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POSITION PAPER

Reflections on surgery for hiatal hernia

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Abstract
Gastroesophageal reflux disease and hiatal hernia are highly prevalent, chronic, and heterogeneous disfunctions with a profound impact on patient's quality of life. Impairment of the antireflux barrier -which includes the lower esophageal sphincter, the gastroesophageal flap valve, and the crural diaphragm- is the main pathophysiological factor responsible for symptoms and complications. Accurate diagnosis mandates a comprehensive multidisciplinary assessment including upper endoscopy, high-resolution manometry, barium esophagram, and ambulatory pH or pH-impedance monitoring to characterize anatomical defects, motility abnormalities, and reflux severity. Well selected individuals with refractory or complicated reflux disease, and those with large hiatal hernia and intrathoracic stomach, may benefit from laparoscopic surgical management including crural repair and fundoplication to restore the antireflux barrier. Nissen fundoplication is highly effective in controlling reflux but it may be associated with postoperative dysphagia and gas-bloat syndrome. Partial fundoplication can offer comparable reflux control with reduced adverse effects, especially in patients with impaired esophageal motility. Novel devices such as the LINX and the RefluxStop show promise in augmenting the lower esophageal sphincter with favorable safety profiles. The role of mesh reinforcement for hiatal repair remains contentious due to unpredictable outcomes and risk of complications. Robotic-assisted surgery offers enhanced technical precision but has yet to demonstrate significant clinical superiority and incurs greater costs compared to laparoscopy. Artificial intelligence applications are emerging as valuable adjuncts for preoperative planning, intraoperative guidance, and postoperative monitoring, potentially improving procedural standardization and surgical outcomes.

Keywords Hiatal hernia · Gastroesophageal reflux disease · Antireflux barrier · Lower esophageal sphincter · Hiatoplasty · Fundoplication

Introduction

Gastroesophageal reflux disease (GERD) is a chronic pathological condition caused by the reverse flow of gastric contents into the esophagus resulting in persistent symptoms and potential complications. Affecting up to 20% of individuals in developed nations, GERD can markedly diminish quality of life and contribute to considerable healthcare expenditures. Although pharmacological management with proton pump inhibitors (PPI) represents the initial approach of choice, surgical intervention is often indicated in patients with refractory reflux symptoms and esophagitis/Barrett's esophagus, and in those with large hiatal hernia (HH) or intrathoracic stomach and obstructive symptoms. Recently, enhanced understanding of the interaction between the diaphragm and the esophagogastric junction has led to a more precise and personalized therapeutic strategy and potential for improved outcomes [1].

Pathophysiology of the antireflux barrier

The antireflux barrier constitutes a sophisticated anatomical-physiological system that serves to impede the retrograde movement of gastric contents into the esophagus,

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while allowing for minimal postprandial reflux, belching, and emesis. The main components of this system are the lower esophageal sphincter (LES), the gastroesophageal junction flap valve (GEFV), and the crural diaphragm (CD). The barrier establishes a high-pressure zone allowing the esophagogastric junction to resist challenges of both intragastric and intra-abdominal pressure without causing outflow obstruction. Incompetence of the LES is associated with decreased basal pressure and increased number of transient LES relaxations (TLESR). Cranial displacement of the LES and of the gastric acid pocket occurring in the presence of HH cause further increase of TLESR episodes and delayed clearing of the refluxate. Non-acid reflux, ineffective esophageal motility, impaired esophageal clearance, and heightened mucosal sensitivity contribute to the clinical manifestations and to the spectrum of tissue injury in GERD. Therefore, a comprehensive understanding of these complex mechanisms provides the foundation for surgical therapy aimed at restoring normal anatomy and function of the esophagogastric junction [2].

