



A 13-year experience with biologic and biosynthetic absorbable mesh reinforced laparoscopic paraesophageal hernia repair

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Received: 27 March 2023 / Accepted: 23 June 2023

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Abstract

Background Mesh reinforced cruroplasty during laparoscopic paraesophageal hernia repair remains controversial due to wide variation in surgical technique and mesh composition. This study aims to review outcomes and rates of recurrence following laparoscopic paraesophageal hernia repair (LPEHR) with mesh reinforced cruroplasty utilizing absorbable mesh at a single institution.

Methods A retrospective review of all patients who underwent LPEHR with mesh was performed. Medical records were reviewed for patient reported, radiographic or endoscopic evidence of recurrence, defined as > 2 cm of vertical intrathoracic stomach. If no studies were available for review, patients were considered to have no recurrence. Outcomes and mesh-related complications were also reviewed.

Results Between 10/2008 and 9/2021, 473 patients underwent LPEHR with absorbable mesh; 1.3% type 2 hernias, 86.0% type 3 hernias, 12.7% type 4 hernias. Three types of mesh were used: initially biologic mesh ($n=83$), then heavyweight synthetic bioabsorbable mesh ($n=261$), and finally lightweight synthetic bioabsorbable mesh ($n=111$). There were no significant differences in age, ASA, BMI, gender, smoking status, chronic steroid use, preoperative acid suppression, hernia type, or recurrent hernia between groups. There were no significant differences in 30-day postoperative outcomes. Reflux Symptom Index, GERD-HRQL, and Dysphagia Scores at 1- and 2-year postoperative timepoints were not significantly different. The overall recurrence rate was 16.7%, with no significant differences in recurrence rates between biologic, heavyweight or lightweight biosynthetic absorbable mesh through 2 years after surgery. A shorter median time to recurrence (10 months, $p=0.016$) was seen in the lightweight group.

Conclusion LPEHR with absorbable mesh reinforced cruroplasty is feasible and safe, with equivalent patient-reported outcomes, including dysphagia, up to 2-years postop regardless of mesh choice. No significant differences in recurrence rates between biologic, heavyweight, or lightweight synthetic bioabsorbable mesh were seen up to 2 years after LPEHR.

Keywords Paraesophageal hernia · Laparoscopic · Absorbable mesh · Biologic mesh · Biosynthetic absorbable mesh

Paraesophageal hernias represent a minority of all hiatal hernias, with significantly more type 1 sliding hiatal hernias

than type 2–4 paraesophageal hernias. However, paraesophageal hernias pose high risk for complications, much more so than sliding hiatal hernias. Patients with paraesophageal hernias can be asymptomatic, experiences intermittent mild symptoms, or have severe symptoms such as epigastric or substernal chest pain, nausea, regurgitation, and early satiety, among others. Common complications include bleeding from Cameron's ulcerations, respiratory symptoms, and gastric volvulus [1]. There continue to be high rates of hernia recurrence following laparoscopic paraesophageal hernia repair (LPEHR) with a primary suture repair of the crura, up to 42% [2, 3]. This has led many surgeons to question if mesh reinforcement, similar to abdominal wall hernias,

Selected for ePOSTER PRESENTATION at the Society of American Gastrointestinal and Endoscopic Surgeons annual meeting, Montreal, Québec, Canada, March 29th -April 1st, 2023.

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offers benefit in either the long or short-term for patients undergoing surgical repair of paraesophageal hernias.

Ongoing debate about mesh reinforced cruroplasty during LPEHR centers around wide variation in surgical technique and mesh composition. Mesh placement varies from on-lay with fixation using sutures, glues, or tacks to use of pledgets alone, bridging mesh when the crura cannot be approximated, to incorporating the mesh into the crural closure. Mesh characteristics can include permanent or absorbable, biologic vs biosynthetic vs synthetic, heavyweight vs lightweight, and more. The most recent SAGES guidelines for hiatal hernia repair show benefit in decreasing short-term hiatal hernia recurrence with the use of mesh-reinforced cruroplasty, but limited benefits in the long-term. Their conclusion is that more evidence is required to better establish the safety and long-term outcomes of mesh use at the hiatus [4].

At our institution, we have routinely utilized an absorbable mesh incorporated into the crural closure during laparoscopic paraesophageal hernia repairs for over 15 years. It remains unclear what type of mesh may benefit patients most in terms of feasibility, safety, and hernia-related outcomes. In this study we review our institutional outcomes related to mesh reinforced cruroplasty during LPEHR over a 13-year period using three different types of absorbable mesh.

Methods and materials

Data collection

A retrospective review of an IRB approved prospective gastroesophageal quality database was performed. All patients who underwent laparoscopic paraesophageal hernia repair with absorbable mesh reinforcement of their crural closure between 2008 and 2021 were included. Charts were reviewed by the authors for radiographic or endoscopic evidence of paraesophageal hernia recurrence, defined as > 2 cm of vertical intrathoracic stomach. If no studies had been performed since the time of operative repair, patients were considered to have no recurrence. One author (JRA) independently reviewed all charts for evidence of hernia recurrence. If any uncertainty existed, a second author (HW) also reviewed the available studies. If ongoing uncertainty about recurrence existed, all available studies for the patient were reviewed by the senior author (MBU). Patients noted to have paraesophageal hernia recurrence were reviewed for mesh related complications at time of reoperation if they underwent repair of their recurrent hernia at our institution.

