

Paraesophageal hernia: the state of the problem and controversial issues. Review

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The literature review focuses on the controversial issues regarding the treatment of paraesophageal hernia. The limitations of the current classification of hiatal hernias are highlighted. It is irrelevant and does not meet clinical needs. Objective criteria for its improvement are proposed. Data on the prevalence and course of hiatal hernias are given. Their pathogenetic factors and diagnostic methods are underlined. Considerable emphasis is placed on the paraesophageal hernia treatment strategies in patients with an asymptomatic and mildly symptomatic clinical course of the disease. Arguments are presented in favour of both wait-and-see tactics and planned hernioplasty. The choice of hernioplasty technique, especially in the case of giant hernias, the feasibility and indications for the use of mesh implants depending on their shape and composition, and the potential complications of allogenioplasty are the main topics for discussion. The problem of selecting a fundoplication method is addressed while weighing the advantages and potential side effects of employing various fundoplication modifications. The effects of correcting a short esophagus and eliminating the axial pressure on the esophageal hiatus are thoroughly evaluated, as these conditions increase the risk of hernia recurrence.

The authors concluded that there are many controversial issues in the treatment of paraesophageal hernia. A consensus is needed on the classification of paraesophageal hernias, which would meet the urgent needs of choosing the method of operative delivery, and, in particular, the definition of the concepts of «large hernia» and «giant hernia.» Further research is required on issues such as the indications for operative treatment of paraesophageal hernias, especially in the case of asymptomatic large hernias and incarcerated hernias; the feasibility of using implants for plastic surgery of the esophageal hiatus; the choice of a fundoplication method; the diagnosis and correction of a short esophagus; and methodology for evaluating long-term treatment outcomes.

KEYWORDS

hernia of the esophageal hiatus, paraesophageal hernia, giant hernia, crurorrhaphy, hernioplasty, fundoplication.

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The hernia of the esophageal hiatus (EH) or hiatal hernia is characterized by the protrusion of any structure of the abdominal cavity, except the esophagus, into the chest cavity (mediastinum) due to the enlargement of the esophageal hiatus [75].

Classification of acquired hiatal hernias

Acquired hiatal hernias are divided into four types according to their anatomical characteristics [69, 119].

Type I – sliding (axial) hiatal hernias, in which the gastroesophageal junction (GEJ) migrates above the diaphragm and the fundus of the stomach remains below the GEJ.

Type II – the GEJ remains in its normal anatomical position, but part of the fundus of the stomach,

adjacent to the esophagus, moves through the diaphragmatic hiatus above the diaphragm.

Type III is a combination of types I and II, with both the GEJ and the fundus of the stomach moving through the hiatus above the diaphragm. The fundus of the stomach lies above the GEJ.

Type IV hernias are distinguished by the presence of a structure other than the stomach inside the hernia sac, such as the omentum or large or small intestine.

Types II–IV are true paraesophageal hernias (PEH) and differ from type I hernias by the relative preservation of the posterolateral phrenic-esophageal ligaments around the GEJ [78].

The term «giant paraesophageal hernia» is often found in the literature, although there is no single

definition of such a hernia. It is proposed to define a giant hernia according to different criteria: as all type III and IV hernias [88]; as hernias when more than a third of the stomach [87] or half of the stomach [95, 12] is in the chest; or according to the gastroscopy findings, a hernia is 6 cm in length [88]; or a distance between the crura of the diaphragm is more than 5 cm [88, 49] or more than 8 cm [42, 12]; or according to the intraoperative assessment, the EH defect is more than 5 cm² [73] or more than 20 cm² [52].

The existing classification of hiatal hernia, which has remained practically unchanged for almost 70 years, has become largely irrelevant and does not meet clinical needs [72]. Attempts to objectify criteria that could improve the classification of PEH are currently ongoing. Granderath et al. [50] first described the intraoperative measurement of the surface area of the hiatal defect, taking into account its length and width. The average calculated value of the EH area was 5.092 cm². According to the obtained data, four variants of cruroplasty were used. V.V. Grubnik et al. then proposed classifying hernias as small (< 10 cm²), large (from 10 to 20 cm²), or giant (20 cm²) based on intraoperative EH area values calculated using a developed formula [52]. Iossa A. et al. used a simplified calculation of the EH surface area according to the formula for the area of a rhombus ($d_1d_2/2$). Depending on the EH area, the authors classified hernias as less than 4 cm² (suture crurorrhaphy was carried out) and ≥ 4 cm² (a mesh was additionally used) [61].

Recently, a number of researchers proved the possibility of calculating the EH area and the volume of the hernia sac before surgery using radiographic studies [68, 90, 108, 25], which may contribute to improving the classification of hernias in the future.

Yano F. et al. studied the possibility of a preoperative diagnosis of a short esophagus. The authors showed that a ratio of the endoscopic length of the esophagus (the distance from the incisors to the GEJ in cm) to the patient's height (in meters) less than 19.5 has 95% specificity for a short esophagus [133].

A number of authors have suggested measuring the tension force when the crura of the diaphragm are folded during laparoscopic plastic surgery in order to optimize the method of closing the EH defect [26, 92].

For the unification of initial data regarding hiatal hernia, Aiolfi A. et al. proposed to classify hernias by the sum of points, taking into account the type of hernia, the size of the EH defect, and the condition of the crura of the diaphragm [3]. Types I–II hernias are given 1 point; types IIIa (< 50% of the stomach in the hernia sac) – 2 points; types IIIb (> 50% of the stomach in the hernia sac) – IV – 3 points; if the distance between the crura of the diaphragm is

< 2 cm, 1 point is given; > 2 and < 4 cm – 2 points; > 4 cm – 3 points; if the crus thickness is > 5 mm, 1 point is given; a thickness of < 5 mm – 3 points. The presence of a relapse adds two more points [3].

