

# Laparoscopic repair of paraesophageal hernias: a Canadian experience

Robin P. Boushey, MD, PhD; Husein Moloo, MD; Stephen Burpee, MD; Christopher M. Schlachta, MD; Eric C. Poulin, MD, MSc; Fatima Hagggar, MPH; Daniel C. Trottier, MD; Joseph Mamazza, MD

**Background:** The surgical approach to paraesophageal hernias (PEH) has changed with the advent of laparoscopic techniques. Variation in both perioperative outcomes and hernia recurrence rates are reported in the literature. We sought to evaluate the short- and intermediate-term outcomes with laparoscopic PEH repair. **Methods:** We performed a retrospective review of patients having laparoscopic repair of PEH between June 1998 and September 2002. We included patients with more than 120 days of follow-up. **Results:** A total of 58 patients with a mean age of 60.4 (standard deviation [SD] 15.0) years had a laparoscopic procedure to repair a primary PEH, as well as adequate follow-up, during the study period. The types of PEH included type II ( $n = 13$ ), III ( $n = 44$ ) and IV ( $n = 1$ ). The most common symptoms were epigastric pain (57%), dysphagia (40%), heartburn (31%) and vomiting (28%). Associated procedures included 56 (96%) Nissen funduplications and 2 (4%) gastropexies. We closed all crural defects either with or without pledgets, and 2 patients required the use of mesh. There was 1 conversion to open surgery owing to intraoperative bleeding secondary to a consumptive coagulopathy; we observed no other major intraoperative emergencies. Minor or major complications occurred in 15 patients (26%). Late postoperative complications included 1 umbilical hernia. The mean length of stay in hospital was 3.8 (SD 2.5) days. After surgery, 19 patients were completely asymptomatic, and the majority of the remaining patients (83%) described marked symptom improvement. Upper gastrointestinal series performed in symptomatic patients in the postoperative setting identified 5 recurrent paraesophageal hernias (8.6%) and 5 small sliding hernias (9%). **Conclusion:** Laparoscopic repair of PEH is associated with improved long-term symptom relief, low morbidity and acceptable recurrence rates when performed in an experienced centre.

**Contexte :** L'avènement des techniques laparoscopiques a modifié l'approche chirurgicale de la hernie para-œsophagienne (HPE). Les publications signalent une variation à la fois des résultats périopératoires et des taux de réapparition des hernies. Nous avons cherché à évaluer les résultats à court et à moyen termes de la réparation de HPE par laparoscopie. **Méthodes :** Nous avons procédé à un examen rétrospectif des patients qui ont subi une réparation d'une HPE par laparoscopie entre juin 1998 et septembre 2002. Nous avons inclus les patients comptant plus de 120 jours de suivi. **Résultats :** Au total, 58 patients de 60,4 (écart-type [ET] 15,0) ans en moyenne avaient subi une intervention laparoscopique pour réparer une HPE primaire et avaient fait l'objet d'un suivi adéquat au cours de la période d'étude. Les HPE étaient de types II ( $n = 13$ ), III ( $n = 44$ ) et IV ( $n = 1$ ). Les symptômes les plus courants étaient la douleur épigastrique (57 %), la dysphagie (40 %), les brûlements d'estomac (31 %) et les vomissements (28 %). Les interventions connexes ont inclus 56 (96 %) fundoplicatures de Nissen et 2 (4 %) gastropexies. Nous avons refermé tous les défauts cruraux avec ou sans tampons et il a fallu utiliser du treillis chez 2 patients. Il y a eu un cas de conversion à la chirurgie ouverte à cause d'un saignement intraopératoire secondaire à une coagulation intravasculaire disséminée. Nous n'avons pas observé d'autres urgences intraopératoires majeures. Il y a eu des complications mineures ou majeures chez 15 patients (26 %). Il y a eu une hernie ombilicale parmi les complications postopératoires tardives.

