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Review

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Tension at the hiatus: the role of lengthening procedures and relaxing incisions in paraesophageal hernias

Alberto Aiolfi, Andrea Sozzi, Davide Bona

Department of Surgery, Istituto Clinico Sant'Ambrogio, University of Milan, Milan 20121, Italy.

Correspondence to: Dr. Alberto Aiolfi, Department of Surgery, Istituto Clinico Sant'Ambrogio, Via Luigi Giuseppe Faravelli 16, University of Milan, Milan 20151, Italy. E-mail: alberto.aiolfi86@gmail.com

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Abstract

Avoiding tension during hernia repair is the goal of every surgeon. In the setting of laparoscopic paraesophageal hernia (PEH) repair, tension along esophageal length (axial) and between the crura (radial) should be considered. The aim of this narrative review is to summarize the current knowledge on techniques for axial and radial tension assessment and possible minimization during laparoscopic PEH repair.

Keywords: Short esophagus, Collis gastroplasty, diaphragmatic relaxing incision, minimally invasive

INTRODUCTION

Laparoscopic paraesophageal hernia (PEH) repair is one of the most challenging procedures facing minimally invasive surgeons. Exhaustive consideration of the operation principles is necessary for long-term symptom relief, quality of life improvement, and recurrence minimization. Hernia relapse has been reported up to 50% in medium/long-term follow-up depending on definition, patient characteristics (i.e., body mass index), technical aspects (i.e., esophageal lengthening, sac excision, gastropexy, mesh reinforcement, *etc.*), surgeon experience, and hospital volumes[1-3].

The pathogenesis of recurrence is multifaceted and caused by a combination of repetitive diaphragmatic/esophageal movements, positive intra-abdominal *vs.* negative intrathoracic pressure, and tension at the crura. Two directions of tension should be pondered: along the length of the esophagus (axial) and between the crural pillars (radial)[4]. To improve repair and ideally reduce recurrence, tension along these vectors should be decreased[5,6]. Axial tension is assessed intraoperatively by measurement of intra-abdominal esophageal length. If shorter than 2 cm, short esophagus (SE) should be suspected[7]. Radial tension is the lateral tensile force exerted from splayed pillars in a centrifugal direction away from the hiatus. There are no simple maneuvers to ease its assessment, and this is generally judged by tactile and visual clues[8-10]. These are prone to heterogeneity, variability, and limited reproducibility.

The aim of this narrative review is to summarize the contemporary knowledge on techniques for axial and radial tension assessment and minimization during laparoscopic PEH repair.

METHODS

The review of current literature was completed until 25 February 2022 using PubMed, Scopus, Web of Science, Google Scholar, Cochrane Review, and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines. Search terms included the following: "paraesophageal hernia" AND "esophageal lengthening" AND " Collis gastroplasty" AND "laparoscopy" AND "minimally invasive" AND "crural repair". Results were thoroughly reviewed for significance.

DISCUSSION

Axial tension-definition and diagnosis of short esophagus

In 1961, John Leigh Collis described his procedure to enable functional esophageal lengthening. The original description consisted in the creation of a neo-esophagus by performing a vertical gastroplasty without fundoplication[11]. Later, the technique was modified with the adding of a transthoracic fundoplication to correct the underlying pathologic gastroesophageal reflux disease (GERD), probably the cause of esophageal fibrosis and consequent visceral shortening.

The definition and identification of short esophagus (SE) remain controversial. Generally, it is defined as a gastroesophageal junction (GEJ) that after surgical mobilization does not lie more than 2 cm below the diaphragmatic hiatus[12]. The pathophysiology is multifaceted. Chronic GERD is considered the foremost cause of shrinking and visceral shortening. Specifically, depending on the site exposed, fibrosis can lead to circumferential strictures (in the case the circular layer is most involved) or shortening (in the case the longitudinal layer is injured)[13]. Caustic ingestion, scleroderma, or inflammatory bowel disease (i.e., Crohn's disease) may be associated with SE. The precise incidence of SE is not defined[14,15], but studies coming from high volume centers show that up to 20% of subjects with GERD will require a lengthening procedure because of SE[16,17].

