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Research Article

Systematic Review and Meta-Analysis of Robotic-Assisted and Laparoscopic Paraesophageal Hernia Repair

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Abstract

Robotic methods undoubtedly provide surgeons with better visibility and maneuverability. Regarding the treatment of paraesophageal hernia, there are only a few studies comparing laparoscopic and robotic surgery in terms of overall postoperative complications, operative time, hospital stay pain and vice versa. Scopus and Cochrane included only comparative studies. Studies on other types of hiatal hernia or children were excluded. The comprehensive analysis was performed using SPSS Statistics version 29.0.0. 10 comparative studies with a total of 186,259 participants were included in the meta-analysis, but unfortunately not all studies reported the full range of effects. There seems to be no difference between conventional laparoscopic and robotic-assisted surgery in terms of total postoperative complication rate [z=-1.65, 95% CI (-2.09, 0.10), p-value = 0.10 > 0.05], mean operative time [z=1.22, 95% CI [-4.25, 18.34], p=0.22 > 0.5] and hospital stay [z=-1.54, 95% CI (-0.48, 0.06), p-value = 0.12 > 0.05]. Only two studies reported evidence of recurrence. Paraesophageal hiatal hernia repair. However, some studies focused on costs and patient characteristics in each group. More comparative and controlled studies with longer follow-up periods are needed to draw more definitive conclusions about the short- and long-term outcomes of each approach.

Keywords: *Paraesophageal, hiatal hernia, laparoscopic, robotic, mesh.*

Introduction

Minimally invasive surgery has become the treatment of choice for many abdominal surgeries, including hiatal hernia repair, as it reduces postoperative pain, facilitates patient mobility, and shortens hospital stay. Laparoscopic hiatal hernia repair is a time-consuming and technically challenging procedure and is generally considered to have two disadvantages: lack of depth due to both visual acuity and limited operation. Robotic service, on the other hand, provides better ergonomics, three-dimensional vision, better access to the mediastinum, and a variety of movements, including wrist movement of the instrument, which is crucial for suture or mesh placement, but also comes with a higher price. The aim of this study is to investigate whether robotic treatment of paraesophageal hernia is better than traditional laparoscopic surgery in terms of morbidity

and operating hours, and therefore whether it is value for money through a review and analysis. Using the PICO method to ask the research question: Is robotic surgery (intervention) better than laparoscopic surgery (comparison) in terms of postoperative complications (comparison) and length of stay in male and female patients with hiatal hernia over 18 years of age (population)? operating time and recurrence (specific)?