*From the Minimally Invasive Surgery Group, The Ottawa Hospital, Ottawa, Ont.*

*Presented in poster format at the Society of Gastrointestinal and Endoscopic Surgeons (SAGES) Annual Meeting, Mar. 31, 2004, to Apr. 3, 2004, in Denver, Cdo.*

*Accepted for publication June 18, 2007*

**Correspondence to:** Dr. R.P. Boushey, Division of General Surgery, University of Ottawa, The Ottawa Hospital—General Campus, 501 Smyth Rd., Rm. 2003, Eye Institute, Ottawa ON K1H 8L6; fax 613 739-6646; rboushey@ottawahospital.on.ca

La durée moyenne du séjour à l'hôpital s'est établie à 3,8 (ET 2,5) jours. Après l'intervention chirurgicale, 19 patients ne présentaient absolument aucun symptôme et la majorité des autres patients (83 %) ont décrit une amélioration marquée des symptômes. Le transit œogastroduodénal pratiqué chez les patients symptomatiques en contexte postopératoire a permis de repérer 5 récurrences de hernie paraœsophagienne (8,6 %) et 5 petites hernies par glissement (9 %). **Conclusion :** La réparation d'une HPE par laparoscopie est associée à une amélioration du soulagement des symptômes à long terme, à un faible taux de morbidité et à des taux de récurrence acceptables lorsqu'elles sont exécutées dans un centre expérimenté.

**L**arge paraesophageal hernias (PEHs) occur most commonly in an elderly, debilitated patient population with existing comorbid illness. The majority of patients are symptomatic due to alterations in gastric and esophageal physiology. Presenting symptoms can vary greatly and usually include obstructive symptoms (e.g., postprandial pain, dysphagia and vomiting) due to axial rotation of the stomach, bleeding due to acute or chronic mucosal ischemia leading to gastric ulceration and pulmonary symptoms due to lung compression.<sup>1-4</sup> Traditional open abdominal and thoracic approaches have been used to repair all PEHs in an attempt to improve symptoms and minimize the risk of a fatal complication such as gastric necrosis, obstruction, perforation or massive hemorrhage.<sup>5-7</sup> However, open surgical approaches involving large incisions with extensive tissue manipulation and trauma are associated with high morbidity and mortality in elderly patients.<sup>8-10</sup>

Laparoscopic techniques offer several advantages compared with open techniques, including improved visualization of the posterior mediastinum, precise handling of tissues in a less traumatic fashion and smaller incisions in the upper abdomen.<sup>11,12</sup> Several studies have demonstrated excellent short-term outcomes with the laparoscopic approach, including reduced postoperative pain and shortened recovery time;<sup>8,13-16</sup> however, there has been considerable variability in the rate of anatomic failures, ranging from 13% to 42% after laparoscopic repair.<sup>6,13,17-21</sup> We sought to review the short- and intermediate-term outcomes of laparoscopic PEH repair at a Canadian institution.

## Methods

### Patients

We performed a retrospective analysis involving 58 consecutive patients who had laparoscopic repairs of PEHs between June 1998 and September 2002. We obtained ethical approval for this study from the research ethics board at St. Michael's Hospital. One of 3 laparoscopic surgeons at this same institution performed the patients' surgeries. All patients were offered a laparoscopic approach; 3 patients were advised not to proceed with surgical treatment because of serious medical comorbidities or short life expectancy. Our study included only patients with a minimum follow-up of 120 days. We excluded 3 patients who were referred for laparoscopic PEH repair after a failed primary repair.

We documented each patient's symptoms before surgery and between 4 and 6 weeks postoperatively. The mean patient follow-up was 177.5 (standard deviation [SD] 35.8) days. Preoperative work-up in all patients included an upper endoscopy and a barium esophagogram, although we carried out selective use of esophageal manometry and pH monitoring in patients with small PEHs. We did not perform these 2 investigations in patients with larger anatomic distortions because they are typically associated with inaccurate results.

We extracted early and late postoperative complications from the patients' medical records. We performed selective postoperative esophagograms in patients with postoperative symptoms.