Accurate diagnosis of SE is mandatory for an efficacious anti-reflux surgery. Preoperative barium swallow study, upper endoscopy, and high-resolution manometry have been proposed to possibly provide some warnings. Specifically, Horvath *et al.* and Urbach *et al.* identified long GERD, failed anti-reflux procedures, lower esophageal sphincter alterations such as hypo- or aperistalsis, a GEJ > 5 cm above the hiatus, grade C-D esophagitis, Barrett esophagus, history of peptic ulcers, and non-reducible hiatus hernia (HH) as potential indicators of SE[18,19]. Unfortunately, none of these criteria show high sensitivity and specificity. Similarly, Yano *et al.* proposed the esophageal length index in an attempt to predict SE[20]. This results from the ratio between the esophageal length, measured from the incisors to the GEJ (in centimeters), and the patient height (in meters). They found that patients with a score higher than 19.5 had an 83% negative predictive

value to have SE. However, a definitive diagnosis of SE is possible only at the time of the operation. Specifically, as stated by Nason *et al.*, intraoperative identification of the true GEJ is mandatory for a precise SE diagnosis. Specifically, the GEJ is identified below the fat pad at the conjunction of longitudinal esophageal fibers, which do not have a serosal lining, as they merge with the stomach, which does have a serosal lining. Therefore, only after fat pad dissection and true GEJ identification can an accurate SE diagnosis be accomplished[21].

Minimally invasive techniques and results

Different techniques have been reported for esophageal lengthening. During the open era, most of them required a thoracotomy due to the arduous surgical approach to the distal esophagus from the abdomen. By contrast, minimally invasive approaches gained progressive acceptance with better results in terms of postoperative functional outcomes and complications. Generally, mediastinal mobilization is necessary to obtain at least 3-4 cm of esophagus below the diaphragm without tension[22]. If this mobilization is not enough, a more extensive transhiatal dissection up to the aortic arch (type 2 mediastinal dissection) may be required.

Despite the extensive mediastinal dissection, in the case of confirmed SE diagnosis, an esophageal lengthening procedure is required with different minimally invasive approaches. Swanstrom *et al.* and Awad *et al.* described two hybrids, thoraco-laparoscopic approach via right and left thoracoscopy, respectively[12,23]. The esophago-gastric junction is approached from the thorax and, with laparoscopic assistance, a neoesophagus is created using an articulating stapler positioned parallel to the esophagus. Two other laparoscopic techniques have been proposed. The first procedure, proposed by Johnson *et al.*, consists in the creation of an entry point on the anterior gastric wall, 3 cm below the His angle[24]. At this level, a 25 mm circular stapler is inserted and fired over a 48 Fr bougie, thus creating a transgastric antero-posterior communication. A linear stapler is then inserted through the hole and fired parallel to the esophagus. Despite the feasibility of this approach, its technical complexity and costs limit its practice utilization. The fourth procedure was described by Terry and colleagues in 2004[16]. After distal esophageal dissection, the upper portion of the gastric fundus is prepared and a 45-48 Fr bougie is inserted. A mark is made 3 cm below the His angle and a wedge fundectomy (WF) is performed starting from the greater curvature. Once the mark is reached, another stapler is oriented parallel to the esophagus. In addition to Collis/fundoplication, previous studies reported the supplementary effect of gastropexy sutures to further reduce tension along the esophageal axis. Specifically, Bellevue *et al.*, in their retrospective study, reported data for Hill gastropexy sutures combined with a traditional Nissen/Collis fundoplication for the treatment of PEH and SE[25]. Two Hill sutures are placed sequentially through the anterior and posterior collar sling musculature of the GEJ and secured to the preaortic fascia.

