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**Review**
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# Modern Approaches to Surgical Treatment of Mechanical Injuries of the Esophagus

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**ABSTRACT** Mechanical damage to the esophagus is a severe urgent pathology characterized by the development of life-threatening complications. With all the variety of modern diagnostic and treatment technologies, the mortality rate in this category of patients remains quite high, which requires the search for new approaches to this problem.

An analysis of modern approaches to the treatment of mechanical injuries of the esophagus and their complications was carried out. In the practice of surgery for esophageal injuries, minimally invasive technologies are becoming increasingly common, including endovideosurgical and oral endoscopic interventions. A special place in this is occupied by endoscopic vacuum therapy, which results have been sufficiently studied in the treatment of complications of gastrointestinal surgery. At the same time, the use of this technology in patients with mechanical damage to the esophagus is limited to small series of observations, which requires further study.

**Keywords:** esophageal injuries, esophageal injuries, esophageal perforation, spontaneous esophageal rupture, mediastinitis, endoscopic vacuum therapy
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EVT – endoscopic vacuum therapy
OTSC – over-the-scope clips
TTSC – through-the-scope clips

Esophageal rupture is a relatively rare but extremely dangerous emergency condition, characterized by a high risk of complications and death [1–5]. According to population studies, the incidence of esophageal injuries, including iatrogenic, spontaneous ruptures and foreign body perforations, is 1–5 cases per 100,000 population annually [6, 7]. Today, mortality rates for esophageal ruptures vary widely, ranging from 13.3 to 80% [8–11].

The damage to the esophagus is accompanied by the development of life-threatening severe complications, the most common and complex are mediastinitis, pleural empyema and pneumonia [12–14]. Even small ruptures of the esophagus are accompanied by the development of mediastinitis and ultimately lead to death from sepsis. The addition of pleural empyema and pneumonia are predictors of an unfavorable outcome in cases of esophageal injury [15]. Necrosis of mediastinal tissue

is accompanied by a high risk of developing arrosive bleeding from the great vessels of the mediastinum (from 2 to 5%), which is often a fatal complication [16]. The most common source of bleeding in esophageal perforations is the thoracic aorta.

Despite the development of new diagnostic and treatment technologies, timely diagnosis of esophageal injuries remains a serious problem, which has a significant impact on treatment outcomes. Thus, according to one study, a delay in treatment of patients with Boerhaave syndrome for one day leads to a twofold increase in the likelihood of death (36% for hospitalization within the first day and 64% for hospitalization later than 24 hours) [17]. It should be noted that in approximately half of the cases of esophageal damage, treatment begins later than 24 hours from the moment of perforation [9].

The location of the esophageal rupture also affects the mortality rate. In particular, it was shown that the lowest mortality rates (6–8%) were observed with injuries to the cervical esophagus [18].

Other reliable factors for unfavorable outcome in cases of esophageal injury include: the age of patients over 65 years of age, septic condition, leukocyte count less than 3,000/μl, level of C-reactive protein in the blood serum more than 100 mg/l [19].

Currently, there is no generally accepted approach regarding the timing and scope of surgical interventions for esophageal perforation.

Treatment of esophageal injuries is complex and has several goals [3]:

— restoration of the integrity of the esophagus;

— cessation of flow of esophageal contents into the mediastinum and pleural cavity;

— prevention and treatment of purulent-septic complications;

— ensuring adequate nutrition.

The choice of treatment tactics for esophageal injuries is determined by the severity of the patient's condition, the duration of the rupture, the location and extent of the defect, the presence of complications, concomitant pathology and other factors [3, 8].

Various approaches to the surgical treatment of esophageal perforations have been suggested [2, 20]:

Open surgical interventions:

— suturing of the esophageal defect from transcervical, transthoracic or transhiatal approaches (including strengthening the suture line with blood-supplied flaps);

— resection of the esophagus with immediate or delayed reconstruction;

— drainage.

