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Mesh-reinforced cruroplasty for type III-IV hiatus hernia repair: a single-center experience using the Patient-Tailored Algorithm

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How to cite this article: De Bernardi S, Aiolfi A, Cammarata F, Manara M, Bonavina G, Cavalli M, Campanelli G, Bonavina L, Bona D. Mesh-reinforced cruroplasty for type III-IV hiatus hernia repair: a single-center experience using the Patient-Tailored Algorithm. *Mini-invasive Surg.* 2025;9:32. <https://dx.doi.org/10.20517/2574-1225.2025.78>

Received: 3 Jun 2025 **First Decision:** 15 Aug 2025 **Revised:** 24 Aug 2025 **Accepted:** 11 Sep 2025 **Published:** 28 Sep 2025

Academic Editor: Giulio Belli **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang

Abstract

Aim: Laparoscopic hiatus hernia (HH) repair with cruroplasty is an effective treatment for symptomatic patients with type III-IV HH. Various techniques have been described for posterior cruroplasty, ranging from simple suture (SS) repair to suture reinforced with mesh. Mesh-buttressed (MB) cruroplasty aims to reduce HH recurrence, but there is no consensus on indications for mesh placement, mesh type, fixation method, or materials. This study aimed to assess the medium-term effectiveness of MB cruroplasty guided by the Patient-Tailored Algorithm (PTA) in laparoscopic repair of type III-IV HH.

Methods: We conducted a single-center, retrospective observational study from November 2019 to April 2023, including patients with type III-IV HH. The institutional PTA, based on intraoperative measurable parameters (HH type, hiatus diastasis, pillars trophism, and redo surgery), was utilized to guide the decision-making process. If the PTA score exceeded 5, MB cruroplasty using a 10 × 7 cm keyhole-shaped Phasix-ST mesh was performed. The primary outcome was HH recurrence, defined as a combination of symptoms and anatomical gastric migration > 2 cm above the diaphragm. Univariate and bivariate analyses were performed. Statistical significance was set at P -value < 0.05.



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Results: Seventy-four patients with a minimum follow-up of 12 months were included. The median age was 66 years and 69% were female. The median follow-up was 38 months (range 12-98). MB cruroplasty was performed in 37 patients (50%). HH recurrence occurred in 7 patients (9.5%), with a clinical trend toward higher recurrence after SS compared with MB (10.8% vs. 8.1%). Postoperative quality of life, measured with the disease-specific GERD-HRQL, improved significantly compared to baseline (20 vs. 3, $P = 0.004$). In the MB group, both GERD-HRQL and Reflux Symptom Index (RSI) scores improved significantly compared to SS (GERD-HRQL: 2 vs. 7, $P = 0.048$; RSI: 3 vs. 10, $P = 0.003$). Trends toward improved SF-36 scores and reduced postoperative proton pump inhibitor (PPI) use were also observed.

Conclusion: MB cruroplasty is associated with favorable medium-term outcomes, including reduced HH recurrence, improved quality of life, and decreased daily postoperative PPI use in patients with type III-IV HH. The PTA provides a simple, reproducible intraoperative strategy for guiding cruroplasty and standardizing surgical decision making in type III-IV HH repair.

Keywords: Minimally invasive hiatus hernia repair, hiatal hernia, mesh reinforcement, cruroplasty, hiatus hernia recurrence

INTRODUCTION

The surgical management of hiatus hernia (HH) is complex and remains a widely discussed topic. Despite extensive literature on laparoscopic repair, there is still no consensus on many technical aspects, which limits the standardization and reproducibility of the procedure. This lack of consensus contributes to the wide range of reported HH recurrence rates after surgery, which vary from 1.2% to 66%^[1-7]. Such variability largely reflects heterogeneous definitions of HH recurrence, representing a major limitation when comparing studies, interpreting results, and evaluating different surgical techniques.

Over the years, several methods have been proposed to reinforce cruroplasty, including mesh placement, pledgets, gastropexy, relaxing incisions, ligamentum teres augmentation, and anterior cruroplasty^[8,9]. Among these, the use of mesh to reinforce cruroplasty and potentially reduce recurrence has generated considerable discussion, yet clear guidelines on indications for mesh reinforcement remain lacking. In this context, we previously proposed a Patient-Tailored Algorithm (PTA) based on four criteria (laparoscopic classification of HH, hiatus diastasis, pillars trophism, and recurrence) to guide the decision-making process for mesh-buttressed (MB) cruroplasty^[10-12].

The aim of this study was to evaluate the medium-term efficacy of PTA-guided MB cruroplasty compared to simple suture (SS) cruroplasty in laparoscopic repair of type III-IV HH.

METHODS

This single-center, retrospective observational study was approved by the local Institutional Review Board and conducted in accordance with the Declaration of Helsinki.

All HH cases treated laparoscopically at IRCCS Ospedale Galeazzi-Sant'Ambrogio were recorded in a prospectively maintained database. We screened patients from November 2019 to April 2023 to include adults (≥ 18 years) who underwent SS or MB cruroplasty with Toupet fundoplication. The inclusion criteria were: (a) adults (≥ 18 years); (b) diagnosis of type III or IV HH; (c) surgical indications according to the latest Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines^[13,14]; and (d) a minimum follow-up of 12 months. Exclusion criteria were: (a) previous gastric surgery preventing fundoplication; (b) patients deemed ineligible for surgery; and (c) follow-up < 12 months. The primary

outcome was HH recurrence, defined as the reappearance of GERD symptoms combined with evidence of > 2 cm of stomach herniation above the diaphragm on follow-up upper gastrointestinal (UGI) endoscopy and/or swallow study^[15]. Secondary outcomes included recurrence-free probability, short-term postoperative complications, and quality of life assessment.

