Experimental assessment of the tightness of mechanical invagination esophagogastronoanastomosis

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Abstract. Objective: The aim of this study is to present a new technique for the formation of a mechanical invagination esophagogastronoanastomosis and to experimentally provide a comparative assessment of the physical tightness of the seams compared with the mechanical circular esophagogastronoanastomosis end to side. Materials and methods: The study was carried out on 20 (10 in each group) of isolated non-fixed gastrointestinal organ-complexes of 10-month old white domestic pigs with an average weight of 150 kg. The physical tightness of the seams of the esophagogastronoanastomosis under investigation was determined by the method of pneumocompression. For the presentation of quantitative data, the mean value of the indicator ( ) and standard deviation (±SD) were calculated. To check the law of the distribution of values for normality, the Shapiro–Wilk criterion was used, to compare the average values of the index in two groups, the Student criterion was used. To assess the magnitude of the difference, a 95% confidence interval of the indicator was calculated (95% CI). Results: It was established that the pressure at the time of loss of tightness of mechanical invagination esophagogastronoanastomosis was on average 99.3 ± 3.0 mm Hg, which is 26 mm Hg higher (p<0.001) than the pressure at the time of loss of tightness of mechanical circular esophagogastronoanastomosis end to side. Conclusion: The data obtained suggest that the mechanical invagination esophagogastronoanastomosis proposed by us has the characteristics of high and sufficient tightness of the sutures to prevent anastomotic leak and can be applied in the clinic.

Key Words: esophagogastronoanastomosis, joint tightness, pig organocomplex, esophagectomy, reconstruction of the esophagus.

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Introduction
The ideology of modern esophageal cancer surgery is based on the principles of achieving minimal invasiveness and radicalism (Tanaka et al 2018). However, resection of the esophagus is still a highly invasive procedure and is accompanied by high mortality and postoperative complications (Klevebro et al 2019, Lindner et al 2014, Rasmussen et al 2018, Takeuchi et al 2014). The desire to minimize the number of postoperative complications of surgical interventions for esophageal cancer stimulates scientific research aimed at improving the consequences of surgical intervention, including those associated with anastomosis (Kikuchi & Takeuchi 2018). Because the frequency of emerging postoperative complications and the rate of mortality directly depends on how well the created gastro-esophageal anastomosis is stable. It is known that the type of anastomosis is the most important factor in the occurrence of anastomosis leakage and benign strictures (Sokouti et al 2013, Chen 2014). As Maas et al (2012) notes with the singing the creation of safe anastomosis after a successful resection of the esophagus is essential to reduce the risk of anastomosis leakages and related complications. Therefore, today the question of choosing the type of esophagogastronoanastomosis (EGA) is one of the most urgent and complex for surgeons. The most frequent complication of esophagectomy with esophagogastroplasty in the postoperative period is the formation of benign strictures, which varies within 10-40% or even more (Zhou et al 2015, Chen 2014, Tanaka et al 2018), which is eliminated by endoscopic methods (drilling, balloon dilation or combinations thereof). A significant variation is due to the fact that the diagnosis of anastomosis stricture is often based on the symptoms of subjective dysphagia (Chen 2014). The second most common complication of esophagectomy is leakage of thoracic anastomosis, which occurs in 5% to 14.3% of cases (Finley, 2014, Kassis et al 2013, Klevebro et al 2019, Low et al 2019, Manghell et al 2019, Zhang et al 2018), and in some centers it reaches 30-44% (Segura et al 2018, Flanagan et al 2015, Verstegen et al 2019) and mortality rates for the 30th and 90th days range from 2.4% and 4.5% to 9.8% and 16.7% respectively (Low et al 2019; Manghell et al 2019). The causes of leakage may be marginal or larger esophageal necrosis stump
or graft – due to poor circulation or poor tissue repair (e.g., diabetes), as well as technical errors: non-alignment of mucous membranes, very frequent stitches, and excessively tight knitting nodes, puncture of the needle of the mucous membranes during the formation of the second row of stitches, tension of the bodies that are sewn (Starikov et al. 2014).

