



Patient-related risk factors associated with symptomatic recurrence requiring reoperation in laparoscopic hiatal hernia repair[☆]

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ABSTRACT

Background: Recurrent hiatal hernia remains a challenge.

Methods: For initial repairs at our center: patients with 1 repair were compared to those who required reoperation for symptomatic recurrence. Subsequently, patients who had 1 repair at our center were compared to all patients who required reoperation (including initial repair at another center).

Results: There were 401 repairs: 308 primary repairs at our center and 93 reoperations, 287/308 (93%) required 1 repair and 21/308 (7%) required reoperation. Comparing 1 repair versus 21 reoperations, risk factors were abdominoplasty odds ratio = 32.0 (4.1–250.6), $P < .001$, postoperative lifting/vomiting odds ratio = 11.6 (3.2–42.1), $P < .0002$, tubal ligation odds ratio = 4.9 (1.1–22.6), $P < .04$ and height <160 cm odds ratio = 3.9 (1.1–13.3) $P < 0.03$. Comparing 287 with 1 repair versus all 93 reoperations, risk factors were post-operative vomiting odds ratio = 22.7 (2.3–218.0), $P < .007$, abdominoplasty odds ratio = 5.6 (1.0–31.4), $P < .0495$, post-operative lifting odds ratio = 5.4 (2.2–12.9), $P < .0002$, age <52 odds ratio = 3.6 (1.8–7.3), $P < .0003$, tubal ligation odds ratio = 3.2 (1.2–8.7), $P < 0.019$ and height <160 cm odds ratio = 3.0 (1.5–6.1), $P < 0.003$.

Conclusions: Younger age, shorter stature, heavy lifting or vomiting after surgery, abdominoplasty and tubal ligation are risk factors associated with symptomatic recurrence requiring reoperation.

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INTRODUCTION

Prevention of recurrence following laparoscopic hiatal hernia repair remains a challenge. The rate of radiographic recurrence following laparoscopic repair of large hiatal hernias in esophageal centers is reported to be 12–16% [1,2] with symptomatic recurrence requiring reoperation in 3.2–11.0% [2,3].

We previously reported the outcomes of laparoscopic repair of large hiatal hernias in 131 patients with 8% symptomatic recurrence requiring reoperation at 25 (8–31) months [4].

The aim of our study was to assess patient related risk factors associated with symptomatic recurrence requiring reoperation in laparoscopic hiatal hernia repair to identify patients at risk and to assess possible preventive measures that would increase the success rate of laparoscopic hiatal hernia repair.

METHODS

A Retrospective review of prospectively collected data of patients who underwent hiatal hernia repair at Memorial Hermann Southeast Hospital from 09/16/2009 to 11/10/2017 was conducted. All procedures were performed by the same surgical and anesthesia team in a single center. The post-operative care was provided by a team of thoracic nurses.

The hiatal hernia size was evaluated on esophagram while patient was in the prone oblique position and was measured in the longitudinal axis. The indications and techniques of laparoscopic Nissen and Toupet funduplications and the indications and techniques for Roux-en-Y esophagojejunostomy were previously reported [4]. All primary hiatal hernia repairs at our center were performed laparoscopically. Nissen fundoplication was performed in patients with main symptoms of heartburn and regurgitation, with positive pH or with esophagitis and/or Barrett's esophagus, with adequate esophageal clearance on esophagram and with more than 70% peristaltic esophageal contractions with amplitude of contractions within normal limits on high resolution manometry. Toupet fundoplication was performed in patients with the main symptoms of dysphagia, chest pain, shortness of breath and melena (mostly symptoms caused by intrathoracic migration of the stomach and its mechanical consequences, rather than GERD), with large hiatal hernia or any evidence of dysmotility on esophagram

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or with less than 70% peristaltic esophageal contractions, or low amplitude of contractions on high resolution manometry.

Over the years, we have changed our practice and we now perform Toupet fundoplication for all patients with large hiatal hernia. This change was as the result of the age of the population with large hiatal hernia, which is associated with some degree of esophageal dysmotility, to prevent the side effect of dysphagia associated with Nissen fundoplication and to preserve the ability to burp and vomit with Toupet fundoplication. Other reasons included no need to place a bougie to construct a Toupet fundoplication, which will prevent the risk of esophageal perforation after extensive mediastinal mobilization and comparable relief of symptoms with both types of fundoplications.