Patients were grouped by type of mesh used to reinforce their crural closure: porcine small intestinal submucosal biologic prosthesis (biologic), heavyweight biosynthetic absorbable mesh, or lightweight biosynthetic absorbable

mesh. Biologic mesh was used from 2008 through 2018, with a heavyweight biosynthetic absorbable mesh adopted and utilized as the primary mesh for LPEHR starting in 2013. Most recently, a lightweight biosynthetic absorbable mesh has been in use since 2019. Demographic data included age, BMI, sex, American Society of Anesthesiology class (ASA), smoking status, chronic steroid use, pre-operative antacid use, motility (normal defined as > 80% effective swallows), presence and type of hernia. Intraoperative data included type of anti-reflux procedure, choice of bougie, redo procedure, operative time in minutes (OR time), estimated blood loss (EBL), and intraoperative complications. Perioperative data included length of stay in days (LOS), pain at discharge as measured with a visual analog scale (VAS), days to cessation of narcotics, days to return of activities of daily living (ADLs), and 30-day outcomes including mortality, complications, emergency room visits, and readmission. Patient-reported quality of life (PRQOL) metrics included the Reflux Symptom Index (RSI), Gastroesophageal Health-Related Quality of Life (GERD-HRQL), and Dysphagia Scores at preop, 3-weeks, 6-month, 1, 2, and 5-years postop. Long-term outcomes included endoscopic or radiographic evidence of recurrence, time to recurrence, and follow-up in months.

Esophageal work-up & operative protocol

Patients referred for surgical management of a paraesophageal hernia or anti-reflux surgery undergo a comprehensive esophageal workup. The work-up includes an esophogram, EGD, pH testing ranging from 24- to 96-h in duration, and manometry. Patients with known paraesophageal hernias do not routinely undergo preoperative pH testing.

Operative repair of paraesophageal hernias is routinely performed laparoscopically at our institution by surgeons in the section of minimally invasive surgery (MIS). The MIS group is comprised of six fellowship trained MIS surgeons, two of whom joined the group during the study period. The procedure begins with hernia reduction and a type II mediastinal dissection until ≥ 3 cm of intra-abdominal esophageal length is obtained. Location of the gastroesophageal junction is confirmed with intraoperative upper endoscopy. If appropriate intra-abdominal esophageal length is not able to be obtained, a Collis gastroplasty is performed in rare cases. Both Vagus nerves are identified and preserved. The crura is then closed with a mesh in a U configuration placed over the posterior crura and extending from beyond the right border of the crus to behind the spleen. Permanent sutures with pledgets, placed in an interrupted or horizontal mattress pattern, are used to secure the mesh in place, incorporating the mesh into the closure. (Fig. 1) Variations in LPEHR technique amongst surgeons in the MIS group center around suture patterns

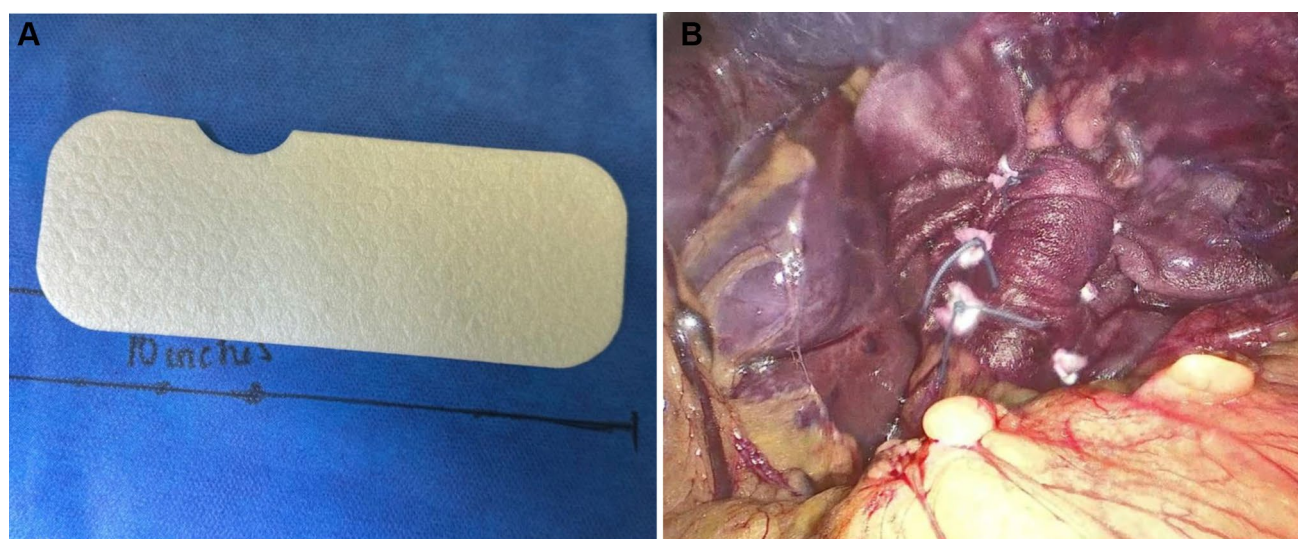


Fig. 1 **A** Absorbable mesh in U-shaped configuration **B** Mesh in situ, secured with horizontal mattress sutures $\times 3$ and pledgets

for crural closure, either interrupted or horizontal mattress. Mesh is routinely placed at the hiatus in all patients with paraesophageal hernias.

Choice of fundoplication, Roux-en-Y gastric bypass, gastropexy or percutaneous gastrostomy tube is at the discretion of the operating surgeon and patient. During fundoplication, choice of traditional hard bougie, the EndoFLIP™ catheter as a soft bougie, or no bougie is also at the discretion of the operating surgeon. During Toupet fundoplication, a gastropexy to the posterior arcuate ligament is performed with two interrupted permanent sutures near the bottom of the posterior wrap. Sutures incorporating the fundus, crus, and esophagus are placed bilaterally. Two additional sutures on the right and two additional sutures on the left of the wrap, each approximately 1 cm inferior to the prior suture, incorporate the fundus and esophagus.