Thus, despite the numerous developments in the methods of overlaying EGA (Henriques et al. 2010, Kesler et al. 2018, Swanstrom 2013, Sokouti et al. 2013, Yasuda et al. 2018, Yongming et al. 2015), a number of aspects of esophageal anastomosis are controversial, and the ideal anastomosis has not yet been found. Referring to Straatman’s et al. thought (2016), we note that further improvement and standardization of anastomosis technique is the way to perform a reliable intrathoracic anastomosis.

The aim of the study – to instruct new technique of formation of invagination mechanical esophagogastroanastomosis and to experimentally provide a comparative estimation of physical sealing of stitches in comparison with circular mechanical esophagogastroanastomosis end to side.

**Material and method**

On the basis of the Department of Experimental Surgery of the Shalimov’s National Institute of Surgery and Transplantology NAMS of Ukraine developed and protected by the patent of Ukraine a new method of forming an invagination mechanical esophagogastroanastomosis (Patent for Utility Model No. 107235) (Usenko et al. 2016). The technique that was worked out involves the removal of the affected area of the esophagus and the formation of the gastric graft, for which the resection of the cardiac part of the stomach with a part of small curvature is performed with the help of linear stapling devices, while leaving a window at the apex of the graft with width up to 4 cm for the insertion of a circular stapling device and one-stage plastics of the esophagus with a gastric tube with the formation of gastroesophageal invagination mechanical anastomosis. For the formation of gastroesophageal invagination mechanical anastomosis on the stump of the esophagus impose a purse stitch after which in the lumen of the esophagus, the “anvil” is formed and fixed with the purse stitch. After which invaginated EGA is done by means of forming lateral edges of anastomosis technique is the way to perform a reliable intrathoracic anastomosis. The aim of the study – to instruct new technique of formation of invagination mechanical esophagogastroanastomosis and to experimentally provide a comparative estimation of physical sealing of stitches in comparison with circular mechanical esophagogastroanastomosis end to side.

Fig. 1. Technique of formation of invagination mechanical esophagogastroanastomosis

Notes: 1 - an overlap of the purse stitch on the esophagus, 2 - the introduction of an anvil in the lumen of the esophagus and the imposition of the purse stitch, 3 - the appearance of the cult of the esophagus with the “anvil” in its lumen, 4 - formation of edges of anastomosis, 5 - the form of mechanical anastomosis with bound ligatures that formed its edges, 6 - the form of mechanical anastomosis with ligated ligatures, forming its edges in a direct projection, 7 - an overlap of serous-serous stitches on the anterior gastric wall, 8 - the final form of invagination mechanical anastomosis.
Fig. 2. Photo of the organ complex with the formed invagination mechanical esophagogastroanastomosis

Fig. 3. Photo of the organ complex with the formed circular mechanical esophagogastroanastomosis

Fig. 4. Photo of the test for the strength of the invagination mechanical esophagogastroanastomosis

Fig. 5. Photo of the test for the strength of the circular mechanical esophagogastroanastomosis

An experimental study was conducted on 20 isolated non-fixed gastro-esophageal organ complexes 10 monthly white swines with an average weight of 150 kg.

Organ complexes were obtained after slaughter of swines in the farm and delivered to the experimental department of the Shalimov’s National Institute of Surgery and Transplantation NAMS of Ukraine within 2 hours after withdrawal. Experimental study was carried out by modeling resection of the esophagus with one-time plastic gastric tube with the formation of various types of esophagogastroanastomosis. The study group consisted of 10 organ complexes, in which a resection of the esophagus with its one-moment plastics with a gastric tube was performed with the formation of the invagination mechanical esophagogastroanastomosis proposed by us. The comparison group also
included 10 organ complexes – with the formation of the circular mechanical esophagogastroanastomosis end-to-side. The completed form of the invagination mechanical esophagogastroanastomosis developed by us is presented in Figure 2. The completed form of circular mechanical esophagogastroanastomosis is shown in Figure 3.