Methods

Eligibility criteria

Inclusion criteria

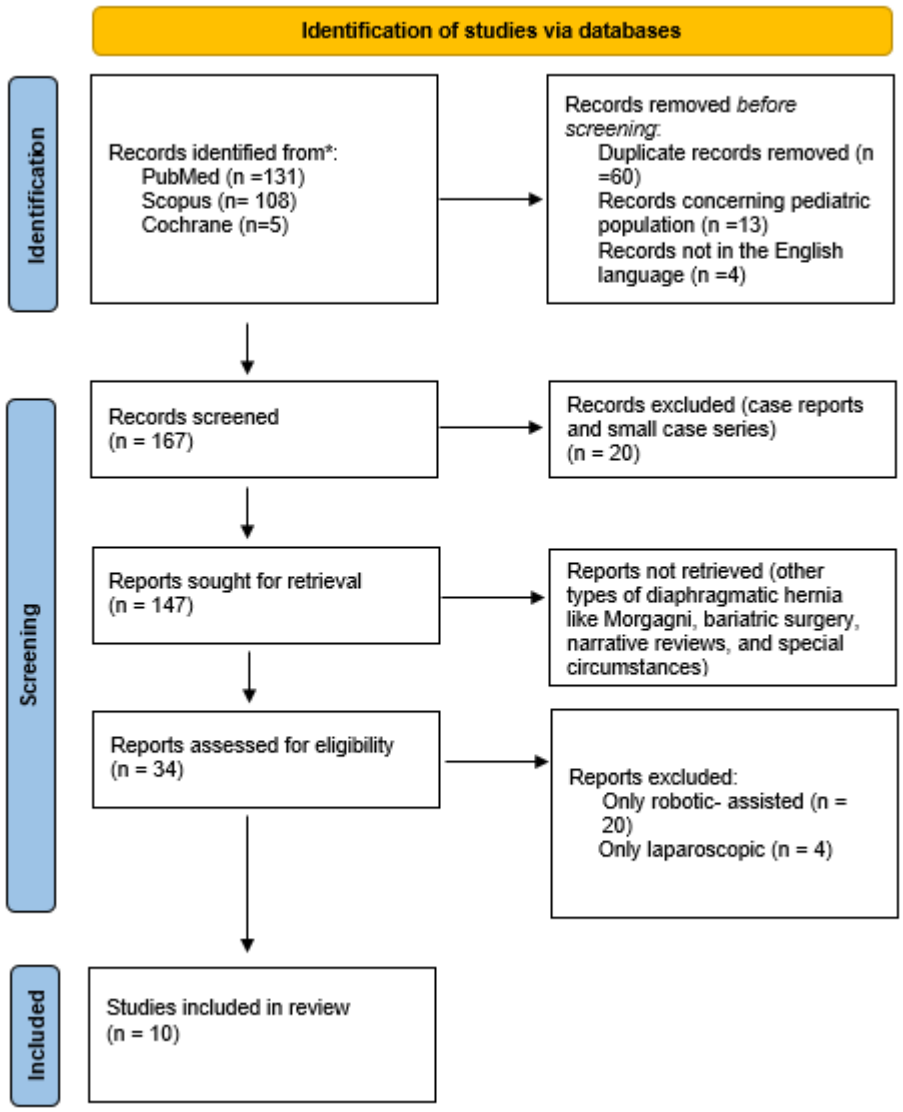
Only comparative studies of robotic and laparoscopic paraesophageal hernia repair in adults were included in the study.

Exclusion criteria

Case reports, small case series, articles not in the English language, as well as articles concerning patients younger than 18 years old were excluded from the study. In addition, articles about other types of diaphragmatic hernia repair like Morgagni, Bochdalec, iatrogenic, post-esophageal, are excluded from this study.

Search strategy

On 1st December 2022, a comprehensive literature search of Medline, Scopus, and the Cochrane Library was conducted, using the keywords robotic AND laparoscopic AND hernia AND (hiatal OR paraesophageal OR diaphragmatic). The evaluation of the studies was performed by two reviewers who worked independently. The design of the study was performed according to the PRISMA 2020 guidelines. No automation tools were used. The study is focusing on the hiatal hernia repair and not the fundoplication technique.



SPSS Statistics version 29.0.0 was used for the meta-analysis and the results are presented in Forest plots. Egger's test was used to estimate publication bias, which is illustrated in Funnel plots. Any missing results were excluded from the analysis. Equations provided by the Cochrane Library were used to estimate missing standard deviations in cases of continuous variables. The random effects model was used for continuous or binary variables and the effect was considered statistically significant when the p-value was below 0,05.

The overall postoperative complications, the mean operation time, the hospital length of stay, the estimated blood loss, and the recurrence rates, are the outcomes intended to study in this review.

The data collected from the studies included in the review are presented in tables 1, 2 and 3.

Table 1: Data for postoperative complications

	Participants (n)		Overall postoperative complications (n)		
Study (year)	Laparoscopy	Robotic	Laparoscopy	Robotic	p-value
gehrig (2012) [1]	17	12	2	1	0,765
soliman (2019) [2]	151	142	29	9	
ward (2020) [3]	158432	9897	17843	1321	
hosein (2020)[4]	6774	835	250	16	0,05
benedix (2021) [5]	85	55	11	6	0,8
Tjeerdsma (2022)[6]	16	42	15	5	0,749