Statistical analysis

Descriptive statistics, such as frequency with percentage, mean with standard deviation, or median with interquartile range were used to summarize results. Group comparisons were made using two-tailed Kruskal–Wallis with the Dwass, Steel, Critchlow–Flinger method for multiple comparisons and chi-square or Fisher's exact tests with the Bonferroni correction for multiple comparisons. Linear regression models adjusting for choice of procedure and bougie were performed to assess PRQOL while controlling for covariates. The Tukey–Kramer adjustment was used for multiple comparisons. All statistical analysis was performed using SAS 9.4 (SAS Institute, Cary, NC) with statistical significance of $p < 0.05$.

Results

There were 473 patients who underwent LPEHR with mesh reinforced crural closure during the study period. Biologic mesh was used from 2008 through 2018 in 83 (17.55%) patients. A heavyweight biosynthetic absorbable mesh was adopted in 2013 and used through 2019 in 261 (55.18%) patients. Most recently, a lightweight biosynthetic absorbable mesh has been in use since 2019 and was used in 111 (23.47%) patients in the study population.

Demographics

Groups did not differ significantly in age, BMI, sex, ASA, smoking status, chronic steroid use, preoperative use of anti-acid medications, or presence and type of paraesophageal hernia. There were significantly more patients with abnormal motility in the Biologic (37.3%) mesh group than the Lightweight Biosynthetic Absorbable (17.1%) mesh group ($p = 0.011$) (Table 1). Over 80% of LPEHR with mesh were performed by a single surgeon in the group, with case break down by surgeon and mesh choice shown in Table 1.

Intraoperative and perioperative data

There were significantly different mixes of anti-reflux procedures performed between groups. Nissen funduplications significantly decreased over time and were performed in 83.1% of patients with biologic mesh, 52.9% of patients with heavyweight biosynthetic absorbable mesh, and only 9.0% of patients with lightweight biosynthetic absorbable mesh ($p < 0.001$). Rates of re-do procedures did not differ between groups. Median operative times differed

Table 1 Demographics by mesh type

	All patients	Biologic	Heavyweight biosynthetic absorbable	Lightweight biosynthetic absorbable	<i>p</i> -value
Total Patients, <i>n</i>	473	83	261	111	—
Age, years [Mean ± SD]	71 ± 11	70 ± 11	71 ± 11	70 ± 10	0.643
BMI, kg/m ² [Mean ± SD]	29.3 ± 5.1	29.8 ± 5.5	29.1 ± 5.1	29.7 ± 4.7	0.546
Female [<i>n</i> (%)]	362 (76.5)	69 (83.1)	196 (75.1)	82 (73.9)	0.258
ASA class 3 or 4 [<i>n</i> (%)]	239 (50.5)	36 (43.4)	131 (50.2)	63 (56.8)	0.180
Smoking status [<i>n</i> (%)]					0.442
Never	254 (53.7)	40 (48.2)	145 (55.6)	60 (54.1)	
Former	206 (43.6)	39 (47.0)	112 (42.9)	48 (43.2)	
Current	13 (2.7)	4 (4.8)	4 (1.5)	3 (2.7)	
Chronic steroid use [<i>n</i> (%)]	24 (5.1)	1 (1.2)	18 (6.9)	5 (4.5)	0.119
Preop antacid use [<i>n</i> (%)]	388 (82.0)	69 (83.1)	221 (84.7)	85 (76.6)	0.169
Motility [<i>n</i> (%)]					0.011*
Normal	215 (45.5)	28 (33.7)	120 (46.0)	63 (56.8)	
Abnormal	126 (26.6)	31 (37.3)	70 (26.8)	19 (17.1)	
No manometry	132 (27.9)	24 (28.9)	71 (27.2)	29 (26.1)	
Hernia type [<i>n</i> (%)]					0.411
2	6 (1.3)	2 (2.4)	2 (0.8)	2 (1.8)	
3	407 (86.0)	70 (84.3)	227 (87.0)	101 (91.0)	
4	60 (12.7)	11 (13.3)	32 (12.3)	8 (7.2)	
Surgeon [<i>n</i> (%)]					<0.001**
A	1 (0.2)	1 (1.2)	0 (0.0)	0 (0.0)	
B	21 (4.4)	7 (8.4)	14 (5.4)	0 (0.0)	
C	5 (1.1)	0 (0.0)	0 (0.0)	5 (4.5)	
D	56 (11.8)	2 (2.4)	51 (19.5)	0 (0.0)	
E	388 (82.0)	73 (88.0)	196 (75.1)	104 (93.7)	
F	2 (0.4)	0 (0.0)	0 (0.0)	2 (1.8)	

SD standard deviation, *BMI* body mass index, *ASA* American Society of Anesthesiology, *Preop* preoperative

*Lightweight biosynthetic absorbable mesh vs. Biologic mesh, $p < 0.05$

**All group comparisons, $p < 0.05$

by a maximum of 13 min between groups and were significantly shorter in the heavyweight biosynthetic absorbable mesh group (136 ± 39 min) than in the biologic group (149 ± 39 min) or lightweight biosynthetic absorbable group (146 ± 36 min, $p < 0.001$). Estimated blood loss decreased significantly over time but was low for the entire cohort at a median of 20 mL (IQR 10–30, $p < 0.001$). There were no significant differences in intraoperative complications between groups, with a low overall rate at 3.8% for the entire study population. Length of stay decreased significantly from a median of 3 days in the biologic group to 2 days in the heavyweight biosynthetic absorbable group to 1 day in the lightweight biosynthetic absorbable group ($p < 0.001$). VAS pain score at time of discharge was significantly lower in the heavyweight biosynthetic absorbable group compared to the biologic group ($p = 0.029$). Narcotics were used significantly longer in the biologic group than either biosynthetic group ($p = 0.001$). Days to return to ADLs did not differ

significantly between groups. Thirty-day perioperative outcomes including mortality, complications, ED visits, and readmissions did not differ significantly between groups. (Table 2).