### Surgical technique

We used a 5-port technique (2 ports 12 mm in diameter and 3 ports 5 mm in diameter). Our approach emphasizes 5 key steps in the repair of PEHs:

1. The entire hernia sac is dissected from the hiatal margin and completely dissected from the mediastinum before being excised.
2. The herniated contents are gently reduced into the abdominal cavity.
3. Adequate esophageal mobilization is confirmed before repairing the hiatal defect. The gastroesophageal junction should reside at least 3 cm below the hiatus in a tension-free manner. Occasionally, a laparoscopic Collis gastroplasty is performed in patients with esophageal shortening.
4. The esophageal hiatus is reconstructed using pledgetted non-absorbable interrupted sutures. However, the first 12 patients in our series underwent crural defect repair with interrupted non-pledgetted sutures. Occasionally, a crural mesh repair is performed using a commercially available product with a polytetrafluoroethylene (PTFE) base in patients with large hiatal defects that cannot be closed in a tension-free manner, or in patients with poor tissue quality prohibiting adequate suture placement.
5. The uppermost short gastric vessels are then divided, and a floppy 2-cm, 360° Nissen fundoplication is performed over a 50F Maloney esophageal bougie. A partial fundoplication is performed in patients with documented esophageal dysmotility. A fundopexy is performed using nonabsorbable suture to

anchor the fundoplicated stomach to the right crus in a tension-free manner. A nasogastric tube is not routinely used; however, antiemetic medications are administered for a 24-hour period postoperatively. Patients are discharged from hospital when they are ambulatory, are able to tolerate a soft diet and demonstrate adequate pain control.

**Statistical analysis**

Quantitative variable results are expressed as means and standard deviations. Categorical variable results are expressed as frequencies and percentages.

**Results**

The study population included 38 women (66%) and 20 men (36%). The mean age of patients was 60.4 (SD 15) years. The average body weight was 77.1 (SD 13.7) kg. Of the 58 patients included, 51 patients (88%) had primary PEH repairs and 7 (12%) were referred to our institution for PEHs after failed Nissen funduplications. This included 4 patients who had a previous laparoscopic Nissen fundoplication, 2 who had open Nissen fundoplication and 1 who had Collis gastroplasty and Nissen fundoplication.

Presenting symptoms are outlined in Table 1. All patients were symptomatic and most commonly presented with epigastric pain (57%), dysphagia (40%), heartburn (31%) and vomiting (28%). Other signs and symptoms included anemia, chest pain, bloating, shortness of breath and regurgitation. There were no asymptomatic patients in this series.

Nine patients had endoscopically proven esophagitis, and 4 of them had Cameron ulcers. After performing a barium esophagogram, we classified the PEHs as pure rolling hiatus hernias (type II) in 13 patients (22%), as mixed hernias (type III) in 44 patients (76%) and as containing small or large bowel contents (type

IV) in 1 patient (2%). Seventeen patients (29%) had a documented gastric volvulus, and 6 patients (10%) required urgent surgery secondary to impending ischemia. We performed esophageal manometry and 24-hour pH monitoring selectively as previously discussed in 25 patients (43%) and 15 patients (26%), respectively.

Operative procedures are outlined in Table 2. We repaired the esophageal hiatal defect in all patients using 0 prolene suture without pledgets (21%), with pledgets (76%) or with the application of an on-lay mesh (3%). In our early experience, we used monofilament polypropylene mesh; however, our preference changed to biologic mesh. Fifty-six patients (97%) had a 360° Nissen fundoplication, and 2 patients (3%) received a gastrostomy tube after crural repair. None of the patients required an esophageal lengthening procedure (Collis gastroplasty). The mean duration of surgery was 236.6 (SD 65.6) min. The estimated blood loss was 124 (SD 174) mL. We converted to an open procedure in 1 patient (2%) because of bleeding secondary to the development of an intraoperative coagulopathy.

