METHODS

Dynamometric Apparatus for Evaluation of Mechanical Properties of Hollow Organs of Small Laboratory Animals

A. Yu. Tsibulevskii, Yu. M. Petrenko, and V. Yu. Titov

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 123, No. 4, pp. 473-475, April, 1997
Original article submitted December 12, 1995

An original dynamometric apparatus is constructed for evaluation of elastic properties of hollow organs (esophagus, bowel, trachea, ureter, and aorta) of small laboratory animals. An adequate algorithm for the processing of experimental data is developed. The method is evaluated on the intestine from intact and vagotomized (14 and 30 days) rats, and its high efficiency is demonstrated. A proximodistal gradient of mechanical characteristics of the small intestine is shown: tensile strength decreases toward the caudal end. Vagotomy leads to an increase in tensile strength and relative extension limit 14 days postoperation, while 30 days after the surgery opposite changes are noted.

Key Words: *dynamometric apparatus; mechanical properties; small intestine; vagotomy*

The study was aimed at developing an apparatus and adequate algorithm for evaluating elastic characteristics of hollow (tubular) organs of small experimental animals (mice, rats, and guinea pigs). The knowledge of mechanical properties of the whole organ, in particular, information on alterations of mechanical characteristics of the stomach, trachea, ureter, vessels, etc. is of interest for both researchers and clinicians. In some pathological processes it is important for choosing the adequate suture technique, material, and instrument [2]. Moreover, these data should be taken into account for the development of optimal homogenization regime for biochemical and biophysical studies [6]. Devices and apparatuses routinely used for the evaluation of elastic properties of various materials (metals, plastics, ceramics, etc.) cannot be applied to biological objects since they are usually designed for large strength and minor deformations and impose heavy demands on the initial size of the specimen. The majority of biological objects cannot resist large mechanical loads, being considerably strained by relatively low strains.

Department of Histology and Embryology, Department of Biochemistry, Russian State Medical University, Moscow

MATERIALS AND METHODS

Figure 1 is a schematic drawing of the proposed apparatus for *in vitro* evaluation of the elastic properties of hollow cylindrical organs from small experimental animals. A specimen of a hollow organ (about 20 mm long) obtained from dead or narcotized animal is mounted using clamps with pointers to movable ties initially fixed in a guide unit with bolts. After mounting, the bolts are loosened, and the specimen elongates due to the action of a constant load (weight of the lower tie). The length of the specimen is measured and taken as the initial length (l_0). The indications of the upper (l_1) and lower (l_2) pointers are also recorded. Thereafter, an electric drive is turned on, and the indications of the pointers are recorded until the specimen breakage (reeling rate 15 mm/min). The obtained parameters are pro-

0007-4888/97/0004-0412$18.00

cessed by the following algorithm: a) $\Delta l_{1i}=l_{1i}-l_{1o}$, b) $\Delta l_{2i}=l_{2i}-l_{2o}$, where l_{1o} and l_{2o} are the initial indications of the upper and lower pointers, respectively, l_{1i} and l_{2i} are these indications on the i-th step, Δl_{1i} is elongation of the elastic element under the action of the applied load, Δl_{2i} is the elongation of the elastic element and the specimen; c) $\Delta L=\Delta l_{2i}-l_{1i}$, where ΔL is the elongation of the specimen under the action of the load on the i-th step of measurement; d) $\Delta L/l_o$ is the relative change in the length of the specimen under load; e) $\Delta l_{1i}\times 0.098$ N/mm is the magnitude of load.

The final mechanical characteristics were relative change in the length of the organ at the moment of break (relative extension limit) and the magnitude of load corresponding to breakage.

The above-described method was applied for 116 specimens of the small intestine from 58 albino nonpedigree male rats weighing 180-210 g, of them 28 rats underwent bilateral subdiaphragmatic truncal vagotomy, while others served as the control. The animals were decapitated 14 and 30 days postoperation and 16-18 h after the last feeding; two 30-35-mm long intestinal fragments were cut off. The first fragment included the duodenum and the proximal part of the jejunum; the second fragment consisted of the remaining part of the jejunum. For each fragment the extension limit and the maximum load were determined. The data were processed statistically as described elsewhere [5].