Discharge instructions with simple guidelines for diet and lifting restrictions following surgery, as previously reported [5], were reviewed with patients by the operating surgeon at the time of discharge and were reinforced by the thoracic nurses immediately prior to discharge. Clear instructions were given to patients prior to surgery and at the time of discharge to strictly avoid lifting more than 4 lbs. for 8 weeks following surgery, and thereafter, avoid any lifting that would require straining of the abdominal muscles. Similarly, it was emphasized to prevent constipation, not drink with straws, and avoid carbonated drinks to decrease bloating.

Patients were seen in the clinic at 2 weeks, 3 months and 1 year after surgery. For the purpose of the study a follow-up questionnaire via phone, as we previously reported [6], was obtained by the operating surgeon to assess potential risk factors associated with recurrence, including heavy lifting, post-operative forceful retching/vomiting or coughing after surgery.

Consents were obtained from patients. The study was approved by Institutional review board at our institution.

Statistical analysis

Statistical analyses included, 1: assessment of patients' characteristics and operative data in patients who had their primary repair at our center, comparing patients who had 1 hernia repair versus patients who required reoperation 2: comparison between patients who had 1 hernia repair at our center to all patients who required a reoperative procedure (including patients referred from other centers). All reoperative procedures were analyzed independently at the time of reoperation. Frequency data were analyzed by contingency table methods and stratified analyses were used to assess interactions between categorical predictor variables. Continuous variables were described as median and interquartile range (IQR), and hypothesis tests were conducted using t tests or Wilcoxon tests depending on data distribution and whether the observations were paired. Relationship between preoperative variables and symptomatic recurrence requiring reoperative procedure, was evaluated by Spearman rank correlation analysis and multiple logistic regression analysis. The odds ratios (OR) are presented as 95% Confidence interval (CI). The null hypothesis was rejected at a nominal alpha of $P < .05$. All computations were performed using SAS software version 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

From 9/16/2009 to 11/10/2017 there were 401 antireflux procedures (367 patients). There were 308 primary repairs performed at our center and 93 reoperative procedures (including patients who had their first repair at another center).

All primary repairs at our centers were performed laparoscopically: 287/308 patients (93%) had 1 repair and 21/308 (7%) required reoperation for symptomatic recurrence. Comparison of patient's characteristics between two groups are shown in Table 1. Abdominoplasty prior to initial hernia repair was seen in 3/287 (1%) vs 3/21 (14%), $P < .005$ and tubal ligation in 19/287(6%) vs 6/21 (29%), $P < .004$, respectively.

Table 1

Patient characteristics for 308 primary repairs at our center, comparing 287 patients who required 1 repair versus 21 who required reoperative procedures

	Total primary n = 308	1 Hernia repair n = 287	Reoperation n = 21	P
age	63(53–72)	63(54–72)	57(50–65)	.13
gender	76 M (25%) 232 F (75%)	71 M (21%) 216 F (75%)	5 M (24%) 16 F (76%)	.92
Height cm	1.65 (1.60–1.73)	1.65 (1.60–1.73)	1.63 (1.57–1.70)	.15
BMI	29.9 (26.8–33.6)	30.0 (26.8–33.6)	29.1 (26.6–33.4)	.46
ASA	III (II–III)	III (II–III)	II (II–III)	.26
diabetes	57/308 (19%)	53/287 18%	4/21 (19%)	.96
Smoking ever	83/308 (27%)	78/287 27%	5/21 (24%)	.72
Preoperative constipation	21/308 (6.8%)	17/287 (5.9%)	4/21 (19%)	.54
Heartburn	227/308 (74%)	211/287 (74%)	16/21(76%)	.81
Regurgitation	251/308 (81%)	234/287 (82%)	17/21 (81%)	.92
Dysphagia	224/308 (73%)	207/287 (72%)	17/21(81%)	.39
Most common symptom	Heartburn 100 (32.47%)	Heartburn 95 (33.1%)	Dysphagia 5 (23.8%)	.15
Weight loss (yes/no)	35 (11.7%)	33 (11.5%)	2 (9.5%)	.31
Weight loss (lb)	0 (0–0)	0(0–0)	0(0–0)	.86
Abdominoplasty	6/308 (2%)	3/287(1%)	3/21(14%)	<.005
Tubal ligation	25/308 (8%)	19/287 (6%)	6/21 (29%)	<.004
Type I	<4 cm 63 (20.2%)	59 (20.6%)	4 (14.29%)	.45
≥4 cm	60 (19.5%)	54 (18.9%)	6 (28.6%)	
Type II	4 (1.3%)	4(1.1%)	0	.45
Type III	52 (16.9%)	49 (17.13%)	3 (14.3%)	.45
Type IV	129/308(42%)	121/287(42%)	8/21(38%)	.45
Size of hiatal hernia	5 (3–8)	5 (3–8)	6 (4–9)	.204

Operative data, perioperative complications and post-operative course of 1 repair versus reoperative group are shown in Table 2.

