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A Device for Studying Hemocirculation in Suture Bands in Interintestinal Anastomoses

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A device for investigating blood pressure in the intramural vessels of hollow organs and determining arterial blood hemoglobin oxygen saturation was developed; the device consists of two chambers, one containing LED lamps and the second, an emitter for determining blood oxygen saturation.

Introduction

The problem of inadequacy of sutures used in interintestinal anastomoses remains current [1, 2],

All investigators agree with the view that the interintestinal anastomosis zone must have a viable hemocirculation after intestinal resection.

Laser Doppler flowmetry, angiotensometry as described by Sigal [3-5], pulsomotorography as described by Sigal [6], redoxometry [7], and electromyography [8] are currently used for assessing the blood circulation in suture bands after intestinal resection and formation of interintestinal anastomoses.

However, suture inadequacy after use of these approaches and devices for assessing the blood circulation in suture bands after intestinal resection and formation of interintestinal anastomoses has been demonstrated [1, 3, 4, 6-9].

Thus, the development of new device for intraoperative assessment of the viability of the suture band of the intestine on formation of interintestinal anastomoses is also a relevant challenge.

The aim of the present work was to develop a new device for assessment of the blood circulation in suture bands in the intestine.

The study addressed the following tasks:

1) to develop a new device for assessing the blood circulation in suture bands in the intestine on formation of interintestinal anastomoses;

2) experimental clinical testing of the new device to study blood pressure in intramural vessels in suture bands in the intestine and oxygen saturation of arterial blood hemoglobin.

Materials and Methods

This article presents results of experimental intestinal resection in 40 dogs and clinical resection in 126 patients of the study group, in whom the device developed here was used to investigate the blood circulation in the zone of interintestinal anastomoses, and 128 patients of the reference group, in whom intestinal resection was performed before we developed the device.

The device (Fig. 1) consists of a rigid rectangular common chamber 56 mm long divided by a metal partition into two chambers (C_1 and C_2), 19 and 37 mm long, respectively. The chamber was 27.5 mm wide. Three LED lamps were mounted in the first chamber. This chamber was connected with a junction piece (JP) consisting of a metal tube with a rubber tube (RT) mounted on one end through which the cable from the step-down transformer to the lamps passes; it is also connected to a manometer for pressure measurement and a rubber bulb for insufflating air.

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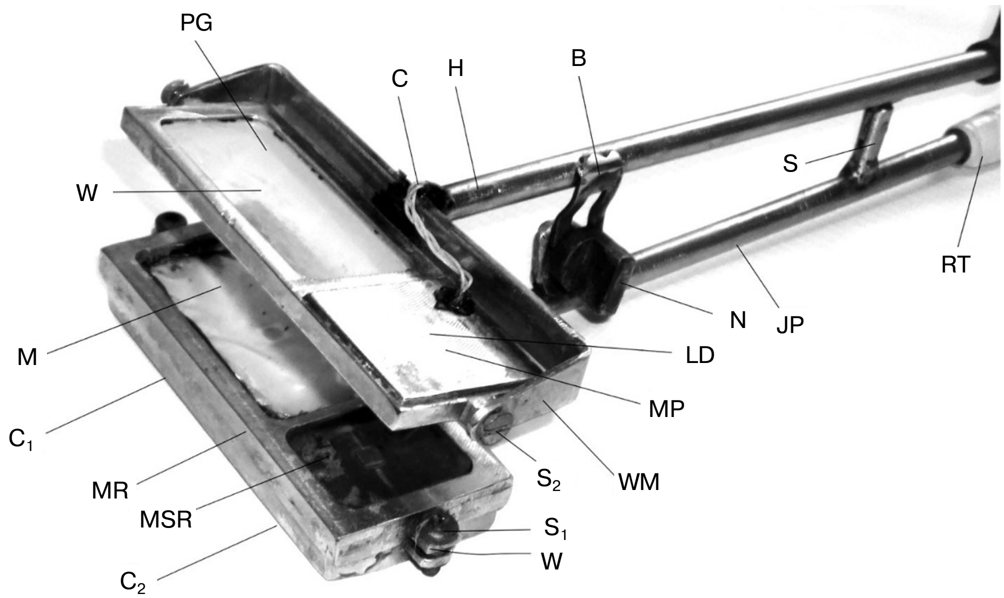

Fig. 1. Illustration of the device developed here.

A metal rim (MR) consisting of plexiglass (PG) and a metal sheet rim (MSR) was attached to the rigid chamber with screws (S_1) at the sides of the chamber, passing through a washer (W). A rubber membrane (M) was positioned between the metal rim and the chamber. A window (W) made of plexiglass (PG) was located above the rubber membrane over the chamber and the metal plate (MP) above the emitter chamber (C_2). The metal frame of the window bore a light detector (LD). The window mount (WM) held the window with screws (S_2) at the sides of the window mount. The light detector was connected via cables (C) passing through handle (H_2) to the monitor. The window, attached to the handle, was moved up and down on hinges by a retainer connecting the handle with the junction piece. The window was held in the required position by a nut (N) in a slot in a bracket (B) on the handle of the device. The handle moved up and down on a strut (S) attached to the junction piece.