In general, the assessment of the size of the EH and hernial sac and the muscle status of the crura of the diaphragm will contribute to the development of an updated, clinically relevant classification system for the EH hernias.

Epidemiology of paraesophageal hernias

The real incidence of hiatal hernias in the general population is unknown, as many patients are asymptomatic and the disease is usually diagnosed incidentally during imaging tests for the chest or due to abdominal pain.

There is only one population-based study on the prevalence of hiatal hernias and the natural course of the condition. The authors studied the frequency, type, and course of hiatal hernias over 10 years in people aged 53 to 94 years in the framework of the Multinational Study of Atherosclerosis (MESA) without clinically significant cardiovascular diseases [22]. Hiatal hernias were discovered in 3,369 out of 6,814 patients who underwent cardiac CT. During the initial examination, the frequency of hiatal hernias (with the presence of a part of the stomach above 2 cm above the diaphragm) was 9.9%. 71% of cases had type I hernias, while 29% had type III hernias. The prevalence of hiatal hernias increased with age, from 2.4% in the 6th decade to 7.0%, 14.0%, and 16.6% in the seventh, eighth, and ninth decades, respectively. Hernias were more common in women (12.7%) than in men (7.0%).

After 10 years, participants underwent a repeat CT scan of the heart, lungs, and EH area, including 81 of 239 who had an EH herniation diagnosed at the initial follow-up. New hernia cases were diagnosed at a rate of 9 per 1000 person-years. Dynamic observation established that the hernia can disappear on its own (6.3%), decrease (12.5%) (by > 10% of the area), or change type from type I to type III (15.0%). As the hernia progressed, the median cross-sectional area of the hernia increased from 9.9 cm² to 17.9 cm². The hernia regression was associated with loss of body weight, and the hernia progression with its increase [71].

The mentioned population study, unfortunately, did not provide an answer to an important question: the evolution of symptomatic, large asymptomatic, and mildly symptomatic hiatal hernias.

Hiatal hernias are thought to be more common in North America and Western Europe, and less common in populations in the East and Africa [44].

Some clinical estimates show that about 50–60 % of patients over the age of 50 have a herniated EH, but only about 9 % have symptoms [4]. More than 95 % of diagnosed hiatal hernias are type I. More than 90 % of type II–IV hernias belong to type III, and type II is the least common [59]. Giant hernias make up 5–10 % of all diaphragmatic hernias [88, 128]. Patients with type IV PEH are older than patients with type III PEH (75.3 years vs. 66.9 years) and have a higher Charlson comorbidity index (4.3 points vs. 2.9 points) [110].

Few data are available on the risk of progression from asymptomatic to symptomatic PEH; it may be around 14 % per year [7]. In patients with PEH receiving only conservative therapy, hospital mortality reaches 16.4 % [118].

Oude Nijhuis RAB et al. [98] studied the natural course of a giant paraesophageal hernia (at least one-third of the stomach is found in the thoracic cavity) in 186 adult patients (73.0 ± 11.6 years). The average duration of observation was 58 months. The majority of patients (64.0 %) did not report changes in the clinical course or any phenomena related to the hernia. 67 (36.0 %) patients had «hernial events», of whom 39 (58.2 %) had progression of symptoms that could still be treated conservatively. Hernia-related complications occurred in 15 (8.1 %) patients, of whom three (1.6 %) were classified as gangrenous complications. The corresponding annual risks of requiring emergency surgery and developing hernia-related complications were 0.2 % per year and 1.7 % per year, respectively.

Pathogenesis of paraesophageal hernias

There are two basic theories of PEH etiology. One theory connects the occurrence of hernias with the shortening of the esophagus and the upward displacement of the GEJ caused by scarring of the esophagus due to damage to its mucous membrane caused by gastroesophageal reflux of hydrochloric acid [101]. Another theory links increased intra-abdominal pressure (vomiting, pregnancy, chronic constipation, chronic obstructive pulmonary disease, obesity) to phrenoesophageal junction deterioration and EH enlargement [66]. It is possible that changes occur primarily in the presence of such risk factors as old age, central obesity, and smoking [134, 20]. Biopsies of the gastro-hepatic, gastro-diaphragmatic, and diaphragmatic-esophageal ligaments in patients with PEH compared to control groups revealed differences in the architecture of the connective tissue matrix, with a higher ratio of collagen type I to collagen type III in patients with PEH [28] and a significant decrease in the number of elastin fibers [35].

There are no clearly identified genetic or somatic mutations underlying the formation of PEH [62]. Also, a certain role is given to the dynamic function of the diaphragm, which is in constant motion due to breathing, coughing, laughing, sneezing, straining the abdominal muscles, and the heartbeat [53, 5, 42]. A certain role is attributed to the contraction of the longitudinal muscles of the esophagus during swallowing (axial contraction of the esophagus), in which the lower esophageal sphincter is drawn into the chest cavity (by approximately 2 cm) [40].

Clinical picture of paraesophageal hernias

PEH causes a wide range of symptoms. They are divided into two types: obstructive and non-obstructive [32]. Obstructive symptoms include dysphagia, regurgitation, epigastric pain, early satiety, feeling full after eating, nausea, vomiting, and abdominal distension due to mechanical obstruction. These symptoms are associated with the possibility of further gastric volvulus [98]. Nonobstructive symptoms include complaints associated with gastroesophageal reflux and erosive esophagitis, chronic iron deficiency anemia (in approximately 50 % of cases [39]) due to mucosal ulcers (Cameron's lesions). Respiratory symptoms such as asthma, cough, or shortness of breath caused by chronic aspiration, recurrent *pneumonia*, and pulmonary compression are also observed [78, 54]. Borchardt's triad of symptoms may be present in patients with acute gastric volvulus: (1) severe epigastric pain, (2) urge to vomit with inability to vomit, and (3) inability to pass a nasogastric tube into the stomach [16].

