Human & Veterinary Medicine
International Journal of the Bioflux Society HVM

OPEN ACCESS
Research Article

Experimental assessment of the tightness of mechanical invagination esophagogastroanastomosis

Olexander Yu. Usenko, Andrey V. Sidyuk, Andrey S. Klimas, Olena Ye. Sidyuk, Georgy U. Savenko, Ivan V. Babii

[1]**Department of Gastrointestinal Surgery, National Institute of Surgery and Transplantology named by O.O. Shalimov, National Academy of Medical Sciences of Ukraine, Kyiv, Ukraine**

Abstract. Objective: The aim of this study is to present a new technique for the formation of a mechanical invagination esophagogastroanastomosis and to experimentally provide a comparative assessment of the physical tightness of the seams compared with the mechanical circular esophagogastroanastomosis 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 esophagogastroanastomosis 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 esophagogastroanastomosis 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 esophagogastroanastomosis end to side. Conclusion: The data obtained suggest that the mechanical invagination esophagogastroanastomosis 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: esophagogastroanastomosis, joint tightness, pig organocomplex, esophagectomy, reconstruction of the esophagus.

Corresponding Author: A.S. Klimas, e-mail: klimas.andrew@gmail.com

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 esophagogastroanastomosis (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, Manghelli 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; Manghelli et al 2019). The causes of leakage may be marginal or larger esophageal necrosis stump

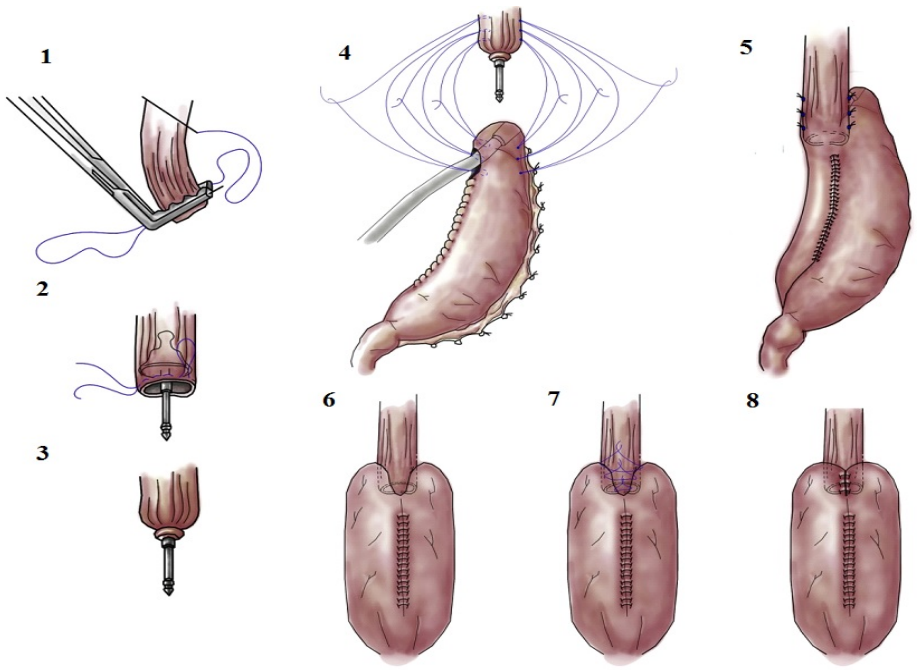

Fig. 1. Technique of formation of invagination mechanical esophagogastroanastomosis
Notes: 1 - an overlap of the purse stitch on the esophagus, 2 - the introduction of an anvil in the lumen of the esophagus and the imposition of the purse stitch, 3 - the appearance of the cult of the esophagus with the "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.

or graft – due to poor circulation or poor tissue repair (eg, 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 a 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" of the circular stapler is started and fixed with the purse stitch. After which invaginated EGA is done by means of forming lateral edges of anastomosis with outer and inner sutures. Lateral edges of anastomosis cover 4-5 cm which requires 3 seromuscular sutures on both lateral sides of the esophagus and gastric graft, after which for the formation of the inner row of sutures through a residual window at the apex of the stomach graft, carry out a suturing circular stapler and form an inner row of sutures. The left window at the apex of the gastric graft is covered with a linear suturing device, after which the seromuscular sutures are connected to the side surfaces of the esophagus and the gastric graft, and the line of the staple seam on the gastric tube is further covered with sero-serous sutures.

Due to the above-mentioned technique, the internal series of anastomosis sutures is immersed in a gastric graft of 3-4 cm.

The technique of formation of invagination mechanical esophagogastroanastomosis is shown in Figure 1.

In order to compare the physical tightness of the sutures of the esophagogastroanastomosis, created by two different methods,

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

Table 1. Physical tightness of sutures of the formed invagination mechanical and circular mechanical esophagogastroanastomosis

Pressure at the time of the appearance of air bubbles	Research group (n=10)	Comparison group (n=10)	p
Minimum-Maximum mmHg	94–105	69–80	<0.001
X ±SD, mmHg	99.3±3.0	73.3±3.5	

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 esophagoplasty, 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

Biere SSAY, Maas KW, Cuesta MA, & van der Peet DL. Cervical or Thoracic Anastomosis after Esophagectomy for Cancer:a systematic review and meta-analysis. Dig Surg 2011;28(1):29–35. doi:10.1159/000322014.