Recurrences

Overall rates of hernia recurrence were significantly higher in both the biologic group (24.1%) and the heavyweight biosynthetic absorbable group (17.6%) compared to the lightweight biosynthetic absorbable group (4.5%, $p = 0.004$). At the 6-months, 1, and 2-year postoperative timepoints, rates of hernia recurrence did not differ significantly between groups. At 5-years postop, the biologic (15.7%) and heavyweight biosynthetic absorbable (15.3%) groups saw comparable rates of recurrence, with no patients more than 5-years out from surgery with a lightweight biosynthetic absorbable mesh. Median follow-up differed significantly based on

Table 2 Intraoperative and perioperative data by mesh type

	All patients	Biologic	Heavyweight biosynthetic absorbable	Lightweight biosynthetic absorbable	<i>p</i> -value
Total patients, <i>n</i>	473	83	261	111	—
Fundoplication type [<i>n</i> (%)]					< 0.001 ^{a,b,c}
None*	37 (7.8)	3 (3.6)	26 (10.0)	8 (7.2)	
Nissen	233 (49.3)	69 (83.1)	138 (52.9)	10 (9.0)	
Toupet	200 (42.3)	9 (10.8)	96 (36.8)	93 (83.8)	
Dor	3 (0.6)	2 (2.4)	1 (0.4)	0 (0.0)	
Bougie type [<i>n</i> (%)]					< 0.001 ^{a,b,c}
None	58 (12.3)	17 (20.5)	24 (9.2)	12 (10.8)	
Soft bougie	56 (11.8)	0 (0.0)	28 (10.7)	28 (25.2)	
Hard bougie	359 (75.9)	66 (79.5)	209 (80.1)	71 (64.0)	
Redo surgery [<i>n</i> (%)]	44 (9.3)	10 (12.0)	18 (6.9)	12 (10.8)	0.243
OR Time, minutes [Mean ± SD]	141 ± 39	149 ± 39	136 ± 39	146 ± 36	< 0.001 ^{b,c}
EBL, mL [Median (Q1–Q3)]	20 (10–30)	25 (5–50)	20 (10–25)	10 (5–20)	< 0.001 ^{a,c}
Intraoperative complication [<i>n</i> (%)]	18 (3.8)	2 (2.4)	11 (4.2)	3 (2.7)	0.640
LOS, days [Median (Q1–Q3)]	2 (1–3)	3 (2–4)	2 (1–3)	1 (1–2)	< 0.001 ^{a,b,c}
VAS [Median (Q1–Q3)]	2 (0–4)	3 (1–4)	2 (0–3)	2 (0–3)	0.029 ^b
Cessation of narcotics, days [Median (Q1–Q3)]	2 (1–5)	4 (2–8)	2 (1–5)	2 (1–3)	0.001 ^{a,b}
Return to ADL, days [Median (Q1–Q3)]	6 (3–7)	7 (3–14)	7 (3–7)	5 (3–7)	0.085
30 Day mortality [<i>n</i> (%)]	3 (0.6)	1 (1.2)	2 (0.8)	0 (0.0)	0.560
30 Day complication [<i>n</i> (%)]	68 (14.4)	14 (16.9)	38 (14.6)	8 (7.2)	0.087
30 Day ED visit [<i>n</i> (%)]	78 (16.5)	14 (16.9)	46 (17.6)	15 (13.5)	0.617
30 Day readmission [<i>n</i> (%)]	47 (9.9)	9 (10.8)	29 (11.1)	7 (6.3)	0.346

^aLightweight biosynthetic absorbable mesh vs. Biologic mesh, $p < 0.05$

^bBiologic mesh vs. Heavyweight biosynthetic absorbable mesh, $p < 0.05$

^cLightweight biosynthetic absorbable mesh vs. Heavyweight biosynthetic absorbable mesh, $p < 0.05$

SD standard deviation, *EBL* estimated blood loss, *Q1–Q3* first quartile – third quartile, *LOS* length of stay, *VAS* visual analog scale, *ADL* activities of daily living, *ED* emergency department

*If no fundoplication performed, alternative procedures included magnetic sphincter augmentation, Roux-en-Y Gastric Bypass, Gastropexy, or percutaneous endoscopic gastrostomy tube placement

the years in which the mesh types were used, longest in the biologic group and shortest in the lightweight biosynthetic absorbable group ($p < 0.001$). Median size of recurrence was not significantly different between groups. (Table 3) Adjusting for procedure and choice of bougie, there were no significant differences in recurrence rates by mesh type at 6-months ($p = 0.973$), 1-year ($p = 0.275$), or 2-years after surgery ($p = 0.126$). Recurrence rates by procedure type and bougie choice for each mesh did not show any statistically significant differences on multivariable analysis, though these analyses were not well powered.

Of the 79 documented recurrences, 4 patients (5.1%) underwent reoperation for their recurrent hernia at our institution. This included one patient from the biologic mesh group, two patients from the heavyweight biosynthetic absorbable mesh group, and one patient from the lightweight biosynthetic absorbable group. For the biologic mesh patient and both of the heavyweight biosynthetic absorbable mesh patients who were reoperated on, their operative

notes documented an extended lysis of adhesions, ≥ 60 min in duration, due to adhesions at the hiatus and in the mediastinum. It was not clearly documented in the operative notes if the dense adhesions were felt to be due to a re-operative field, previous mesh at the hiatus, or a combination of the two. The single patient who had a biologic mesh and was reoperated on required a relaxing incision. There were no other documented complications noted from prior mesh placement.