Table 2: Data for length of stay and estimated blood loss

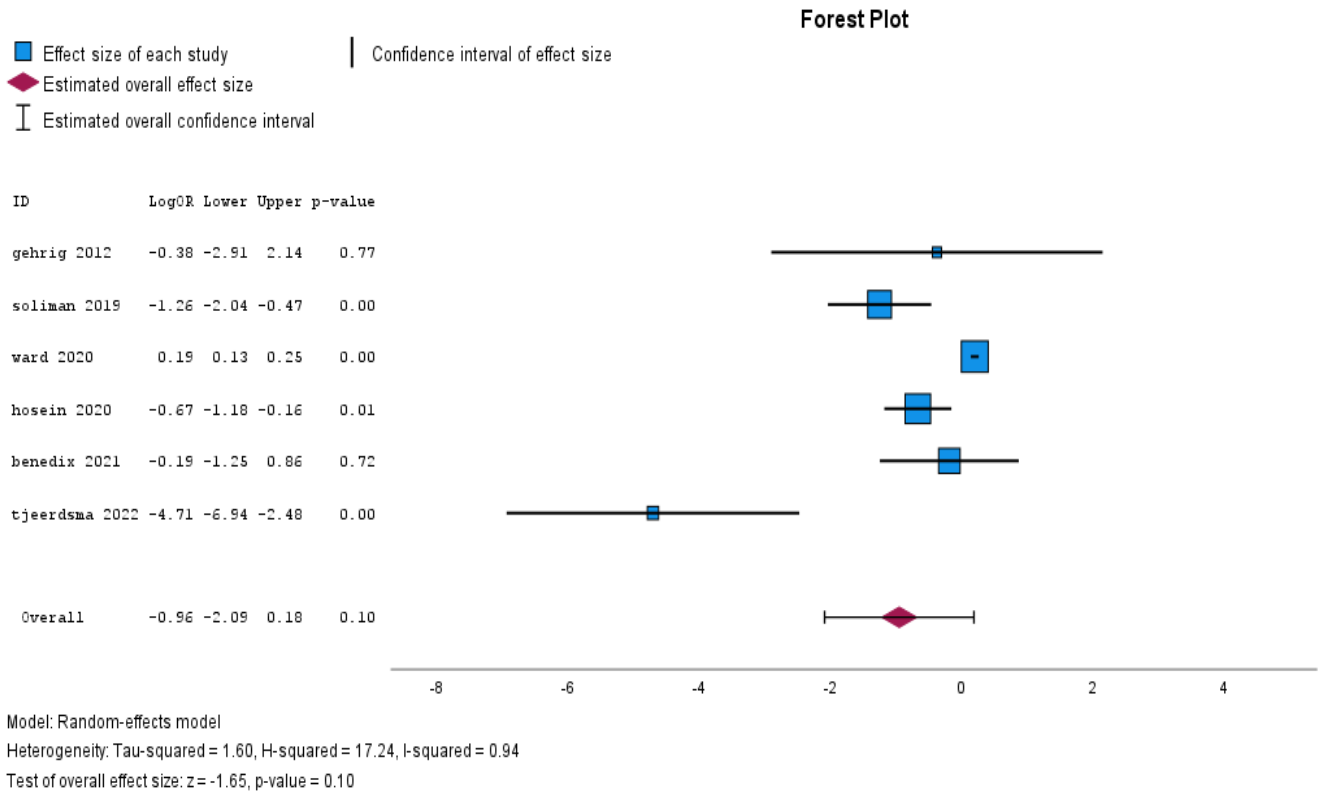
	Participants (n)		Length of stay (days)			Estimated blood loss (ml)		
Study (year)	Lap	Robotic	Lap	Robotic	p-value	Lap	Robotic	p-value
gehrig (2012) [1]	17	12	6,5	7,8	0,272	24	33	
soliman (2019) [2]	151	142	1,8	1,3	0,003			
o'connor (2020) [7]	278	114	3,3	2,3	0,003			
gerull (2020)[8]	1024	830	2,9	1,8	0,001	89,3	27,3	0,001
hosein (2020) [4]	6774	835	3,9	3,44				
Kulshrestha (2021) [9]	5962	1520	2	3	0,001			
benedix (2021) [5]	85	55	4	3,6	0,2	44,2	57,2	0,25
lekarczyk (2022) [10]	42	31	2,55	2	0,09			
Tjeerdsma (2022) [6]	42	16	2,5	3	0,301			