Borráez BA, Montoya JA, Meneses PA, Abadía M, Pinilla RE, & Oliveros R. Esofagectomía en un centro suramericano de tratamiento del cáncer. Revista Colombiana de Cirugia 2018;33(1):71–78. DOI:https://doi.org/10.30944/20117582.49.

Chekan E & Whelan R. Surgical stapling device–tissue interactions:what surgeons need to know to improve patient outcomes. Medical Devices: Evidence and Research 2014;2014(7):305–318. DOI:https://doi.org/10.2147/MDER.S67338.

Dong Z, Quan-Xing L, Xu-Feng D, Jia-Xin M, Ji-Gang D. Comparison of two different mechanical esophagogastric anastomosis in esophageal cancer patients:a meta-analysis. Journal of Cardiothoracic Surgery 2015;10:67. DOI 10.1186/s13019-015-0271-4.

Finley RJ. Step by Step Management of Anastomotic Leaks after Esophagectomy [Electronic resource]. American Association for Thoracic Surgery Annual Meeting, Toronto, April 26-30, 2014.

Flanagan JC, Batz R, Saboo SS, Nordeck SM, Abbara S, Kernstine K, & Vasan V. Esophagectomy and Gastric Pull-through Procedures:Surgical Techniques, Imaging Features, and Potential Complications. Radio Graphics 2015;36(1):107–121.

Guryanov VG, Lyakh YuE, Pariy VD. Biostatistics guide. Analysis of the results of medical research in the EZR package (R-statistics):tutorial. Kyiv:Vistka, 2018:208 p.

Henriques AC, Godinho CA, Jr RS, Waisberg DR, Zanon AB, Speranzini MB, & Waisberg J. Esophagogastric anastomosis with invagination into stomach:New technique to reduce fistula formation. World J Gastroenterol 2010;16(45):5722–5726. doi:10.3748/wjg.v16.i45.5722.

Hirotoshi Kikuchi, & Hiroya Takeuchi. Future Perspectives of Surgery for Esophageal Cancer. Ann Thorac Cardiovasc Surg 2018;24(5):219–222.

Ivashchuk OI. Restoration of patency of the intestinal tract after right-sided hemiclectomy and some aspects of the formation of compensatory changes:diss.cand. med. scien.:14.01.03. Kyiv, 1997:159 p.

Kassis ES, Kosinski AS, Ross P, Koppes KE, Donahue JM, & Daniel VC. Predictors of anastomotic leak after esophagectomy: An analysis of the society of thoracic surgeons general thoracic database. The Annals of Thoracic Surgery 2013;96(6):1919–1926. DOI:10.1016/j.athoracsur.2013.07.119.

Ke-Neng C. Managing complications I:leaks, strictures, emptying, reflux, chylothorax. Journal of Thoracic Disease (Surgery for Esophageal Malignancy) 2014;6(3):355–363. doi:10.3978/j.issn.2072-1439.2014.03.36.

Kesler KA, Ramchandani NK, Jalal SI, Stokes SM, Mankins MR, Ceppa D, et al. Outcomes of a novel intrathoracic esophagogastric anastomotic technique. The American Association for Thoracic Surgery. 2018;156(4):1739–1745.e1. DOI:https://doi.org/10.1016/j.jtcvs.2018.05.088.

Klevebro F, Boshier P, & Low DE. Application of standardized hemodynamic protocols within enhanced recovery after surgery programs to improve outcomes associated with anastomotic leak and conduit necrosis in patients undergoing esophagectomy. J Thorac Dis 2019;11(5):S692–S701. DOI:10.21037/jtd.2018.11.141.

Lee L. Swanstrom. (2016). United States Patent 9375235, IPC:A61B17/34;A61B1/018/ Method and system for transhiatal esophagectomy. Boston, DC:U.S. Patent and Trademarc Office.

Lindner K, Fritz M, Haane C, Senninger N, Palmes D, & Hummel R. Postoperative complications do not affect long-term outcome in esophageal cancer patients. World J Surg 2014;38(10):2652–61. doi:10.1007/s00268-014-2590-3.

Low DE, Kuppusamy MK, Alderson D, Cecconello I, Chang AC, Darling G, et al. Benchmarking Complications Associated with Esophagectomy. Ann Surg 2019;269:291–8. DOI:10.1097/SLA.0000000000002611.

Maas KW, Biere SSAY, Scheepers JJG, Gisbertz SS, Turrado Rodriguez V, van der Peet DL, et al. Minimally invasive intrathoracic anastomosis after Ivor Lewis esophagectomy for cancer:a review of transoral or transthoracic use of staplers. Surg Endosc 2012;26(7):1795–1802. doi:10.1007/s00464-012-2149-z.

Manghelli JL, Ceppa DP, Greenberg JW, Blitzer D, Hicks A, Rieger KM, et al. Management of anastomotic leaks following esophagectomy:when to intervene? J Thorac Dis 2019;11(1):131–137. doi:10.21037/jtd.2018.12.13.