Patient-reported quality of life outcomes

GERD-HRQL and RSI scores did not differ at preop or up to 5-years postoperatively, though there were zero patients with PRQOL data at a 5-year postoperative timepoint in the lightweight biosynthetic absorbable group. Dysphagia scores did not differ significantly between groups at preop. The only significant difference in patient-reported quality of life data was a higher Dysphagia Score (scale 1–5) at

Table 3 Paraesophageal hernia recurrence rates by mesh choice

	All patients	Biologic	Heavyweight biosynthetic absorbable	Lightweight biosynthetic absorbable	<i>p</i> -value
Total patients, <i>n</i>	473	83	261	111	—
Recurrence at any time [<i>n</i> (%)]	79 (16.7)	20 (24.1)	46 (17.6)	5 (4.5)	0.004 ^{a,c}
Months to recurrence [Median (Q1-Q3)]	32 (17–54)	42 (17–72)	32 (18–50)	10 (6–13)	0.016 ^{a,c}
Recurrence within 6 Months [<i>n</i> (%)]	4 (0.8)	1 (1.2)	2 (0.8)	1 (0.9)	0.933
Recurrence within 1 Year [<i>n</i> (%)]	11 (2.3)	4 (4.8)	4 (1.5)	3 (2.7)	0.322
Recurrence within 2 Years [<i>n</i> (%)]	27 (5.7)	8 (9.6)	12 (4.6)	5 (4.5)	0.187
Recurrence within 5 Years [<i>n</i> (%)]	62 (13.1)	13 (15.7)	40 (15.3)	5 (4.5)	0.011 ^{a,c}
Hernia size at recurrence [Median (Q1-Q3)]	3.5 (3.0–4.3)	3.1 (2.8–5.0)	3.7 (3.0–4.0)	5.0 (4.1–6.0)	0.109
Follow-up, months [Median (Q1-Q3)]	60 (28–92)	116 (100–128)	62 (42–80)	10 (4–19)	<0.001 ^{a,b,c}

^aLightweight biosynthetic absorbable mesh vs. Biologic mesh, *p* < 0.05

^bBiologic mesh vs. Heavyweight biosynthetic absorbable mesh, *p* < 0.05

^cLightweight biosynthetic absorbable mesh vs. Heavyweight biosynthetic absorbable mesh, *p* < 0.05

Q1–Q3 first quartile–third quartile

6-months postop in the lightweight biosynthetic absorbable mesh group (1.5 ± 0.9 , *n* = 14) compared to the biologic mesh group (1.0 ± 0.0 , *n* = 15, *p* = 0.038). This difference resolved by 1-year postop and dysphagia outcomes remained equivalent at 2-years postop. Response rates varied from 35 to 59% at preop to a nadir of 13–18% at 6-months after surgery and 14–38% at 2-years after surgery amongst the three groups. (Table 4).

When comparisons were adjusted for choice of procedure and choice of bougie, the only significant difference between groups was a significantly higher Dysphagia Score at a 3-weeks postoperative timepoint in the lightweight biosynthetic absorbable mesh group (2.4 ± 0.9) compared to the heavyweight biosynthetic absorbable group (1.9 ± 0.9 , *p* = 0.036). This, too, resolved by 6-months postop and remained resolved at 1 and 2-years postoperative timepoints. (Table 4).

Discussion

There is ongoing controversy about use of mesh-reinforced crural closure during LPEHR, with high rates of hernia recurrence; up to 40% following primary repair at 5-years, up to 57% following absorbable mesh repair at 5-years, and up to 43% following permanent mesh repair at 5-years [5–14]. Current SAGES guidelines for the management of hiatal hernias published in 2013 reviewed existing literature on use of mesh in hiatal hernia repair [4]. They note higher rates of hernia recurrence in patients with larger hernias and mixed data supporting mesh reinforced cruroplasty. The SAGES guidelines give a strong recommendation for mesh reinforced cruroplasty in order to decrease early recurrence rates following repair of large

hiatal hernias. However, the three randomized controlled trials included in their literature review use a PTFE mesh encircling the esophagus in one, a rectangular polypropylene mesh placed in an on-lay fashion in a second, and a U-shaped porcine small intestinal submucosal biologic prosthesis placed in an on-lay fashion in a third [5–8].

A systematic review and meta-analysis of LPEHR with and without mesh published by Angeramo et al. in 2022 includes 4 additional studies published since the most recent iteration of the SAGES hiatal hernia repair guidelines were published in 2013. Their conclusion is that rates of both early and late recurrence do not differ in primary repair vs mesh repair, but that morbidity is higher in patients repaired with permanent mesh [9]. The additional studies included were from Oor et al. in 2018, comparing primary repair vs permanent mesh with no differences in clinical outcomes or recurrence rates at 1-year between groups [10]. Ilyashenko et al. evaluated primary repair vs permanent mesh and found significantly less recurrence and more improved GERD-HRQL scores at 48-months in the mesh group [11]. Watson et al., published 2020, compares primary repair vs biologic vs permanent mesh with no significant differences in clinical outcomes or recurrence rates. However, Watson et al. utilized criteria for defining recurrence that were more lax, with any height of herniated vertical intrathoracic stomach counting as a recurrence, not only those > 2 cm [12, 13]. Also published in 2020, Analatos et al. evaluated primary repair vs PTFE repair and found no significant difference in recurrence rates at 3-years postop [14]. It is hard to draw definitive conclusions from these studies due to wide heterogeneity in mesh choice, method for incorporating the mesh into the repair, definition of recurrence, and length of follow-up.