Whether there are asymptomatic PEHs remains an open question. There is an opinion that up to 50 % of patients with PEH, including giant ones, do not have clinical symptoms [113]. Others believe that mild symptoms are present in many patients and that the hernia is discovered incidentally on a chest radiograph performed for another reason [78, 54]. Expert opinion suggests that asymptomatic PEHs do exist but are rare. When the patient is carefully questioned, they often mention certain hernia symptoms [77].

Diagnosis of paraesophageal hernias

Preoperative investigations for an uncomplicated PEH should include radiography of the esophagus and stomach with contrast, esophagogastroduodenoscopy (EGD), computed tomography of the chest, abdomen and pelvis with contrast, high-resolution esophageal manometry (HRM), and

cardiopulmonary testing (e.g., pulmonary function tests, cardiac stress tests).

Plain radiography of the chest may present evidence of PEH, especially a giant hernia (gastric air bubble or gas in the ileum in the projection of the chest).

An x-ray examination of the esophagus and stomach with contrast is the best initial examination to help determine the size and anatomical location of the esophagus and stomach, in particular the position of the GEJ and its relationship to the EH [75]. It also allows for determining the axis of the gastric volvulus around the longitudinal axis of the cardia-pylorus (organoaxial volvulus), perpendicular to the longitudinal axis (mesoenteric volvulus) [18]. This study also provides information on the gastric outlet or esophagus obstruction. Its presence allows for the detection of a short esophagus.

It should be noted that the hernia size determined by the X-ray examination may be inaccurate. D. Kumar et al. [76] described an interesting phenomenon of inconsistency of hernia size according to manometry, esophagography, and CT studies (performed on different days) in all types of PEH. The authors explain this by stating that, similar to type I hernias, types II and III are likely to have a sliding phenomenon, at least partially if not completely.

Esophagography is also the most commonly used method for detecting hernia recurrence [42, 49, 97, 132]. However, there is no consensus regarding the definition of relapse criteria. Some authors consider the presence of > 2 cm of stomach above the diaphragm to be a recurrence [94], while others consider any size of stomach above the diaphragm to be a recurrence.

An EGD is performed in all patients with suspected PEH. This allows the physician to directly visualize the mucosa and help determine the anatomy and degree of lower esophageal sphincter failure, according to L. D. Hill et al. [55]. An EGD also helps to detect other pathologies such as Barrett's esophagus, esophagitis, stricture, and esophageal or gastric cancer.

Esophageal manometry can determine the level of the crura of the diaphragm, the point of respiratory inversion, and the location of the lower esophageal sphincter (LES). The procedure also allows for calculation of the size of the sliding component of the hiatal hernia, particularly with the help of new high-resolution mobility technology. Esophageal motility testing is critical for correct placement of the pH probe above the LES in patients with a sliding hiatal hernia and symptoms of gastroesophageal reflux.

For the diagnosis of hernias, pH testing is of limited value, but it is crucial for the detection of abnormal gastroesophageal reflux, which is a surgical indication and a reason for taking antacids after surgery [32].

Until recently, it was believed that although CT contributes to clarifying the hernia anatomy, allowing the surgeon to distinguish type III from type IV hernias, it often does not change the plan of surgical intervention and is not mandatory [32]. Instead, recent studies have demonstrated the ability of MSCT to assess in detail the distance between the crura of the diaphragm as well as the EH area [68, 90, 108, 25], which can significantly influence the choice of hernioplasty method. In addition, based on CT, a technique for preoperative modeling of camera fields of view and access angles of instruments, depending on the location of the trocar, is presented. This allows predicting visibility and maneuverability for any placement of trocars during laparoscopic access and identifying candidates for thoracoscopic access in case the laparoscopic approach is dangerous [79].

Thus, all patients with PEH should be prescribed the additional imaging methods that are now available in order to select the optimal approach and optimize the results of the operation.

The paraesophageal hernias treatment strategy

The standard of PEH treatment strategy until 2002 was surgical intervention, regardless of the presence of clinical symptoms. This strategy was based on fears of potentially life-threatening complications in 29 % of cases [119, 56], including approximately 14 % per year of acute gastric volvulus, strangulation, bleeding, or obstruction [128, 124], and a high mortality rate during long-term follow-up of up to 17 % of these complications [119].

However, even at that time, the benefit of planned hernioplasty in patients with small or even large but asymptomatic and mildly symptomatic hernias was questioned. Based on the published data, 23 unoperated patients with PEH did not develop any acute hernia-related complications during an average follow-up of 6.5 years and did not require emergency surgery [6]. P.J. Treacy and G.G. Jamieson [128] examined 29 untreated patients with the PEH, and although 13 (45 %) patients subsequently required elective surgery due to progression of symptoms, none required emergency care. Based on 20 published studies at that time, N. Stylopoulos et al. [123] developed a Markov Monte Carlo decision-analytic model for a hypothetical cohort of patients with asymptomatic or minimally symptomatic PEH in 2002. The model reflected possible clinical outcomes associated with two treatment tactics: elective laparoscopic surgery and wait-and-see (conservative treatment). According to the model, mortality from elective surgery will be 1.4 %,

but with the wait-and-see strategy, the annual probability of emergency surgery will be only 1.1 %. In addition, the wait-and-see strategy was the optimal treatment strategy in 83 % of patients, and elective laparoscopic hernioplasty in asymptomatic patients reduced life expectancy and quality of life in patients aged 65 and older. The authors concluded that the wait-and-see strategy is a reasonable alternative for the management of patients with asymptomatic or mildly symptomatic PEH, and even if emergency surgery is required, the burden of the procedure is not as great as it is believed to be.

