



# Application of robotic surgery for paraesophageal hiatal hernia repair: a narrative review

Tyler R. Grenda<sup>1</sup>, Rishindra M. Reddy<sup>2</sup>

<sup>1</sup>Division of Thoracic Surgery, Sidney Kimmel Medical College, Philadelphia, PA, USA; <sup>2</sup>Section of Thoracic Surgery, University of Michigan, Ann Arbor, MI, USA

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*Correspondence to:* Tyler R. Grenda. 211 S 9th Street, Suite 300, Philadelphia, PA 19107, USA. Email: tyler.grenda@jefferson.edu.

**Background and Objective:** Paraesophageal hiatal hernia (PEH) repair has undergone evolution from open approaches (e.g., laparotomy, thoracotomy) to minimally-invasive techniques with laparoscopy. While the laparoscopic approach has offered decreased morbidity, issues related to PEH recurrence persist. As a result, there has been a continued need for innovation of PEH repair techniques to address recurrence. Increased uptake in robotic surgery has allowed for application of this technology to PEH repair. While increasing in adoption, the efficacy of robotic approach to PEH continues to undergo evaluation.

**Methods:** We performed a review of randomized and non-randomized studies surrounding robotic-assisted PEH repair using PubMed/MEDLINE. We evaluated the literature across aspects pertaining to perioperative outcomes, long-term outcomes, and costs compared to traditional surgical approaches. There were no publication date restrictions.

**Key Content and Findings:** Current literature suggests that robotic PEH repair is feasible and offers perioperative outcomes similar to standard laparoscopic approaches. Limited reports of long-term outcomes, specifically related to PEH recurrence and patient-reported outcomes, suggest the efficacy of robotic PEH repair. Initial cost comparisons with standard laparoscopic approaches demonstrate similar intraoperative costs, but are limited and continue to be evaluated. In addition, there is data suggesting robotic PEH repair may be applicable to large PEH (>30% intrathoracic stomach).

**Conclusions:** Review of current literature suggests that robotic PEH repair is feasible and has similar perioperative outcomes when compared to standard laparoscopic techniques. The learning curve for transition from laparoscopic to robotic PEH repair needs to be considered, even among experienced laparoscopic surgeons. Future prospective multi-institutional studies will be needed in order to fully evaluate the value (quality/costs) of robotic PEH repair to ensure efficacious and cost-effective adoption.

**Keywords:** Paraesophageal hiatal hernia (PEH); robotic-assisted; minimally-invasive

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## Introduction

Surgical management of paraesophageal hiatal hernia (PEH) has evolved over time from the first report of elective hiatal hernia repair in 1919, to established open surgical approaches (e.g., laparotomy, thoracotomy), to minimally-invasive laparoscopic techniques (1). Despite laparoscopy

becoming the most common approach to PEH repair due to low morbidity, there are still concerns related to long-term rates of recurrence, with or without the use of mesh (2-4). The dissemination of robotic surgical technology and high recurrence rates have driven further innovation and allowed for the application of this technology to PEH repair. As

**Table 1** Literature search strategy summary

Items	Specification
Date of search	2021
Databases and other sources searched	PubMed/MEDLINE
Search terms used	Paraesophageal hiatal hernia, robotic-assisted, laparoscopic, type III hiatal hernia, recurrent hiatal hernia, minimally-invasive
Timeframe	No date restriction
Inclusion and exclusion criteria	English language only
Selection process	Authors reviewed selected studies

a result, experience with PEH repair has been growing with an increasing body of literature surrounding excellent outcomes related to robotic approaches (5). Consequently, there has been increasing enthusiasm surrounding robotic PEH approaches.

While experience robotic surgery has been growing, conclusions regarding the role of robotic surgery compared to traditional approaches for PEH repair have not been definitively established (6). As a result, questions surrounding the robust evidence to demonstrate the efficacy of robotic surgery compared to established approaches have been raised (7). Evaluations of robotic PEH repair have examined across several areas, including perioperative outcomes, recurrence, and costs. This has resulted in a limited, but growing body of literature detailing the feasibility and safety of robotic PEH repair. In addition, studies have begun to examine costs as a critical aspect of the value analysis for application of robotic approaches to PEH repair (8). Given the body of literature surrounding robotic PEH repair, a more extensive review of literature is needed to examine the current utility of PEH repair compared to other traditional approaches (e.g., laparoscopic, transthoracic).

In this context, we searched peer-reviewed literature surrounding robotic-assisted PEH repair. We evaluated the literature across aspects pertaining to perioperative outcomes, long-term outcomes, and costs compared to traditional surgical approaches. We present the following article in accordance with the Narrative Review reporting checklist (available at <https://vats.amegroups.com/article/view/10.21037/vats-21-44/rc>).

## Methods

We performed a review of randomized and non-randomized

studies surrounding robotic-assisted PEH repair using PubMed/MEDLINE (*Table 1*). We identified studies that were published in English language. There were no publication date restrictions.

