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Mechanical Properties of Various Segments' Walls of the Intestinal Tube.

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ABSTRACT

Controlled draining of choledochojejunoanastomosis and pancreaticojejunoanastomosis is associated with a range of objective problems, for example, with impossibility of performing endoscopic control, especially after radical surgery on pancreaticoduodenal area. In this article we have presented results of study of mechanical characteristics of various segments of intestinal tube and urinary tracts on autopsy material and laboratory animals. There has been presented justification of stent spiral's stiffness and possibility of its excision through the wall of hollow organ.
Keywords: medical implant, stent, inflammation, draining, biological compatibility, biomechanical compatibility.

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INTRODUCTION

Internal stenting, because of its minimal traumaticity and relative simplicity of performing manipulations, is currently considered as a priority draining method in pancreatobiliary surgery and urology [1-4].

Controlled draining of extrahepatic biliary tracts is associated with a range of objective problems [5-7]. It is not always possible to perform endoscopic control, especially after radical surgery on pancreaticoduodenal area [7]. External draining through natural vials increases the draining length and risk of its obstruction. Performing draining through the wall of hollow organ increases the risk of inflammatory complications [8,9]. Leaving "the lost" draining makes it impossible to timely remove it [3,7,10].

THE METHOD

The study of mechanical characteristics of hollow organ has been performed on autopsy material (twisted, empty and sigmoid intestines, choledochous duct and ureter), as well as in regards to thoracal segment of esophagus, proximal segment of small intestine and distal segment of large intestine in male rats of Wistar line, having the weight of 281-315 g. after overdose of chloral hydrate. The number of tested samples is presented in Tables 1 and 2. Mechanical tests were performed on testing machine Instron ElectroPuls E3000 (made in the USA), with application of sensor of increasing stretching/compression with the range of tested loads of 0÷250 N and measuring accuracy of 0.5%.

Nonstructural spiral stent (NSS) was made of prolene suture with a diameter of USP 0 (0,4 mm), which was protected with original nano-sized covering, based on amorphous carbon and atomic silver. The stent was removed by non-spiral part in perforating wall of hollow organ. From the outer part perforation site of non-spiral part of NSS was fortified with Z-shaped stitch and Polysorb 5-0. Traction was performed with constant effort of 0.1 N. Wall's intactness was assessed through pneumatic pressure at logging into the water, warmed to 37ºC, at a depth of 5 cm, evidenced by minimal pressure in the gap of hollow organ that induces air bubbles through the site where NSS was removed, as well as on the base of morphological study of section of hollow organ's wall, performed in its plane, i.e., normal to direction of NSS traction.

Table 1: The number of tested samples of autopsy material

Studies segment	Index number of the dead body					**Total**
	1	2	3	4	5	
Twisted intestine	5	5	5	5	5	**25**
Empty intestine	5	5	5	5	5	**25**
Sigmoid intestine	5	5	5	5	5	**25**
Choledochous duct	5	5	5	5	5	**25**
Ureter	5	5	5	5	5	**25**

Table 2: The number of tested samples of various segments of rats' gastrointestinal tract

Studies segment of GIT	Index number of animal					Total
	1	2	3	4	5	
Esophagus	5	5	5	5	5	25
Small intestine	5	5	5	5	5	25
Large intestine	5	5	5	5	5	25

