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The bioimpedance analysis of a parenchyma of a liver in the conditions of its extensive resection in experiment

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Abstract. The liver failure which is result of disharmony of functionality of a liver to requirements of an organism is the main reason for unsatisfactory results of an extensive resection of a liver. However, uniform effective criterion of definition of degree of a liver failure it isn't developed now. One of data acquisition methods about a morfo-functional condition of internals is the bioimpedance analysis (BIA) based on impedance assessment (full electric resistance) of a biological tissue. Measurements of an impedance are used in medicine and biology for the characteristic of physical properties of living tissue, studying of the changes bound to a functional state and its structural features. In experimental conditions we carried out an extensive resection of a liver on 27 white laboratory rats of the Vistar line. The comparative characteristic of data of a bioimpedansometriya in intraoperative and after the operational period with the main existing methods of assessment of a functional condition of a liver was carried out. By results of the work performed by us it is possible to claim that the bioimpedance analysis of a liver on the basis of an invasive bioimpedansometriya allows to estimate morphological features and functional activity of a liver before performance of an extensive resection of a liver. The data obtained during scientific work are experimental justification for use of an impedansometriya during complex assessment of functional reserves of a liver. Preliminary data of clinical approbation at a stage of introduction of a technique speak about rather high informational content of a bioimpedansometriya. The subsequent analysis of efficiency of the invasive bioimpedance analysis of a liver requires further accumulation of clinical data. However even at this stage the method showed the prospect for further use in clinical surgical hepathology.

1. Introduction

At the present stage of development of surgical hepatology and anesthesiology of the indication to accomplishment of extensive resections of a liver considerably extended. However, the frequency of postoperative complications and a lethality remains high and makes, according to different data, 40% and 16% according to [1,2,3].

The main reason for unsatisfactory results in extensive liver resection is liver failure, which is the result of the functional capacity of the liver to the body's needs [4].

To date, there are a large number of methods of assessing the degree of hepatic dysfunction. The most informative indicators of liver function available in clinical practice are: total bilirubin, albumin, albumin-globulin index, leukocyte index of intoxication, the level aspartataminotransferaza, alanine aminotransferase and duration of cholestasis before operation, indices of protein, pseudocholinesterase, fibrinogen, fibrins, prothrombin index, clearance test, indocyanine green [4,5,6].

However, a single effective criterion for determining the degree of hepatic insufficiency is not currently developed.

One of the methods of obtaining data on morpho-functional state of internal organs is bioimpedance analysis (BIA), based on the estimated impedance (full electric resistance) of biological tissues [7,8]. Biological tissue consists of a cellular component and communication routes, including the vascular and interstitial slits, each of which is characterized by different resistance and a different ability to conduct alternating electric current.

Impedance measurements are used in medicine and biology to characterize the physical properties of living tissues, study of the changes associated with the functional status and structural features [9].

Although the research underlying the impedance were carried out at the beginning of the last century, the method is constantly evolving and finding more and more new diagnostic applications.

Work purpose: an assessment of biophysical characteristics of a parenchyma of a liver after its extensive resection.

2. Materials and methods.

The study was conducted on 27 white rats of Vistar line of both sexes weighing 180-230 g, which under ether anesthesia performed laparotomy, and measured the electrical impedance of the liver. Then we conducted extensive resection of the organ being examined (70%) and re-measured the electrical impedance of the parenchyma of the remaining lobe of the liver, then made a revision and suturing of the abdominal cavity.

After 72 hours was performed a relaparotomy, and measured the electrical impedance of the liver parenchyma. Experimental animals also conducted biochemical analysis of blood. Blood sampling was performed up to simulation of a pathological process and in 3 days after extensive liver resection. Animals were taken from experiment and a fragment of the liver were sent for histological examination.

At histologic research degree of dystrophy of hepatocytes was estimated in 25 viewing fields on a ball scale where 0 – normal hepatocytes; 1 – slight intracellular dystrophy of hepatocytes (mainly proteinaceous); 2 – moderate intracellular dystrophy of hepatocytes (small-drop fatty dystrophy); 3 – the expressed intracellular dystrophy of hepatocytes (largedropped fatty dystrophy); 4 – necrosis of hepatocytes. Expected a median of the sum of balls to ORP and the 3rd days after a liver resection.

The invasive bioimpedance was carried out by means of bipolar needle electrodes and the original device for measurement of total electrical resistance of biological tissues – BIM-II (The Russian Federation patent No. 2366360, OOO "Center for transfer of innovative technologies", Smolensk). Measurement was performed at frequencies of 2 kHz, 10 kHz, 20 kHz and voltage less than 1 volt with the subsequent calculation of coefficients of dispersion (D).

$$D = Z_{nch} / Z_{vch}$$

where D – coefficient of dispersion of an electric impedance, Z_{nch} – the electric impedance measured at a low frequency, Z_{vch} – the electric impedance measured at a high frequency.

Biochemical indicators of serum of blood investigated on the semi-automatic MiniScreen analyzer (HospitexDiagnostix, Italy).

3. Results and discussion

In the postoperative period the lethality made 52% (14 animals).

The electric impedance of an intact liver was equal 3,2±0,2 kOhm at a frequency of 2 kHz, 2,3±0,1 kOhm at a frequency of 10 kHz and 1,7±0,11 at a frequency of 20 kHz (n=27).

Table 1. An electric impedance of a parenchyma of a liver at experimental animals.