A description of the structural assembly of the device is given below.

Considering that the device is intended for measuring the level of oxygen saturation of arterial blood hemoglobin and also for measuring blood pressure in the intramural vessels of the intestinal suture band of interintestinal anastomoses in patients, the structural scheme must include the following units and assemblies (Fig. 2):

– stabilized power supply (SPS);
– red LED emitter (RLED);
– infrared LED emitter (IRLED);
– visible LED emitters (VLED1-VLED8);
– wideband light detector (WBLD);
– pressure probe (PP);
– portable oximeter (PO);
– portable tonometer (PT);

Thus, the scheme of the device consists of two main parts:

1. a set of components for measuring the degree of blood oxygen saturation in capillaries in the intestinal suture band, including the RLED, IRLED, WBLD, and PO;

2. a set of components for measuring blood pressure in the intramural vessels of the suture band, which includes VLED1-VLED8, the PP and the PT.

The system for measuring the level of oxygen saturation of arterial blood hemoglobin functions as follows. Optical irradiation created by LEDs RLED and IRLED in the red and infrared ranges respectively arrive on the test biological target (TBT). Partially absorbed in the veins, arteries, and tissues of the TBT, it reaches the light-sensitive diode WBLD and is converted into an electrical signal and sent to the processor block of the PO. From the signal this extracts the spectrum left after absorption by arterial (“pulsating”) blood. This is achieved by means of time binding of the pulse wave signals to the optical irradiation. The signal resulting from this processing is pulsatile in nature. This signal was processed and the result was presented on the display of the device, the screen showing the percentage content of oxygen in the blood.

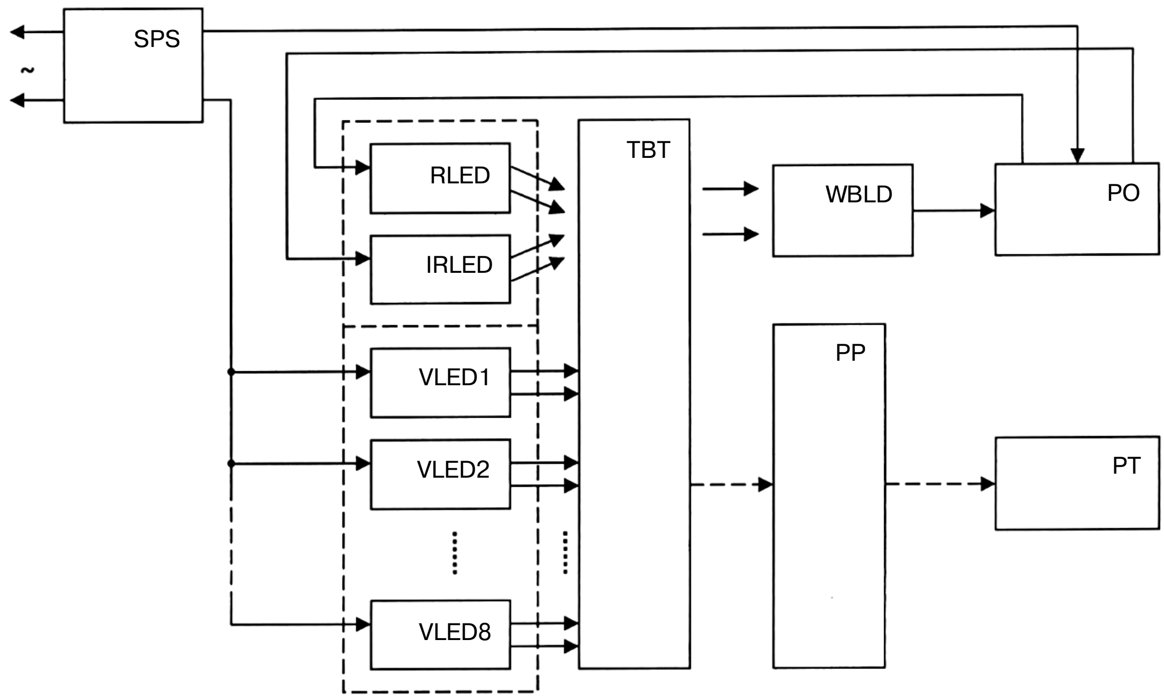

Fig. 2. Structural scheme of the device.

Blood pressure was measured in the intramural and extraorgan vessels by placing the study part of the intestinal wall between the window, which was fixed to the handle, and the rim, beneath which the rubber membrane was positioned. The visible-range LEDs (VLED1-VLED8) illuminated the study part of the intestinal suture band via the inflated transparent elastic rubber membrane ensuring good contact with the hollow organ. Air was pumped in with the rubber bulb to increase the pressure in the chamber (C_1), thus increasing pressure in the system. As air entered the chamber (C_1), the pulsatile blood flow was recorded on the manometer (systolic pressure), along with complete filling of arteries (diastolic pressure) and veins (venous pressure).