The wait-and-see strategy decreases the risk of acute symptoms (less than 2 % per year) that require emergency surgical intervention and reduces the mortality rate to 0–5.4 % [124].

At the same time, there were opinions that surgical treatment is indicated for patients with an expected life expectancy of more than 8 years and who require lifelong therapy due to insufficiency of the lower esophageal sphincter [41], as well as for patients with large, even asymptomatic hernias to prevent complications [87] or improve quality of life [37]. S. Paul et al. demonstrated the benefits of planned PEH surgery [103]. The authors analyzed data on 193,554 patients with PEH who were hospitalized and operated on in US clinics from 1999 to 2008. In patients who underwent planned surgery, mortality was significantly lower (1 %) than in the case of acute complications, such as obstruction (4.5 %) or gangrene of the stomach (27.5 %), with the wait-and-see strategy. The analysis also showed a small but real benefit of elective PEH plastic surgery in patients aged 50 to 70 years, or if the operative mortality in the clinic is 1 % or less [103].

In 2013, until now, the only recommendations for the management of PEH were issued, which indicate that all symptomatic hernias should be operated on, especially for symptoms of acute obstruction [75]. In the case of asymptomatic hernias, the indications are not so clear, and, as noted, planned surgery may not always be indicated and should take into account the patient's age and concomitant diseases [75].

The uncertainty regarding the treatment of asymptomatic and minimally symptomatic PEHs has persisted until now. S. Choi et al. [32] actually supported the 2013 recommendations after 6 years, believing that planned surgery is indicated in the case of symptomatic PEH in the absence of serious concomitant diseases and that it is individual in the case of asymptomatic hernias. Also, J. J. Jung et al. [65] concluded (using a Monte Carlo Markov decision analysis model with a hypothetical cohort of patients with asymptomatic PEH, predominantly female with a mean age of 62.5 years) that patients

with asymptomatic PEH who choose the wait-and-see strategy are more likely to receive health benefits compared to elective surgery. However, an article by E. H. Morrow et al. with a similar design was published almost simultaneously, in which the authors, on the contrary, show that in patients with asymptomatic or mildly symptomatic PEH, planned laparoscopic hernia repair is superior to the wait-and-see strategy in terms of quality of life [89]. One of the undesirable consequences of the wait-and-see strategy is an increase in the specific weight of elderly and senile patients, who may need urgent surgery [63]. Under such conditions, emergency surgery is associated with a higher rate of complications (33.4 vs. 16.5 %, $p < 0.001$) and mortality (3.2 vs. 0.37 %, $p < 0.001$) than planned intervention [63].

Surgical treatment of paraesophageal hernias

Traditionally, surgical treatment of PEH was carried out using an open laparotomy or thoracotomy approach. The complications associated with these approaches prompted the introduction of innovative minimally invasive methods: laparoscopic and robotic [86].

There are no controlled comparative studies of the open and laparoscopic approaches. However, initial studies have shown that the recurrence rate after laparoscopic hernioplasty compared with the open approach is higher than expected at medium-term follow-up. In 2000, S. R. DeMeester et al. [53] reported an objective recurrence rate (determined by the video esophagograms) of 42 % after laparoscopic PEH hernioplasty, compared with 15 % after open hernioplasty. A decade later, after the introduction of a resorbable mesh for the EH plasty, the same authors did not find a statistical difference in the recurrence rate (after one year) for the two approaches: 12.3 % after laparoscopic hernioplasty and 24.7 % after open, $p = 0.09$ [135].

The first fully laparoscopic PEH procedure using Collis gastroplasty and Nissen fundoplication was performed in 1998 [64]. Today, laparoscopic access has become a generally accepted method of surgical treatment for the PEH. A minimally invasive approach provides better visualization of the diaphragm area than a laparoscopic approach. It allows precise identification of anatomical structures (e.g., vagus nerves, parietal pleura, distal esophagus) and is associated with low complication and mortality rates, reduced postoperative pain, shorter hospital stays, and lower costs to the health care system compared to the traditional approach [115]. Operative

treatment of giant paraesophageal hernias is also performed using a minimally invasive technique. Numerous studies have confirmed the safety and effectiveness of this approach.

The principles of restoring the anatomy of the EH in the case of a large hernia during a laparoscopic approach are similar to the principles of an open procedure, which include: dissection of the hernial sac, retraction of the hernial contents into the abdominal cavity, excision of the sac [131, 82], avoiding exposure of the muscles of the crura of the diaphragm [4, 31], full 360° mobilization of the esophagus to the level of the lower pulmonary veins, elimination of the EH defect, and a fundoplication or a gastropexy [114].

At the same time, the laparoscopic approach has certain disadvantages: inaccurate assessment of the intra-abdominal length of the esophagus due to lifting of the diaphragm by the pneumoperitoneum; reduction of adhesions during laparoscopic intervention compared to open access; less tactile feedback to determine the tension of the suture used for the crus of the diaphragm; and the risk of performing a deep suture when using laparoscopic suturing devices [5, 60, 74, 109].

Despite the recognized advantages of laparoscopic PEH treatment compared to open access, there remains a high level of anatomical recurrence in the long-term postoperative period, ranging from 15% to 66% with an average follow-up period of 12 to 40 months [94, 53, 36, 82, 10]. In patients with giant PEH, Hashemi M. et al. discovered a recurrence rate of 42% with an average follow-up period of 17 months [53], Dallemagne et al. — in 66% with an average observation period of 99 months [36], Oelschlaeger et al. — more than 50% within 5 years [94].