Conversion occurred in 2 patients who had 1 repair: 1 was as the result of an esophageal perforation during Bougie insertion at the time of a Nissen fundoplication in a patient with an intrathoracic stomach. The perforation was treated with laparotomy and primary repair. The second conversion occurred as the result of severe adhesions at the level of gastroesophageal junction in a patient with an intrathoracic stomach who had undergone excision of a distal esophageal leiomyoma via a left thoracotomy. There have been no conversions in the last 156 primary repairs in this series and to date.

Esophageal leak occurred in 2 patients who had 1 repair and had a Toupet fundoplication, 1 on POD 7, in a patient with type III hiatal hernia, and 1 on POD 18, in a patient with type IV hiatal hernia. Both were treated with drainage and an esophageal stent, which resolved both leaks. Each developed stricture, requiring stents and dilations. There have been no esophageal leaks in the last 211 primary repairs in this series and to date. Gastric leak occurred in 1 patient, which was diagnosed POD #1 and was in the fundus of the stomach at the level of short gastric vessels probably as the result of thermal injury. The leak resulted in a fluid collection in the left upper quadrant and was treated with a drain placed by interventional radiology.

There has been no gastric leak in the last 51 primary repairs in this series and to date.

None required Collis gastroplasty. In 2/308 (0.7%) patients who had severe esophageal dysmotility, the hernia was repaired with crural closure and gastropexy and without fundoplication.

The duration from the initial repair to the first reoperative procedure was 25 months (12–34), 2/21 patients had recurrent hiatal hernia in the perioperative period as the result of retching and vomiting, one of whom had developed acute gastric distension and retching. Mesh was used in 245/308 (80%) and was not used in 63/308 (20%). Reoperation was required in 16/245 (7%) with mesh versus 5/63 (8%) without mesh, OR 0.83, $P = .73$.

Although there were more recurrences in patients who had undergone a Nissen fundoplication as shown in Table 1, OR = 2.56 (95% CI, 1.03–6.3), statistical adjustment determined that Nissen

Table 2

Operative data, perioperative complications and post-operative course for 308 primary repairs at our center, comparing 287 patients who required 1 repair versus 21 who required reoperation

	Total primary n = 308	1 Hernia repair n = 287	Reoperation n = 21	P
Operative data				
Duration of operation	128 (107–156)	130 (107–156)	119 (107–131)	.39
Toupet	230/308(75%)	218/287(76%)	12/21(57.1%)	.037
Nissen	73/308(24%)	64/287(23%)	9/21(43%)	.037
Others	5/308 (1.6%)	5/287 (1.7%)	0	.55
Mesh	245/308(80%)	229/287(80%)	16/21(76%)	.67
Conversion	2 (0.7%)	2 (0.7%)	0	.32
Intraoperative Esophageal perforation	1 (0.3%)	1 (0.3%)		
Adhesions	1 (0.3%)	1 (0.3%)		
Transfusion	3 (1%)	2 (0.7%)	1 (4.8%)	.32
Perioperative complications (< 30 days)				
NGT for gastric distension	11 (3.6%)	10 (3.5%)	1 (4.8%)	.283
Post Op Afib	6 (1.9%)	5 (1.7%)	1 (4.8%)	.36
Reintubation	5 (1.6%)	5 (1.7%)	0	.99
Pulmonary emboli	3 (1%)	3 (1.1%)	0	.99
Surgical hematoma evacuation	2 (0.7%)	2 (0.7%)	0	.99
Esophageal leak	2 (0.7%)	2 (0.7%)	0	.99
Heparin induced Thrombocytopenia	2 (0.7%)	2 (0.7%)	0	.99
Pneumonia	1 (0.3%)	1 (0.3%)	0	.99
Gastric leak	1 (0.3%)	1 (0.3%)	0	.99
Temporary dialysis	1 (0.3%)	1 (0.3%)	0	.99
Laparoscopic retrieval of retained Penrose	1 (0.3%)	1 (0.3%)	0	.99
Pulmonary effusion requiring drainage	1 (0.3%)	1 (0.3%)	0	.99
Length of stay	2 (1–3)	2 (1–3)	2 (1–3)	.47
30 day/ in hospital mortality	none	none	none	-
Complications after 30 days				
Esophageal dilation	11 (3.6%)	10 (3.5%)	1 (4.8%)	.283
Post Op Afib	2 (0.7%)	1 (0.3%)	1 (4.8%)	.99
Gastrostomy tube	2 (0.7%)	2 (0.7%)	0	.99
Decortication for empyema	1 (0.3%)	1 (0.3%)	0	.56
Pulmonary effusion requiring drainage	1 (0.3%)	1 (0.3%)	0	.56
Laparoscopic port site hernia repair	1 (0.3%)	1 (0.3%)	0	.56