Minimally invasive interventions:

— endoscopic clipping of an esophageal defect using clips of various versions ,TTSC and OTSC;

— closing the defect using stitching devices (Apollo OverStitch);

— suturing of the esophageal defect using videothoracoscopic or videolaparoscopic access;

— video thoracoscopic resection of the esophagus;

— esophageal stenting using self-expanding stents;

— endoscopic vacuum therapy (EVT).

Most researchers believe that suturing the esophageal defect is the method of choice for early diagnosis of non-tumor perforation (up to 24 hours) and the absence of necrotic changes in the mediastinal tissue [10, 11, 15, 17, 21–24].

However, when it comes to choosing the optimal treatment method for late diagnosis of perforation and in patients admitted in extremely serious condition, there are diametrically opposed approaches. This determines the difficulty of systematizing treatment results and requires improvement of diagnostic and treatment tactics.

Leakage of esophageal sutures develops in approximately 30% of cases [25], while the risk of its development increases in the conditions of late interventions and the presence of purulent complications. To prevent this complication, the suture line of the esophagus is strengthened with blood-supplied tissues, including: the fundus of the stomach, a flap of the diaphragm, pleura, muscles of the neck and chest wall [3]. However, the use of flaps

does not always solve this problem. In a comparative study, Yan XL et al. (2020) demonstrated that the results of late surgical interventions with strengthening of the suture line in patients with spontaneous esophageal rupture are significantly worse compared to simple suturing performed within 24 hours from the moment of perforation. This indicates that the effectiveness of surgical intervention primarily depends on the timing of the operation and, to a lesser extent, on the technique of eliminating the defect [26].

In recent years, there has been a widespread introduction of minimally invasive technologies in the treatment of esophageal injuries [24, 25, 28]. In general, minimally invasive surgery for esophageal trauma is a promising approach in selected patients with a stable condition and in specialized centers [27].

With early diagnosis of perforation of the thoracic esophagus, depending on the location, it is advisable to suturing the defect using a thoracoscopic or laparoscopic transhiatal approach [29]. In addition, endovideosurgery allows for sanitation of the mediastinum and pleural cavities by excision of non-viable tissue and removal of pathological fluid accumulations.

In a study by Veltri A. et al. [30] the results of suturing an esophageal defect using a laparoscopic transhiatal approach with fundoplication in 9 patients with spontaneous esophageal rupture are highlighted. The authors noted the absence of intraoperative complications and mortality. It should be noted that 8 out of 9 patients were operated on within the first 24 hours from the moment of esophageal rupture.

Currently, intraluminal interventions are actively developing for ruptures of the esophagus. Endoscopic treatment is the gold standard for iatrogenic perforations diagnosed during the procedure. If the esophageal defect is small (up to 2 cm) and there are no inflammatory changes, endoscopic clipping is performed. A number of studies have shown the successful use of clips in various versions of TTSC and OTSC [20, 24, 31].

Esophageal stenting is indicated when the length of the defect is more than 2 cm or when endoscopic clipping is unsuccessful [32]. For this purpose, self-expanding metal and plastic stents are used. Esophageal stenting is used as an independent method or in combination with thoracoscopic sanitation and drainage of the mediastinum and pleural cavities as indicated. The effectiveness of the method depends on the timing of treatment and with early intervention reaches 77–84% [33], which is comparable to the results of surgical treatment. When stenting is performed 3 days after perforation, a twofold decrease in effectiveness is observed compared with earlier interventions [34]. At the same time, the method is a good additional tool in the treatment of incompetence after surgical treatment of esophageal perforation.

Among the disadvantages of the method, it is necessary to note migration of the stent, which is observed in approximately 40% of cases and requires repeated endoscopic interventions [35], the risk of developing a violation of the blood supply to the esophageal wall, and arrosive bleeding from the vessels of the mediastinum. Due to the risk of developing granulation stenosis of the esophagus, the recommended duration of stenting for non-tumor perforation does not exceed 2–4 weeks [36].