The major intraoperative and postoperative complications are listed in

Table 3. Six intraoperative, 8 early postoperative and 1 late postoperative complications occurred. There were 3 intraoperative gastric perforations and 2 early postoperative leaks. We managed all intraoperative perforations laparoscopically at the time of the initial surgery, and we managed the 2 early postoperative leaks with laparoscopic drainage and total parenteral nutrition. The majority of complications in the early postoperative period were cardiopulmonary complications, including atelectasis (3%), pulmonary embolus (2%), myocardial infarction (2%) and atrial fibrillation (2%). No patients died within the 30 days after surgery, and the overall morbidity was 26%. The mean length of stay in hospital was 3.8 (SD 2.5) days.

At a mean follow-up of 177.5 (SD 35.8) days, 19 patients (33%) were completely asymptomatic, 32 patients (55%) described symptom improvement and were satisfied with their surgeries, and 7 patients (12%) failed to describe any change in clinical symptoms. The most common symptoms described were likely related to the antireflux procedure. They are outlined in Table 1, and include bloating (16%), heartburn (9%) and dysphagia (9%). Other symptoms in-

**Table 1**

**Presenting and postoperative symptoms in 58 patients who had laparoscopic repair of a PEH**

Symptom	Time, no (%) of patients	
	PR	PO
Epigastric pain	33 (57)	2 (3)
Dysphagia	23 (40)	5 (9)
Heartburn	18 (31)	5 (9)
Vomiting	16 (28)	—
Anemia	13 (22)	—
Chest pain	13 (22)	1 (2)
Bloating	9 (16)	9 (16)
Shortness of breath	8 (14)	—
Regurgitation	7 (12)	—
Diarrhea	—	4 (7)
Flatulence	—	4 (7)
Asymptomatic	—	19 (33)

PEH = paraesophageal hernia; PO = postoperative; PR = presenting.

**Table 2**

**Laparoscopic paraesophageal hernia procedures\* in 58 patients**

Procedure	No. (%) of patients
Nissen fundoplication	56 (97)
Gastrostomy tube only	2 (3)
Crural repair	58 (100)
With pledgets	44 (76)
Without pledgets	12 (21)
Mesh	2 (3)
Monofilament polypropylene / ePTFE	1 (2)
Monofilament polypropylene	1 (2)
Collis gastroplasty	—

ePTFE = expanded polytetrafluoroethylene; SD = standard deviation.  
 \*Outcomes included a mean surgery duration of 236.6 (SD 65.6) min, a mean length of stay in hospital of 3.8 (SD 2.5) d and a conversion to open procedure rate of 2%.

cluded flatulence (7%), diarrhea (7%), epigastric pain (3%) and chest pain (2%). Interestingly, all 7 patients who had a previous failed Nissen fundoplication were completely asymptomatic after the laparoscopic PEH repair.

Of the 58 patients included in our study, 21 patients (36%) had a postoperative barium esophagogram. As shown in Table 4, 5 patients (9%) had an anatomic recurrence, and 2 of these patients (3%) required subsequent surgeries for residual postprandial pain. All recurrences occurred in patients with large type III PEHs, and 3 of these patients had initially presented with an organo-axial gastric volvulus. One of these patients required emergency surgery at the time of presentation. None of the patients with documented recurrences were closed with mesh, and 4 patients had pledgets for closure of their crural defects.

Five patients (9%) had small sliding hernias but did not require further surgical intervention because their reflux symptoms were adequately managed using standard medical therapies. All sliding hernias occurred in patients who presented initially with large type III PEHs

involving more than 50% of the stomach in the thoracic cavity and in the single patient with a type IV hernia. We performed emergency surgery on 1 patient. Two of the small sliding hernia recurrences occurred early when we used absorbable polydioxanone (PDS) sutures to close the crural defect.