fundoplication was not associated with risk of reoperation (multi-variable analysis, $P = .11$).

Esophageal dilation for postoperative dysphagia was required in 11/308 primary repairs (10/303 who had either Toupet or Nissen funduplications). The need for dilation was similar between patients who underwent a Toupet fundoplication: 5/230 (2.2%) versus those who underwent a Nissen fundoplication: 5/73 (6.9%): $P = .07$.

At the time of follow up questionnaire was administered there were 10 deaths (8 who had their initial surgery at our center and 2 who had their initial surgery at another center) with median age of 79.5 year (68.5–87), at 13.5 months (8.7–28.0) from the time of surgery, 9/10 were unrelated deaths including 5 cardiac etiology, 1 syncope with head trauma, 1 lung cancer and 2 generalized weakness (1 of 2 had severe hypokalemia),

1/10 was a related death which occurred in a patient who had undergone repair of a type III hiatal hernia, had aspiration pneumonia

and required tracheostomy and PEG tube who died 63 days after surgery from a head trauma following a fall in a nursing facility.

Questionnaire was obtained in 222/300 (74%) of living patients who had primary repair at our center at 18.8 months (10.7–37.3): 206/279 (74%) of patients with 1 repair at 18.5 months (10.7–36.0) versus 16/21 (76%) of reoperative group at 28.2 months (17.0–47.8), data shown in Table 3. Post-operative heavy lifting was seen in 6.8% vs 43.8%, $P < .0001$, post-operative vomiting in 1% vs 25%, $P < .0001$.

The 93 reoperative procedures were performed in 80 patients, 21 of whom had first repair at our center and 59 had first repair at another center, 67 patients had 1 repair and 13 had more than 1 procedure prior to the reoperative surgery at our center. The 93 reoperative included 68 laparoscopic, 10 open transabdominal hiatal hernia repair and 15 open Roux- en-Y esophagojejunostomy. The causes of reoperative procedures included, herniated fundoplication in 84/93 (90.3%), tight fundoplication in 5/93 (5.4%), delayed gastric emptying

Table 3

Questionnaire was obtained in 222/300 (74%) living patients who had primary repair at our center: 206/279 (74%) who required only 1 repair versus 16/21(76%) who required reoperation for symptomatic recurrence

	Total primary 222/300 (74%)	1 Repair 206/279 (74%)	Reoperation 16/21(76%)	P
Duration to questionnaire (months)	18.8 (10.7–37.3)	18.5 (10.7–36.0)	28.2 (17.0–47.8)	.10
Post-operative heavy lifting	21 (9.5%)	14 (6.8%)	7 (43.8%)	.0001
Post-operative vomiting	6 (2.7%)	2 (1%)	4(25%)	.0001
Coughing	7 (3.2%)	7 (3.4%)	3/16 (18.8%)	.027
Able to return to daily activity < than 2 weeks	168 (75.7%)	160 (77.7%)	8 (50%)	.241
Weight change	0 (–10–5)	0 (–10–5)	0 (–17.5–5)	.160
Diarrhea	21 (9.5%)	20 (9.7%)	1 (6.3%)	.99
Gas bloating	35 (15.8%)	33 (16%)	2 (12.5%)	.157
Excessive gas	40 (18%)	38 (18.5%)	2 (12.5%)	.564