However, it should be noted that the frequency of symptomatic recurrence is much lower than that of radiological recurrence. For example, Antiporda M. et al. discovered anatomical recurrence in 34.2% of patients after giant PEH treatment, symptomatic recurrence in 9.9% of patients, and 4.9%, or according to other data, 3% of patients required reoperation [10, 83].

The causes of relapses, especially in the event of large hernias, are associated with tension in the EH area, either in the axial direction (in the case of a short esophagus) or in the lateral direction (in the case of crurorrhaphy of the crura of the diaphragm) [5, 51].

The surgical research is currently focused on measures that prevent PEH recurrence and improve the quality of life of patients: establishing optimal methods of eliminating the EH defect, choosing the method of fundoplication, and identifying and treating a short esophagus.

Methods of esophageal hiatus defect elimination

When M. A. Toupet first described his fundoplication technique in 1963, suture cruroplasty was recommended only in the case of a large EH defect [127]. Today, cruroplasty is an integral element of the operative treatment of PEH. Various options for closing the EH defect have been described, including bringing the crura together with sutures (suture crurorrhaphy), which are mostly placed behind the esophagus (posterior crurorrhaphy), mesh implantation (absorbable or non-resorbable), and combinations of crurorrhaphy with mesh implantation [3, 7, 85, 106, 117, 130]. However, there remains a debate regarding the best method of hernioplasty, which is currently non-standardized and left to surgeons' preferences and the feeling of «weak crura» [3, 15].

The esophageal hiatus in patients with PEH is often wide, usually with thin right and left crura of the diaphragm. This can make direct closure of the EH with sutures (suture crurorrhaphy) problematic due to the tension required to bring the crura together and the high risk of suture perforation.

The use of crurorrhaphy alone to close the EH defect was associated with a high recurrence rate. According to P. A. Le Page et al., after 455 operations for PEH mainly using crurorrhaphy (in 94%), the frequency of anatomical recurrences up to 1 year was 13.7%, after 5–10 years — 40.1%, over 10 years — 50.0%, while the frequency of recurrences with migration > 2 cm of the stomach above the diaphragm was 3.4%, 9.5%, 13.8%, and 25.0%, respectively [80].

Closing the EH defect «without tension» with the help of a mesh allograft and a biological mesh fixed at the edges of the defect (in lay) of the diaphragm or strengthening (reinforcing) the sutures of the crurorrhaphy with a mesh (on lay) seems logical in view of the effectiveness of this approach in patients with anterior hernias of the abdominal wall.

An analysis of the American College of Surgeons (ACS) NSQIP database between 2011 and 2014 [116] showed an annual mesh utilization rate of approximately 40%. Similarly, a survey of SAGES members [43] found that 25% of surgeons use mesh in more than half of their PEH operations.

Various materials and mesh configurations are used, but there is no consensus on the best option [19].

E. M. Bonrath and T. P. Grantcharov, using the Delphi consensus process (a method of obtaining information from an expert group in the absence of sufficient empirical evidence [47]), received information from 18 identified experts on the PEH treatment. No consensus was reached on the importance of mesh use and mesh type [23]. Furne'e et al. [45]

published the results of a web-based questionnaire on the treatment of PEH completed by 165 European surgeons as defined by the European Association for Endoscopic Surgery. The majority of respondents (77.6 %) used a mesh selectively, depending on the size of the hiatus and the tension of the sutures during crurorrhaphy. Polypropylene mesh was the most commonly used (52.6 %), followed by ePTFE (32 %), and biological mesh (27.9 %).

A survey of SAGES members showed that American surgeons most often used absorbable meshes (67 %) [105].

The mesh configuration also causes controversy. The most commonly used designs include U-shaped, rectangle, inverted C-shaped, and keyhole shapes [70]. The U-shaped mesh allows a surgeon to reinforce the suture of the crura of the diaphragm but does not strengthen the hiatus above the esophagus. It has been previously reported that recurrent EH hernia defects usually occur anteriorly and to the left of the esophagus [112]. This has led 10 % to 25 % [105] of surgeons to use a keyhole, «reverse C» mesh configuration to ensure the strength of the EH around the esophagus. A number of studies have determined a low rate of recurrence when using a keyhole graft compared to crurorrhaphy [112]. At the same time, this type of implant location has a risk of dysphagia, stricture, and erosion of the esophagus [43, 121]. There is currently insufficient long-term evidence to recommend one mesh configuration over another.

The use of implants in laparoscopic hernioplasty in patients with paraesophageal hernias

In 1993, G.G. Kuster and S. Gilroy described the technique of using an implant for the treatment of PEH [77]. At the turn of the 20th century, a series of reports reported lower recurrence rates after laparoscopic hernioplasty with implants compared with suture-only crurorrhaphy at short-term follow-up [42, 48, 95]. Based on these data, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines for the treatment of hiatal hernia recommend the use of mesh to repair large hernias [75].

Currently, there are many studies in favour of the use of allograft in the surgical treatment of PEH. A meta-analysis of randomized trials published by Antoniou et al. in 2015 showed a fourfold reduction in the risk of anatomical (radiological) recurrence when using mesh (from 22.2–26 % to 0.8–9 %) [11]. M. Morino et al. established that hernioplasty with the use of a mesh for giant PEHs can reduce the percentage of recurrences to 35 %, compared to

77 % with suture crurorrhaphy [88]. Similar results were obtained by Memon et al. in a meta-analysis and systematic review of randomized controlled trials published in 2016 [84]. B. P. Müller-Stich et al., based on a meta-analysis of three randomized and nine observational clinical trials (915 patients), found a significantly lower short-term recurrence rate with mesh (12.1 %) than without mesh (20.5 %) [91]. In 2016, Tam et al., in a systematic review of the surgical treatment of large PEHs, found a lower probability of hernia recurrence after reinforcing cruroplasty with mesh compared to cruroplasty alone (13 % vs. 24 %) and reoperation (3.7 % vs. 6 %) [125]. A meta-analysis by C. Zhang et al. also confirms that the use of mesh is associated with lower rates of short-term recurrence and reoperation, improved quality, and no difference in the rate of postoperative dysphagia (1.5 % with mesh and 1.7 % with crurorrhaphy) [37].