Angiotensometry in the intramural vessels of the intestine was performed in experimental and clinical conditions as described by Sigal [5] using the device described here, use of which provides for studies of oxygen saturation of arterial blood hemoglobin, pulse, perfusion level, and the presence of intramural metastases in the suture band. The index of viability of the suture band was then calculated using the formula derived by Ramazanov [2]:

$$I = [(D_a + D_m) - 20]/D_s \geqslant 1,$$

where D_a is intramural pressure in the antimesenteric margin of the intestine, D_m is the intramural pressure in the mesenteric margin of the intestine, and D_s is the systemic pressure in the patient's arm measured by the Korotkov method.

Experimental studies were carried out on male mongrel dogs weighing 12-15 kg in compliance with the requirements of USSR Ministry of Health Order No. 755 of August 12, 1977, amended and ratified by Order No. 742 of November 13, 1984, and after approval by the ethics committee of Dagestan State Medical University.

The method used for the experimental studies was as follows. Dogs were premedicated with i.m. Dimedrol (1%, 1 mL) and Ketorol (1 mL). Anesthesia was induced with nitrous oxide and oxygen at a ratio of 2:1 delivered via mask. Anesthesia was maintained with i.v. thiopental sodium at a dose of 10 mg/kg body weight. Analgesia was with i.m. Ketorol (0.5-1 mg/kg). Laparotomy was performed. This was followed by selection of an intestinal loop and measurement of blood pressure using the Sigal method and arterial blood hemoglobin oxygen saturation in the intestinal wall using the device described here.

After mobilization of the intestine, it was resected. Suture bands of the proximal and distal loops were studied using our device before formation of the interintestinal anastomosis. The abdominal cavity was closed in layers. Dogs were euthanized at 7, 14, and 30 days by overdosage with i.v. thiopental sodium. Interintestinal anastomoses were studied histologically.

Inclusion criteria for patients were: surgical pathology of the colon, informed written content from the patient to take part in the study.

Exclusion criteria were: severe kidney or liver failure, chronic heart failure, and refusal by the patient to take part in the study.

Dropout criteria for patients were the occurrence of drug side effects and refusal of the patient to continue participation in the study.

Values were subjected to statistical processing using database analysis software: Statgraf and Stat4, as well as SPSS version 7.5.

Results

At the first stage, the device was tested in experiments on 40 dogs using formation of interintestinal anastomoses to allow it to be used at the second stage, in the clinic.

Interintestinal anastomoses in 30 dogs of the study group were formed after resection of the intestine at a blood pressure in the intramural vessels of the proximal suture band of $(101 \pm 1.8)/(68.7 \pm 1.2)$ mm Hg and an arterial blood hemoglobin oxygen saturation of $92 \pm 1\%$, while values for these parameters in the distal suture band were $(98.3 \pm 1.6)/(66 \pm 1.2)$ mm Hg, with a systemic blood pressure of $(120.3 \pm 1.8)/(76.6 \pm 1.4)$ mm Hg and an oxygen saturation of $93 \pm 1\%$. The index of viability of the suture bland was greater than unity. During the postoperative period, interintestinal anastomoses healed by primary intention.

In the 10 dogs of the reference group, interintestinal anastomoses were formed at a blood pressure in vessels in the proximal suture band of $(22.3 \pm 0.7)/(22.3 \pm 0.7)$ mm Hg and a systemic pressure of $(122 \pm 0.7)/76 \pm 0.5)$ mm Hg, and blood pressure in the vessels of the distal suture band of $(19.4 \pm 0.5)/(19.4 \pm 0.5)$ mm Hg at the same systemic pressure. The index of viability of the suture band was less than 1. All 10 dogs died from peritonitis on days 6-7 due to failure of the anastomosis sutures.

After successful testing at the first stage in experiments on 30 dogs, we used the new device in 126 patients of the study group, who underwent intestinal resection and formation of interintestinal anastomosis with investigation of the blood circulation in the suture band.

Discussion

Two patients of the 126 in the study group showed low values of arterial blood hemoglobin oxygen saturation (28%) on the background of an index of viability of 1 in the suture band. On the background of gastric bleeding, the blood hemoglobin level in these two patients was 45. These two patients were found to have failure of the sutures of the interintestinal anastomosis.

Our studies provided evidence that the device developed here effectively evaluated the hemocirculation in the intestinal suture band, as 124 patients of the study group did not experience suture failure in the post-operative period after intestinal resection and formation of interintestinal anastomoses, while some of the 128 patients of the reference group showed suture failure after analogous operations (9.5%).

Conclusions

1. The device developed here is effective in studying arterial blood hemoglobin oxygen saturation, the pulse, the perfusion level, and blood pressure in the intramural vessels of the suture band of interintestinal anastomoses.

2. Formation of interintestinal anastomoses after intestinal resection is recommended when the index of viability of the suture band is greater than 1 and arterial blood hemoglobin oxygen saturation is above 92%.

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