Clinical presentation and diagnostic pathway

Exclusive reliance on symptoms is inadequate to diagnose and properly treat patients with suspected GERD. An objective assessment requires a comprehensive and multidisciplinary diagnostic pathway to identify the disease phenotype, inform management strategies and optimize outcomes. Upper endoscopy enables to diagnose erosive esophagitis, Barrett's esophagus, strictures, and to appreciate the characteristics of the GEFP and HH. Barium esophagram is very useful and should be the first-line test in individuals presenting with dysphagia and suspected diverticula, achalasia, or large HH. High-resolution manometry (HRM) can provide detailed pressure topography of the esophageal body and LES to definitely rule out achalasia and possibly identify other esophageal motility disorders before surgical planning. It can also establish the extent of hiatal hernia by measuring separation between the LES and the crural diaphragm. Ambulatory 24-h pH monitoring or combined pH-impedance monitoring represent the gold standard for objective quantification of reflux burden. Conventional catheter-based probes are positioned proximal to the LES. Limitations include patient discomfort and impact on daily activity, potentially affecting the reliability of results [3]. The Bravo wireless telemetric pH monitoring system addresses these concerns by employing an endoscopically placed capsule that transmits pH data over 48 to 96 h. The extended monitoring period can enhance diagnostic precision and symptom correlation. The capsule is designed to detach spontaneously and pass through the gastrointestinal tract without requiring endoscopic removal [4]. The integration of all of the above diagnostic modalities enables precise characterization of anatomical abnormalities, motility disorders, and reflux pattern and severity, thereby guiding patient selection and tailoring surgical interventions.

Current surgical strategies for LES augmentation

Lifestyle modifications, changes in dietary habits, and pharmacological acid suppression are the first-line approach in most patients with GERD, but may be ineffective in some, especially those with refractory symptoms or large HH. Surgical intervention for GERD predominantly involves restoration of the antireflux barrier through crural repair and fundoplication. The Nissen fundoplication (360-degree wrap) remains the most standardized and extensively evaluated technique. High-quality evidence, including a landmark randomized controlled trial, demonstrated superior symptom control and mucosal healing compared to medical management, with success rates exceeding 85% at five years [5]. Previous studies have confirmed the efficacy and durability of the Nissen fundoplication [6–8]. Despite these strengths, Nissen fundoplication carries an increased risk of persistent postoperative dysphagia and gas bloat syndrome which are attributed to the tighter, circumferential wrap that may impair esophageal transit and the ability to belch and vomiting [9]. Partial fundoplication has been developed to reduce such adverse effects while maintaining effective reflux control [10]. The Toupet posterior 270-degree fundoplication offers a less constrictive wrap and show comparable reflux suppression but significantly lower rates of postoperative dysphagia compared to the Nissen fundoplication [11–13]. Recent meta-analyses of randomized trials demonstrated a significantly reduced incidence of postoperative dysphagia, gas-bloating, and flatulence with similar reflux symptoms control and patient reported outcomes measures for the Toupet fundoplication [14]. Standardization of the technique of Toupet fundoplication has been associated with improved outcomes, better procedure reproducibility, and easier teaching [15, 16]. Further, the anterior fundoplication has demonstrated favorable functional outcomes with less dysphagia and gas symptoms [17, 18]. Both the posterior and anterior partial wraps are particularly advantageous in patients with impaired esophageal motility, supporting individualized procedural selection [19]. Meta-analyses of randomized trials comparing Dor and Toupet fundoplication have shown that the postoperative dysphagia score was lower for Dor fundoplication. Nevertheless, esophageal acid exposure time, postoperative heartburn rate, and reoperation rate were higher among patients who underwent Dor fundoplication. There were no significant differences between the two techniques regarding regurgitation, inability to belch, and gas bloating [20–23].

Role of hiatoplasty

Since the CD represents a complementary sphincteric mechanism working in synergy with the LES, a well-executed hiatoplasty is fundamental for durable surgical success [24]. Precise and tailored closure of the diaphragmatic crura to reduce radial tension can augment the antireflux barrier and prevent hernia recurrence [25, 26]. Before repairing the crura, release of longitudinal esophageal tension by adequate mediastinal dissection to obtain at least 3 cm of tension-free intra-abdominal esophagus is mandatory. Hiatoplasty is typically completed using either interrupted or continuous non-absorbable sutures on the posterior crura to approximate the right and left crus. To achieve a more anatomical closure and reduce the potential for posterior esophageal misalignment—which could increase the risk of postoperative dysphagia—one or two additional lateral sutures may be placed on the anterior-left side, particularly in patient with large round-shaped hiatus [27, 28]. Also, a right crural relaxing incision has been reported to reduce radial tension [29]. The adjunctive use of mesh reinforcement for large hiatal defects remains debated. A comprehensive meta-analysis highlighted a lower recurrence rate with mesh placement but also reported significant complications such as mesh erosion or fibrosis, necessitating cautious application [30–32]. Newer biosynthetic meshes show promise in reducing adverse events, yet no consensus on routine use exists, emphasizing the need for tailored surgical plans [33, 34]. The choice of mesh placement and type of mesh is usually left to the operating surgeon feeling and personal expertise, thereby introducing significant inter-operator variability and selection bias. Hence, the decision to place a mesh could be standardized using an intraoperative "patient-tailored" algorithm that provides a more objective method for assessment of crural gap and tissue quality [35]. The utilization of biosynthetic absorbable mesh has been shown to provide satisfactory medium-term results in terms of minimized mesh-related complications and HH recurrence rate [36, 37].

