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Laser doppler for diagnosis of changes of microcirculation in the perioperational period in patients with acute adhesive obstruction of small gut

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ABSTRACT

The article deals with changes in the amplitude-frequency spectrum of blood flow fluctuations in the perioperative period in patients with adhesive intestinal obstruction using computer diagnostics. To study the state of the microcirculatory bed and the mechanisms of its regulation, laser Doppler flowmetry was performed. Available results indicate significant changes at the level of the microcirculation system. Violation of blood circulation of tissues and decrease in body temperature at the end of surgery leads to hypoxia of organs and systems of the body, their dysfunction, and subsequently – insufficient functioning of the parenchymal organs and the development of complications.

Keywords: acute adhesive small intestinal obstruction; microcirculation; computer diagnostics; laser doppler fluometry

1. INTRODUCTION

In the problem of development, prevention, diagnosis and treatment of adhesive intestinal obstruction is still extremely urgent, despite considerable research¹. It is known from literary sources that the perioperative period is a decisive step in the formation of complications². During the operation, the systemic microcirculation status is influenced by a number of factors, in particular: drugs used for premedication, muscle relaxation and anesthesia³, the body's response to surgical trauma⁴, hypothermia due to heat loss through an operating wound³, caused by major disease, changes in the coagulation system, etc.

Microcirculatory dysfunction is closely related to pathologies such as diabetes⁵, peripheral neuropathy, obesity, arterial hypertension, cardiomyopathy⁶, cerebral vasospasm⁷, systemic scleroderma, amylopermosis, amyloperidosis, amyloidosis, heart disease⁸, hypertension⁹, rheumatology¹⁰, inflammatory bowel disease¹¹. Until recently, there was no reliable and convenient way to assess the status of the microcirculatory bed, which would allow the control of peripheral tissue perfusion throughout the operation. With the development of the IT industry, one of the methods of computer diagnostics available today is laser dopplerometry, which allows recording real blood flow rates of up to 98%. It is important to determine the impact of various regulatory factors on the status of the microcirculatory bed¹². The technique is easy to use, non-invasive, allows you to quickly and accurately determine the state of microcirculation at a given time and during the disease¹². In addition, this method allows to analyze the influence of various factors on microcirculation, that is, to establish changes in the basic mechanisms of regulation of peripheral hemodynamics^{13,14}.

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Also, laser Doppler fluorometry is governed by European guidelines¹⁵⁻¹⁷, following the study protocols in various medical fields, which greatly expanded the field of microcirculation, and evaluate the effectiveness / ineffectiveness of the prescribed therapy¹⁸⁻²⁰.

The purpose of the article is determination of the change in the amplitude-frequency spectrum of blood flow oscillations in the perioperative period in patients with adhesive intestinal obstruction using computer and optical diagnostics.

2. MATERIALS AND METHODS

The study is based on the results of observations of 62 patients with acute small intestinal obstruction who were treated in the surgical department of the municipal non-profit enterprise "Ternopil City Clinical Hospital of Emergency Medical Services" (Ternopil, Ukraine) in the period from 2015 to 2019. 33 patients undergoing open-label surgery and 29 patients with minimally invasive interventions were examined. The stage of compensation was established in 17 patients, the subcompensation – in 37 patients, and the stage of decompensation – in 8 patients. Clinical and laboratory and instrumental examination of patients with acute intestinal obstruction and the plan of medical measures were carried out in accordance with the criteria for diagnosis and assessment of the severity of the condition according to the order of the Ministry of Health of Ukraine No. 297 of 02.04.2010²¹.

In order to study the state of the microcirculatory bed and the mechanisms of its regulation, laser Doppler flowmetry (LDF) was performed on a single-channel laser microcirculation analyzer ЛАКК-02 (laser beam length 0.8 μm). They used the software LDF_2.2.510 in the mode Канал КР. This method consists in registering the laser beam reflected from the tissues by means of a light-conducting probe comprising three light-conducting fibers. One optical fiber is used to transmit the probe beam, and the other two to receive the signal through which the radiation reflection goes to the information processing device. Changes in the flow of red blood cells are estimated using the LDF method²². To do this, the reflected signal is processed electronically, and as a consequence, the result of fluometry is a signal whose amplitude is proportional to the rate and number of red blood cells.

