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Laparoscopic Repair of Giant Diaphragmatic Hernias: Evolving Technical Aspects and Outcomes

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ABSTRACT: **Background:** Laparoscopic repair of giant diaphragmatic hernias (GDH) can be challenging, especially when partial or complete volvulus of the herniated stomach is encountered.

Objectives: To review our experience with laparoscopic repair of GDH, emphasizing preoperative investigation, technical aspects, and outcome.

Methods: We conducted a retrospective review of patients operated on for GDH who were diagnosed when at least half the stomach was found in the mediastinum at surgery. Technical aspects and surgical outcomes were evaluated.

Results: Fifty patients underwent laparoscopic GDH repair during an 8 year period. Four patients admitted with acute symptomatic volvulus of the stomach were initially treated by endoscopic decompression followed by surgery during the same admission. Two cases were converted to open surgery. Initial surgery was successful in 45 patients; 3 had an immediate recurrence, 1 was reoperated for dysphagia during the same admission, and 1 had a mediastinal abscess. During long-term follow-up, six patients required reoperation for recurrent hernias. Another four patients had asymptomatic partial herniation of the stomach. The main reason for failure was incomplete reduction of the hernia sac, especially the posterior component. No correlation was found between the type of repair and surgical failure. Most patients who did not undergo an anti-reflux procedure had postoperative reflux unrelated to their preoperative workup.

Conclusions: Laparoscopic repair of GDH is challenging, but practical and safe. It should be the treatment of choice for this potentially life-threatening condition. Careful attention to pitfalls, such as the posterior element of the sac, and routine performance of an anti-reflux procedure are crucial.

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KEY WORDS: giant diaphragmatic hernia (GDH), gastric volvulus, laparoscopic repair

Giant diaphragmatic hernia is an unusual disorder of the esophageal hiatus that occurs in approximately 5% of all hiatal hernias [1,2]. It is found mainly in the elderly and may present with obstructive symptoms or sometimes retrosternal discomfort mimicking cardiac and respiratory symptoms. It may cause chronic bleeding and, if left untreated, can cause life-threatening mechanical problems including incarceration with strangulation or volvulus of the stomach. In patients who develop acute volvulus or strangulation of the herniating stomach the rates of severe morbidity and mortality are high [1,2]. Symptomatic GDH is considered an absolute indication for elective surgical repair when the condition is diagnosed [3,4].

The operation has traditionally been performed as open surgery, by either trans-thoracic or trans-abdominal approaches, with high success rates and a relatively low incidence of complications [5,6]. Laparoscopic repair may further reduce the morbidity and recovery time associated with surgical intervention. Indeed, laparoscopic repair of small diaphragmatic hernias is now routinely performed with good results [6,7]. However, laparoscopic repair of GDH can be technically challenging [8], especially when chronic partial gastric volvulus is present. The repair of GDH with partial or complete volvulus of the stomach, herniation of the omentum, or less frequently herniation of the colon or spleen is even more difficult. In such cases, preoperative information on the anatomic position of the stomach and other organs is essential for determining the operative strategy.

The objective of the present study was to review our growing experience with the laparoscopic repair of GDH.

PATIENTS AND METHODS

We reviewed all laparoscopic GDH operations, with special attention to the preoperative investigation, technical aspects of the repair, and the short and long-term results. Giant diaphragmatic hernia was diagnosed when over half the stomach was found, at laparoscopy, to be herniated into the thoracic cavity.

Preoperative imaging studies included gastroscopy, upper gastrointestinal series, and 24 hour pH monitoring. Most patients also underwent esophageal manometry. In cases where the anatomy was not clear a computed tomography scan with 3-D reconstruction was added.