Since the 90s of the last century, the world has seen the introduction of vacuum therapy techniques in various areas of surgery. A number of studies have shown that vacuum therapy helps reduce wound size [37–39]. The mechanism of action of vacuum therapy is associated with stretching and deformation of wound bed tissue under the influence of negative pressure, which promotes cell migration and proliferation. Increased angiogenesis, extracellular matrix remodeling, and wound granulation under negative pressure have been demonstrated [40]. An important component of the effect of vacuum therapy is the effect on the expression of a number of cytokines with a shift towards an anti-inflammatory state [41]. There was a decrease in the degree of bacterial contamination of wounds after vacuum therapy, which leads to a decrease in the incidence of

infections and repeated surgical interventions [40].

Since 2006, the EVT method has been used around the world. Initially, the method was used to treat patients with anastomotic leaks after rectal surgery [42, 43]. Later, the EVT technique was adapted for the treatment of patients with pathologies of the upper gastrointestinal tract. The use of EVT has been described for gastrointestinal anastomotic failure, in patients after pancreaticoduodenectomy, and duodenal perforation [44–50].

To carry out EVT, the sponge system is inserted using an endoscope. With the intraluminal method of treatment, the sponge is placed in the lumen of a hollow organ at the level of the defect or outside the lumen - in the pathological cavity. A vacuum is applied to the nasal end of the vacuum system (negative pressure from 100 to 125 mm Hg), which leads to flattening of the lumen along with the spongy system and its fixation. With this method of treatment, closure of the wound defect and drainage of the wound are simultaneously ensured, with acceleration of its healing. The sponge is changed at intervals of 3–5 days [49, 51, 52].

The effectiveness of the EVT method for esophageal perforations, according to summary data, ranges from 70 to 100% [53]. One of the first reports on the results of using EVT in 10 patients with esophageal perforation was published in 2010 [54]. With a median treatment duration of 12 days, all patients showed healing of the esophageal defect.

In 2015, Möschler O. et al. presented the results of using EVT in 10 patients with injuries or leakage of the esophageal anastomosis. Treatment failure was noted in 3 cases (30%) due to the development of pleural empyema, sepsis, and multiple esophageal-bronchial fistulas. It was noted that deaths were observed among patients with late diagnosis of perforation, while all patients who received treatment from the first day recovered [49].

The largest study on EVT today was published in 2017 [52]. The study included 52 cases, including those with instrumental (9) and spontaneous esophageal rupture (4). The average duration of treatment was 22 days, the sponge was replaced on average 6 times (1–25) with an interval of 3–5 days. Healing of the esophageal defect was observed in 94.2% of cases.

The results of another large study were published by Jung C.F.M. et al. in 2021. The study included 30 cases of esophageal perforation, including 7 patients with mechanical damage. The effectiveness of the method was 83.3% (25 out of 30), while in the group with mechanical damage to the esophagus it was 71.4% [55].

According to Manfredi M.A. et al. [56] in case of instrumental rupture of the esophagus, the effectiveness of EVT is comparable to stenting. In a comparative study, Brangewitz M. et al. [44] showed that in case of esophageal anastomosis failure, the rate of defect healing with EVT is significantly higher compared with stenting (84.4% versus 53.8%), and the rate of development of esophageal strictures is significantly lower (9.4% versus 28 .2%).

EVT for esophageal ruptures is accompanied by a statistically significant decrease in the content of inflammatory markers in the blood serum, in particular C-reactive protein, as well as normalization of the number of leukocytes [52, 53].

According to Möschler O. et al. [49] the main advantage of EVT is the possibility of sanitation of the paraesophageal space using a minimally invasive approach. When using this method, it is possible to achieve cleansing even of consolidated cavities with walls covered with fibrous tissue, which indicates the high potential of EVT.

