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Electrical Impedancometry Technique for the Evaluation of Myocardial Infarction

Yu.I.Borodin, I.N.Putalova, and A.S.Osennii

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The energy metabolism of cell,organ, and tissue changes under the influence on a biological object of different physical and chemical factors of the external and internal environment: temperature, pressure. volume, electrolyte concentration, stress on functional systems, as well as pathological changes [3,6]. It will thus be correct to say that passive electric properties carry information about the state and functioning of not only an organ, but also the organism as a whole. In this connection it is important to find an indicator, which could depict the phenomenon of polarization mostly completely and carry information about the state of energy exchange.

Electrical resisance is usually measured in biological objects. The modulus of the whole electrical resistance, expressed by the formula: $X = R_o + R_c$, where R_o is the ohmic resistance R_c the capacitive resistance, is called impedance.

In the measurement of impedance the frequency of the test current has great significance. Frequencies of 10^6 and 10^4 Hz were selected for impedance measurement, because the maximum electroconductivity of an object is determined at a frequency of 10^6 Hz, and a break of the dispersion curve is observed at a frequency of 10^4 Hz. The ratio of impedance measured at a the frequency of 10^4 to impedance measured at a the frequency of 10^6 Hz is the coefficient of polarization dispersion, or CPD [5]. Its value in normal intact cells and tissues depends upon the position of the biological object in the evolutionary ranking.

MATERIAL AND METHODS

Impedance measurement at two fixed frequencies was carried out with a Biotemp device [2], developed by us; in terms of its structure, this is a multifunctional measuring device with a spatial division of the measuring channels and one depicting device.

White Wistar rats served as the object of investigation, in which an experimental myocardial infarction (EMI) was caused by ligation of the descending branch of the left coronary artery. Electric impedance measurement in the heart muscle was conducted in the zone of ligation and in an intact section, i.e., in the lateral part of the right ventricle, 1, 2, 5, 9, 15, and 21 days after EMI.

The results of electroimpedancometry were compared with morphologic data.

RESULTS

According to our data, one day after EMI in the zone of ligation of the left corony artery an increase of impedance at higher frequencies of heart muscle (689.0±31.9, in the control 458.8±14.70 Ohm, $p<0.01$) and a sharp decrease of the coefficient of polarization dispersion are registered. The changes in cardiomyocytes and muscle fibers develop from the first minutes of experimental ischemia. The activity of intracellular enzyme systems changes. Hypoxia develops, as a result of which all the intracellular organelles in the cardiomyocytes are affected. These disturbances and their severity progress by the minute during the first day, as is manifested in hemodynamic disorders: plethora and stasis in capillaries, hemorrhage, and stroma edema. Most cardiomyocytes preserve their borders, but the intercellular space shrinks on account of the intracellular edema.

Cells of inflammatory infiltrate in the zone of infarction appear during the very first hours after ligation. At the same time the number of polymorphonuclear leukocytes increases rapidly and attains maximum values by the end of the 1st day. The test current on its way encounters resistance both due to the ohmic resistance increase and due to the enlargement of the capacitive structures. Electroconductivity of the heart muscle in the zone of infarction drops sharply.

Three days later, in the ischemic zone the specific number of muscle cells and their nuclei decreases, as

Institute of Clinical and Experimental Lymphology, Novosibirsk

agrees with published data [1]. The cardiomyocytes look swollen, without any signs of cross-striation. Of the cell elements in the zone of infarction just a few stroma cells, as well as neutrophils and eosinophils and macrophages remain. The latter are actively resorbing necrotized myocardial fibers. After the destruction of cell membranes, protein accumulation occurs in the just symbolically existing intercellular spaces, with the result that large quantities of lymph, finding no way out, are accumulated in the interstitial tissue. The current encounters practically no resistance, as is shown by the electrical impedance decrease at low frequencies by the end of the 3rd day of EMI (1258.3±95.2, in the control 1545.8±59.8 Ohm, $p<0.05$).

After 5 days the elimination of necrotic masses comes to an end and granulation tissue formation begins. Simultaneously the processes of microcirculatory bed (MCB) formation are going on, these intensifying after 7-10 days. By this time the polymorphonuclear leucocytes are rapidly disintegrating, whereas the total number of macrophages quantity changes less, as does the specific lymphocyte quantity. The infarction zone is clearly demarcated; along its periphery scar tissue develops, which has no defined nature as yet, and is represented by fibroblasts and mature collagen fibers. After 7 days the fibroblast population is dominant, exceeding the total quantity of other cells more than 2 times. Due to the large specific quantity of cell elements, the forming MCB components and scar tissue, an increase in the total electrical impedance and a CPD drop (2.14±0.16, in control 3.38±0.14, $p<0.01$) are recorded during the 5th-9th day.