The examination was carried out in a continuous mode, from laying the patient on the operating table and ending with surgery. The sensor receiving the signal was fixed to the ear area. The entire study period was conditionally divided into three periods. The first period was about 15–20 minutes, it began from laying the patient on the operating table before the start of surgery (incision). The second period was the first 30 minutes of surgery. And the third period lasted from 30 minutes until the end of surgery. These periods were selected taking into account the physiological features of anesthesia and preoperative preparation. Thus, during the first period, the impact of preoperative preparation and premedication drugs (narcotic analgesics, antispasmodics, antihistamines, infusion therapy) and the impact on the body of pain, psycho-emotional experiences, etc. were analyzed. During the second period, the influence of medical agents for anesthesia on central and peripheral hemodynamics (centralization of blood circulation, inhibition of central units of regulation of blood supply and thermoregulation) was evaluated. At the stage of the third period, the compensatory reactions of the microcirculatory bed were studied in response to the long-term influence of drugs for anesthesia and changes in temperature homeostasis¹³.

During the examination of patients, the main indicators of microcirculation (tissue perfusion state (M)) and the amplitude-frequency spectrum (ASF) of blood flow oscillations were evaluated¹³. A wavelet analysis²³ was used to analyze the ASF of oscillations²³, which in addition to the main microcirculation²⁴ indicators allows to calculate active (endothelial, neurogenic and myogenic oscillations) and passive (cardiac and respiratory oscillations)^{14,25}.

3. RESULTS AND DISCUSSION

Begin While using computer diagnostics (laser microcirculation analyzer ЛАКК-02) in patients undergoing laparotomy access, in the first period of surgery there is a significant increase in the level of tissue perfusion by 40% compared with the indicators of healthy individuals ($p < 0,05$). During the second period of surgery, a significant decrease in M to 1.28 ± 0.08 perfusion units (pf. Units) was found, which is significantly lower than the value during the first period and relative to the indices of healthy individuals (Fig. 1). During the third period of surgery, the indicators were lower than the values of healthy individuals, but did not differ significantly from the values of the second period of surgery. However, in patients with compensated intestinal obstruction during the first period, M was lower than the values in the groups with more severe disease course, and the indices in patients with subcompensated and decompensated disease

course did not differ significantly. During the second period of surgery, the values of tissue perfusion were not significantly different in the groups depending on the severity of the disease, although the percentage of change was higher in patients with subcompensated and decompensated obstruction. At the end of surgery M at compensated intestinal obstruction approached values in the preoperative period, and during the subcompensated course of the disease – decreased to values $(1,18 \pm 0,07)$, and at decompensation – remained at the level of the second period of operation.

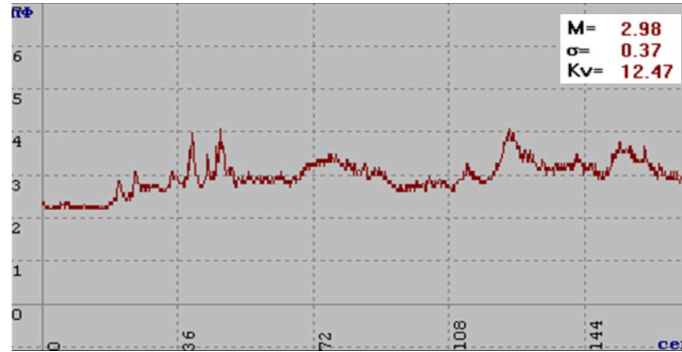


Figure 1. Perfusion rate in healthy individuals.

In patients undergoing laparoscopic surgery, during the first period of surgery, an increase in M ($p > 0.05$) was detected, similar to the previous group of patients (Figs. 2, 3). In this case, the perfusion of peripheral tissues in patients with compensated intestinal obstruction was twice lower than the value in patients operated on because of the subcompensated course of the disease ($p < 0.05$).

