Photocompression Study of Tissue Blood Flow

F. S. Zhizhin, S. L. Tochilov, and V. M. Chuchkov

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 136, No. 11, pp. 598-600, November, 2003
Original article submitted January 27, 2003

Non-pulsed optical density of the small intestine was studied in 32 dogs and the results were compared with the data of angiotensometry and pulsomotorography. New regularities of blood circulation in the small intestine were detected: more than half of the total volume specific blood flow in the intestinal tissue is normally realized in vessels at a pressure below 40 mm Hg. An additional criterion of viability of the small intestine during ischemia is developed.

Key Words: *blood flow; vessels; intestine; optical density*

Reliability of evaluation of blood flow in tissues, reversibility of ischemia, and accuracy of topical diagnosis of necrotic foci remain disputable problems in experimental and clinical studies. Available reports necessitate the search for additional methods for lifetime investigation of blood microcirculation [1,2].

MATERIALS AND METHODS

Experimental studies were carried out on 32 mongrel dogs of both sexes (6.3-29.6 kg) in accordance with the regulations for handling experimental animals under combined narcosis. The study was carried out using transillumination angiotensometry (ATM), pulsomotorography (PMG), and by evaluating changes in non-pulsed relative optical density (NROD) of the small intestine under conditions of dynamic compression. The intestinal wall was placed between elastic membrane of a pressure chamber with a radiation source (Z. M. Sigal's device) and a rigid transparent plate with a built-in FD-7k photodetector. The method consisted in short-term local atraumatic compression the intestine followed by its dosed decompression (10 mm Hg step) and simultaneous recording of blood filling (in arb. units) by the photooptic method.

The amplitude of pulse wave (APW), maximum (P_{max}), minimum (P_{min}), and pulse (P_{pulse}) pressure in submucosal vessels, pressure in the concurrent veins (P_{vein}), and NROD were measured every 10 mm of decompression.

Apart from absolute values of NROD in the specified decompression range, the relative drop of NROD gradient per 10 mm Hg was estimated (in percent). This parameter reflects distribution of functioning vascular collectors in a certain moment at a local site of the studied intestine. It represents the percentage of vessels involved in circulation, the pressure in these vessels corresponding to a certain range (0-10 mm Hg, 10-20 mm Hg, 20-30 mm Hg, *etc.*) and allows evaluation of vascular function for any pressure range depending on the purpose of the study (0-40 mm Hg, 60-120 mm Hg, from P_{max} to P_{min}, from P_{vein} to 0, *etc.*).

RESULTS

The dynamics of NROD of the intestinal wall in the compression spectrum indicated that the maximum value was attained at 0 mm Hg (no compression) and the minimum at 160 mm Hg. The initial value of NROD (at 0 mm Hg) was determined by the stroma and circulating blood. During complete compression of the local site of the intestine at the level significantly surpassing P_{max} (according to preliminary ARM) NROD depended only on the structure of the intestinal wall, because blood flow in the studied punctate site ceased. The resultant NROD gradient between complete and zero compression was determined by the integral blood flow in the studied site of the intestine. Division of the total gradient into components corresponding to

Department of Hospital Surgery, Izhevsk State Medical Academy

0007-4888/03/1365-0530$25.00

TABLE 1. Pulsomotorography and Angiotensometry Values in Intact Small Intestine (*M*±*m*)

Parameters	Value
APW	3.84±0.12
P_{max}	115.13±3.02
P_{min}	85.79±2.16
P_{pulse}	29.54±1.70
P_{vein}	43.37±1.27

10-mm Hg decompression steps gives a picture of functioning of vascular collectors, where blood pressure surpassed instant compression pressure.

At 160 mm Hg NROD of the intestinal wall was determined by intestinal stroma and blood flow in vessels where blood pressure surpassed this level. At 150 mm Hg NROD increased due to recruitment of vessels with internal pressure >150 mm Hg and so on.

Hemodynamic parameters were measured in 52 local sites of intact small intestine after laparotomy without additional interventions; NROD parameters were compared with the results of ATM and PMG.

The intact small intestine, viable according to visual examination and histological analysis, was characterized by normal hemodynamic parameters according to ATM and PMG (Table 1). NROD was 17.18± 1.13 opt. density units (Table 2). During gradual compression of the intestine to 130 mm Hg this parameter increased and did not change with further compression. NROD changed more intensely at low values of external pressure (0-40 mm Hg).