After 15 days the spatial ordering of the majority of the granulation tissue cells occurs. Stabilization of their quantity correlates with the formation of fiber structures. A decrease not only in their quantity, but also in their size occurs, because during granulation tissue maturation the fibroblasts differentiate into fibrocytes. The fibrous structures, cell elements, and MCB take on their definite appearance, orientate along the course of the preceding cardiomyocytes. After 15 days granulation tissue formation in the ischemic zone is on the whole complete. In this period during impedancometry the heart muscle resistance in the zone of ligation at low frequencies drops on the average 1.5 times (1264.3±70.0, in the control 1545.8±59.8 Ohm, $p<0.05$). It is the most significant drop in the impedance dynamics. It is interesting to note that precisely during this period, when the development of primary granulation tissue in the zone of myocardial infarction is completed in experimental animals,in human blood a second increase of granulocyte content is observed [1]. This provides evidence of the similar direction of the processes taking place in man for an uncomplicated course of the disease and in experimental animals.

After 21 days in the zone of ligation mature scar tissue areas are revealed, with a predominance of collagen fibers. The density of cells in the zone of infarction significantly exceeds that in other parts of the myocardium. Postinfarction scar formation and the maximum density of cells in the zone of ligation lead to a slight increase in electrical impedance (from 407.0±31.5 Ohm on the 15th day up to 435.3±9,.0 Ohm on the 21th day, $p<0.05$). At the same time CDP has a high value for the heart muscle, attesting to compensated heart muscle activity during this period.

In the comparison of the electrical resistance in the zone of infarction and in the intact zone the general dynamics of the changes was revealed. The results of our research prove that the designation "intact" accepted in the literature is undoubtedly arbitary. There is no part of the heart wall which does not suffer in some way or other during myocardial infarction. It should just be mentioned that the degree of expression and the times of appearance of morphological changes in the zone of ligation and in the "intact" zone are different. Thus, the electroimpedancometry indications in the region of the right ventricle wall, obtained at a low current frequency, approach the control values after the acute period of myocardial infarction, i.e., after 5 days, while the coefficient of polarization dispersion from the 15th day attains high values together with a tendency to increase during the following period of the experiment (3.73±0.27 after 15 days, 3.91±0.26 after 21 days, in the control 3.28±0.14).

Thus, we established that the results of electroimpedancomentry fully reflect the phenomena taking place in the heart wall during different stages of development of myocardial infarction. The sign of energy metabolism decrease in the cells is connected with the phenomenon of cell nucleoli fragmentation [4]. In turn, ATP deficiency under conditions of the separation of oxidation and phosphorylation, occurring in this case under conditions of myocardial ischemia lead to disturbances in cell plastic maintenance, causing functional failure and death. As to normal healing of the infarction zone, this is ensured by the cells of the inflammatory infiltrate and the interdependent changes in the conditions of the continuously beating heart. The different density of the cellular elements, their functional activity, and their production at different stages of myocardial infarction affect the state of energy exchange in the heart muscle and the results of impedancomentry.

The method of electrical impedancomentry allowed us to reveal the general trend of healing processes in experimental animals and in man and to confirm that such a disease as myocardial infarction affects not an isolated region, but the heart muscle as a whole.

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Macroscopic and Functional Assessment of the Efficacy of Ovary Regeneration with Fibrin Glue and Various Suture Materials Following its V-Shaped resection

L. V. Adamyan and O. A. Mynbaev

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Reconstructive surgery on the ovaries involves a risk of postoperative adhesions and tuboperitoneal sterility. V-shaped resections and restoration of the ovaries result in sterility because of adhesions in one third of patients [4]. The efficacy of surgery depends on the suture material used, on strict adherence to reconstructive surgery principles, and on the surgical technique. There are essential differences in the methods of reconstructive surgery on the ovaries; postoperative adhesions are less frequent after V-shaped resection of the ovary and laser hemostasis then after microsurgical restoration of this organ [3,6].

Published data [7] and our clinical and experimental findings [1,2] provide evidence of the efficacy of fibrin glue in reconstructive surgery on the uterine tubes. Still, we have not come across studies describing fibrin glue application in reconstructive surgery on the ovaries.

The present research was aimed at investigation of the effects of fibrin glue and various suture materials on ovarian tissué.

TABLE 1. Macroscopic Changes of Rabbit Ovaries after Reconstruction with Fl-1, prolene, and catgut

Group	Ovarian abnormalities		
	pronounced inflammation	sclerotic changes	total
1. FG-1, n=30	1 (3.3%)	2 (6.7%)	3 (10%)
2. Prolene, n=20	1 (5%)	3 (15%)	4 (20%)
3. Catgut, n=10	3 (30%)	4 (40%)	7 (70%)

MATERIAL AND METHODS

A total of 60 experiments on 30 chinchilla rabbits weighing 2.5-3.5 kg were carried out. In group 1 fibrin glue (FG-1) was used for reconstructivon of the ovary in 30 experiments, in group 2 prolene 7/0 Eticon suture material was used in 20 experiments, and in group 3 catgut 3/0 with an atraumatic needle was used in 10 experiments. The operations were carried out under general anesthesia with intramuscular diazepam (1.6 mg/kg) and droperidol (0.83 mg.kg) premedication and calypsol (ketamine) (50 mg/kg) narcosis. The duration of anesthesia was 1 to 2 h. Calypsol was additionally injected as needed during surgery. The animals were fixed in a supine position on the table. The wool on the abdomen was shaved and the operative field washed with soap solution and treated with iodonate and ethyl alcohol. The abdominal cavity was then opened by two

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