**Discussion**

Laparoscopic surgical techniques have been shown to be safe and to provide several short-term advantages over traditional open techniques for patients with PEHs.<sup>8,13-16,22-25</sup> The benefits include a shortened stay in hospital, reduced requirement for analgesia, fewer cardiorespiratory complications and improved quality of life.<sup>12</sup> The patient morbidity of 26% that we observed is in keeping with other studies reporting on laparoscopic PEH repair.<sup>12-15,26</sup> These numbers compare favourably with previously reported series of open paraesophageal hernia repairs, which had a morbidity of 11.8%–60% and a mortality of 0.5%–20%.<sup>4,9,10,12,27-30</sup> There were no deaths in this series, though this difference likely can be attributed in part to improvements over the last decade in preoperative optimization of patients and postoperative care. The majority of early postoperative complications were cardio-respiratory in nature, and this emphasizes the high

incidence of comorbid illness in this patient population.<sup>12-26</sup>

Although several authors have advocated for the use of prosthetic mesh to close hiatal defects,<sup>12,22,31,32</sup> this series seems to indicate that most large hiatal defects can be successfully closed without mesh, using pledgetted nonabsorbable sutures. Posterior closure of the hiatus is routinely performed, with an occasional anterior closure stitch if the defect is especially large and ovoid in shape. Despite theoretical risks of posterior esophageal angulation, no patients had long-term dysphagia.

A prosthetic mesh was required to close the hiatal defect in only 2 patients. We performed the first of these mesh repairs in a patient with a type IV PEH. We closed the large diaphragmatic defect with a monofilament polypropylene mesh, and a gastrocutaneous fistula subsequently developed following mesh erosion into the stomach. Despite attempts at conservative management, including laparoscopic drainage of residual collections, insertion of drainage catheters and nutritional support, the patient eventually required complete excision and removal of the mesh and distal esophagogastrectomy. The use of prosthetic mesh to obtain a tension-free repair has been successful with other types of hernias such as inguinal and ventral defects. Despite the reduction in recurrence rates with the use of prosthetics to repair the diaphragmatic crura,<sup>12,32-35</sup> erosions such as the one encountered in our study are a rare but very real possibility.<sup>10,31,36-39</sup> Furthermore, the hiatus is a dynamic area where movement owing to breathing and swallowing can potentially increase the risk of such erosions as the mesh comes into contact with the esophagus. When required, mesh repairs are now done using bioprosthetic mesh rather than polypropylene mesh. Recent reports on the use of bioprosthetic mesh are quite promising.<sup>12,40</sup>

Thirty-three percent of patients were completely asymptomatic after

**Table 3**

**Complications associated with laparoscopic paraesophageal hernia repair in 58 patients**

Timing; complication	No. (%) of patients
<b>Intraoperative</b>	
Gastric perforation	3 (5)
Bleeding	1 (2)
Corneal abrasion	1 (2)
Pneumothorax complication	1 (2)
Injury to surrounding structures	—
<b>Early postoperative</b>	
Postoperative leak	2 (3)
Ileus	1 (2)
Pulmonary complication	3 (5)
Cardiac complication	2 (3)
<b>Late postoperative</b>	
Umbilical hernia	1 (2)

**Table 4**

**Findings after clinical and radiological follow-up\***

Finding	No. (%) of patients
<b>Symptom</b>	
Asymptomatic	19 (33)
Improvement	32 (55)
No improvement	7 (12)
<b>UGI series†</b>	
Recurrent PEH	5 (9)
Sliding hernias	5 (9)

PEH = paraesophageal hernia; SD = standard deviation; UGI = upper gastrointestinal.  
 \*The mean follow-up was 177.5 (SD 35.8) days.  
 †Performed in symptomatic patients only.

surgery, whereas the remaining patients described symptoms such as bloating, dysphagia, heartburn and flatulence, which were often different from their presenting symptoms and likely related to the antireflux procedure performed as part of the PEH repair. Many authors have questioned the routine use of fundoplication after PEH repair because the incidence of postprocedural reflux has been reported to be as low as 3% in some series that do not perform fundoplication.<sup>27,29</sup> Despite this data, the creation of a loose 2-cm Nissen fundoplication is routinely performed in all patients. The only exception is patients with a known esophageal motility disorder because formal preoperative esophageal manometry and 24-hour pH monitoring are sometimes challenging owing to difficulty inserting the manometric catheter or because the catheter is easily displaced. The antireflux component of the repair is advocated since extensive mobilization of the thoracic esophagus in the posterior mediastinum is often necessary to reduce type III PEHs, which can predispose patients with no previous history of reflux to experience symptoms. Also, it is likely that the fundoplication and accompanying fundopexy help to anchor the gastroesophageal junction below the diaphragm thereby reducing the incidence of anatomic recurrence. It is advisable to inform asymptomatic patients with PEHs that they may experience symptoms related to the antireflux procedure following surgery.