Table 4
Patient characteristics of 287 patients who required only 1 hernia repair at our center versus 93 reoperative procedures

	1 Repair n = 287	Reoperative n = 93	P
age	63 (54–72)	56 (49–66)	.001
gender	71 M (21%) 216 F (75%)	22 M (24%) 71 (76%)	.83
Height cm	1.65(1.60–1.73)	1.63 (1.57–1.70)	.006
BMI	30.0(26.8–33.6)	29.3 (25.8–32.8)	.16
ASA	III (II–III)	III (II–III)	.80
diabetes	53/287 (19%)	7/93 (8%)	.013
Smoking ever	78/287 (28%)	25/93 (27%)	.91
Preoperative constipation	17/287 (5.9%)	11/93 (11.8%)	.068
Heartburn	211/287 (18%)	67 (72%)	.743
Regurgitation	234/287(82%)	83 (89%)	.09
Dysphagia	207/287 (72%)	75 (81%)	.11
Most common symptom (Heartburn)	95 (33.1%)	26 (28%)	.10
Weight loss (yes/no)	33 (11.5%)	24 (25.8%)	.17
Weight loss (lb)	0 (0–0)	0 (0–5)	.001
Abdominoplasty	3/287(1%)	8/93 (9%)	.001
Tubal ligation	19/287(6%)	15/93 (16%)	.011
Type I			
<4 cm	59 (20.6%)	18 (21.2%)	.77
≥4 cm	54 (18.9%)	32 (37.6%)	.0001
Type II	4(1.1%)	0	.58
Type III	49 (17.13%)	22 (25.9%)	.29
Type IV	121/287(42%)	13/85 (15.3%)	.0001
Size of hiatal hernia	5 (3–8)	4 (3–5)	.8

in 3/93 (3.2%) and slipped fundoplication in 1/93 (1.1%). The most common type of recurrent hiatal hernia requiring reoperation was type I ≥ 4 cm, seen in 32/93 (37.6%) of reoperative procedures. The median size of recurrent hiatal hernia was 4 cm (3–5). None had type II hiatal hernia. Type IV hiatal hernia was seen in 13/93 (14%).

In 27/93 reoperative procedures (in 21 patients), the initial hiatal hernia repair was performed at our center (17 had 1 operation and 4 had more than 1). The duration from the initial repair to the first reoperative procedure was 25 months (12–34), 26 reoperative procedures were performed for recurrent hiatal hernia and 1 for tight fundoplication. In 66/93 reoperative procedures (in 59 patients), the initial procedure was performed in another institution (50 had 1 reoperative procedures and 9 had more than 1 repair). The duration from the initial repair at outside hospital to the reoperative procedure at our hospital was 54 months (28–143).

Roux- en-Y esophagojejunostomy was required in 15 /367 (4.1%) patients, 4/308 (1.2%) had the initial procedures at our center and 11/59 (18.6%) had the initial surgery at another center. Indications for Roux- en-Y esophagojejunostomy included recurrent hernia in 10/15 (66.7%), delayed gastric emptying in 3/15 (20%) and tight fundoplication in 2/15 (13.3%).

Patient characteristics of 287 patients who required only 1 hernia repair at our center compared to 93 reoperative procedures are shown in Table 4. All data were analyzed independently at the time of the

reoperative procedure. Comparison between these 2 groups showed: age 63 (54–72) vs 56 (49–66), $P < .001$, Height 1.65 (1.60–1.73) vs 1.63(1.57–1.70), $P < .006$. Abdominoplasty was seen in 3/287 (1%) vs 8/93 (9%), $P < .001$ and tubal ligation in 19/287 (6%) vs 15/93 (16%) $P < .011$.

The questionnaire was obtained in 57/78 (73%) living patients who had undergone reoperation at 36.4 months (19.3–48.6). The questionnaire data comparing the 206/279 (74%) living patients who had 1 primary repair at our center to 57/78 (73%) living patients who had reoperation (including patients who had initial repair at another center) are shown in Table 5. Post-operative heavy lifting was seen in 6.8% with 1 repair versus 21% reoperative procedures $P < .003$, and post-operative vomiting in 1% vs 7%, $P < .007$.

