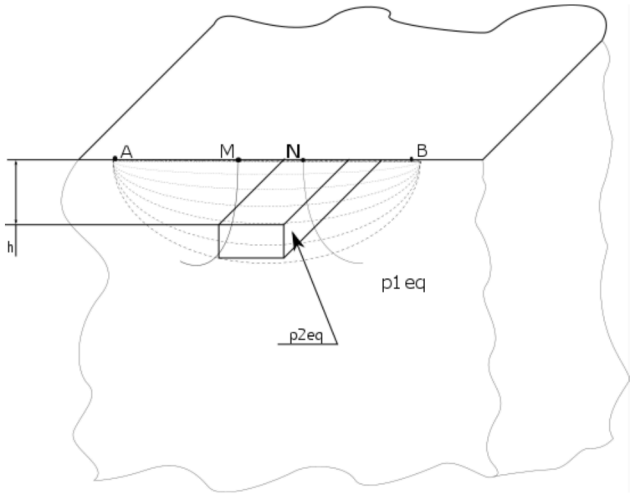

Figure 2: The construction of model

During the simulation evaluated the biological tissue resistance changes depending on the applied linear characteristics of electrode assembly.

Table 2: Impedance changes depending on the characteristics of the linear electrode assembly, mΩ

Electrodes diameter, mm		Electrode spacing Current/Potential, mm/mm			
		20x10	40x20	60x30	80x40
2		0,4	1,5	17	3
4		2	5	32	8
6		X	9	35	12

During the simulation was selected assembly with linear dimensions: diameter of electrodes 4 mm, the distance between the electrodes 60x30mm, despite the fact that the assembly 6 mm diameter electrodes is more effective, its execution is not possible due to the anthropomorphic characteristics of some patients.

The studies used laboratory multichannel electrical impedance measurement system REO32. REO32 is not commercial system, used only for scientific researches of biological tissues. This system got 32 channels, which allows to carry out measurements of electrical impedance of biological tissues, but in our research have been used only 5 channels. Specifications are given in Table 2. During the studies used steel electrodes. REO32 system allows simultaneous measurement of electrical impedance to 5 channels.

Table 3: Parameters of the multichannel electrical impedance measurement system REO32

Characteristic	Value
Number of electrical impedance channels	5
Sampling frequency	3 141 rad/s
Rheography method	tetrapolar
The amplitude of the measuring current	3 mA
Current frequency	628 320 rad/s

Terms of experimental studies:

The patient or a healthy volunteer was lying on his stomach. There were 2 objects, first is the volunteer with a herniated disc, and second volunteer has got no damaged intervertebral discs (the healthy volunteer)

Room temperature: from 21 to 25 C,

We used 5 electrical impedance measurement channel

We used 1 thoracic channel to accommodate soft tissue blood supply,

We used the standard steel electrodes with a diameter of 4 mm,

During experimental studies electrode systems were arranged on the back of patient along the line of the spine at a distance of 12 mm from the axis of the spine. We used tetrapolar electrode systems with dimensions of 60x30 mm (where the 60 mm - the distance between the current electrodes, 30 mm - between the measurement electrodes).

Measurements were carried out on two volunteers, one of whom was a patient with a herniated disc L0 / L1. As a result of measuring the presence of a herniated disc in a patient, it was confirmed (Figure 3.) Figure 3 shows an increased change in signal amplitude, associated with increased blood supply to the muscle tissue in the area of the affected intervertebral disc.

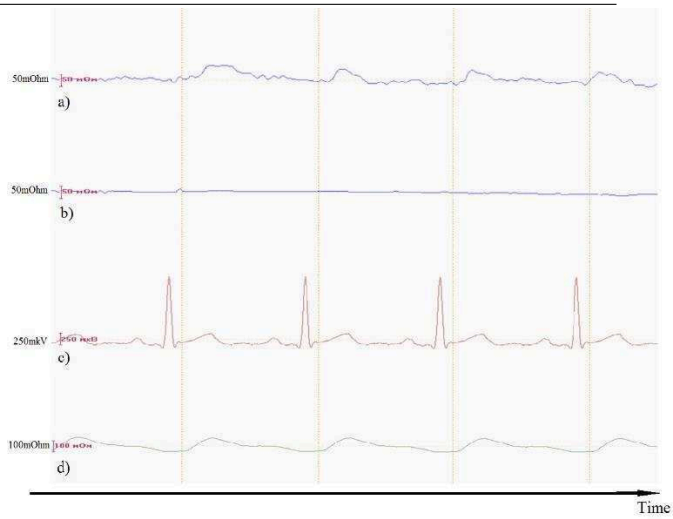

Figure 3: Electrical impedance signals a) Damaged back muscle blood supply; b) Healthy muscle tissue c) ECG-signal; d) Thoracic signal.

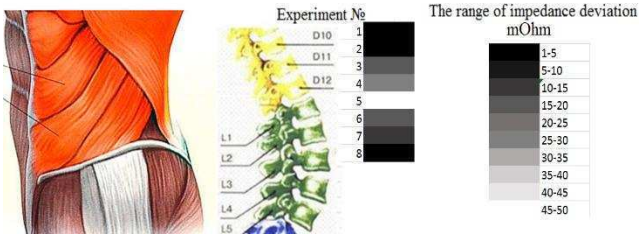

Figure: 4 Map of electrical impedance signal deviation in damaged area.

There is changing of impedance in the damaged spinal area of 46 mΩ (Figure 4).

Results

Was developed determination of blood filling model by muscular spine extensor muscle tissue.

It was chosen the optimal assembly for measuring blood filling of the spine muscles.

In the area of the damaged intervertebral disc there is a change of the impedance of the biological value of 46 mΩ, caused by a change of blood filling the muscle tissue.

Conclusions

These results suggest the possibility of localization of the affected intervertebral disc, based on the measurement of changes in resistance of the biological tissue of the back extensor muscles. These results suggest the possibility of developing hardware and software system that will allow, on the basis of the results obtained to diagnose patients in the screening mode and clinical examination for the detection, damage to the intervertebral discs to patient treatment with severe pain.

References

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