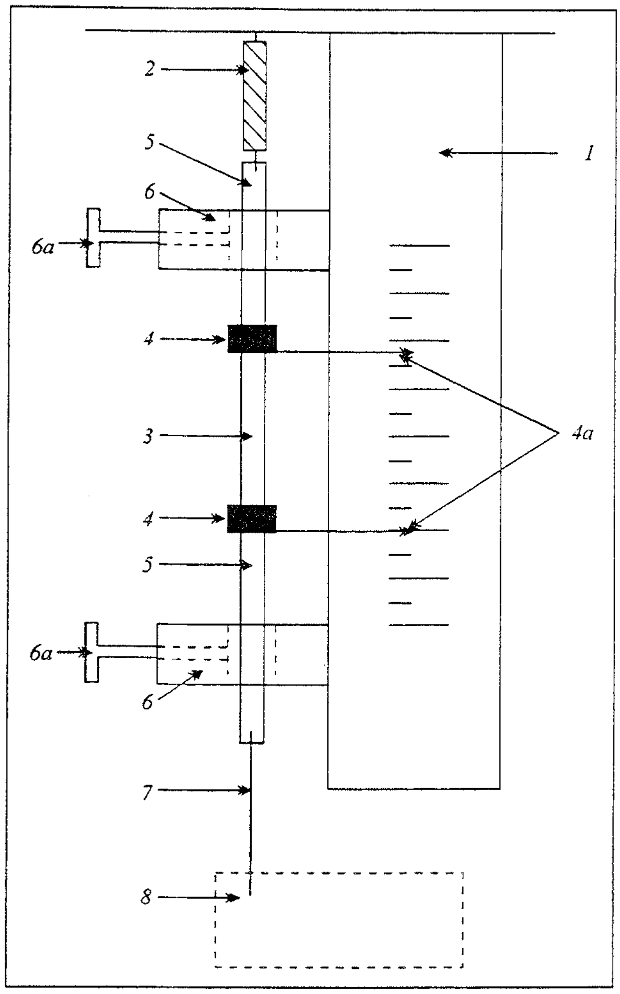

Fig. 1. A principal scheme for evaluation of elastic characteristics of the small intestine in rats. *1*) support rail with measuring scale; *2*) elastic element (spring) with known coefficient of elasticity (0.098 N/mm); *3*) fragment of the small intestine; *4*) clamps with pointers (*4a*); *5*) upper and lower movable ties; *6*) guide units with fixing bolts (*6a*); *7*) rigid thread; *8*) electrical drive with a commutation reducer for regulation of the rate of reeling.

RESULTS

In intact rats, the maximum load was 3.06 and 1.96 N for the first and second intestinal fragments, respectively, i.e., the proximal fragment is more resistant (56%) to breakage than the distal one. The relative extension limit for fragment 1 also surpassed that for fragment 2 by 31% (Table 1). This proximodistal gradient of mechanical characteristics is most likely due to unequal distribution of the connective tissue along the intestine. The existence of analogous gradient for the muscular layer also cannot be excluded. Fourteen days postoperation, the resistance to breakage and the relative extension limit of fragment 1 increased by 17 and 10%, while no changes in these parameters were noted in fragment 2. Thirty days postoperation, the maximum load for fragment

TABLE 1. Mechanical Characteristics of the Small Intestine in Intact and Vagotomized Rats

Fragment	Parameter	Intact rats	Vagotomy, days	
			14	30
Fragment 1	Maximum load, N	3.06±0.11	3.58±0.09*	2.63±0.10*
	Relative extension limit	0.55±0.06	0.61±0.04	0.51±0.07
Fragment 2	Maximum load, N	1.96±0.08	1.88±0.10	2.02±0.09
	Relative extension limit	0.42±0.04	0.41±0.02	0.43±0.05

Note. *$p<0.05$ in comparison with the intact rats.

1 decreased by 14%, while the relative extension limit did not differ from the control, similar to the same parameters of fragment 2. The distribution of the values of maximum load and relative extension limit for both intestinal fragments varied considerably in control and vagotomized animals throughout the experiment (Table 1). It can be hypothesized that the rise of mechanical resistance of the intestine in vagotomized animals is due to the connective tissue growth (fibrosis), while the decrease is related to dystrophy of structural components of the intestine, primarily, its muscular layer. Analogous alterations were described for the duodenum in truncal vagotomy in dogs [1]. Nonphysiological activation of lipid peroxidation in biological membranes probably also modifies structural and functional properties of the small intestine, since lipid peroxidation is known to affect mechanical characteristics of various cells, tissues, and organs.

REFERENCES

1. V. A. Kotel'nikov, in: *Surgical Correction of Diseases of the Peritoneal Cavity* [in Russian], Sverdlovsk (1966), p. 17.
2. I. Littman, *Operative Surgery* [in Russian], Budapest (1989).
3. F. Z. Meerson, *Pathogenesis and Prevention of Stress- and Ischemia-Induced Damage to the Heart* [in Russian], Moscow (1984).
4. V. Z. Parton and E. M. Morozov, *Mechanics of Elastic Break* [in Russian], Moscow (1985).
5. R. B. Strelkov, *Statistical Tables for Express Analysis of Experimental and Clinical Material* [in Russian], Obninsk (1980).
6. P. Latimer and C. Eubanks, *Arch. Biochem. Biophys.*, **98**, 274-285 (1962).

Hydrodynamic Reasons for Choosing a Variant of Cavapulmonary Anastomosis

L. A. Bokeria, L. A. Roeva, K. V. Shatalov, and R. R. Movsesyan

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 123, No. 4, pp. 476-480, April, 1997
Original article submitted June 20, 1996

In order to optimize the technique of cavapulmonary anastomosis and to determine mutual position and orientation of the inflow and outflow axes of implanted anastomoses, hemohydrodynamic studies are carried out using laser Doppler anemometry. The most hydrodynamically optimal variant of the cavapulmonary bypass, a crucial anastomosis with a half-diameter shift and an angle of 60° with the outflow axis, is determined.

Key Words: *optimization; vortex formation; turbulence*

One of the most important problems of cardiosurgery is the study of blood flow in the branched vascular bed.

The total cavapulmonary bypass (TCB) was developed as an alternative for cardiopulmonary bypass in patients with congenital heart failure with critically decreased pulmonary circulation [1,5,6].

The TCB is based on the separation of venous and arterial blood through creation of a bypass around the right heart and forcing passive pulmonary circulation [3-5].

A. N. Bakulev Center of Cardiovascular Surgery, Russian Academy of Medical Sciences, Moscow

The aim of the present study was to choose hemodynamically optimal variant of anastomosis in TCB ensuring an adequate pulmonary circulation.

MATERIALS AND METHODS

The study of flow structure in modeled vascular bed in TCB was carried out using laser knife and laser Doppler anemometry techniques.

Noninvasive methods (laser Doppler anemometry) allowed us to develop a new instrument for measurement of flow rate in the given point.

This method offers the following advantages:

0007-4888/97/0004-0414$18.00