Table 4 Patient-reported quality of life scores by mesh type

	Biologic	Heavyweight bio-synthetic absorbable	Lightweight bio-synthetic absorbable	<i>p</i> -value	<i>p</i> -value
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Unadjusted	Adjusted*
Preop	<i>n</i> = 29 (35%)	<i>n</i> = 118 (45%)	<i>n</i> = 65 (59%)		
RSI	14.6 $\pm$ 13.6	16.4 $\pm$ 11.1	14.1 $\pm$ 10.0	0.369	0.448
GERD-HRQL	12.7 $\pm$ 12.0	13.0 $\pm$ 10.3	13.0 $\pm$ 10.2	0.870	0.921
Gas/Bloat	1.9 $\pm$ 1.7	2.1 $\pm$ 1.5	1.9 $\pm$ 1.5	0.588	0.712
Dysphagia score	1.2 $\pm$ 0.4	1.4 $\pm$ 0.7	1.4 $\pm$ 0.8	0.712	0.450
3 Weeks	<i>n</i> = 25 (30%)	<i>n</i> = 105 (40%)	<i>n</i> = 24 (22%)		
RSI	10.3 $\pm$ 8.2	9.5 $\pm$ 8.5	12.8 $\pm$ 10.6	0.515	0.124
GERD-HRQL	6.1 $\pm$ 5.9	5.5 $\pm$ 6.9	5.9 $\pm$ 7.6	0.784	0.413
Gas/Bloat	1.7 $\pm$ 1.6	1.5 $\pm$ 1.4	1.6 $\pm$ 1.4	0.779	0.515
Dysphagia score	2.0 $\pm$ 0.8	1.9 $\pm$ 0.9	2.4 $\pm$ 0.9	0.072	0.036 ^b
6 Months	<i>n</i> = 15 (18%)	<i>n</i> = 42 (16%)	<i>n</i> = 14 (13%)		
RSI	6.5 $\pm$ 9.2	8.0 $\pm$ 7.9	6.5 $\pm$ 8.4	0.451	0.843
GERD-HRQL	3.9 $\pm$ 5.1	4.2 $\pm$ 5.6	4.7 $\pm$ 8.4	0.929	0.991
Gas/Bloat	1.5 $\pm$ 1.2	1.8 $\pm$ 1.3	1.6 $\pm$ 1.6	0.629	0.604
Dysphagia score*	1.0 $\pm$ 0.0	1.1 $\pm$ 0.3	1.5 $\pm$ 0.9	0.038 ^a	0.167
1 Year	<i>n</i> = 20 (24%)	<i>n</i> = 76 (29%)	<i>n</i> = 43 (39%)		
RSI	6.3 $\pm$ 6.7	7.9 $\pm$ 8.5	7.2 $\pm$ 7.8	0.701	0.818
GERD-HRQL	4.0 $\pm$ 5.0	4.3 $\pm$ 5.9	3.9 $\pm$ 4.9	0.972	0.758
Gas/Bloat	1.7 $\pm$ 1.7	1.4 $\pm$ 1.3	1.9 $\pm$ 1.3	0.155	0.727
Dysphagia score	1.2 $\pm$ 0.5	1.2 $\pm$ 0.6	1.2 $\pm$ 0.5	0.795	0.758
2 Years	<i>n</i> = 21 (25%)	<i>n</i> = 99 (38%)	<i>n</i> = 15 (14%)		
RSI	7.0 $\pm$ 7.2	8.2 $\pm$ 9.0	11.1 $\pm$ 8.4	0.130	0.315
GERD-HRQL	3.8 $\pm$ 4.0	5.0 $\pm$ 7.6	6.7 $\pm$ 6.5	0.340	0.393
Gas/Bloat	1.7 $\pm$ 1.5	1.6 $\pm$ 1.4	1.6 $\pm$ 1.4	0.976	0.860
Dysphagia score	1.1 $\pm$ 0.3	1.2 $\pm$ 0.6	1.3 $\pm$ 0.5	0.271	0.579
5 Years	<i>n</i> = 27 (33%)	<i>n</i> = 33 (13%)	<i>n</i> = 0 (0%)		
RSI	10.0 $\pm$ 9.8	6.5 $\pm$ 9.2	–	0.107	0.050
GERD-HRQL	4.6 $\pm$ 4.6	4.8 $\pm$ 9.2	–	0.400	0.980
Gas/Bloat	1.5 $\pm$ 1.4	1.4 $\pm$ 1.3	–	0.759	0.415
Dysphagia score	1.2 $\pm$ 0.8	1.2 $\pm$ 0.8	–	0.669	0.573

^aLightweight biosynthetic absorbable mesh vs. Biologic mesh, *p* < 0.05^bLightweight biosynthetic absorbable mesh vs. Heavyweight biosynthetic absorbable mesh, *p* < 0.05

*Adjusted for procedure type and choice of bougie

SD standard deviation, *Preop* preoperative, *RSI* reflux symptom index, *GERD-HRQL* gastroesophageal reflux disease health-related quality of life

At our institution, we have routinely elected to use absorbable mesh during LPEHR for the last 15 + years. Choice of mesh has evolved over the study period, initially biologic mesh through 2018, with decreased usage from 2013 on when we adopted a heavyweight biosynthetic absorbable mesh. The choice to transition from a biologic mesh to a biosynthetic mesh was multifactorial but included literature published in 2013 noting religious leaders' preference to avoid porcine derived implants as well as availability of new alternative absorbable mesh products for use at the hiatus [15]. In addition, biosynthetic mesh is less expensive than biologic mesh with longer durability, roughly 6 months as

opposed to 3 months for biologic mesh. This, at least in theory, provides mesh reinforcement of the crural closure through 6 months, the period traditionally considered early recurrence. From 2019 on, we have almost exclusively utilized a lightweight biosynthetic absorbable mesh, as we have found the lightweight mesh easier to maneuver laparoscopically. The ease of maneuverability during incorporation of mesh into the crural closure has been a significant factor in continuing with a lightweight rather than heavyweight biosynthetic mesh in our practice.