Role of esophageal lengthening procedures and gastropexy

Although an extensive mediastinal dissection may be enough to obtain a sufficient length (3–5 cm) of tension-free intra-abdominal esophagus in most individuals, about 10% of patients appear at risk of recurrent HH because of unrecognized short esophagus, crura weakness, and/or a large hiatus gap [38]. Therefore, reducing axial esophageal tension by repositioning the EGJ entirely within the intra-abdominal cavity is critical. A transabdominal esophageal lengthening procedure (Collis-Nissen) [39–42] or a modified posterior Hill gastropexy [43] have been recommended to secure the antireflux repair below the diaphragm in some circumstances of suspected shortened esophagus.

Devices for LES augmentation

The magnetic sphincter augmentation (LINX) system consists of a flexible, expandable ring made of linked magnetic titanium beads implanted laparoscopically around the LES. The magnetic attraction between beads augments sphincter closure pressure without causing esophageal compression, yet allowing the ring to expand during swallowing, belching, or vomiting. Clinical efficacy of LINX procedure has been demonstrated in multiple prospective trials. A single-center study with 6 years of follow-up reported significant symptom improvement, with over 80% of patients discontinuing proton pump inhibitors (PPI) and normalization of esophageal acid exposure at 12 months [44]. A five-year follow-up study confirmed durable symptom control and patient satisfaction, with low rates of serious adverse events [45, 46]. Compared to Nissen fundoplication, LINX offers a favorable side effect profile, particularly regarding reduced gas bloat and ability to belch [47]. Recently, the device has also been introduced for the treatment of pathologic GERD after sleeve gastrectomy with promising medium-term results [48]. Dysphagia remains the most common complication, affecting up to 30% of patients early postoperatively but typically resolves or improves over time with dietary suggestions, steroids, or endoscopic dilation [49–51]. Additionally, the device is contraindicated in patients with MRI requirements above 1.5 Tesla; also, collagen disease and metal allergies may preclude its use. Device removal is rarely required for persistent symptoms or complications such as device erosion or migration [52–56].

The RefluxStop procedure represents a novel mechanical approach that differs from wrapping or constricting the LES. It is a small silicone implant positioned laparoscopically on the gastric fundus in a pre-shaped pocket and is designed to keep the LES and gastroesophageal flap valve in a stable intra-abdominal position [57]. The theoretic advantage lies in its minimal interference with esophageal motility, potentially reducing postoperative dysphagia or gas-related symptoms [58, 59]. Preliminary real-world data, indicate promising results with effective reflux symptom relief and improved esophageal acid exposure at short-term follow-up [60, 61]. A recent 5-year follow-up study in 44 patients showed significantly reduced GERD-HRQL and AET% up to 5 years. Patients demonstrated a rapid return to oral intake with minimal dysphagia and favorable quality of life scores [62]. However, this technology remains in early adoption phases with limited published data and small patient cohorts. Larger randomized controlled trials with

long-term follow-up are needed to validate efficacy, safety, and durability compared to already established procedures and devices.