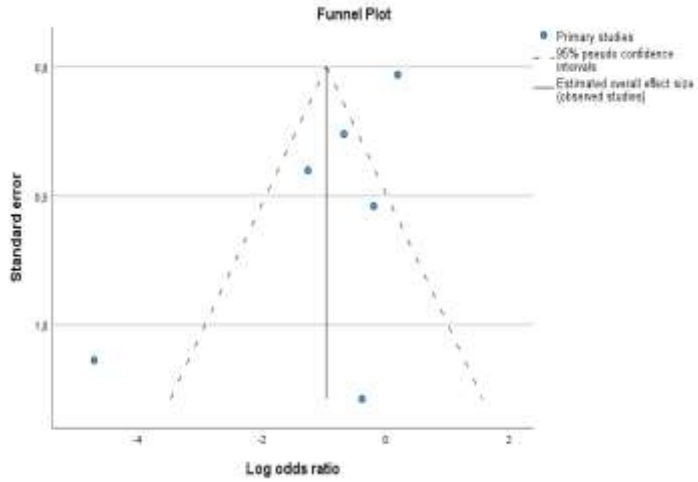
Table 3: Data for operation time

	Laparoscopic (n)	Operation time (min)	Robotic (n)	Operation time (min)	p-value
Gehrig (2012)	17	168	12	172	0,785
Soliman (2019)	151	158	142	186,5	0,001
o'connor (2020)	278	175	114	179	0,681
Gerull (2020)	1024	187,3	830	174,1	0,001
Benedix (2021)	85	125	55	149	0,01
Lekarczyk (2022)	42	256,7	31	257,6	0,48

Results

Only 6 studies provided enough evidence about the overall postoperative complication rates.