Rasmussen SR, Nielsen RV, Fenger A-S, Siemsen M, & Ravn HB. Postoperative complications and survival after surgical resection of esophageal squamous cell carcinoma. J Thorac Dis 2018;10(7):4052–4060. doi:10.21037/jtd.2018.07.04.

Sergeev DA. Proximal resection of the stomach using a sero-muscu-lo-submucosal sheath:diss. cand. med. scien. Astrakhan state med. academy. Astrakhan, 2004:21p.

Shijie Z, Weiming H, Xiangzheng L, Jian L. Pilot study on preventing anastomotic leakage in stapled gastroesophageal anastomosis. Thorac Cancer 2018;9(1):142–145. doi:10.1111/1759-7714.12552.

Sokouti M, Golzari SE, Pezeshkian M, Farahnak MR. The Role of Esophagogastric Anastomotic Technique in DecreasingBenign Stricture Formation in the Surgery of Esophageal Carcinoma. J Cardiovasc Thorac Res 2013;5 (1):11–16. doi:10.5681 / jcvtr.2013.003.

Starikov VI, Vinnik YuA, & Majboroda KYu. Redkie oslozhneniya v hirurgii raka pishevoda i kardialnogo otdela zheludka [Rare complications in surgery of cancer of the esophagus and the cardiac department of the stomach]. Kharkivska khirurhichna shkola [Kharkiv Surgical School] 2014;5:22–27.

Straatman J, van der Wielen N, Nieuwenhuijzen GA, Rosman C, Roig J, Scheepers JJ, et al. Techniques and short-term outcomes for total minimally invasive Ivor Lewis esophageal resection in distal esophageal and gastroesophageal junction cancers:pooled data from six European centers. Surgical Endoscopy 2016;31(1):119–126. doi:10.1007/s00464-016-4938-2.

Takeuchi H, Miyata H, Gotoh M, Yuko K, Hideo B, Wataru K, et al. A risk model for esophagectomy using data of 5354 patients included in a Japanese nationwide web-based database. Ann Surg 2014;260:259–66. DOI:10.1097/SLA.0000000000000644.

Takushi Y, Osamu S, Mitsuru I, Tomoki M, Hiroaki K, Yutaka K. Novel esophageal reconstruction technique via transmediastinal route from posterior to anterior mediastinum after esophagectomy. The Journal of thoracic and cardiovascular surgery 2018;156(2):859–866.

Tanaka K, Makino T, Yamasaki M, Nishigaki T, Miyazaki Y, Takahashi T, et al. An analysis of the risk factors of anastomotic stricture after esophagectomy. Surg Today 2018;48(4):449–454. doi:10.1007/s00595-017-1608-5.

Usenko OYu, Sydiuk AV, Klimas AS, & Sydiuk OYe. Postoperative anastomotic complications in patients with malignant tumors of the esophagus and esophageal gastric junction cancer. World of Medicine and Biology 2019;2(68):135–140. DOI:10.26724/2079-8334-2019-2-68-135-140.

Usenko OYu, Sidyuk AV, Klimas AS. Pat. Ukraine № 107325, IPC:A61B 17/00 A61B 17/115. Method of performing esophagectomy. Kyiv:State Patent Office, 2016.

Verstegen MHP, Bouwense SAW, van Workum F, ten Broek R, Siersema PD, Rovers M, & Rosman C. Management of intrathoracic and cervical anastomotic leakage after esophagectomy for esophageal cancer:a systematic review. World J Emerg Surg 2019;14:17. doi:10.1186/s13017-019-0235-4.

Yoshihiro Tanaka, Tomonari Suetsugu, Takeharu Imai, Nobuhisa Matsuhashi, & Kazuya Yamaguchi. Recent advancements in esophageal cancer treatment in Japan. Annals of Gastroenterological Surgery 2018;2(4):253–265. https://doi.org/10.1002/ags3.12174.

Zhang Yongming, LI Hui, & LI Zhao-min. Patent CN №104382619 (A), IPC:A61B17/00/ Free towing device for esophagectomy. China. Patent and Trademarc Office, 2014.

Authors

•Usenko Oleksandr, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: usenko@shalimov.org.

•Sydiuk Andrii, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: siduk1978@gmail.com;

•Klimas Andrii, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: klimas.andrew@gmail.com

•Sydiuk Olena, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: siduk1978@gmail.com

•Savenko Georgii, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: savenkogeorgiy@gmail.com

•Babii Ivan, Department of Gastrointestinal Surgery, Shalimov`s National Institute of Surgery and Transplantology, 30 Geroev Sevastopolia, Kyiv, Ukraine, email: promedol1992@gmail.com

Citation	Usenko OY, Sidyuk AV, Klimas AS, Sidyuk OY, Savenko GU, Babii IV. Experimental assessment of the tightness of mechanical invagination esophagogastroanastomosis. HVM Bioflux 2019;11(3):116-121.
Editor	Antonia Macarie
Received	2 May 2019
Accepted	29 July 2019
Published Online	12 August 2019
Funding	None reported
Conflicts/ Competing Interests	None reported