After the formation of the gastroesophageal anastomosis, the leak tightness of its sutures was determined using O.I. Ivashchuk’s methodology (1997), which was adapted to our conditions, by which the lumen of the gastric tube should be blocked with a clamp. In the esophageal lumen conducted a tube connected to a manometer which was fixed it by using the purse stitch. Organ complexes with formed anastomoses was immersed in water and, pumping the air, measured the pressure (mmHg) gauge, in which air bubbles appear on the anastomosis line. Representation of the test for the strength of the invagination mechanical esophagogastroanastomosis is shown in Figure 4. Representation of the test for the strength of the circular mechanical esophagogastroanastomosis is shown in Figure 5.

Statistical data processing was carried out in the MedStat package (Guryanov et al 2018). The average of the ( ) and standard deviation (± SD) was calculated to represent the quantitative data. In order to check the law of distribution of values for normality, the criterion of Shapiro-Wilka was used, for comparing the mean values of the indicator in two groups, the Student’s criterion was used. A 95% probability interval (95% CI) was calculated to estimate the magnitude of the difference.

### Results

The results of the experimental study of the physical tightness of the sutures of the formed esophagogastroanastomosis in two different ways are given in Table 1.

It was found that the pressure that maintains esophagogastroanastomosis in the study group reaches an average of 99.3 ± 3.0 mm Hg, while the mean value of pressure at the moment of loss of anastomosis tightness in the comparison group was 73.3 ± 3.5 mm Hg (the difference is statistically significant, p <0.001). Thus, the proposed variant of the formation of esophagogastroanastomosis allowed to increase (p<0.001) pressure at the time of the appearance of air bubbles at 26 mm Hg (95% VI 22.9 mm Hg – 29.1 mm Hg).

### Discussion

The technique of formation of anastomosis improves with technological progress. For thoracic anastomosis, most surgeons today use mechanical techniques, which reduced their time of execution, increased the accuracy of the matching of cross-linked tissues, aseptic strength and tightness of the stitches (Biere et al 2011). All this greatly improved the results of esophagectomy and esophageoplasty, but the experience of the surgeon remains a critical factor. After all, the main factor in creating a stable anastomosis is the integrity of the stitching line, which depends on adequate tissue compression (Chekan & Whelan 2014). Therefore, it is important that the research is based on the results of the work of the same team of surgeons, which was provided in our work. In the previously published results of our study of 30 patients who underwent this new reconstruction procedure, the contribution of each method to the frequency of leakage of anastomoses, benign strictures and reflux esophagitis was demonstrated, and the benefits of using the proposed method (Usenko et al 2019) were demonstrated.

The results of this experimental study prove the effectiveness of the developed invagination mechanical esophagogastroanastomosis, because it exceeds its leakproofness mechanical circular esophagogastroanastomosis end to side. It should be noted that the physiological pressure in the human stomach is 2.6-8.6 mm Hg, while stagnant – about 20 mm Hg (Sergeev 2004). The latter points to the fact that the achieved increase in pressure at the time of the appearance of air bubbles of the proposed anastomosis indicates its good physical tightness, which is important in preventing esophagogastroanastomosis leakage. The conducted experimental research substantiated the better quality of the proposed invagination mechanical esophagogastroanastomosis and the possibility of using this method in the implementation of esophagectomy in the clinic.

### Conclusions

It was found that the average pressure at the moment of loss of tightness of the invagination mechanical esophagogastroanastomosis is 99.3 ± 3.0 mm Hg on average and 73.3 ± 3.5 mm Hg in the circular mechanical esophagogastroanastomosis. The proposed mechanical invagination esophagogastroanastomosis has the characteristics of sufficient physical tightness to prevent its leakage and can be applied in the clinic.

### References


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