GDH = giant diaphragmatic hernia

OPERATIVE TECHNIQUE

After general anesthesia, the patient was placed in a supine position with legs apart. The surgeon stood between the patient's legs, with the assistant at the patient's right side and the scrubbed nurse on the left. After pneumoperitoneum was achieved (Surgineedle®, Autosuture, Tyco Healthcare Group, USA) through an incision just left of the mid-abdominal line, between the xyphoid and the umbilicus, the needle was replaced by a 12" trocar and a 30° scope was introduced. Another 12" trocar was introduced at the left upper abdominal wall below the costal margin. Three 5" trocars were placed, one just below the xyphoid, another at the right upper abdomen, and the third at the left anterior axillary line below the costal margin. The left lobe of the liver was retracted anteriorly revealing the hiatus. The stomach and other herniated organs were carefully reduced into the abdominal cavity. After complete reduction of the stomach to its normal position, it was usually possible to advance a nasogastric tube into the stomach and achieve complete decompression. Complete dissection of the hernia sac from the mediastinum was performed with a harmonic scalpel (Ethicon Endo Surgery, Blue Ash, OH, USA).

Based on the outcomes of our first 12 cases, special attention was given to the complete resection and reduction of the posterior component of the sac. Usually a large lipoma was found within the posterior sac adjacent to the esophagus, adherent to the mediastinum, which was reduced, allowing further lengthening of the esophagus. This lipoma, unless specifically sought for, can be missed, as happened in our early cases. Care was taken not to harm the anterior and posterior vagus nerves during dissection. The crural repair was done using 2-0 non-absorbable sutures (Ethibond Excell®, Ethicon, Johnson & Johnson Intl., Belgium). When the crura could not be approximated due to tension, the hiatus was closed with a prosthetic patch (Dual Mesh Gore-Tex®, USA, or Crurasoft Bard®, Belgium) which was sutured to the crura. In cases where the diaphragmatic crura appeared weak, at the discretion of the surgeon a prosthetic patch was added over the crural repair after suturing. In the early cases, a partial or complete fundoplication was performed only when gastro-esophageal reflux was found in the preoperative workup. In the later cases, a floppy 360° wrap was routinely performed. A sump drain was placed adjacent to the hiatus and was removed after 24 hours.

POSTOPERATIVE PROCEDURES

On the first postoperative day, a study with water-soluble contrast (Telebrix® Gastro, Guerbet, France) was conducted to establish the precise position of the stomach within the abdominal cavity and to rule out a leak or obstruction. A soft diet was then allowed. Most patients were discharged 2 to 4 days postoperatively. After discharge, all patients were seen at the outpatient clinic at 1 week, and then at 3 month intervals for 1 year, and every 6 months thereafter.

RESULTS

During the 8 year period, January 2004 to December 2010, 50 patients (31 females and 19 males) with a preoperative diagnosis of giant diaphragmatic hernia were operated on laparoscopically. The mean age of the patients was 74.3 years (range 33–91 years). The mean follow-up period was 42 months (range 12–96 months).

Presenting symptoms included retrosternal pain in 26 patients, heartburn in 14, regurgitation and recurrent vomiting in 24, upper gastrointestinal bleeding in 14, abdominal pain in 11, and shortness of breath in 7. In six patients, the hernia was detected incidentally on a chest X-ray performed for other reasons [Table 1]. Four patients were admitted urgently due to acute volvulus of the stomach. They presented with severe abdominal pain radiating to the chest and were initially treated conservatively. An urgent gastroscopy was performed and decompression of the stomach was achieved in all four. A nasogastric tube was inserted under gastroscopic guidance, and although there was no stomach ischemia the mucosa appeared friable and hyperemic in three patients. They were kept in the hospital with the nasogastric tube in place for drainage and treated with intravenous fluids and H2 antagonists. All four patients were successfully operated on after 4 to 10 days of conservative treatment.

During the operation the entire stomach was found to be herniated in 14 patients, while in the other 36 at least half the stomach was in the mediastinum. Partial or complete volvulus of the herniated stomach was found in 18 patients. In eight, the greater omentum and the transverse colon were found together with the stomach in the mediastinum, and in one case the spleen.