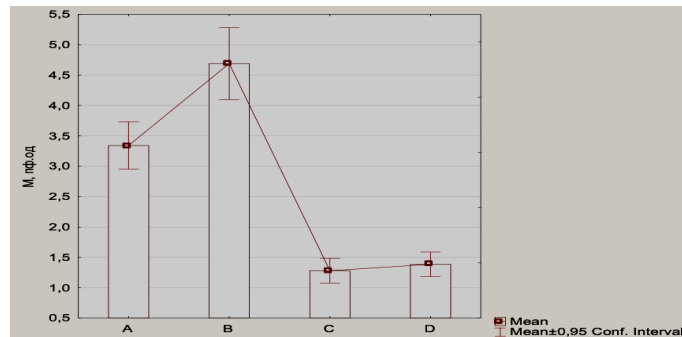


Figure 2. Perfusion rate during laparotomy surgery (A – indicators of healthy persons; B – I period of operation; C – II period of operation; D – III period of surgery).

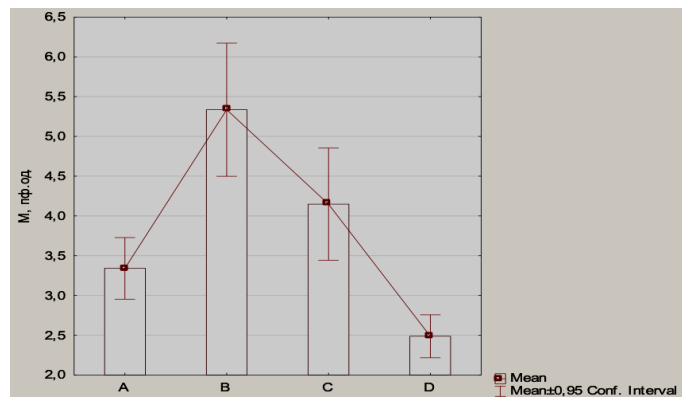


Figure 3. Perfusion rate during laparoscopic surgery (A – indicators of healthy individuals; B – I period of operation; C – II period of operation; D – III period of surgery).

During the second period of surgery, a slow decrease in perfusion was found, compared to the previous group of patients, with the values of M during this period were significantly higher than the values of the group of patients operated on laparotomy and the group of healthy persons.

During the last period of minimally invasive surgery, the values of perfusion decreased significantly ($p < 0.05$), but were higher than the group of patients operated on laparotomy.

In the process of using computer diagnostics, it has been found that healthy individuals have a major influence on the regulation of blood flow to the microcirculatory bed by the sympathetic-adrenal system and the intrinsic tone of the vascular wall (active oscillations). A significant contribution to the regulation of blood flow is made by the vascular endothelium, the influence of which in the mechanisms of management of vascular tone is about 25% (Table 1).

Table 1. Percentage contribution of the main mechanisms in the regulation of blood flow during surgery in patients with adhesive intestinal obstruction.

Survey group / the period of surgery	Active components of blood flow regulation, %			Passive components of blood flow regulation, %	
	Amplitude of endothelial oscillations	Neurogenic oscillation amplitude	The amplitude of myogenic oscillations	Respiratory amplitude	Heart rate amplitude
Laparoscopic surgery (n-33)					
I-th period of operation	25.96±1.30	25.63±0.91*	23.04±0.76*	18.57±0.20*	6.80±0.31
II-th period of operation	21.47±0.82	21.41±0.50*	23.45±0.61*	23.11±0.8*	10.56±0.51*
III-rd period of operation	21.08±0.86	24.20±0.53*	20.20±0.52*	22.68±0.84*	11.84±0.64*
Laparoscopic surgery (n-29)					
I-th period of operation	24.38±0.42	24.74±0.47*	26.05±0.51*	17.55±0.54*	7.29±0.35
I-th period of operation	26.83±0.98*	23.85±0.76*	22.56±0.65*	18.99±0.79*	7.66±0.42
II-th period of operation	18.27±0.82*	15.78±0.63*	27.15±0.74*	28.32±1.02*	10.52±0.56*
III-rd period of operation	24.52±0.45	30.28±0.36	29.98±0.51	8.50±0.47	6.72±0.34

Note: * – the significance of the difference between the indicators and the group of healthy individuals $p < 0.05$;
□ – the reliability of the difference between the metrics and the previous data $p < 0.05$

In patients undergoing laparoscopic surgery, during the second period of surgery, an increase in the influence of the endothelial factor of regulation was detected, with a significant decrease in this index below the values of healthy individuals. As with open surgery, in this group of patients a decrease in the influence of neurogenic ($15 \pm 1.3\%$) and myogenic ($14 \pm 1.8\%$) mechanisms with an increase in the percentage of passive regulatory mechanisms was detected. In contrast to the previous indicators, during the third period of laparoscopic surgery, significantly lower values of the influence of endothelial and neurogenic mechanisms were established, and significantly higher indicators of myogenic and respiratory factors, which indicates a pronounced stagnation of blood in the capillary^{26,27}.