Up to date, the most commonly adopted procedure for esophageal lengthening is WF. This technique has documented high technical success rates (up to 90%) with control of reflux symptoms and high patient satisfaction rate[16,17,26,27]. Postoperative complications after Collis gastroplasty have been reported in up to 36% of cases[17]. Specifically, pulmonary complications such as atelectasis, pneumonia, and pleural effusion should be considered in the case of thoracic approach, while staple line leak has been reported in up to 2.7% of cases[28-30]. Hernia recurrence and recurrent symptoms have been reported ranging from 2% to 30% of cases, and approximately up to 6% of patients will need complex redo surgeries[29]. Results are multifaceted, as the Collis procedure is a compromise. The segment of neo-esophagus is a relatively adynamic segment without peristalsis, which can lead to dysphagia (3%-13% of patients), particularly in patients with *ab initio* altered esophageal motility. Furthermore, conduit size discrepancy can lead to postoperative medium- and long-term concerns (gradual dilation if too wide/dysphagia if too narrow), and the ectopic gastric mucosa can continue to produce acid with chronic intra-esophageal acid secretion and esophagitis[31,32]. A 2013 study

by Mor *et al.* compared the acid clearance time between Nissen fundoplication and Nissen-Collis gastroplasty[33]. They found a higher esophageal acid clearance time and pathologic esophageal acid exposure in the Nissen-Collis group compared to the Nissen fundoplication one. This means that patients may require chronic full dose long-term acid suppression medications.

Radial tension-definition and diagnosis

Relaxing incisions are commonly used as component separation maneuvers during large and complex ventral hernia repair. The concept is that making a defect in an adjacent less critical area of muscle or fascia allows the tissues to come together in the area of interest. In the setting of PEH repair, relaxing incisions seem ideal because the diaphragm is theoretically available on each side, while repair of these new defects with mesh has almost limited downside, thus allowing easier crura approximation with reduced tension[5]. Posterior cruroplasty is the main step of laparoscopic PEH repair, while tension-free crural closure has always been indicated as crucial to achieving symptoms control and possibly reducing recurrence rate[3-5,34]. Reconstruction of the diaphragmatic crura cannot be exempt from a careful evaluation of the complex anatomical conformation and the forces that occur at the hiatus during everyday activities. In particular, the diaphragm moves 15,000-20,000 times a day with respiration and contracts vigorously with coughing, sneezing, or vomiting.

Radial tension is related to the splayed pillars that, in the case of large hernia, come together with substantial tension. This is not as easily recognized, and there are no universally accepted maneuvers that may simplify its assessment. For most surgeons, crural tension is assessed by tactile and visual clues during laparoscopic approximation[5,8]. However, these are prone to variability and have partial reproducibility[6]. To overcome these limitations and standardize the tension measurement at the hiatus, Bradley *et al.* first described a laparoscopic calibrated tensiometer (Brief Pain Inventory Medical, Fife, WA®)[4]. Specifically, the tension is measured by placing the hooks at the hiatus during approximation, while multiple measurements are taken. In the case that the tension is judged significant, relaxing incisions are considered.

Minimally invasive techniques and results

The use of relaxing maneuvers has an impact on the tension necessary to close the diaphragm and may theoretically translate into a minor recurrence rate[5]. Right- and left-sided relaxing incisions have been described[4,5]. The right-side incision is made by opening the right crus parallel to the inferior vena cava, saving a 3 mm cuff of tissue along the cava to allow a patch to be sewn in place. This incision entails a full-thickness section of the right crus into the right pleural space that should be opened before to exclude any possible adhesion with the parenchyma. The incisions start in the midportion of the right crus and ends below the anterior crural vein. The incision should not be extended inferiorly toward the aortic hiatus because the posterior crura always easily come together. Furthermore, the thoracic duct would be at risk of inadvertent injury. In contrast, the left-side incision starts to the left of the hiatus and follows the course of the seventh rib laterally, saving a 1-2 cm cuff of diaphragm adjacent to the rib. To gain sufficient relaxation of the left diaphragm, the incision may be extended lateral to the spleen. Attention should be paid to avoiding damage to the phrenic nerve with paralysis of the left diaphragm. After incision, the diaphragmatic defect is repaired with a polytetrafluoroethylene (PTFE) patch, while the crura is covered with an absorbable mesh.