All operations were performed laparoscopically. There were two conversions to open surgery: in one patient due to adhesions from previous surgery, and in the other due to technical difficulty.

The hernia was repaired primarily using only sutures in 32 patients. A prosthetic mesh was used in another 14 patients,

Table 1. Presenting symptoms of patients with giant diaphragmatic hernia (n=50)

Symptom	No. of patients
Retrosternal pain	26
Heartburn	14
Regurgitation, recurrent vomiting	24
Upper gastrointestinal bleeding	14
Abdominal pain	11
Shortness of breath	7
Incidental finding	6
Acute incarceration/volvulus	4
Asymptomatic	4

and in the remaining 4 the repair was done using sutures and mesh reinforcement.

In our first 14 cases, a Toupet or Nissen fundoplication was added selectively at the discretion of the surgeon based on preoperative findings of reflux. However, all six patients without an anti-reflux procedure suffered postoperative reflux even if they did not have reflux symptoms before surgery. After these early cases we changed our policy and in the next 36 patients routinely performed a 360° (Nissen) fundoplication after the hernia repair. Only 2 of these 36 patients complained of mild reflux symptoms, which resolved with proton pump inhibitors. Six patients experienced mild upper abdominal discomfort due to gastric bloating which resolved after 2 to 3 months. Another two patients reported mild dysphagia following a partial (Toupet) fundoplication while one patient with the Nissen fundoplication had similar complaints [Table 2].

In three early cases a contrast study 24 hours after surgery showed recurrent herniation of the stomach into the mediastinum. These were all reoperated and repaired. The original repair had been done without mesh in one and with a mesh in the other two. In all three cases the second operation showed that the posterior component of the hernia sac had not been completely resected and a remaining bridge of tissue was found pulling the stomach up into the mediastinum. No further immediate failures occurred once we began giving special attention to the complete dissection of the posterior component of the sac with its accompanying lipoma.

An additional patient was operated upon electively 6 months after an acute attack of retrosternal pain. After a negative cardiac evaluation a GDH was found. The operation was technically challenging due to obesity and because the whole stomach was strongly adherent to the mediastinum. After reduction into the abdominal cavity, the stomach was extremely friable and part of the herniated omentum appeared ischemic. The stomach was fixed to the hiatus with sutures, with no fundoplication. The initial postoperative course was normal and the patient was discharged after 2 days. He was readmitted a week later with shortness of breath and fever. A CT scan showed an abscess in the mediastinum, but no leak of contrast material was seen. At laparotomy, parts of the lesser omentum were necrotic. The abscess was drained and necrotic omentum resected. The patient recovered and the stomach remained in the abdominal cavity, but he has regurgitation.

Another early failure occurred in an 82 year old patient with a floppy 360° fundoplication who had severe dysphagia immediately after the operation; he was reoperated and the wrap was undone, but he continued to have dysphagia. The patient subsequently had prolonged gastroparesis. He underwent gastroscopy and although the pyloric channel looked patent, gastric stasis continued. Ten days later a gastrostomy and feeding jejunostomy were performed. Three months later he was able to resume an oral diet with normal emptying of the stomach but continues to have reflux and regurgitation and requires treatment with a proton pump inhibitor. We did not find a reasonable explanation for the persistent gastroparesis, since during the second operation both vagus nerves were observed to be intact.

No correlation was found between the preoperative manometry study findings and postoperative symptoms of dysphagia or reflux. Subsequently, preoperative manometry was omitted from the routine workup of the later patients. With no evidence to support routine performance of either one of the fundoplication techniques, a "floppy" Nissen fundoplication became the anti-reflux procedure of choice in GDH repair.

Another three patients (one with a primary mesh repair and the other two with sutures only) had symptomatic recurrence of the hernia 4 to 8 months after the operation. They were reoperated. In one patient, the second operation was successfully performed laparoscopically, while the other two procedures were converted to open surgery. Severe mediastinal adhesions of the mesh were found in one, while the other had a perforation of the esophagus during the dissection.