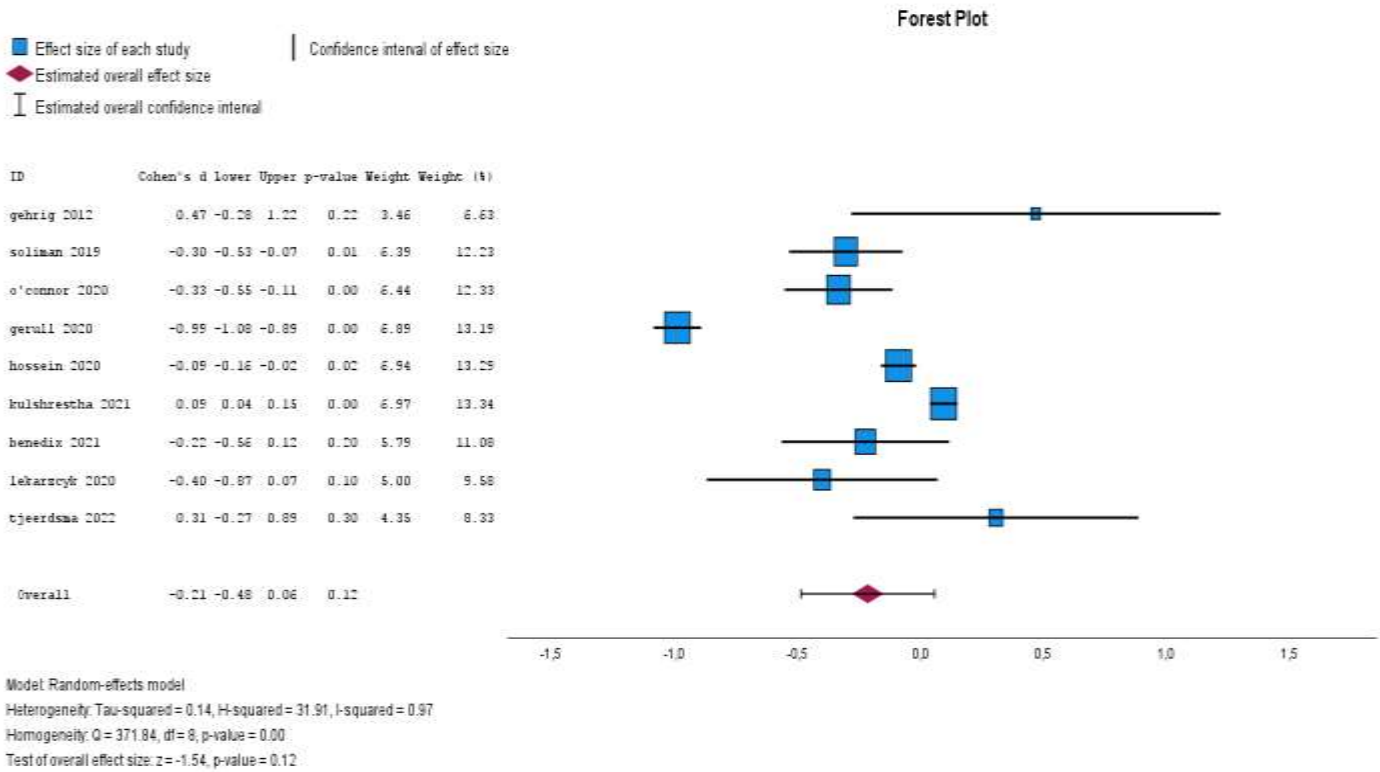


Ward et al [3] published the study with the most participants, from the National Inpatient Sample database during the time period 2010-2015, and reported that the complications in the robotic group were significantly higher OR (95%CI)= 1,17 (1,07, 1,27), and specifically respiratory failure [OR (95%CI)= 1,68 (1,37, 2,05)] and esophageal perforation [OR (95%CI)= 2,19 (1,42, 3,93)], even in high volume centers. On the other hand, Soliman et al [2] reported that older age and laparoscopic approach were associated with more postoperative complications, but it was not a randomized study. According to the meta-analysis, there is no statistically important difference considering the overall postoperative complications rates between laparoscopic and robotic hiatal hernia repair; z=-1.65, 95% CI (-2,09, 0,10), p-value= 0,10> 0,05. Egger's test p-value= 0,867.

Some of the most frequent complications are dysphagia, pleural effusion [5], pneumonia, venous thromboembolism, cardiac failure [3], atrial fibrillation [11], atelectasis, delayed gastric emptying, wound infections [1], thoracic or abdominal infections [11], and Mediastinitis.

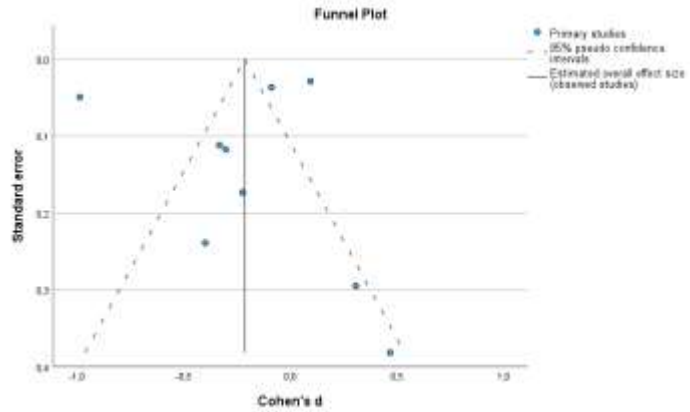
Regarding the intraoperative complications, the most common are bleeding [5], perforation [6] and pneumothorax [1]. An important information missing from the majority of the studies is the type of fundoplication used and whether a mesh was placed or not.

Another area of interest is whether robotic-assisted hiatal hernia repair is related with shorter hospital length of stay (LOS). 9 out of 10 studies provided data about the LOS.