Randomized controlled trials, prospective observational, and retrospective cohort studies were included. We evaluated the literature across aspects pertaining to perioperative outcomes, long-term outcomes, and costs compared to traditional surgical approaches. Studies were evaluated for inclusion based on title and abstract. The authors then performed a more detailed review of the full manuscript for inclusion.

## Evolution of robotic surgery to PEH repair

The traditional approach for PEH repair was open surgical repair performed through a laparotomy or thoracotomy (9). As experience with laparoscopic gastrointestinal surgery increased, there was adoption of laparoscopic techniques to PEH repair (10-14). With growing case volume and experience, comparisons between laparoscopic techniques and standard open approach have emerged. In initial comparisons, laparoscopic PEH demonstrated improvements in short-term outcomes, with decreased length of stay and lower perioperative morbidity when compared to open PEH repair (15). Further comparisons between open and laparoscopic approaches have continued to support the benefits of laparoscopic repair (16-19). Despite improvements observed with the adoption of laparoscopic approaches and significant experience that has been achieved, high rates of recurrence have been observed exceeding 50 percent at long-term follow up, even with the addition of mesh (4,20). As a result, a focus has been placed understanding and mitigating the risk of PEH recurrence (4,21).

As robotic technologies emerged, there was expansion across a growing number of surgical procedures (6). As adoption broadened and extended to foregut procedures such as Nissen fundoplication, there was eventual application to more complex procedures, such as PEH repair. Initial reports of robotic hiatal hernia repair, detailed the potential surgeon advantages of robotic technology compared to standard laparoscopy, including increased degrees of freedom during intrathoracic dissection through a narrow hiatus, three-dimensional view, and intracorporeal suturing advantages (22).

With extension of robotic technology to PEH, reports began to emerge detailing the experience and outcomes of robotic PEH repair (23,24). As a result, initial experiences with application of robotic technology to PEH began to grow. With emerging data evaluating the feasibility of robotic approaches, there was a new focus to evaluate the efficacy of robotic PEH repair compared to standard operative approaches.

### Perioperative and short-term outcomes

Previous literature has evaluated the utility of robotic surgery with respect to conventional laparoscopic surgery for perioperative outcomes (25). As robotic technology expanded to foregut surgery, randomized trials evaluated the utility of robotic Nissen fundoplication for gastroesophageal reflux disease, highlighting feasibility and safety compared to laparoscopic surgery (26,27). However, higher costs and longer operative times were observed in the robotic groups. As robotic technology expanded from procedures such as Nissen fundoplication to be applied to PEH repair, there were early reports detailing the experience (23). In an early small retrospective review of a single surgeon's series of patients undergoing robotic Nissen fundoplication and robotic PEH repair, there were similar short-term outcomes, including length of stay, operative time, and morbidity between the two groups (23). This study concluded that the skills necessary for robotic Nissen fundoplication could be applied to robotic PEH repair.

With no randomized trials to specifically compare robotic PEH repair to standard laparoscopic repair, there are several single institution studies evaluating short-term outcomes of the robotic approach (28-31). In a retrospective cohort study of 392 large or PEH repairs (278 laparoscopic; 114 robotic), there was no significant difference in operative time (175 *vs.* 179 min;  $P=0.08$ ) or perioperative morbidity. Recurrence at one year (radiographic or endoscopic

detection) was observed to be lower in the robotic group (13.3% *vs.* 32.8%;  $P=0.008$ ) (32). There were no specific details of the perioperative complication profile.

In one of the largest studies to date, a single surgeon's series of 1,854 patients (830 robotic; 1,024 laparoscopic) from 2009 to 2019 demonstrated that the robotic group had decreased conversion to open (e.g., laparotomy, thoracotomy) (0% *vs.* 7%), shorter operative time (174.1±63.8 *vs.* 187.3±65.3 min;  $P<0.001$ ), and decreased intraoperative injury (0.6% *vs.* 2.7%;  $P<0.001$ ). While the authors note intraoperative injury, thromboembolic events, and 30-day in-hospital mortality, there was not a detailed account of more specific complication profile (8). In addition, the authors noted that only one patient in the robotic group required esophageal lengthening procedure, suggesting that the robotic platform facilitates improved access to mobilize the esophagus higher in the mediastinum (33).

When evaluating national perioperative outcomes, Ward and colleagues performed a retrospective analysis of 168,329 patients undergoing laparoscopic ( $n=158,432$ ) or robotic ( $n=9,897$ ) PEH repair from 2010–2015. Overall, the study demonstrated a significantly higher incidence of overall adjusted rate of complications in the robotic group (OR =1.17, 95% CI: 1.07–1.27). More specifically, the authors noted an increased risk of respiratory failure (OR =1.68, 95% CI: 1.37–2.05) and esophageal perforation (OR =2.19, 95% CI: 1.42–3.93) in the risk-adjusted analysis across all hospitals, regardless of volume. Furthermore, the authors noted significantly higher complication rates in the robotic group even at high-volume centers (>20 operations per year) (34).