Interestingly, there was no need for a Collis gastroplasty in any of the patients in our study. This is an often discussed technique; however, with adequate mobilization of the esophagus it appears that this may not be a necessary manoeuvre.<sup>14,27</sup>

Although our data and that of other studies consistently demonstrate that laparoscopic PEH repair can be performed safely with low complication rates,<sup>5,13,25</sup> data in the literature regarding anatomic recur-

rences have been variable, ranging from 18% to 42% of patients.<sup>13,17-20</sup> Anatomic failures in symptomatic patients in our cohort presented as either recurrent paraesophageal herniations (5 patients, 9%) or as sliding hiatal hernias (5 patients, 9%). We performed barium esophagography selectively in symptomatic patients, and we offered subsequent laparoscopic surgery only to a subgroup of patients who were severely debilitated by their symptoms and able to tolerate a second surgical procedure.

Only 2 patients with PEH recurrences underwent successful second surgeries. The remaining 3 patients experienced tolerable symptoms, and they were observed with no documented long-term sequelae. This may suggest that PEH recurrences should be considered to be distinct entities and that they can be managed differently than primary PEH. Further longitudinal studies are needed to determine whether the accepted practice of performing immediate surgery after diagnosing a PEH applies to the management of recurrent PEHs. Data are emerging that support a selective approach to managing this subgroup of patients.<sup>13,41</sup>

Because barium studies involving asymptomatic patients are not routinely performed, it is not possible to determine the true anatomic recurrence rates in this patient population. However, all documented recurrences in our study occurred in patients with large type III PEHs; 3 patients presented initially with organoaxial gastric volvulus and, of these patients, 1 received emergency surgery. We closed all defects primarily without the use of mesh, and 4 of the crural repairs were pledgetted. Because most of these PEHs were type III, recurrences were not secondary to a short esophagus but likely were due to a breakdown of the hiatal crural repair caused by increased tension and poor quality connective tissue.

One possible criticism of this study is that we did not perform post-

operative barium studies on all patients. Therefore, as mentioned previously, the true recurrence rate is not known. However, we investigated any patients who warranted imaging based on clinical indications. Ultimately, the most important aspect of this repair relative to the patient is the number of recurrences that required another procedure for relief of intractable symptoms. This number was low at 3% (2 patients) and demonstrates the efficacy of the repair.

None of the 5 patients who presented with small sliding hiatal hernias following surgical repair of their PEHs required further surgical intervention because their reflux symptoms were adequately managed using standard medical therapies. All sliding hernias occurred in elderly patients who presented initially with large type III PEHs involving more than 50% of the stomach in the thoracic cavity and in the single patient with a type IV hernia who received emergency surgery. Two of the small sliding hernia recurrences occurred early when we used PDS to primarily close the crural defect. We quickly transitioned to the use of nonabsorbable sutures and pledgets to close all hiatal defects.

## Conclusion

Laparoscopic repair of PEH can be performed safely and is associated with low morbidity and improved long-term symptom relief. Although the true recurrence rate cannot be discerned from these data, symptomatic recurrences were low at 8.6% and, most importantly, only 3% of patients required surgery for their recurrences.

**Competing interests:** None declared.

**Contributors:** Drs. Boushey, Poulin and Mamazza designed the study. Drs. Boushey, Burpee, Schlachta, Poulin and Mamazza acquired the data, which Drs. Boushey, Moloo and Trotter and Ms. Hagggar analyzed. Drs. Boushey and Trotter wrote the article. All authors reviewed the article and gave final approval for its publication.