Analysis of the percent distribution of NROD gradient in the compression spectrum showed that minimum changes corresponded to external compression of 110-130 mm Hg (Table 3). Extrapolation of the percent ratio to the intestinal wall hemodynamics means that only 2.51±0.34% intestinal vessels functioned in this range of pressure values. These vessels are large arteries. P_{max} (115.13±3.02 mm Hg) shown by ATM confirms the presence of blood flow in submucosal arteries under these compression conditions. At values below P_{min} blood circulation was detected in 85.83± 1.38% blood vessels and 11.14±1.06% blood vessels were additionally involved in the blood flow in the P_{pulse} range.

One more parameter was taken into consideration: blood flow enhancement during external decompression of the intestine from 40 to 0 mm Hg. It is noteworthy that it surpassed 50% (51.20±1.62%). At intravascular blood pressure of 40-130 mm Hg 48.80± 1.62% vessels were open in the intestinal wall. We should like to distinguish the compression level corresponding to 40 mm Hg. At this pressure in the arterial bed the pulsatile blood flow most often transfor-

TABLE 2. NROD of the Small Intestine in Specified Compression Spectrum (*M*±*m*)

External pressure	Value
160	0±0
150	0±0
140	0±0
130	43.14±2.76
120	43.03±2.76
110	42.70±2.76
100	41.72±2.72
90	40.44±2.65
80	38.89±2.61
70	37.06±2.40
60	35.15±2.31
50	32.88±2.21
40	30.90±2.17
30	28.27±2.05
20	24.79±1.80
10	21.27±1.53
0	17.18±1.13
$NROD_{max}$	43.14±2.76
$NROD_{min}$	17.18±1.13
NROD gradient	25.96±1.89

TABLE 3. Distribution of NROD in the Small Intestine in Specified Compression Spectrum (*M*±*m*, %)

P_{extern} gradient	Value
160-150	0±0
150-140	0±0
140-130	0±0
130-120	0.5±0.14
120-110	2.01±0.42
110-100	4.05±0.46
100-90	5.24±0.59
90-80	6.54±0.58
80-70	6.52±0.69
70-60	7.49±0.76
60-50	8.66±0.78
50-40	8.28±0.80
40-30	10.22±0.83
30-20	12.65±0.82
20-10	13.20±0.68
10-0	15.13±0.97
Below 40 mm Hg	51.20±1.62
Above 40 mm Hg	48.80±1.62
Below P_{min}	85.83±1.38
Within P_{pulse}	11.14±1.06

med into continuous, while venous pressure in submucosal vessels was close to the above level (43.37± 1.27 mm Hg according to ATM). This collector of the microcirculatory bed between continuous arterial and intravenous blood flow is least studied by dynamic methods, including ATM and PMG. It is noteworthy, however, that volume blood flow in this collector surpassed half of the total blood flow volume.

The method proposed by us allows evaluation of the summary specific blood flow in a small tissue area including arteries, arterioles, precapillaries, capillaries, postcapillary venules and veins, which only in their complex determine the hemodynamics of biological tissues, their ischemia and viability. Experiments on models of arterial, venous, and mixed ischemia (3- and 9-cm skeletization) and morphological studies showed that this tissue pathology is reversible under condition of functioning of more than 17% vascular collectors with blood pressure >40 mm Hg. Evaluation of the intestine viability by this method in patients with strangulation acute ileus and ischemia of other origin yielded no erroneous conclusions.

Hence, photometry of NROD under conditions of dynamic compression of hole abdominal organs notably supplements our knowledge on microhemodynamics, detects new regularities for the search of additional criteria for evaluation and prediction of the severity and type of ischemic disorders in the small intestine and for monitoring the efficiency of drug and other than drug correction of reversible ischemia.

REFERENCES

1. Z. M. Sigal, A. P. Kravchuk, and V. M. Kamashev, *Khirurgiya*, No. 3, 38-41 (1984).
2. W. H. Pearce, D. N. Jones, G. Warren, *et al.*, *Arch. Surg.*, **122**, No. 3, 308-310 (1987).