Few published studies reported data for diaphragmatic relaxing incision during laparoscopic HH repair. Greene *et al.* in a 2013 retrospective study reported data on 15 patients who underwent paraesophageal hernia repair and received relaxing incision to achieve crural closure[5]. The relaxing incision was right-sided in 13 patients, left-sided in 1 patient, and bilateral in 1 patient. All procedures were completed laparoscopically and in all patients a fundoplication was fashioned [Nissen (n = 10) or Toupet (n = 5)]. The

diaphragmatic defect created by either relaxing incision was repaired with a PTFE patch, while crural closure was buttressed with absorbable mesh. The authors reported encouraging results in term of postoperative recurrence rate (10%) in a short-term follow-up (median 15 months) with 27% complication rate [pleural effusion (n = 3) and pulmonary embolism (n = 1)]. Similarly, Bradley *et al.* in 2014 reported outcomes for 33 patients who underwent PEH repair with concomitant relaxing maneuver: iatrogenic left pneumothorax without diaphragmatic incision (n = 12), right relaxing incision (n = 15), and both (n = 6)[4]. Left diaphragmatic incision was not performed. The authors described significantly reduced crural basal tension after left pneumothorax, left pneumothorax plus right diaphragmatic incision, and right diaphragmatic incision alone. They concluded that, when tension is deemed to be significant, creation of a left pneumothorax and/or a right diaphragm relaxing incision will significantly reduce tension. Alicuben *et al.*, in a retrospective 2014 article, reported data for 82 patients treated for symptomatic PEH[9]. Overall, 10 patients (12%) required crural relaxing incision to close the primary defect; specifically, the authors performed eight right side incisions, one left side one, and in one case the incision was bilateral. The most common postoperative complication was pleural effusion, managed successfully with percutaneous drainage in most of the patients.

To further reduce tension at the hiatus, different buttressing techniques for crural reinforcement have been described[35]. Even though their use is controversial, different type of meshes with various shapes (i.e., keyhole, reverse C-shape, U-shape, *etc*.) have been reported to reinforce the hiatus and possibly release crural tension[36]. A permanent synthetic mesh has been reported to reduce the hernia recurrence rate, but at the risk of infection, stricture, and esophageal-gastric erosion[37,38]. This seems related to the chronic "sawing" motion of the esophagus over the mesh with each swallow. An alternative to non-resorbable mesh is an absorbable or biologic mesh[39,40]. Absorbable meshes were introduced with the intent to decrease the hernia recurrence rate without the related morbidity of non-absorbable meshes. These may be biologic or synthetic. While their safety over non- absorbable meshes is often discussed, long-term efficacy and cost-effectiveness remain controversial. Theoretically, the ideal mesh should assist in reinforcing crural repair without undue tension, erosion, or dysphagia, combined with long-term durability. Unfortunately, the ideal mesh material has yet to be realized, and, nowadays, the SAGES guidelines conclude there is insufficient evidence for or against the use of mesh[41].

CONCLUSIONS

Axial and radial are two vectors of tension that should be considered when performing laparoscopic HH repair. Axial tension is assessed intraoperatively by a short esophagus (< 2 cm), which has an estimated incidence of up to 20%. Laparoscopic wedge fundectomy is the most commonly adopted minimally invasive technique for esophageal lengthening (Collis gastroplasty). Results related to lengthening procedures are heterogeneous with a not negligible risk of postoperative dysphagia and chronic GERD. Radial tension is not easily recognized, while its objective assessment and measurement are challenging. Different techniques for diaphragmatic relaxing incision have been described in an attempt to reduce radial tension; however, evidence is weak and results heterogeneous. Therefore, there are insufficient data to recommend these approaches.

DECLARATIONS

Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation: Aiolfi A, Sozzi A, Bona D

Performed data acquisition, as well as provided administrative, technical, and material support: Aiolfi A, Sozzi A, Bona D

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All authors declared that there are no conflicts of interest.

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Not applicable.

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