## References

1. Wu JS, Dunnegan DL, Soper NJ. Clinical and radiologic assessment of laparoscopic paraesophageal hernia repair. *Surg Endosc* 1999;13:497-502.
2. Morino M, Giaccone C, Pellegrino L, et al. Laparoscopic management of giant hiatal hernia: factors influencing long-term outcome. *Surg Endosc* 2006;20:1011-6.
3. Hill LD. Incarcerated paraesophageal hernia: a surgical emergency. *Am J Surg* 1973;126:286-91.
4. Pearson FG, Cooper JD, Ilves R, et al. Massive hiatal hernia with incarceration: a report of 53 cases. *Ann Thorac Surg* 1983;35:45-51.
5. Trus TL, Bax T, Richardson WS, et al. Complications of laparoscopic paraesophageal hernia repair. *J Gastrointest Surg* 1997;1:221-8.
6. Low DE, Trisha U. Open repair of paraesophageal hernia: reassessment of subjective and objective outcomes. *Ann Thorac Surg* 2005;80:287-94.
7. Skinner DB, Belsey RHR. Surgical management of esophageal reflux and hiatus hernia: long-term results with 1,030 patients. *J Thorac Cardiovasc Surg* 1967;53:33-54.
8. Andujar JJ, Papisavas PK, Birdas T, et al. Laparoscopic repair of large paraesophageal hernia is associated with a low incidence of recurrence and reoperation. *Surg Endosc* 2004;18:444-7.
9. Maziak DE, Todd TR, Pearson FG. Massive hiatus hernia: evaluation and surgical management. *J Thorac Cardiovasc Surg* 1998;115:53-60; discussion 61-2.
10. Schauer PR, Ikramuddin S, McLaughlin RH, et al. Comparison of laparoscopic versus open repair of paraesophageal hernia. *Am J Surg* 1998;176:659-65.
11. Granderath FA, Carlson MA, Champion JK, et al. Prosthetic closure of the esophageal hiatus in large hiatal hernia repair and laparoscopic antireflux surgery. *Surg Endosc* 2006;20:367-79.
12. Oelschlager BK, Pellegrini CA, Hunter J, et al. Biologic prosthesis reduces recurrence after laparoscopic paraesophageal hernia repair: a multicenter, prospective, randomized trial. *Ann Surg* 2006;244:481-90.
13. Mattar SG, Bowers SP, Galloway KD, et al. Long-term outcome of laparoscopic repair of paraesophageal hernia. *Surg Endosc* 2002;16:745-9.
14. Pierre AF, Luketich JD, Fernando HC, et al. Results of laparoscopic repair of giant paraesophageal hernias: 200 consecutive patients. *Ann Thorac Surg* 2002;74:1909-16.
15. Swanson LL, Jobe BA, Kinzie LR, et al. Esophageal motility and outcomes following laparoscopic paraesophageal hernia repair and fundoplication. *Am J Surg* 1999;177:359-63.
16. Targarona EM, Bendahan G, Balague C, et al. Mesh in the hiatus: a controversial issue. *Arch Surg* 2004;139:1286-96.
17. Edey MB, Canin-Endres J, Gattorno F, et al. Durability of laparoscopic repair of paraesophageal hernia. *Ann Surg* 1998;228:528-35.
18. Hashemi M, Peters JH, DeMeester TR, et al. Laparoscopic repair of large type III hiatal hernia: objective follow up reveals high recurrence rate. *J Am Coll Surg* 2000;190:553-61.
19. Horgan S, Eubanks TR, Jacobsen G, et al. Repair of paraesophageal hernias. *Am J Surg* 1999;177:354-8.
20. Oddsdottir M, Franco AL, Laycock WS, et al. Laparoscopic repair of paraesophageal hernia. *Surg Endosc* 1995;9:164-8.
21. Dahlberg PS, Deschamps C, Miller DL, et al. Laparoscopic repair of large paraesophageal hiatal hernia. *Ann Thorac Surg* 2001;72:1125-9.