Measurement period	2 kHz		10 kHz		20 kHz	
	Z, kOhm	n	Z, kOhm	n	Z, kOhm	n
To ORP	3,2±0,2	27	2,3±0,1	27	1,7±0,11	27
After ORP	3,1±0,16	27	2,2±0,11	27	1,8±0,08	27
For the 3rd days after ORP	4,0±0,13 *	13	2,5±0,07	13	1,7±0,08	13

* - p <0,05 in comparison with data to and right after ORP

After an extensive resection the studied indicator at 20 rats decreased at a frequency of 2 kHz and 10 kHz a little and averaged at the corresponding frequencies: 3,1±0,16 kOhm, 2,2±0,11 kOhm, 1,8±0,08 kOhm (n=27, distinctions are not reliable, p> 0,05) that, is possible, knitted with increase in a blood-groove in the remained liver share.

In 72 hours after surgery the electric impedance of a parenchyma of a liver authentically increased to 4,0±0,13 kOhm (n=13, p <0,05) at a frequency of measurement of 2 kHz.

Coefficients of dispersion of an electric impedance were calculated only for the survived rats (n=13) and reduced in table 2.

Table 2. Coefficient of dispersion of an electric impedance of a liver of experimental rats.

Measurement period	Dispersion coefficient		
	D2kgts/20kgts	D2kgts/10kgts	D10kgts/20kgts
To ORP	1,95±0,12	1,43±0,10	1,40±0,10
After ORP	1,79±0,11	1,4±0,06	1,23±0,07
For the 3rd days after ORP	2,45±0,10 *	1,6±0,07	1,55±0,10

* - p <0,05 in comparison with data to and right after ORP

Coefficients of $D_{2kHz/10kHz}$ and $D_{10kHz/20kHz}$ authentically did not change throughout experiment. The liver parenchyma $D_{2kHz/20kHz}$ coefficient to a resection was equal 1,95±0,12, and then decreased right after a resection to 1,79±0,11 a little (n=13, distinctions are not reliable, p> 0,05). For the 3rd days after ORP $D_{2kHz/20kHz}$ coefficient authentically increased to 2,45±0,10 in comparison with initial indicators (n=13, distinctions are not reliable, p <0,05).

The value of the coefficient D depends on the structure, functions and status of biological tissue. Moreover, the higher it is, the more intense metabolism in the test body.

In the course of biochemical studies in experimental animals for 3 days there was a statistically significant increase in AST levels with 243,69±20,47 to 377,18±25,43 u/l (p<0.05) (table 3).

The concentration of total protein and albumin in the serum after modeling pathological process has also decreased slightly compared to the norm: total protein content from 84.1±7,92 g/l to 71,58±7.15 g/l (p>0.05), albumin – from 23.86±2.3 g/l to 21.85±2.8 g/l (p>0.05). Statistically significant differences between indicators were not observed.

Increase of concentration of nuclear heating plant in blood serum at the 3rd day after accomplishment of an extensive resection of a liver demonstrates existence of moderately expressed syndrome of a cytolysis.

At the time of Histological research of all surviving animals showed characteristic morphological picture. The liver parenchyma was represented by hepatocytes with intact girder structure, uneven hyperemia in the sinusoids and blood-filled veins big. Observed small focal perivascular lymphoid infiltrates. Hepatocytes were manifestations of fatty degeneration more pronounced in the periphery of the hepatic lobules, and in the center of lobules was determined by protein deposits. The nuclei of hepatocytes was with lumpy chromatin, clear nucleolus, sometimes two.

Table 3. Biochemical indicators of serum of blood of experimental rats before and after ORP.

Terms supervision	Biokhimicheskiyepokazateli			
	ALT, El	Nuclear heating plant, El	General protein, g/l	Albumine, g/l
	M±m	M±m	M±m	M±m
Before carrying out ORP	264,73±18,53	243,69±20,4784,1±7,92[1]		23,86±2,3
For the 3rd days after carrying out ORP	225,23±18,66	377,18±25,4371,58±7,15[1]		21,85±2,8

Note: distinctions are statistically significant at $p < 0,05$
[1] – between two groups

In the area of resection was observed formed a zone of demarcation with a zone of large-focal necrosis fibrinoidous and drain lymph leukocyte infiltration, sometimes extending to the liver parenchyma. Also was determined the drain hemorrhages with hemosiderin deposits and hemosiderofagus.

During the morphometry revealed that degeneration of hepatocytes, resected liver tissue was at the level of 9 points (min=7; max=15). However, 3 days later the PPR was observed severe degeneration of hepatocytes at the level of 60 points (min=50; max=68).

During surgical intervention on the liver in the hepatic parenchyma along with the processes of destruction of liver cells at the same time, the processes of regeneration. According to the literature, after performing a right hemihepatectomy for living-related liver transplantation within 10 days of the filling volume of the hepatic parenchyma is increased by 75% of the initial volume of the parenchyma and the regeneration of liver cells is triggered by increasing metabolic process [10].

Compensation of the disturbed functions of the liver is provided in all the variety of forms of regenerative reaction cell (mitotic division) and intracellular (compensatory hyperplasia ultrastructure and the actual intracellular regeneration).

During the post-resection regeneration actively divide by mitosis, not only hepatocytes, but also copperhouse cells and endothelial cells of blood capillaries. The maximum level of proliferation of hepatocytes largely depends on the scope of resection: the major part of the liver removed, the higher is the mitotic index in the period of the highest rise of mitotic activity [11].

Apparently, after the PPR in rats by 3 days of the experiment along with the phenomena of degeneration of hepatocytes, as evidenced by the increasing concentartion transamine blood, began an active process of cell regeneration of the liver, which was accompanied by intensive metabolism and increased functional activity of liver parenchyma. In this regard, there was a significant increase in the dispersion coefficient $D_{2kHz/20kHz}$ and the absolute value of electrical impedance at the frequency of 2kHz.

Thus, the electrical impedance parameters of liver reflect changes in the functional activity of the parenchyma and can be used to develop diagnostic technologies in surgical hepatology.

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