The multivariable analysis of risk factors associated with symptomatic recurrence requiring reoperation in 21 patients who required reoperation after the initial operation at our center, and all 93 reoperations (including patients who had their initial operation at another center) are shown in Table 6. The prospective prediction of reoperation from baseline characteristics of 21 patients who required reoperation showed that significant factors were abdominoplasty: OR = 32.0 (95% CI, 4.1–250.6), $P < .001$, tubal ligation OR = 4.9 (95% CI, 1.1–22.6), $P < .04$ and height < 160 cm: OR = 3.9 (95% CI, 1.1–13.3) $P < .03$.

DISCUSSION

It seems that symptomatic recurrence requiring reoperation following laparoscopic hiatal hernia repair is a multifactorial complication related to a series of risk factors that can be divided into 3 groups: 1. Pre-operative patient related risk factors including shorter height, younger age, prior tubal ligation and abdominoplasty which were seen in our study and higher BMI in morbidly obese patients as previously reported [7] but not seen in our study, as the median BMI of our population was 30.0. 2. Operative and perioperative related risk factors caused by failure of reconstruction of antireflux barrier with its 3 main known components, including tension free intra-abdominal esophageal length, tension free crural closure and fundoplication, and perioperative vomiting as was shown in our study, and 3. Postoperative patient related risk factors, most importantly heavy lifting as was shown in the present study.

The preoperative patient related risk factors identified in our study included a younger age, identified by a cutoff at the age < 52 . The age factor does not seem to be an isolated factor, solely related to age of the patient, but possibly related to an increased activity level and the potential for more heavy lifting after surgery in a younger population. Shorter height defined by a cut off height < 160 cm as a risk factor may be related to a lower abdominal height and a higher pressure applied to a smaller intra-abdominal space in shorter patients. Other important patient related risk factors identified in our study included surgeries prior to hiatal hernia repair including abdominoplasty which increases the intra-abdominal pressure, and tubal ligation as a possible surrogate of multiple pregnancies. At first glance it seems ironic that abdominoplasty which increases the tone of anterior abdominal wall

Table 5
The questionnaire data comparing 206/279 (74%) living patients who had 1 primary repair at our center to 57/78 (73%) living patients who had reoperation (including patients who had initial repair at another center).

	263/357 (74%) All	206/279 (74%) 1 repair	57/78 (73%) Reoperative	P
Duration to questionnaire (months)	21.1 (12.2–41.5)	18.5 (10.7–36.0)	36.4 (19.3–48.6)	.0001
Post-operative heavy lifting	26 (9.9%)	14 (6.8%)	12 (21.1%)	.003
Post-operative vomiting	6 (2.3%)	2(1%)	4/93(7%)	.007
Coughing	10 (3.8%)	7 (3.4%)	3 (5.3%)	.70
Able to return daily activity < than 2 weeks	187 (71.1%)	160 (77.7%)	27 (47.4%)	.001
Weight change	0 (–10–5)	0 (–10–5)	0 (–10–7)	.014
Diarrhea	26 (9.9%)	20 (9.7%)	6 (10.5%)	.317
Gas bloating	40 (15.2%)	33 (16%)	7 (12.3%)	.782
Excessive gas	47 (17.9%)	38 (18.5%)	9 (15.8%)	.808

Table 6

The multivariable analyses of risk factors associated with symptomatic recurrence requiring reoperation: 287 with 1 repair versus 21 who required reoperation after the initial operation at our center and 287 with 1 repair versus all 93 reoperations (including patients who had their initial operation at another center)

	OR (95% CI)	P
287 with 1 repair vs 21 who required reoperation after the initial operation at our center		
Abdominoplasty	32.0 (4.1–250.6)	<.001
Post-operative heavy lifting or vomiting	11.6 (3.2–42.1)	<.0002
Tubal ligation	4.9 (1.1–22.6)	<.04
Post-operative heavy lifting	9.3 (2.2–38.8)	<.002
Height < 160 cm	3.9 (1.1–13.3)	<.03
287 with 1 repair vs all 93 reoperations (including initial operation at another center)		
Post-operative vomiting	22.7 (2.3–218.1)	<.007
Abdominoplasty	5.6 (1.0–31.4)	<.0495
Post-operative heavy lifting	5.4 (2.2–12.9)	<.0002
Age < 52	3.6 (1.8–7.3)	<.0003
Tubal ligation	3.2 (1.2–8.7)	<.019
Height < 160 cm	3.0 (1.5–6.1)	<.003

muscles and multiple pregnancies which decreases the tone of the abdominal wall muscles and the diaphragm, are both associated with increased risk of symptomatic recurrence requiring operation. One possible explanation is that abdominoplasty increases the pressure applied to the abdominal cavity in a constant manner that can result in herniation of the stomach through a crus that is continuously exposed to a higher intra-abdominal pressure and is not caused by stretching of the abdominal wall and the diaphragm, as seen in patients with multiple pregnancies. In contrast, in patients with multiple pregnancies there is stretching of the abdominal wall and the diaphragm which results in widening of the crural opening that facilitates reherniation, and not caused by the constant increase in intra-abdominal pressure, as seen in patients with abdominoplasty.