22. Keidar A, Szold A. Laparoscopic repair of paraesophageal hernia with selective use of mesh. *Surg Laparosc Endosc Percutan Tech* 2003;13:149-54.
23. Kercher KW, Matthews BD, Ponsky JL, et al. Minimally invasive management of paraesophageal herniation in the high-risk surgical patient. *Am J Surg* 2001;182:510-4.
24. Leeder PC, Smith G, Dehn TCB. Laparoscopic management of large paraesophageal hiatal hernia. *Surg Endosc* 2003;17:1372-5.
25. Velanovich V, Karmy-Jones R. Surgical management of paraesophageal hernias: outcome and quality of life analysis. *Dig Surg* 2001;18:432-8.
26. Gangopadhyay N, Perrone J, Soper N, et al. Outcomes of laparoscopic paraesophageal hernia repair in elderly and high-risk patients. *Surgery* 2006;140:491-9.
27. Draaisma WA, Gooszen HG, Tournioj E, et al. Controversies in paraesophageal hernia repair: a review of literature. *Surg Endosc* 2005;19:1300-8.
28. Ellis FH, Crozier RE, Shea JA. Paraesophageal hiatus hernia. *Arch Surg* 1986;121:416-20.
29. Williamson WA, Ellis FH, Streitz JM, et al. Paraesophageal hiatal hernia: Is an antireflux procedure necessary? *Ann Thorac Surg* 1993;56:447-52.
30. Targarona EM, Novell J, Vela S, et al. Mid term analysis of safety and quality of life after laparoscopic repair of paraesophageal hiatal hernia. *Surg Endosc* 2004;18:1045-50.
31. Johnson JM, Carbonell AM, Carmody BJ, et al. Laparoscopic mesh hiatoplasty for paraesophageal hernias and fundoplications: a critical analysis of the available literature. *Surg Endosc* 2006;20:362-6.
32. Frantzides CT, Madan AK, Carlson MA, et al. A prospective, randomized trial of laparoscopic polytetrafluoroethylene (PTFE) patch repair vs simple cruroplasty for large hiatal hernia. *Arch Surg* 2002;137:649-52.
33. Frantzides CT, Richards CG, Carlson MA. Laparoscopic repair of large hiatal hernia with polytetrafluoroethylene. *Surg Endosc* 1999;13:906-8.
34. Carlson MA, Richards CG, Frantzides CT. Laparoscopic reinforcement of hiatal herniorrhaphy. *Dig Surg* 1999;16:407-10.
35. Granderath FA, Schweiger UM, Kamolz T, et al. Laparoscopic Nissen fundoplication with prosthetic hiatal closure reduces postoperative intrathoracic wrap herniation. *Arch Surg* 2005;140:40-8.
36. Fernández Lobato R, Martínez Santos C, Ortega Deballon P, et al. Colocutaneous fistula due to polypropylene mesh. *Hernia* 2001;5:107-9.
37. Losanoff JE, Richman BW, Jones JW. Entero-colocutaneous fistula: a late consequence of polypropylene mesh abdominal wall repair: case report and review of the literature. *Hernia* 2002;6:144-7 [Epub].
38. Miller K, Junger W. Ileocutaneous fistula formation following laparoscopic polypropylene mesh hernia repair. *Surg Endosc* 1997;11:772-3.
39. Carlson MA, Condon RE, Ludwig KA. Management of intrathoracic stomach with polypropylene mesh prosthesis reinforced transabdominal hiatus hernia repair. *J Am Coll Surg* 1998;187:227-30.
40. Desai KM, Diaz S, Dorward IG, et al. Histologic results 1 year after bioprosthesis repair of paraesophageal hernia in a canine model. *Surg Endosc* 2006;20:1693-7.
41. Stylopoulos N, Scott Gazelle G, Rattner DW. Paraesophageal hernias: operation or observation. *Ann Surg* 2002;236:492-500; discussion 500-1.