### Long-term outcomes

The issue related to recurrence observed following laparoscopic PEH repair, the current standard of care, highlights the importance of following long term outcomes to assess efficacy of application of robotic technology to this procedure (20). While short-term outcomes have demonstrated the feasibility and safety of robotic-assisted PEH repair, there is a paucity of data evaluating long-term outcomes. As a result, focus must be placed on long-term outcomes, such as recurrence and patient-reported outcomes.

In a large prospective study of 233 patients undergoing robotic PEH repair from 2010 to 2014 at a tertiary medical center, radiographic recurrence at 5 years (62% follow up

at 5 years) was 9%. In addition, the investigators observed a significant improvement in the GERD-HRQL score at 5 years (35). The most common symptoms in the follow up cohort at 5 years were “heartburn” (8.3%), bloating (7.6%), and regurgitation (5.5%). Similarly, Vasudevan and colleagues performed a retrospective review of 28 patients undergoing robotic PEH repair over a 2-year period and found a low rate of symptomatic recurrence (1 patient; 3.4%) during the 12-month follow up period (5).

The use of mesh cruroplasty and its influence in recurrence has been a focus of debate for PEH repair. Recent data has suggested that there are no advantages of mesh with respect to long-term outcomes (4). The body of robust data related to use of mesh cruroplasty is based in the traditional laparoscopic approach. There are no specific trials comparing the efficacy of utilization of mesh versus primary crural repair in a robotic cohort. As a result, it is difficult to derive conclusions related to any beneficial effect of mesh beyond what has been published in the traditional laparoscopic approach.

### Costs

There have been concerns surrounding costs related to the application of robotic technologies to a growing number of procedures. With the increased focus on value (e.g., ratio of quality/costs) related to surgical care, costs have been another key area of comparison for robotic procedures (36). Previous literature has raised the concern that robotic surgery may be more costly when compared to traditional approaches (37,38). While the safety of robotic surgery has undergone evaluation to examine the clinical rationale for adoption, analyses of cost efficiency of potentially expensive resources is important to examination of robotic application to PEH repair.

Gerull and colleagues series of 1,854 patients undergoing laparoscopic or robotic-assisted PEH repair demonstrated that a 2-year subset of intraoperative equipment costs were reported as similar between robotic and laparoscopic approaches (\$2,147±312.5 *vs.* \$2,058±345.5) (8).

### Learning curve

There has been limited data examining the learning curve for robotic PEH repair. There has been some data detailing potential challenges in the transition from laparoscopic to robotic-assisted hiatal hernia repair (39). However, has been some evidence suggesting a relatively short learning curve

in surgeons proficient in laparoscopic repair (40). When limited to patients undergoing any hiatal hernia repair, a retrospective review of a single surgeon’s experience of 169 patients demonstrated the learning curve according to three distinct phases: initial training phase (cases 1–40), improvement phase (cases 41–85), and mastery phase (case 86 and beyond) (41). Another single institution retrospective study of 61 patients undergoing robotic-assisted PEH repair, demonstrated a steep learning curve using operative time as a metric. Measurable change in operative time was observed as early as case 16 and there were sustained improvements until case 30, suggesting a relatively short learning curve (42). Consideration of competency-based pathway may need to be needed in order to ensure safe robotic skill acquisition (43).

### Special considerations

While most literature has focused on initial PEH repair, there has been application across PEH in the recurrent setting. Patients undergoing repair in the recurrent setting pose a more complex clinical scenario, as this is typically associated with increased morbidity and poorer functional outcomes (44). A single institutional retrospective study of 298 patients (247 primary repair, 51 recurrent) comparing robotic primary repair to recurrent PEH demonstrated that robotic approach in the recurrent setting was associated with longer operative times, increased length of stay, and increased utilization of mesh (45). However, similar perioperative outcomes were observed among the two groups.

Additional literature has examined the feasibility of the robotic approach in the giant PEH (>30% of intrathoracic stomach) setting (46). Sarkaria and colleagues presented a case series of 24 patients undergoing robotic-assisted giant PEH repair and found short-term perioperative and functional outcomes to be similar to laparoscopic approaches (40). A retrospective study of 19 patients undergoing robotic repair of giant PEH demonstrated similar morbidity to laparoscopic repair (47).

### Conclusions

Increasing diffusion of robotic technology across surgical procedures has allowed for a growing experience of robotic PEH repair. While the literature surrounding robotic PEH repair continues to mature, current data suggests that robotic PEH repair is feasible and offers perioperative

outcomes similar to standard laparoscopic approaches. Limited reports of long-term outcomes, specifically related to PEH recurrence and patient-reported outcomes, suggest the efficacy of robotic PEH repair. Limited cost comparison data with standard laparoscopic approaches demonstrate relatively similar intraoperative costs, but are limited and will require continued evaluation. Furthermore, the learning curve for transition from laparoscopic to robotic PEH repair needs to be considered, even among experienced laparoscopic surgeons. Future large multicenter studies will be needed to continue to compare the value of robotic PEH repair. In addition, additional data evaluating the long-term outcomes, including hernia recurrence and patient-reported outcomes will be needed to fully evaluate the value (quality/costs) of robotic PEH repair to ensure efficacious and cost-effective adoption.

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## Footnote

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