Recently, laparoscopic repair of a large EH hernia using mesh (Gore Bio-A®) and partial fundoplication has been shown to be associated with symptom relief, no side effects, and a significant improvement in disease-related quality of life and general condition at a 2-year follow-up. At the same time, the frequency of radiological hernia recurrence was 5.4 %, without the need for surgical intervention [117].

Castelijns et al. [30] published a systematic review of 16 nonrandomized studies and found a relatively low recurrence rate with mesh, which was, however, statistically significantly lower with synthetic mesh (6.8 %) compared to biological mesh (16.1 %). There is little data on the use of biosynthetic mesh for crurorrhaphy reinforcement. A recent study by Panici Tonucci in 2020 reported a recurrence rate of 3.2 % with Phasix ST® biosynthetic mesh in patients with giant PEHs at a mean follow-up of 17 months [99].

E. Tartaglia et al. [126] retrospectively analyzed the results of laparoscopic treatment of giant PEH using biosynthetic resorbable mesh (Gore Bio-A®) in 44 patients. One year after surgery, radiological recurrence was observed in 4.5 % of patients. None of the patients had symptoms associated with recurrence or the need for reoperation. After three years, there were no mesh-related complications.

In a retrospective cohort study, Asti et al. reported the results of their first 100 cases of repair of any esophageal hiatal hernia (90 % PEH) using Bio-A (polyglycolic acid/trimethylene carbonate) absorbable synthetic mesh and reported a recurrence rate of only 9 % at a mean follow-up of 30 months [14]. Zehetner et al. reported similar results (9.5 % of relapses) with a median follow-up of 14 months when using a Vicryl mesh (polyglactin) in 35 patients [136].

A somewhat lower recurrence rate (8%) at one-year follow-up was reported by W.F. Abdelmoaty et al. for laparoscopic PEH hernioplasty in 50 patients using Phasix-ST absorbable synthetic mesh. [1]. No patient had a reoperation, mesh infection, or mesh erosion.

P.R. Armijo et al. [13] compared the results of surgical treatment of PEH using three types of resorbable meshes in 292 patients: human tissue matrix (HTM) – 162, biosynthetic mesh (BIOS) – 83 and porcine tissue matrix (PTM) – 47. The average observation time was 27 months. The overall recurrence rate was 39%, significantly lower with the use of BIOS than with PTM and HTM (17% vs. 19% and 31%, respectively, $p = 0.038$).

But over time, studies appeared that questioned the feasibility of using mesh to reduce the frequency of relapses. After 2.5 years of follow-up, B.K. Oelschlager et al. discovered the same high rate of hernia recurrence with absorbable mesh (59%) compared to suture crurorrhaphy (54%) [94], though at 6 months of follow-up, a lower recurrence rate was observed with absorbable mesh (9%) compared to suture (24%) [95].

Antiporda M. et al. [10] showed that after laparoscopic plastic surgery of giant PEHs with an average follow-up period of 6 months, the overall rate of anatomical recurrence was 34.2%. Neither patient demographics nor PEH characteristics (size, presence of Cameron erosions, Barrett's esophagitis) were correlated with anatomic recurrence. Technical factors during surgery (mobilized intra-abdominal length of esophagus, Collis gastroplasty, number of anterior and posterior sutures, use of relaxing incisions, use of knotted or mattress sutures, or gastrostomy) were also not associated with recurrence. Only surgeon experience (annual volume of operations less than ten cases per year) was associated with an increased risk of recurrence (54% vs. 33%), according to multivariate analysis.

Watson et al. [132] compared the results of laparoscopic hernioplasty of giant PEH performed by suture crurorrhaphy with reinforced synthetic mesh ($n = 42$), biological mesh ($n = 41$), and without the use of mesh ($n = 43$). After 5 years, clinical outcomes were obtained in 89.9% of cases and from objective observation in 72.3%. Hernia recurrence (of any size) was found in 39.3% of cases with suturing, 56.7% with absorbable mesh, and 42.9% with non-absorbable mesh ($p = 0.371$). Clinical outcomes at 5 years were similar, except for chest pain, diarrhea, and abdominal distension symptoms, which were more common after resorbable mesh. That is, no benefit of mesh hernioplasty was demonstrated in terms of recurrence rate, and clinical outcomes were worse after absorbable mesh hernioplasty.

In 2020, Campos V. et al. [29] published a meta-analysis of seven studies on the robotic treatment of giant PEHs (three randomized trials with the highest strength of evidence, two randomized trials with low methodological quality, and two prospective cohorts) examining outcomes up to 6 months. No statistically significant differences were found in favor of any of the intervention methods (mesh or suture cruroplasty) in terms of recurrence rates, intraoperative and postoperative complications, deaths, or repeated operations [29].

In 2022, Petric J. et al. [104] analyzed seven randomized controlled trials (RCTs) comparing mesh cruroplasty of the EH (non-absorbable mesh: $n = 296$; absorbable mesh: $n = 92$) with suture crurorrhaphy ($n = 347$). The authors found no significant differences between the groups regarding short-term hernia recurrence (within 6–12 months): 10.1% with mesh versus 15.5% with suture crurorrhaphy, $p = 0.22$; and long-term hernia recurrence: within 3–5 years, 30.7% with mesh versus 31.3% with suture crurorrhaphy, $p = 0.69$. The only statistically significant difference was that mesh placement required a longer operating time. The authors of the meta-analysis concluded that both methods provided good and comparable clinical results, with the suture-only method still being the relevant approach [104].