During the follow-up period another four patients had a partial herniation of the fundus of the stomach into the mediastinum that was found on routine upper gastrointestinal series. The wrap of the fundoplication was seen above the diaphragm, but all four patients were asymptomatic and were not treated.

There were no cases of "short esophagus" among the patients. Our impression was that careful and complete dissection of the sac, especially the posterior component, allowed at least 3 cm of the lower esophagus to be reduced into the abdominal cavity without tension.

Table 2. Results of laparoscopic repairs (n= 50)

Event	Total no. of patients
Conversion to open surgery Adhesions from previous surgery (n=1) Technical difficulty (n=1)	2
Reoperation within the same admission Reherniation (n=3) Mediastinal abscess (n=1) Dysphagia (n=1)	5
Postoperative reflux Without fundoplication With fundoplication (1 immediate reoperation for dysphagia)	 6/6 2/44
Transient bloating	6
Mild dysphagia	3
Recurrence Early reoperation (n=3) Late symptomatic (n=3) Asymptomatic (n=3)	9

DISCUSSION

We describe our growing experience with laparoscopic repair of giant diaphragmatic hernias. During an 8 year period 50 consecutive patients were operated on; all but 3 were symptomatic.

Four patients were admitted with acute symptomatic volvulus of the stomach and were successfully treated by endoscopic decompression and then operated on during the same hospitalization. Therefore, we recommend a two-stage strategy for patients admitted urgently with acute volvulus: emergency gastroscopic decompression with aggressive resuscitation and a few days of conservative treatment under intense monitoring followed by a semi-urgent operation. This will allow for a simpler and safer laparoscopic operation. All four patients experienced a rapid recovery and were discharged 3 to 4 days after the operation. It is imperative though to rule out ischemia and to achieve immediate successful gastroscopic decompression, followed by careful monitoring. An additional five patients needed early reoperations: three patients with immediate failure, the fourth due to an abscess in the mediastinum and another patient due to early dysphagia. There was no perioperative mortality.

After reviewing our initial preoperative workup protocol, we later omitted mandatory manometry and pH monitoring since postoperative reflux and dysphagia did not correlate with the preoperative workup findings. With the early cases, while relying on the manometry and pH monitoring, we simply repaired the diaphragmatic hernia without an anti-reflux procedure in patients with weak peristalsis of the stomach and no significant reflux in an attempt to prevent postoperative dysphagia. Soon after the operation these patients began to experience heartburn and regurgitation, probably due to the disruption of the lower esophageal sphincter mechanism during the dissection [6,7]. However, there was no correlation between "weak peristalsis" and postoperative dysphagia, or the type of fundoplication performed. Similar findings were recently reported by other authors [9,10]. Following these early cases it became apparent that a floppy Nissen fundoplication should be a routine part of the procedure. The addition of an anti-reflux procedure may also assist in preventing reherniation of the stomach into the mediastinum since the wrap may function as an anchoring point for the stomach in the abdominal cavity [6,8,11-13].

In many cases preoperative CT scan with 3-D reconstruction was helpful in planning the operation, especially when partial volvulus was present or when additional organs were herniated. Although we did not find evidence supporting this practice in the literature, we felt that knowing the exact position of the stomach and other organs was important when attempting to reduce them into the peritoneal cavity at the beginning of the operation.

The importance of careful and complete dissection of the sac to attain the necessary esophageal length and to minimize recurrent herniation cannot be overemphasized. Special attention should be given to the dissection of the posterior component of the hernia sac as this area can be overlooked. Sometimes the posterior sac is merely incised which allows direct visualization of the crura, giving the false impression that it has been resected, as happened in our three cases of early recurrence. A lipoma that was usually found adherent to the posterior sac became a useful landmark for us in the later cases.

We believe that meticulous dissection allowed us to achieve at least 3 cm of the esophagus in the abdominal cavity in all our patients and no cases of short esophagus were encountered. Madan and colleagues [14] reported similar findings, calling the short esophagus a "myth."