According to Laukoetter M.G. et al. [52], EVT is more effective than other treatment methods, while its undoubted advantages are the ability to regularly visualize the esophageal defect and purulent cavity with high-quality drainage, which allows you to effectively control the purulent-inflammatory process.

At the same time, a number of factors are pointed out that limit the use of this method in the treatment of esophageal perforations. One of the disadvantages of EVT is the need for repeated endoscopic interventions, which lengthens hospitalization time and the overall duration of treatment [53]. The duration of hospitalization for EVT varies from 16 to

180 days (median, 53 days), according to other data - from 3 to 110 days (median - 42 days) [52, 53].

Another important aspect is the need for repeated anesthesia, which is not always possible in patients in serious condition [52]. At the same time, the endoscopic intervention itself takes little time and is not associated with extensive traumatic approaches, which can undoubtedly be attributed to the advantages of the technique.

Among the complications of EVT in the early stages, it is necessary to note the possibility of rupture and fragmentation of the sponge during its removal, and dislocation of the sponge [49]. Among the most dangerous complications, arrosive bleeding from large vessels of the mediastinum should be noted. Thus, according to Laukoetter M.G. et al. [52] in 2 patients (3.8%) out of 52, fatal bleeding was noted, and therefore the authors recommend performing a computed tomography scan before each replacement of the drainage system to clarify the location of the sponge in relation to large vessels. Minor bleeding that required conservative treatment, according to the authors, was noted in 1.3% of cases.

In the long term after EVT, observations of the development of esophageal strictures have been described, but their relationship with vacuum therapy remains unstudied [53]. According to Laukoetter M.G. et al. [52] when observing patients for 4 years, the incidence of stricture development was 8.5%.

When implementing EVT, an extremely important aspect is to ensure adequate enteral nutrition, but there is no consensus on this matter. A number of authors perform percutaneous endoscopic gastrostomy or jejunostomy, others provide nutrition through a nasogastric tube or provide parenteral nutrition [49, 52, 53]. Inserting a nasogastric or nasojejunal tube under endoscopic control allows you to provide nutrition and temporarily exclude the esophagus from the act of digestion. At the same time, the presence of the probe in the cardioesophageal zone promotes gaping of the cardia, and therefore gastroesophageal reflux, which prevents the rapid healing of the esophageal defect. In addition, prolonged standing of the probe is an additional traumatic factor and can contribute to the development of bedsores of the esophagus and stomach, peptic ulcers and bleeding, and aspiration of gastric contents [57].

In recent years, percutaneous endoscopic gastrostomy has become increasingly popular in clinical practice, becoming the method of choice in a number of countries for patients requiring long-term nutritional support, as well as with dysphagia and esophageal injuries [58, 59]. The main distinctive features of the method are minimal invasiveness, speed of manipulation (15–20 minutes), a small number of postoperative complications (less than 2%), the possibility of starting nutrition from the first day, ease of maintenance and the possibility of quick removal.

When providing enteral nutrition, the greatest difficulties arise in patients with a rupture of the distal esophagus, since the contents of the stomach are inevitably thrown into the esophagus. In such situations, the issue can be resolved by inserting a gastrojejunal tube through a gastrostomy tube, which will provide both nutrition and gastric decompression [60]. An alternative solution is laparoscopic fundoplication.

Thus, an analysis of domestic and foreign literature indicates that despite the development and widespread introduction of new diagnostic and therapeutic technologies, many issues of diagnosis and treatment of mechanical damage to the esophagus remain unresolved. There is a clear trend towards expanding the indications for the use of new minimally invasive treatment methods. The effectiveness of EVT has been sufficiently studied in cases of incompetent esophageal anastomoses; at the same time, the use of this method in cases of mechanical damage to the esophagus is limited to small series of observations, which indicates the need for more in-depth study. There is no differentiated approach to the use of minimally invasive technologies depending on the duration of esophageal perforation and the prevalence of purulent-inflammatory complications; the sequence of interventions has not been determined.

These unresolved questions are a reason for new scientific research.

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