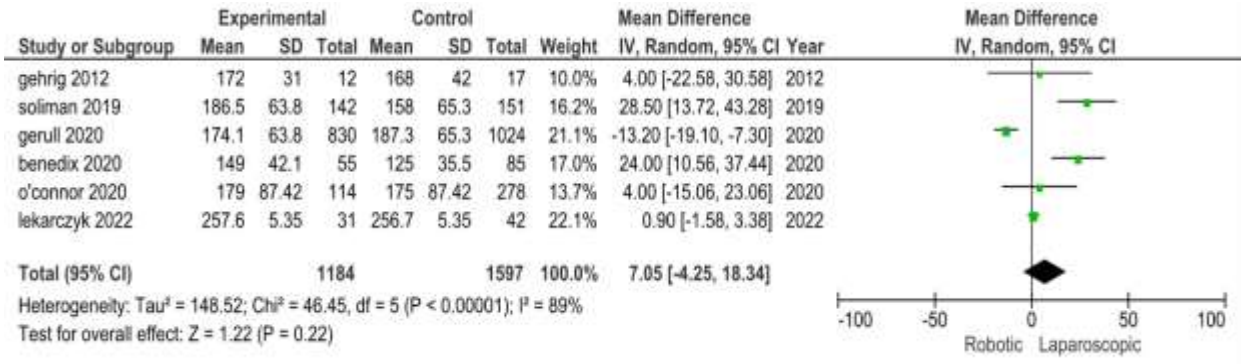


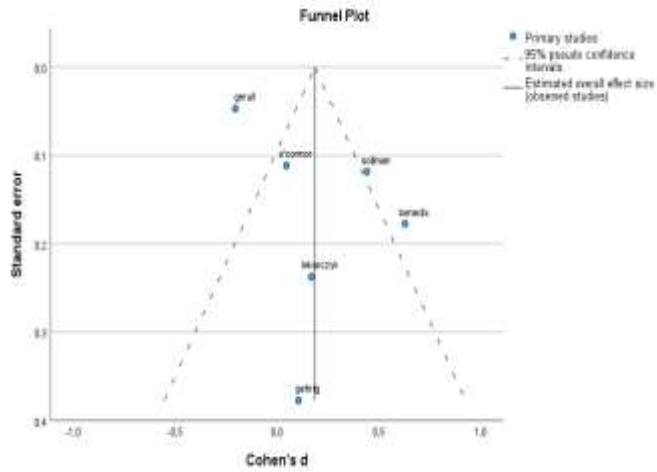
There was no statistically significant heterogeneity among the studies, and neither publication bias (Egger's test= 0.84>0.05, 95% CI -0.973, 0.78), as shown in the funnel plot. According to the meta-analysis, there is no statistical significance considering the LOS between the robotic and the laparoscopic approach; RE z=-1,54, 95% CI (-0.48, 0.06) , p-value= 0.12> 0.05.

Although the meta-analysis proved equivalent results regarding the length of stay, a considerable number of studies, as shown in Table 1, reported shorter hospitalization in the robotic group. A different adaptation of Enhanced Recovery After Surgery (ERAS) protocols might be the explanation to this fact. [7]



Concerning the mean operation time, only 6 studies provided information about this outcome.





There is no significantly important difference concerning the operation time between robot-assisted and laparoscopic hiatal hernia repair; z=1,22, 95% CI [-4.25, 18.34], p=0,22> 0,5. Regarding publication bias, Egger's test's p value= 0.910 >0.05, so there is no significant important publication bias, as illustrated in the funnel plot. However, it should be noticed that the operation time might decrease over time, as for example mentioned by Benedix et al [5], as the surgeons become more experienced. This notice might consist a learning curve bias especially for small size studies. The surgeons who performed the operations reported by Soliman et al [2] had little or no experience with the robotic surgery. In addition, mesh placement, which might affect the operation time, is mentioned in only two studies. [5, 6] O' Connor et al [7] reported that mesh placement was performed more frequently in the laparoscopic group with a p-value < 0,001.

Only three studies provided evidence in regards to estimated blood loss. Gehrig et al [1] stated that there is no statistical important difference between laparoscopic and robotic group.

Not enough data were provided concerning the recurrence rates in order to perform the meta-analysis. Only O' Connor [7] et al stated that the robotic group had a lower radiologic recurrence rate (13,3% compared to 32,8% in the laparoscopic group, with a p-value= 0,008) in a one-year follow-up.

Unfortunately, all of the studies included in the meta-analysis are retrospective and none of them is

randomized.