During the long-term follow-up six patients experienced a recurrent diaphragmatic hernia. Three symptomatic patients had a successful second operation. The other three patients were asymptomatic and only the fundus with the wrap was above the diaphragmatic hiatus. They were followed for up to 4 years and continued to be asymptomatic and without further herniation. No evidence-based data exist for these cases and we continue to observe them, an approach supported by others [15].

In the present study, no correlation was found between the type of repair, the use of prosthetic mesh or type of mesh, and the risk of reherniation, since about half the recurrences were in patients with mesh. It is generally accepted that a mesh should probably be used whenever there is tension in approximating the crura, when the diaphragmatic defect is large, or when the tissues are weak and friable [10,16]. A word of caution is warranted however, since we found it very difficult to remove the mesh from the mediastinum in a recurrent case. Furthermore, the use of prosthetic material carries the risk of erosion into the esophagus [17,18]. Lately, the use of a biologic prosthesis is advocated to decrease the risk of erosion, but its benefits in reducing recurrence seem to diminish at long-term follow-up [19]. Moreover, the high price of these devices warrants a cost-effectiveness review. In view of the results of the present study, as well as of others [20,21], the routine use of prosthetic mesh and the type of mesh in every repair is still controversial and should be applied cautiously at the discretion of the surgeon.

In conclusion, based on the present and previous studies, laparoscopic repair of giant diaphragmatic hernias is challenging, but practical and safe [22]. It should be the treatment of choice for these potentially life-threatening conditions. Our limited experience shows that careful attention to the main pitfalls of the operation, such as the posterior element of the sac, and routinely adding an anti-reflux procedure are important components of successful surgery. In the present study, no correlation was found between the type of crural repair (with sutures, prosthetic patch, or both) and recurrence rates. Urgent cases of acute gastric volvulus or incarcer-

ation may be initially treated conservatively with emergency endoscopic decompression and close monitoring, followed by semi-urgent surgery if immediate decompression is achieved and no signs of ischemia are found during gastroscopy.

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Capsule

Stabilization of cooperative virulence by the expression of an avirulent phenotype

Pathogens often infect hosts through collective actions: they secrete growth-promoting compounds or virulence factors, or evoke host reactions that fuel the colonization of the host. Such behaviors are vulnerable to the rise of mutants that benefit from the collective action without contributing to it; how these behaviors can be evolutionarily stable is not well understood. Diard and colleagues address this question using the intestinal pathogen *Salmonella enterica* serovar *Typhimurium*, which manipulates its host to induce inflammation, and thereby outcompetes the commensal microbiota. Notably, the virulence factors needed for host manipulation are expressed in a bistable fashion, leading to a slow-growing subpopulation that expresses virulence genes, and a fast-growing subpopulation that is phenotypically avirulent. The authors show that the expression of the genetically identical but phenotypically avirulent subpopulation is essential for the evolutionary stability of virulence in this pathogen. Using a combination of mathematical modeling, experimental evolution and competition experiments they found that within-host evolution leads to the emergence of mutants that are genetically avirulent and fast-growing. These mutants are defectors that exploit inflammation without contributing to it. In infection experiments initiated with wild-type *S. typhimurium*, defectors increase only slowly in frequency. In a genetically modified *S. typhimurium* strain in which the phenotypically avirulent subpopulation is reduced in size, defectors rise more rapidly, inflammation ceases prematurely, and *S. typhimurium* is quickly cleared from the gut. Their results establish that host manipulation by *S. typhimurium* is a cooperative trait that is vulnerable to the rise of avirulent defectors. The expression of a phenotypically avirulent subpopulation that grows as fast as defectors slows down this process, and thereby promotes the evolutionary stability of virulence. This points to a key role of bistable virulence gene expression in stabilizing cooperative virulence and may lead the way to new approaches for controlling pathogens.

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