Revisional surgery and emergency repair

Revisional surgery may be indicated in patients experiencing recurrent GERD symptoms, HH greater than 3 cm in axial length, or in those individuals presenting with severe postoperative dysphagia. Disruption of a prior fundoplication or crural repair is the most common clinical presentation [63]. Recent research suggests that, rather than being attributable solely to failure of previous posterior hiatoplasty, recurrence may result from progressive deterioration of the central tendon with enlargement of the anterior-left lateral diaphragm [64, 65]. In managing HH recurrence, it is therefore essential to identify and address the underlying mechanisms causing the persistent or recurrent symptoms. The previous fundoplication should be completely taken down and the wrap refashioned making sure to respect symmetry and avoid esophageal twisting. An intact and properly performed fundoplication herniated in the chest can be preserved and reduced in the abdominal cavity by further dissecting the mediastinum to gain further esophageal length [66]. Crural repair with possible mesh reinforcement may be considered in such circumstances to minimize the risk of re-recurrence, which may approach 20% [36]. Special care must be taken to visualize and preserve the posterior vagus nerve during revisional surgery to minimize the risk of iatrogenic injury, which can result in refractory gastroparesis or diarrhea [67–69].

Early onset of postoperative dysphagia due to hiatal stenosis or improper construction of the fundoplication -more commonly a Nissen wrap- at the index procedure, may also warrant revisional surgery [70, 71]. High-resolution esophageal manometry should be performed before revisional surgery to rule out pseudoachalasia and a partial fundoplication may be more appropriate for such patients [72].

Emergency surgical intervention may be indicated for patients presenting with acute onset obstruction or even perforation due to primary or recurrent large intrathoracic stomach with volvulus. Mediastinal dissection to achieve at least 3 cm of tension-free intraabdominal esophagus is essential. Gastric perforation with necrosis may require stapled resection. Even in such emergent scenarios, a minimally invasive approach with or without biosynthetic mesh reinforcement may be considered. Partial fundoplication and/or anterior gastropexy have also been described as adjunctive techniques [73–76].

Robotic surgery

Multiport and single-port robotic surgery has emerged as a promising modality for the management of HH, providing increased surgical precision relative to conventional techniques [77]. Advanced robotic platforms afford surgeons enhanced dexterity and three-dimensional visualization, facilitating precise dissection and suturing within the confined anatomical space of the hiatus [78]. Nonetheless, recent data from observational studies and meta-analyses indicate no significant differences in patient outcomes, including postoperative dysphagia, regurgitation, gas bloat, or HH recurrence, when compared to traditional approaches [79, 80]. Furthermore, robotic procedures may be associated with higher risk of pulmonary embolism [81]. Last but not least, extended operative times and increased costs due to specialized equipment and maintenance should be considered.

Artificial intelligence and antireflux surgery

Artificial intelligence (AI) is increasingly transforming surgical care by enhancing preoperative planning, intraoperative precision, and postoperative outcomes. Machine learning algorithms analyze extensive preoperative datasets—including high-resolution manometry, pH-impedance monitoring, and imaging studies—in an attempt to stratify patients and predict surgical success [82]. Also, laparoscopic and robotic video-data capture and analysis can contribute to procedural standardization and reduced variability in surgical outcomes [83, 84]. Patients at higher risk of postoperative complications like dysphagia or HH recurrence may be identified by AI-driven predictive modeling, enabling surgeons to provide individualized treatment strategies [85, 86]. Intraoperatively, AI integration with robotic surgical systems offers augmented visualization, motion scaling, and real-time feedback, improving the accuracy of hiatal dissection, crural repair, and wrap construction [87]. Novel AI-enhanced imaging techniques may assist in precisely defining anatomic landmarks and tissue planes, reducing operative time and technical variability [88]. Postoperative monitoring based on AI-based analysis of patient-reported outcomes and telemetry may facilitate early detection of complications and guide timely interventions. Furthermore, surgical databases powered by AI support quality improvement through outcome benchmarking and identification of best practices. Although still in early stages, AI-assisted surgery holds significant promise for advancing safety, precision, standardization, and personalization of surgical therapy for GERD and HH. Continued research and collaboration between surgeons, data scientists, and engineers are essential to translate AI innovations into clinical reality.

Conclusion

Hiatal hernia and GERD represent intertwined pathological conditions greatly impairing patients' health. Surgical intervention consisting of precise hiatal repair combined with fundoplication is pivotal in managing patients with refractory GERD and complex HH. The role of mesh in reinforcing the hiatoplasty remains controversial. The choice among different types of fundoplication and novel device-based options should be individualized based on GERD phenotype and physiological assessment. Responsible development and integration of AI into the diagnostic and therapeutic pathways holds great promise.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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