In the course of the study it was found that during the perioperative period the condition of the microcirculatory bed changes under the operation period. In the first period of surgery, there is an increase in all indicators of microcirculation, regardless of the type of surgery. This indicates an increase in blood supply to the tissues, activation of the active components of the regulation of blood flow (endothelial, neurogenic and myogenic), as a result of activation of the sympatho-adrenal system, and the body's response to the introduction of drugs for anesthesia and premedication. Subsequent periods of surgery changes in the microcirculatory bed vary depending on the type of surgery, with laparotomy surgery in the second period revealed a sharp decrease in the level of M (< 1.3 pf. units), bypass rate (< 1) and decreased activity of all components of blood flow regulation in some cases below healthy individuals. This situation is a consequence of the influence of drugs for anesthesia on the main links of blood circulation regulation and heat regulation. In addition, it is also reflected in a decrease in body temperature, with the decrease in temperature being the fastest throughout surgery. It was also found that a decrease in body temperature during this period was closely associated with a decrease in peripheral tissue blood supply. During the third period of operation, low values ($< 1.5 \pm 0.09$ pf. units) of tissue perfusion (below those of healthy individuals) and high amplitudes of vibrations of the passive components of blood flow regulation (respiratory and cardiac oscillations) were detected. This indicates a decreased blood supply to the peripheral tissues, increased resistance of arterioles and impaired blood flow from the capillary bed. At the same time, the amplitudes of endothelial, neurogenic and myogenic oscillations are not significantly

different from those of healthy individuals. This increases the bypass rate (1.5 ± 0.11), which further deepens the hypoxia of the peripheral tissues. Against this background, the body temperature decreases (to $35.44 \pm 0.07^\circ\text{C}$), the more pronounced the stagnation in the capillary bed (the higher the amplitude of the respiratory vibrations), the lower the body temperature^{28,29}.

In laparoscopic operations, changes in the capillary line occur more slowly. Thus, during the second period of operation, a moderate decrease in the perfusion (up to 4.2 ± 0.13 pf. units) of tissues and a slow decrease in the amplitude of all components of blood flow regulation were detected. Of course, there are positives to this, such as slow adaptation of the body, no sharp changes in regulatory effects, slow decrease in body temperature. But there are downsides – high amplitude numbers of the passive components of blood flow regulation (stagnation of blood in the capillary bed and deterioration of blood flow to the capillaries), an increase in the shunting index (capillary bedding), which can lead to an increase in peripheral tissue hypoxia. During the third period of laparoscopic surgery, higher rates (1.5 ± 0.12 pf. units) of tissue perfusion were found, compared to the group of patients operated on by laparotomy access, and higher values of respiratory amplitude (0.55 ± 0.08) and a sharp decrease in the bypass rate (0.58 ± 0.09). Despite better tissue filling, the pressure in the capillaries more than with open surgery increases pressure, stagnation and overflow of the capillary canal, which can lead to hypoxia and thrombosis.

All this gives grounds to claim that open and laparoscopic surgical interventions have their advantages and disadvantages in relation to the investigated indicators, which should be taken into consideration during the operative procedures.

4. CONCLUSION

The laser Doppler flowmetry method using computer diagnostics and computer technology in complex diagnostics can be successfully used to monitor the state of the microcirculation system in the perioperative period in patients during surgery, to detect peripheral tissue perfusion disorders. Available results indicate significant changes at the level of the microcirculation system. Violation of blood circulation of tissues and decrease in body temperature at the end of surgery leads to hypoxia of organs and systems, the development of dysfunction, and in the subsequent – insufficient functioning of parenchymatous organs and the development of complications. Thus, the influence on the detected changes in the microcirculation will significantly improve the course of the disease and prevent the development of severe complications in patients with adhesive small intestinal obstruction.

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