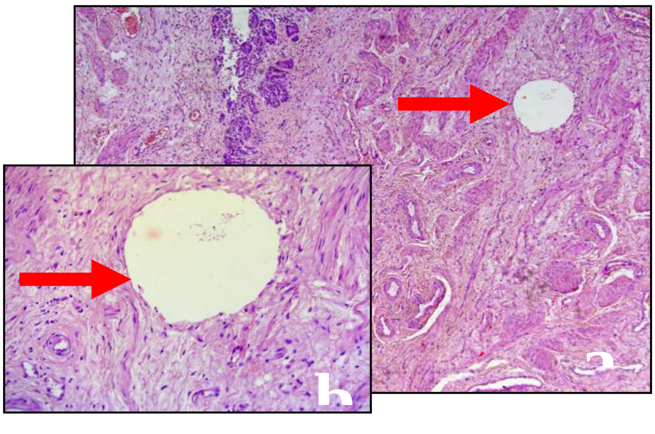
THE MAIN PART

Mechanical strength of autopsy material of GIT samples, choledochous duct and ureter samples was defined by the type of biological object, though such indices as ultimate resistance and maximal deformation at stretching didn't have normal distribution, which is connected with necrotized changes in studies tissues (for example, spastic anastalsis of leiomyocytus). The best indices of specificity in regards to studied biological objects were typical for modulus of elasticity. Maximal values of the latter were observed at choledochous duct ureter, while statistical difference of it was absent, which equaled 1247.7±316.2 and 961.4±218.5 kPa, respectively ($p>0,05$). Empty and twisted intestines also had comparative indices of Young's modulus of 645.9±51.2 and 594.7±66.2 kPa, respectively ($p>0,05$), while they were significantly different from choledochous duct and ureter samples (p<0,05). Minimal statistically significant differences of elasticity modulus were observed in sigmoid intestine 298.3±48.6 kPa (p<0,05). Mechanical tests of various GIT segments of laboratory rats of Wistar line demonstrated quality differences of the values of mechanical resistance of the wall. At the some time, quantitative indices of Young's elasticity modulus and ultimate resistance had stereotypic showings; the latter were defined by the type of biological object. Thus, maximal values of these parameters were registered in esophagus' wall and equaled 660.5±117.1 and 414.8±98.1 kPa, respectively. The least strength capacity was received fro samples of distal segment of large intestine: 160.8±22,1 and 134,5±22,7 kPa, respectively (p<0,01). Nevertheless, maximal deformation at stretching in large intestine's samples was significantly higher than in other segments of esophagus and equaled 3.21±0.15. Indices of maximal deformation at stretching in the latest groups did have significant differences as well: 2.46±0.12 and 1.38±0.09, respectively (p<0,05). Strength characteristics of the wall of proximal segment of small intestine had intermediate value of Young's modulus and ultimate resistance (395.8±53.5 and 241.3±36,1 kPa, respectively) and were statistically different from similar showings of mechanical strength of esophagus and distal segment of large intestine (p<0,05).

For investigation of possibility of NSS excision from the well of hollow organ, spiral made of prolene suture with a diameter of USP 0 (0,4 mm) was used. After checking 10 samples NSS spiral had elastic coefficient that equaled 23.1±4.7 N/m. NSS was excised with non-spiral part through perforating wall of hollow organ. Traction of the stent with constant effort of 0.1 N provided detorsion of the spiral and removal of all studies stent samples, which took 7.4±2.2 seconds. There was no dependence of thickness of the wall, through which removal is performed, i.e., no matter which biological object is used. Obtained results may be explained by good surface characteristics of stent's suture that minimizes friction.

Results of pneumatic pressure of studied biological objects demonstrated enough mechanical air-tightness of the wall of hollow organ after removal of stent, and they exceeded recommended values of mechanical air-tightness raphe (50 Mmhg). Air-tightness of the removal site of the stent depended on studied biological object and was defined by thickness of its wall. Minimal values of mechanical ar-tightness without statistically significant differences were registered for kidney pelvis, gall bladder and sigmoid intestine – 93,5±15,1, 104,2±13,6 and 127,1±29,5 Mmhg (p>0,05). Minimal values of pneumatic pressure were obtained in regard to wall of urinary bladder; pressure that degraded its air-tightness was 319,3±45,5 Mmhg (p<0,01). Interjacent location with statistically significant difference with previous biological objects was taken by empty and twisted intestines (p<0,05). Their indices of mechanical air-tightness equaled 212,9±33,5 and 194,1±23,8 Mmhg, respectively.

Morphological picture of the wall of hollow organ after removal of NSS wasn't specific depending in the examined object and was characterized by the presence of perforation hole with the diameter of 238,5±26,4 micron (Picture 3), which was detected in muscular layer. Lower diameter of the hole is connected with recession that took place during fixation. In submucosal layer and in the area of tissues' deformation of Z-shaped stitch, this effect was not observed. None of the samples provided evidence of wall's destruction and there were no sawing damages of surrounding tissues during removal of NSS (Picture 1).



Picture 1: Perforation hole (as shown by the arrow) after removal of NSS. Dye: haematoxylin+eosin. Magnification: a – x200, b – x400.

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CONCLUSION

Obtained results of mechanical resistance of various segments of intestinal tube on autopsy material and in laboratory animals may be explained by the difference in relative (in comparison with the thickness of the whole wall) thickness of sub submucosal layer, which is mostly expressed in choledochous duct and ureter, and it has the least presence in the wall of sigmoid intestine. Submucosal layer, comparing to other structures of hollow organ's wall, contains maximum amount of collagen and it provides preservation of mechanical resistance, which corresponds to literature data of various studies that are devoted to analysis of mechanical strength of intestinal raphe.

SUMMARY

- Determination of elasticity modulus (Young's modulus) was characterized by the most specificity in relation to studied biological objects;
- The value of elasticity modulus was determined by relative thickness of submucosal layer;
- Elasticity coefficient of NSS spiral of 23,1±4,7 N/m allowed easily remove it form the wall of studied hollow organs;
- Results of pneumatic pressure, obtained while investigating mechanical air-tightness of site of stent's removal, were determined by the thickness of hollow organ's wall and exceeded minimal acceptable values from 1.5 to 5.3 x.

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