The demographics of the patients, including rates of re-do procedures, did not change significantly over the study

period other than rates of abnormal motility decreasing over time. In addition to evolving mesh choice, we have opted to perform more Toupet funduplications and less Nissen funduplications over the study period. The majority of all LPEHR with mesh reinforced cruroplasty were performed by a single surgeon during the study period. An even higher percentage of cases were performed by the same single surgeon after adoption of the lightweight biosynthetic absorbable mesh. While this limits generalizability of our results to a broader group of general surgeons, and warrants discussion of learning curve over the 13-year study period, this data was obtained in a large group of MIS surgeons who perform variable amounts of foregut procedures. We therefore believe our data still demonstrates feasibility, safety, and comparable rates of paraesophageal hernia recurrence following mesh reinforced cruroplasty with variable absorbable mesh types.

Intraoperative and perioperative complications were low overall, without significant differences between groups. Thirty-day outcomes were comparable with the published literature. There were three observed mortalities (0.6%), an overall complication rate of 14.4%, with 16.5% of patients visiting the ED within 30-days and 9.9% of patients being readmitted within 30-days. [5–7, 10, 11, 13, 14] Pham et al. reported on a case series of 23 patients after LPEHR with biosynthetic absorbable mesh fixed in an on-lay position using a single suture with concurrent Dor fundoplication. They saw 3.13% early mortality and 6.25% early minor complications including one DVT and one case of atelectasis [16]. Learning curve over the 13-year study period did not appear to contribute significantly to rates of complication between mesh types, as no significant differences were noted.

Length of stay decreased significantly over time, likely due to our updated early discharge protocols and no longer leaving a mediastinal drain or obtaining a postoperative esophogram prior to discharge. With the onset of the COVID-19 pandemic in 2020, paraesophageal hernia patients have routinely been discharged on postoperative day one, with type 1 hiatal hernia patients routinely discharged from the post anesthesia care unit on the day of surgery. Return to activities of daily living did not differ significantly between groups, with all patients back to baseline function at a median of 6 days.

Recurrence rates did not differ significantly through 2-years postop, but time to recurrence analysis is confounded by no routine protocols to screen for recurrence. Many of the endoscopic and radiographic studies reviewed were obtained for other reasons, and presence of a recurrent hernia was an incidental finding. Asymptomatic patients likely will not seek out diagnostic testing, and recurrences are either not captured or are identified at the time of imaging for separate medical conditions. As follow-up was significantly longer in both the biologic and heavyweight biosynthetic absorbable

groups, it is possible that at 5-years, recurrence rates in the lightweight biosynthetic absorbable group will be equivalent to the other mesh types. Limited conclusions about differences in long-term rates of hernia recurrence between mesh choices can therefore be drawn from this data. Furthermore, variations in surgical technique including a shift from predominantly Nissen to Toupet funduplications performed as a concurrent anti-reflux procedure may affect recurrence rates, though we did not see any effect of fundoplication or bougie choice on recurrence rates with multivariable analysis.

Patient-reported quality of life scores including the GERD-HRQL evaluating typical GERD symptoms and the RSI evaluating atypical GERD symptoms did not differ between mesh choices at any time from preop through 5-years postop. Though Dysphagia Scores were higher at 3-weeks (adjusted) or 6-months (unadjusted) postoperative timepoints in the lightweight biosynthetic absorbable group, these differences resolved by 1-year postop and remained resolved at 2-years postop.

Concerns about placement of mesh at the hiatus include the risk of complications such as mesh erosion, esophageal stenosis, pericardial tamponade, and effusion [4]. If no definitive benefit has been shown to use of mesh reinforced cruroplasty, many question why risk the significant potential complications. Expert opinion, however, suggests that synthetic permanent mesh used as a crural bridge is most likely to be associated with esophageal erosion, and should therefore be avoided [4]. In our cohort, very few patients underwent reoperation at our institution for their recurrent paraesophageal hernias. No mesh related complications were noted, though 75% of patients did require an increased operative time for their hiatal and mediastinal dissection due to dense adhesions.

Limitations

The retrospective nature and lack of standard prospective protocol to obtain surveillance for paraesophageal hernia recurrence mean we undoubtedly did not capture all hernia recurrences in our cohort. It is unclear how many recurrences were not captured as asymptomatic recurrences may never undergo repeat endoscopy or imaging studies. Patients may also leave the hospital system and have studies that show recurrent hernias outside of our institution. Furthermore, symptomatic recurrences may seek care with a different surgeon than that who performed their index operation. The majority of all LPEHR in this series were performed by a single MIS surgeon, limiting generalizability of our findings. Changes in choice of fundoplication from a predominance of Nissen to a predominance of Toupet over the study period may ultimately affect recurrence rates. Low patient-reported quality of life survey response rates also limit interpretation of subjective data.

Conclusion

Laparoscopic paraesophageal hernia repair with absorbable mesh reinforced cruroplasty is feasible and safe. Patient-reported outcomes, including dysphagia, are equivalent up to 2-years after surgery regardless of mesh choice. No significant differences in recurrence rates between biologic, heavyweight, or lightweight synthetic bioabsorbable mesh were seen up to 2-years after laparoscopic paraesophageal hernia repair.

Acknowledgements Dr. H. Mason Hedberg for use of images included in Figure 1.

Funding None.

Declarations

Disclosures Dr Julia R Amundson, Ms Kristine Kuchta, Dr Hoover Wu, and Dr Vanessa N VanDruff all have no conflicts of interest to disclose. Dr Stephen P Haggerty is a data safety monitoring board member and participates in industry-sponsored research for Syneos Health, he is a consultant for Medtronic Renal Division. Dr John Linn receives speaking and teaching honoraria from WL Gore and Associates, he participates in WL Gore and Associates and BD industry-sponsored research. Dr Michael B Ujiki is a scientific advisory board member for Boston Scientific and Apollo, a consultant and speaker for WL Gore and Associates and a speaker for Medtronic.