C.A. Angeramo et al. published a meta-analysis in 2022 that included seven RCTs that compared the outcomes of laparoscopic operations with plastic surgery of the EH defect with a mesh ($n = 383$) and without a mesh – suture crurorrhaphy ($n = 352$). It was established that patients who had a mesh applied had a similar frequency of relapses as patients without a mesh in the early and late postoperative periods. Similar results were found when patients were stratified by the type of mesh used (absorbable vs. nonabsorbable). Intraoperative complications and the frequency of reoperations were also similar in both groups. However, the overall complication rate was higher with nonabsorbable mesh (OR = 1.45; 95% CI 1.24–1.71; $p < 0.01$). [9]

Doubts about the expediency of routine use of implants in the surgical treatment of PEH are reinforced by reports of complications associated with them: shrinkage, mesh migration [24, 107, 34], infection (abscesses, fistulas) [33, 67], cardiac tamponade, erosion of the aorta [91], esophagus or stomach [75, 2], esophageal stenosis [121], severe dysphagia, and fibrotic reaction that may complicate new esophageal surgery [122]. A recent survey of surgeons showed that 21% and 25% of respondents diagnosed mesh erosion and esophageal stenosis, respectively [57].

Wrapping the abdominal part of the esophagus with a hernial sac will prevent migration of the mesh into the lumen of the esophagus or erosion within 41 ± 28 months [27].

Complications are described for all types of implants [70], and while the frequency is low (0.8 % for polypropylene, 2.5 % for PTFE, 1.3 % for biological implants) [91], the consequences can be disastrous. Partial or total esophagectomy or gastrectomy was necessary in 45 % of reoperations due to complications with synthetic mesh [122]. Other data show that similar operations are necessary in 30 % of patients who require repeated intervention due to complications caused by synthetic mesh [100]. At the same time, complications associated with bio-synthetic meshes are less severe and are mainly treatable with endoscopic means [121].

There is an opinion that synthetic mesh can be used without the risk of complications to strengthen the zone of the relaxing incision on the diaphragm (behind the liver), which is performed to reduce the tension of the suture crurorrhaphy in giant PEHs [4, 51, 21].

The obtained data show that some surgeons refrain from using mesh, even with giant PEHs [5]. E. T. Alicuben et al. believe that only 13 % of patients need cruroplasty with a mesh, mainly during repeated operations [5]. Others suggest that mesh hernioplasty should be limited to mesh of biological origin for use only in large paraesophageal hernias or recurrences [12, 70].

Therefore, the interpretation of the results of the use of implants is limited by a significant variety of studies that differ in indications for hernioplasty, types or sizes of the EH hernias, types, shape, and position of the mesh, method of fixation of the mesh, type of fundoplication, interpretation of recurrence by the surgeon's experience, etc. The heterogeneity of the raw data limits the reliability of any of the conclusions regarding the use of mesh and requires further investigation.

Choice of a fundoplication method

Fundoplication is considered by many surgeons to be an integral (obligatory) procedure in the surgical treatment of the EH hernias to eliminate or prevent gastroesophageal reflux [91, 81] because suturing the EH defect alone does not prevent this. Also, routine fundoplication is recommended as a means of keeping the stomach below the diaphragm to prevent recurrence [31]. At the same time, D. Solomon et al., after analyzing scientific articles from 1995 to 2019, expressed doubts about the ability of fundoplication to reduce the risk of relapse [120]. But the

follow-up period for patients in the relevant articles was short — up to 12 months — which is a significant limitation regarding the conclusions.

The Nissen fundoplication, which involves wrapping the distal part of the esophagus around the bottom of the stomach for 360° and fixing it in this position, was the most common [93]. There are also many options for partial fundoplication, each of which is characterized by incomplete wrapping of the esophagus with the bottom of the stomach (by $180\text{--}270^\circ$). The most common are anterior partial fundoplication according to Dor or, when performed transthoracically according to Belsey mark IV, and posterior partial fundoplication according to Toupet [127].

Some researchers believe that Nissen fundoplications should be performed on all PEH patients [9]. This opinion is based on the work of M. G. Patti et al., who compared the treatment outcomes for groups of patients with a differentiated choice of fundoplication method (partial or total) depending on the results of preoperative manometry and with total fundoplication regardless of manometry data. The study did not reveal any differences in the frequency of postoperative dysphagia, but the antireflux effect was better in the total fundoplication group [102].

Instead, a number of authors [38] insist on the concept of individual choice of fundoplication, which entails performing fundoplication while taking patient factors such as esophageal motility and the severity of gastroesophageal reflux disease (GERD) into account. Nissen fundoplication has been shown to create a resistance to the evacuation of esophageal contents of approximately 20 mm Hg and, therefore, in patients with ineffective esophageal motility, contraction amplitudes closer to 20 mm Hg lead to severe dysphagia [17]. Obviously, a balance must be considered between the advantages and potential side effects of Nissen fundoplication, including the inability to belch or vomit and increased flatulence, the frequency and severity of which may be higher compared to partial fundoplication. While postoperative pH-metry demonstrates that Nissen fundoplication provides the best reflux control compared to other fundoplications [102], S. R. DeMeester asserts that patients with moderately severe reflux disease are clearly better suited to partial fundoplication [38].

A number of researchers compared different variants of fundoplication during laparoscopic treatment of PEH. According to M. Trepanier et al., in patients operated on for giant PEHs, the incidence of severe dysphagia at one month was lower in the Dor group than in the Nissen group (0 % vs. 8 %)

with similar reflux symptoms. Subsequently, the differences between the groups leveled off [129].