Discussion

Robotic- assisted surgery is becoming more and more popular among surgeons, since it overcomes the technical difficulties of conventional laparoscopy. Its safety and efficacy has been proven even for oncologic procedures, while its cost has been justified for procedures with limited anatomic space, such as radical prostatectomy, low anterior resection and bariatric procedures. Especially for the paraesophageal hernia repair, which is a technically challenging procedure, demanding high mediastinal dissection, complete removal of the hernia sac, a low- tension hiatal reconstruction with sutures, with or without mesh placement, robotic technology seems a very useful tool to overcome these difficulties, restricting the need to conversion to open surgery [12] [13]. However, according to the presented meta-analysis, the short-term outcomes with regard to operation time, length of stay and post-operative complications are equivalent, whereas there is not enough data in the literature concerning the long-term outcomes and specifically the recurrence rates.

Robotic approach might be very useful for the repair of recurrent or complex hiatal hernias [7], which are accompanied by higher morbidity and mortality as well as less satisfactory symptomatic outcome [14]. Seetharamaiah et al [15] reported a series of nineteen robotic repair of giant paraesophageal hernias, with only two surgery related complications, one conversion to open approach and no recurrence in a mean follow up period of 15,6 months. Taking into consideration that the majority of complications are pulmonary events and pneumonia, the robotic approach enables better visualization and ergonomics during the dissection of the hernia sac from the delicate pleura. [7] In addition, it provides high quality hiatal reconstruction and suturing even in the reoperative field, which is characterized by changed anatomical planes and demands extensive adhesiolysis. As a result, the surgeons, being aware of the capabitities of the robot, feel more confident, a fact which explains the lower conversion to open procedure rates for redo hiatal hernias [14]. The conversion rate for redo hiatal hernias with the laparoscopic approach might be as high as 11% [16] . Gerull et al [8] also reported a higher percentage of redo hernias in the robotic group, as well as lower percentage of esophageal lengthening procedure, such as Collis gastroplasty and wedge fundectomy. Mertens et al [11] presented a large series of both primary and redo robotic assisted hiatal hernia repair with major complication rate up to 5,2% and 2,6% respectively, while the incidence of complications of any severity were 17,1% and 10,6%, indicating that the low number of complications in the redo group was not significantly different from the primary procedure group. The presence of strong adhesions and the strangulation of a significant portion of abdominal viscera consist the two main reasons for conversion in the robotic group. [11] Sowards et al [17]

mentioned longer operative times, increased hospital length of stay and use of mesh in the recurrent group, in compare with the primary, without any significant difference in intraoperative complications, estimated blood loss or postoperative dysphagia, while no conversion was noticed. On the other hand, a single center retrospective study by Tolboom et al [14] reported significant reduction in conversion rates and in hospitalization time in the robotic assisted redo group, whereas the most common complication was the perforation of the esophagus or the stomach. Nevertheless, previous laparoscopic antireflux surgery does not suggest an indication for open approach in case of recurrence; if robotic platform is available in combination with experienced surgical team, a robotic approach is recommended.

Experience from robotic redo hiatal hernia repair after primary robotic procedure is provided by Arcerito et al [18], who mentioned increased possibility of conversion to open approach due to the severe scar tissue lying between hiatal crura and fundoplication, which developed more likely from the placement of an absorbable mesh. However, no mesh related complications are mentioned during a two and a half-year time period [18], thanks to the absorbable property, even in longer follow-up periods [19].

Regarding the learning curve, it is believed that the robotic approach has a shorter learning curve compared to laparoscopy for advanced surgical procedures, while a significant case volume and dedicated operation room staff can significantly reduce the operation time [20]. Galvani et al [21], in a large cohort of 61 robotic procedures all performed by one surgeon, claimed a learning curve of 36 cases, comparable to conventional laparoscopy. Sarkaria et al [13] in a series of 24 patients, noticed that the operation time was decreased by 98 minutes between the second and the first half of the series. Washington et al [22] also reported shorter operative time between the early and the late robotic experience, 184 and 142 minutes respectively, as well as a significant decrease in conversion rates, after only one year of thirteen robotic procedures.