Surprisingly, the size and the type of hiatal hernia were not risk factors associated with increased risk of symptomatic recurrence requiring reoperation.

The use of mesh has been shown to reduce the rate of recurrent hiatal hernias in some studies [8,9]. A multi-center, randomized trial showed a reduction in recurrence of hiatal hernia after primary laparoscopic paraesophageal hernia repair at 6 months with the use of biologic prosthetic mesh (9%) compared to primary closure (24%) [10]. However, follow up at 58 months showed no difference between the 2 groups, with 54% radiological recurrence in the group who had biologic prosthetic mesh versus 59% in the group who had primary crural closure [11].

We used mesh for reinforcement of the crural closure in the majority of our patients who had a large hiatal hernia where an atrophic right crus was seen or if there was tension at the time of crural closure. Our present study showed that the use of mesh was not associated with lower risk of recurrence in our follow up period. Randomized studies and longer follow up may show different results.

We previously reported our outcomes of laparoscopic repair of large hiatal hernia without the use of Collis gastroplasty in 131 patients [4] and similarly, we did not perform Collis gastroplasty in any of our patients in the present study. We believe the use of PPI has transformed the clinical presentation of patients with GERD and large hiatal hernia, as near eradication of esophageal stricture has made shortened esophagus, previously seen in majority of patients with large hiatal hernia, a rare entity.

Other factors related to surgery such as intraoperative conversion or leak did not seem to play a role in symptomatic recurrence. The rate of conversion in laparoscopic primary repair of giant paraesophageal hiatal hernia in specialized centers is reported to be 0.8%–1.5% [12,13]. We had 2/308 (0.6%) conversions in our series and none required a reoperative procedure for symptomatic recurrence. Similarly, esophageal leak seen in 2/308 (0.6%) and gastric leak seen in 1/308 (0.3%) were not associated factors. Interestingly, esophageal dilation for post-

operative dysphagia which may result is stretching of the crural closure and possible disruption of the crural stitches was not associated with increased risk of symptomatic recurrence requiring reoperation. Similarly, gastric distention requiring an NGT, did not increase the risk of recurrence. We believe NGT should be inserted if there is postoperative bloating associated with abdominal pain, abdominal distention on physical exam or gastric distension on radiographic studies. One of our recurrences in the perioperative period was caused by acute gastric distension and herniation of the entire stomach into the chest. It was not possible to pass the NGT or decompress the stomach endoscopically, as the pressure caused by a distended stomach on the gastroesophageal junction had obstructed the entrance into the stomach. Therefore, the patient required emergent reoperation for gastric decompression by gastrostomy and repair of the recurrent hiatal hernia.

It seems that the multifactorial nature of symptomatic recurrence requiring reoperation may make this complication a complex entity that will be difficult to eradicate. Many preoperative patient related factors are fixed and out of control of the surgical team, but the recognition of these factors will help surgeons in patient selection and informing patients of their potential risk of recurrence.

Surgeons have a partial control over prevention of recurrence by correct application of surgery related factors and creating the three known pillars of antireflux barrier including adequate intra-abdominal esophageal length, tension free crural closure and a fundoplication. The surgical techniques known to esophageal surgeons to prevent recurrence include extensive esophageal mediastinal mobilization to allow a tension free intra-abdominal esophageal length, avoid placing too tight stitches at the time of crural closure that may result in muscular strangulation and necrosis, and meticulous handling of the crus to prevent muscular tears. Other crucial elements include preservation of the peritoneum overlying the right and left crus to increase the strength of the crural closure, and the division of the splenic attachments to the left crus to prevent tension at the time of crural closure as described previously [14]. The fundoplication is performed as the completion component of an antireflux barrier but its role in prevention of recurrence is not clear. For true assessment of the rate of recurrence we should evaluate patients who had their initial operation at our institution, as we are not aware as how the esophagus was mobilized, the crura was closed or how the mesh was applied, even after reading the operative report in patients in whom the initial operative report was available. In addition the variability in the surgical team in patients who had their operation at another institution plays an important role.