C. T. Huerta et al. compared the long-term results of laparoscopic hernioplasty using Nissen and Toupet funduplications in 77 patients with type III and IV paraesophageal hernias after 54 months for Nissen and 25 months for Toupet. All operations were performed by one surgeon. Among patients undergoing Nissen fundoplication, 26% reported use of a proton pump inhibitor compared with 31% of patients undergoing Toupet fundoplication ($p = 0.486$). Patient satisfaction with the current condition was statistically similar between the groups (67% Toupet, 72% Nissen) [58].

A recently presented randomized clinical trial comparing Nissen fundoplication ($n = 32$) and Toupet fundoplication ($n = 38$) [8] in the surgical treatment of PEH established a lower frequency of obstructive complications and an improved quality of life after Toupet fundoplication in comparison to Nissen.

Despite the proven expediency of fundoplication in patients with paraesophageal hernias, some authors do not consider it mandatory. In particular, E. T. Alicuben et al. perform gastropexy in patients with giant paraesophageal hernias and primary obstructive symptoms, postprandial pain or vomiting, dysphagia, shortness of breath, anemia, and early satiety [4].

Therefore, the choice of fundoplication method remains debatable. When choosing a surgical strategy for a fundoplication option (partial or total), the risk of their complications and mechanical side effects should be taken into account. This may be particularly relevant for patients without GERD, who account for 30% of patients with PEH [31].

Short esophagus

An important condition for the successful treatment of PEH is the elimination of the axial pressure on the EH; otherwise, there is a high risk of relapse regardless of the surgical technique used (suture crurorrhaphy or the use of an implant). This is possible if the esophagus is of sufficient length and the GEJ is located below the hiatus [88, 111].

The frequency of shortening of the esophagus in large PEH ranges from 2% to 80% [53, 88]. Such a wide range of values indicates a lack of consensus regarding this phenomenon. Preoperative diagnosis of a short esophagus is extremely difficult, especially with large hernias. The final length of the esophagus should be measured intraoperatively after almost complete intrathoracic mobilization of the esophagus [64, 95]. For this purpose, intraoperative endoscopic control is performed to assess the position of the GEJ [4].

If the esophagus is short, Collis-Nissen gastroplasty [64, 95] is performed to create a 3 cm intra-abdominal neoesophagus (Collis segment). This will allow fundoplication 2.5–3 cm below the diaphragm. It is important not to create more length than necessary, since too much resection of the gastric fundus leads to excessively tight fundoplication and subsequent dysphagia [4].

At the same time, the risk of perforation of the esophagus or stomach during laparoscopic Collis-Nissen gastroplasty ranges from 2% to 7.5% [64, 95]. Considering this fact, prosthetic hiatoplasty is considered contraindicated in these conditions [4].

Therefore, there are still many unanswered questions in the treatment of PEH. Obviously, a consensus is needed on the classification of PEH, which would meet the urgent needs of choosing the method of operative delivery and include the definition of the concept of large and giant hernias. Some issues require further research: indications for surgical treatment of PEH, especially in the case of a few symptomatic large hernias and incarcerated hernias; the expediency of using implants for EH plastic surgery; the role of anatomical peculiarities and diagnostic radiological methods in making the optimal decision; choice of implant; choice of a fundoplication method; diagnosis and correction of a short esophagus; methodology for evaluating long-term treatment outcomes.

DECLARATION OF INTERESTS

Authors have no conflicts of interest to declare.

AUTHORS CONTRIBUTIONS

T. Tarasov: concept and design of the study, drafting and revision of the manuscript; T. Tarasov, L. Markulan: collection, analysis, and interpretation of data.

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Параезофагеальна грижа, стан проблеми та невирішені питання. Огляд

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Огляд літератури присвячений дискусійним питанням менеджменту параезофагеальної грижі (ПЕГ). Висвітлено недоліки сучасної класифікації гриж стравохідного отвору діафрагми (СОД), яка є неактуальною і не відповідає клінічним потребам. Запропоновано об'єктивні критерії її вдосконалення. Наведено дані щодо поширеності та перебігу гриж СОД. Висвітлено їхні патогенетичні чинники та методи діагностики. Значну увагу приділено тактиці лікування ПЕГ у хворих із безсимптомним і малосимптомним клінічним перебігом захворювання. Наведено аргументи на користь як вичікувальної тактики, так і планової герніопластики. Акцентовано увагу на питаннях вибору методу герніопластики, особливо при гігантських грижах, доцільності та показаннях до застосування сітчастих імплантатів залежно від їхньої форми і складу та потенційних ускладненнях алогерніопластики. Обговорено питання вибору варіанта фундоплікації з урахуванням балансу між користю і можливими побічними ефектами використання різних модифікацій фундоплікації. Критично оцінено результати корекції короткого стравоходу та усунення осьової нагрузки на зону пластики СОД, за наявності якої ризик рецидиву грижі є високим.

Автори дійшли висновку, що в лікуванні ПЕГ є багато невирішених питань. Потребує консенсусу класифікація ПЕГ, яка б відповідала нагальним потребам вибору методу оперативного втручання, зокрема визначення поняття «велика грижа» та «гігантська грижа». Не з'ясовано показання до оперативного лікування ПЕГ, особливо у разі малосимптомних великих гриж і гриж з елементами защемлення, доцільність використання імплантатів для пластики СОД, вибір методу фундоплікації, діагностика та усунення короткого стравоходу, методологія оцінки віддалених результатів.

Ключові слова: грижа стравохідного отвору діафрагми, параезофагеальна грижа, гігантська грижа, крурафія, герніопластика, фундоплікація.

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