Another topic of interest is the application of the robotic platform in the emergency setting in cases of strangulation of the hernia contents. According to a study published by Hosein et al [4], minimally invasive approaches predominate even in the urgent setting, with better postoperative outcomes, with the open approach being selected only for extremely ill patients. The robotic approach was superior to the open one for mild to moderate ill patients, but not superior to the laparoscopic approach. In another study by Vasudevan et al [20], 40% of the robotic procedures were performed on patients presenting with acute symptoms and neither higher operative time nor conversions were observed in compare to elective cases. Arcerito et al [18] also suggested the robotic approach for the treatment of acutely presented hiatal hernias even on the admission day. Equivalent outcomes were noticed even for complete upside-down stomach hiatal hernias [23]. Because of the higher cost, the robotic approach is reserved for giant or revisional hiatal hernias in some centers. [4]

Regarding the recurrence rates, there is not enough evidence in the literature concerning the long-term outcomes. Mertens et al [11] reported two cases of early symptomatic recurrence requiring redo surgery during the 30-day postoperative period. Draaisma et al [24] reported a low mid-term recurrence rate after one year of follow-up. Brenkman et al [25] ,in a cohort of 40 patients and during an 11-month follow-up period, reported only one symptomatic recurrence (2,5%). He attributed this result to the application of the robotic platform and the Toupet-fundoplication, which attaching to the crus, provides further support to the hiatal repair, while no mesh was placed. Galvani et al [17] in a cohort of 61 patients, where mesh was used in all cases, and during a median follow-up period of 24 months, reported a radiologic recurrence rate up to 42%, pointing out that the majority of the patients were asymptomatic and indicating than the durability of the repair decreases over time. Arcerito et al [18] also provided promising evidence regarding the long term recurrence rate during a two-and-a-half years of follow-up. In one of the largest studies with paraesophageal hiatal hernia repair by Gerull et al [12], a radiographic recurrence rate of only 9% during five years of observation is reported, in combination with clinically significant quality of life benefits. Perhaps the presentation of recurrence does not depend only on the surgical technique, but also on the fact that patients with hiatal hernia have got ultrastructural abnormalities at the muscular tissue of the crura, with a high incidence of severe muscular lesions, which are not present in patients with normal gastroesophageal junction. [26] This evidence supports the application of mesh in order to strengthen the hiatal repair and lower the recurrence rates.

Robotic procedures in general are associated with higher cost. Interestingly, Gerull et al [8] reported that the operation equipment costs were similar between robotic and traditional laparoscopic paraesophageal hernia repair, with a mean difference of only 89$. Lekarczyk et al [10] found out similar hospital profits for the robotic group despite higher supply costs and charges. However, Kulshrestha et al [9] , in a study with more participants, reported that both open and robotic assisted procedures had significantly higher median index hospitalization costs compared to laparoscopic ones. The most common reasons that increased the cost were upper endoscopy and reoperation, followed by emergent priority, increased comorbidity index and length of hospital stay. Hosein et al [4] also demonstrated that the laparoscopic approach was the least expensive. However, the increased experience of the surgeons with the robotic platform, which will lead to less complications, length of stay and postoperative exams, as well as the fact that the cost of the robotic equipment will go down over time, might diminish this difference in the future.

The robotic platform has been used successfully for the repair of other diaphragmatic hernias, such as Morgagni [27, 28], Bochdalek [29], even post- esophagectomy hiatal hernias [30], indicating its potentials in technically demanding procedures.

Over the last decades, esophageal surgery has evolved from open approaches including both laparotomy and thoracotomy to minimally invasive procedures. The robotic assisted hiatal hernia repair is superior to the traditional open approach in terms of overall complication rate, mortality [4], postoperative pain and length of stay. However, its superiority over conservative laparoscopy has not been proven yet.

Conclusion

The present meta-analysis did not demonstrate any advantage of the robotic-assisted paraesophageal hernia repair over the conventional laparoscopic approach, which remains the most cost-effective approach. Robotic paraesophageal hernia repair is safe and feasible, but still not superior to laparoscopy, unless cases with recurrent of complex hernias. It is obvious that more comparative and mainly randomized control studies with subgroup analysis need to be performed in order to reach more accurate conclusions and find out which patients would benefit most. A long-term follow-up of the patients is essential because there is a lack of evidence in the literature concerning the recurrence rates of each approach.

Other information

The review was not registered and a protocol was not prepared.

No financial support was provided.

There are no competing interests to declare.

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