It seems that despite applying all known surgical principles of antireflux surgery, recurrent hiatal hernia remains a challenge difficult to abolish. The dynamic of crural closure with repetitive stress applied to crural stitches with each breath plays an essential role, manifested in the common pattern of failure requiring reoperation, known as herniation of the fundoplication through a partially or fully undone crural closure [15–18]. Similarly, in our previous report of 50 reoperative antireflux procedures in 47 patients in 2016 [6], the most common pattern of failure was herniation of the fundoplication in 45/50 (90%). The present study two years later once again confirms this finding as herniation of the fundoplication was found in 84/93 (90%) of all reoperative procedures.

It seems that recognition of risk factors not directly related to surgery, but related to the preoperative patient characteristics and post-operative care and patient behavior, may play an equally important role in the prevention of symptomatic recurrence requiring reoperation. While we should continue to focus on delivering the surgical principles of antireflux surgery, including, adequacy of esophageal intra-abdominal length, crural closure, fundoplication, and improvement of our surgical knowledge and skills, we should pay equal attention to non-surgical related factors. These factors include preoperative patient related factors such as younger age, and shorter stature, prior abdominoplasty and tubal ligation as risk factors that allows us a better selection of patients, attention to perioperative related

factors such as prevention of perioperative vomiting and educating patients about post-operative relating factors, most importantly, the damages caused by heavy lifting and the need for strict prevention of heavy lifting following surgery.

A multifactorial preventive approach with involvement of patients from the moment of our first contact with patients in clinic and empowering both the patients and care givers with the knowledge and understanding of preoperative, perioperative and postoperative risk factors associated with symptomatic recurrence requiring reoperation, may decrease the risk of recurrence and increase the success rate of laparoscopic hiatal hernia repair.

Conclusions

Symptomatic recurrence requiring reoperative procedure after laparoscopic hiatal hernia is rare, but prevention of recurrence remains a challenge. Younger age, shorter stature, lifting or vomiting after surgery, abdominoplasty which increases the intraabdominal pressure, and tubal ligation, as a surrogate of multiple pregnancies, are factors associated with increased risk of recurrence requiring reoperation. Careful selection of patients, informing patients of risk factors and application of possible preventive measures are essential and may increase the success rate of laparoscopic hiatal hernia repair.

Limitations of the study

We acknowledge the limitations of our study, including the retrospective nature and low number of patients with recurrence who had initial repair at our center, for whom preoperative and post-operative data are available. Inclusion of patients who had their initial operation at another hospital makes the risk assessment for recurrence difficult because of lack of knowledge of patients' characteristics prior, their post-operative course after their initial operation, and the lack of homogenous operative approach, as procedures were performed by different surgical teams.

Tubal ligation considered as a surrogate of multiple pregnancies, does not represent the accurate number of pregnancies, as many patients who have multiple pregnancies do not chose to undergo tubal ligation and some may have a tubal ligation after 1 pregnancy. The exact number of pregnancies would be more accurate for risk assessment. We were not aware that number of pregnancies or tubal ligation may be a risk factor for recurrent hiatal hernia, until we saw results of the study. Now we ask patients about both number of pregnancies and history of tubal ligation. Tubal ligation and abdominoplasty do not add any information for male population, but they are relatively important information in treatment of large hiatal hernia as majority are females.

The fact that Collis gastroplasty was not used in any of our patients may be considered as a risk factor for recurrence for surgeons who are advocates for the use of Collis gastroplasty.

We are not aware of number of patients who may have presented to other centers with symptomatic recurrence. Lastly, the symptomatic recurrence requiring reoperation does not represent radiographic recurrence, which is probably at much higher rate and may be asymptomatic, yet represents failure of the procedure.

Author contribution

Ryan Ellis for study design and data collection,
Grant Garwood for study design and data collection;
Anshu Khanna for study design, data collection and statistical analysis;

Maamoun Harmouch for study design, data collection;
Charles Miller for study design, statistical analysis and critical review;

Farzaneh Banki for study design, collecting data, writing the manuscript, and critical review.

Conflict of interest

None of the authors have any conflict of interest.

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