References

1. Khalaris P (2023) Hiatus hernia. UptoDate. <https://www.uptodate.com/contents/hiatus-hernia>
2. Hashemi M, Peters JH, DeMeester TR, Huprich JE, Quek M, Hagen JA, Crookes PF, Theisen J, DeMeester SR, Sillin LF, Bremner CG (2000) Laparoscopic repair of large type III hiatal hernia: objective followup reveals high recurrence rate. *J Am Coll Surg* 190:553–560 (discussion 560–551)
3. Wiechmann RJ, Ferguson MK, Naunheim KS, McKesey P, Hazelrigg SJ, Santucci TS, Macherey RS, Landreneau RJ (2001) Laparoscopic management of giant paraesophageal herniation. *Ann Thorac Surg* 71:1080–1086 (discussion 1086–1087)
4. Kohn GP, Price RR, DeMeester SR, Zehetner J, Muensterer OJ, Awad Z, Mittal SK, Richardson WS, Stefanidis D, Fanelli RD (2013) SAGES guidelines Committee. Guidelines for the management of hiatal hernia. *Surg Endosc* 27(12):4409–28. <https://doi.org/10.1007/s00464-013-3173-3>
5. Frantzides CT, Madan AK, Carlson MA, Stavropoulos GP (2002) A prospective, randomized trial of laparoscopic polytetrafluoroethylene (PTFE) patch repair vs simple cruroplasty for large hiatal hernia. *Arch Surg* 137:649–652
6. Granderath FA, Schweiger UM, Kamolz T, Asche KU, Pointner R (2005) Laparoscopic Nissen fundoplication with prosthetic hiatal closure reduces postoperative intrathoracic wrap herniation: preliminary results of a prospective randomized functional and clinical study. *Arch Surg* 140:40–48
7. Oelschlager BK, Pellegrini CA, Hunter J, Soper N, Brunt M, Sheppard B, Jobe B, Polissar N, Mitsumori L, Nelson J, Swanson L (2006) Biologic prosthesis reduces recurrence after laparoscopic paraesophageal hernia repair: a multicenter, prospective, randomized trial. *Ann Surg* 244(4):481–490. <https://doi.org/10.1097/01.sla.0000237759.42831.03>. PMID: 16998356; PMCID: PMC1856552
8. Oelschlager BK, Pellegrini CA, Hunter JG, Brunt ML, Soper NJ, Sheppard BC, Polissar NL, Neradilek MB, Mitsumori LM, Rohrmann CA, Swanson LL (2011) Biologic prosthesis to prevent recurrence after laparoscopic paraesophageal hernia repair: long-term follow-up from a multicenter, prospective, randomized trial. *J Am Coll Surg* 213:461–468
9. Angeramo CA, Schlottmann F (2022) Laparoscopic paraesophageal hernia repair: to mesh or not to mesh. Systematic Review and Meta-analysis *Ann Surg* 275(1):67–72. <https://doi.org/10.1097/SLA.0000000000004913>. (PMID: 33843796)
10. Oor JE, Roks DJ, Koetje JH, Broeders JA, van Westreenen HL, Nieuwenhuijs VB, Hazebroek EJ (2018) Randomized clinical trial comparing laparoscopic hiatal hernia repair using sutures versus sutures reinforced with non-absorbable mesh. *Surg Endosc* 32(11):4579–4589. <https://doi.org/10.1007/s00464-018-6211-3>. (Epub 2018 May 15 PMID: 29766301)
11. Ilyashenko VV, Grubnyk VV, Grubnik VV (2018) Laparoscopic management of large hiatal hernia: mesh method with the use of ProGrip mesh versus standard crural repair. *Surg Endosc* 32(8):3592–3598. <https://doi.org/10.1007/s00464-018-6087-2>. (Epub 2018 Feb 8 PMID: 29423552)
12. Watson DI, Thompson SK, Devitt PG, Smith L, Woods SD, Aly A, Gan S, Game PA, Jamieson GG (2015) Laparoscopic repair of very large hiatus hernia with sutures versus absorbable mesh versus nonabsorbable mesh: a randomized controlled trial. *Ann Surg* 261(2):282–289. <https://doi.org/10.1097/SLA.0000000000000842>. (PMID: 25119120)
13. Watson DI, Thompson SK, Devitt PG, Aly A, Irvine T, Woods SD, Gan S, Game PA, Jamieson GG (2020) Five year follow-up of a randomized controlled trial of laparoscopic repair of very large hiatus hernia with sutures versus absorbable versus nonabsorbable mesh. *Ann Surg* 272(2):241–247. <https://doi.org/10.1097/SLA.0000000000003734>. (PMID: 32675536)
14. Analatos A, Håkanson BS, Lundell L, Lindblad M, Thorell A (2020) Tension-free mesh versus suture-alone cruroplasty in antireflux surgery: a randomized, double-blind clinical trial. *Br J Surg* 107(13):1731–1740. <https://doi.org/10.1002/bjs.11917>. (Epub 2020 Sep 16 PMID: 32936951)
15. Eriksson A, Burcharth J, Rosenberg J (2013) Animal derived products may conflict with religious patients' beliefs. *BMC Med Ethics* 1(14):48. <https://doi.org/10.1186/1472-6939-14-48>
16. Pham M, Cohen-Hallaleh R, Berney CR (2021) Laparoscopic repair of para-esophageal hernia using absorbable biosynthetic mesh. *J Vis Exp*. <https://doi.org/10.3791/59565>

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