Data collection

Baseline demographics and patient characteristics were collected, including age, sex, body mass index (BMI, kg/m²), comorbidities, proton pump inhibitor (PPI) usage, HH size, operative parameters (duration, hiatus diastasis, pillars trophism, laparoscopic HH classification), and short-term outcomes (90-day morbidity and mortality). HH-related symptoms were evaluated using specific questionnaires: the Reflux Symptom Index (RSI)^[16], GastroEsophageal Reflux Disease Health-Related Quality of Life (GERD-HRQL)^[17,18], and 36-Item Short Form Health Survey (SF-36)^[19]. Preoperative evaluation routinely included chest X-ray, barium swallow study, and UGI endoscopy. Selected patients additionally underwent high-resolution manometry (HRM), 24-hour pH-impedance testing, and/or chest and upper abdominal CT scans. Perioperative complications were classified according to the Clavien-Dindo classification^[20].

Surgical technique

All surgeries were performed using a standardized laparoscopic procedure. Patients were positioned in reverse Trendelenburg, with the lead surgeon standing between the patient's legs. Five trocars were inserted, after which HH classification was assigned. The gastrohepatic ligament was divided to expose the anterior esophagogastric junction and the angle of His. Circumferential esophageal dissection was performed to create a retroesophageal window for fundoplication. Mediastinal dissection and caudal mobilization of the esophagus ensured at least 3 cm of tension-free intra-abdominal esophagus. The hernia sac and any associated lipoma were excised. Using a laparoscopic ruler, the transverse diameter of the hiatal opening, pillars trophism, and right pillar length were measured to calculate the PTA [Supplementary Table 1] and hiatal surface area (HSA)^[21].

For PTA ≤ 5, posterior cruroplasty was performed with interrupted non-absorbable sutures tied extracorporeally (Prolene® 2-0, Ethicon). Closure began posteriorly at the junction of the crura and proceeded anteriorly. For PTA ≥ 6, a 10 × 7 cm keyhole-shaped biosynthetic absorbable mesh (Phasix ST®, Bard), made of poly-4-hydroxybutyrate (P4HB) with a hydrogel barrier, was positioned over the hiatoplasty and fixed with two resorbable sutures (Vicryl® 2-0, Ethicon).

After dividing the upper short gastric vessels using a harmonic scalpel, a 270° Toupet fundoplication was performed following the “critical view” concept^[11]. Once the gastric fundus was mobilized, four “cardinal” non-absorbable stitches (Prolene® 2-0, Ethicon) were placed to stabilize the wrap while minimizing manipulation of the fundus. The two cranial sutures included the esophagus, gastric fundus, and respective crus; the two distal sutures, placed 3 cm below, included the esophagus and gastric wall. A running barbed absorbable suture (3-0 polybutester/V-Loc™) secured the gastric wall to each side of the esophagus while preserving the anterior vagus nerve. The nasogastric tube was routinely removed at the end of the procedure, and a mediastinal drain was optionally left in place for 24 h. To prevent postoperative nausea and vomiting, patients received intravenous Ondansetron 4 mg and Dexamethasone 8 mg. On postoperative day 1, a chest X-ray and gastrographin swallow study confirmed the correct position of the gastroesophageal junction and excluded leakage. If unremarkable, patients were started on a semiliquid diet and typically discharged on postoperative day 2^[10,12,22,23].

Follow-up

Follow-up included:

outpatient visits at 1, 3, 6, and 12 months postoperatively, and annually thereafter;

- barium swallow study, routinely at 6 months;
- UGI endoscopy, performed 1 year after surgery.

Subsequent imaging (UGI endoscopy and/or barium swallow) was performed annually or whenever patients reported symptoms. Quality of life was assessed at baseline and follow-up using the RSI^[24], GERD-HRQL^[18], and SF-36^[25] questionnaires.

Statistical analysis

Continuous variables were presented as mean \pm standard deviation or median (interquartile range, IQR). Categorical variables were reported as counts and percentages. Unpaired *t*-tests were used for continuous variables, and Fisher's exact test was applied to categorical variables. Two-sided *p*-values were computed. Although no variable had a *P*-value < 0.2 in univariate analysis, several clinically relevant parameters were included in a binary logistic regression to identify independent predictors of HH recurrence. These included age, laparoscopic HH classification, hiatus diastasis, pillars trophism, and mesh placement. Multicollinearity testing was performed to identify correlations among variables. For multivariate analysis, age and hiatus diastasis were categorized: age (< 65 years *vs.* ≥ 65 years) and hiatus diastasis (< 2 cm, ≥ 2 cm but < 4 cm, ≥ 4 cm), reflecting the three PTA classes. Statistical significance was defined as *P* < 0.05 , and 95% confidence intervals were reported. Recurrence-free probability was estimated using the Kaplan-Meier method. All analyses were performed with IBM SPSS Statistics version 26.

RESULTS

During the study period, 89 patients meeting the inclusion criteria underwent laparoscopic HH repair with Toupet fundoplication at our institution. During follow-up, three patients died from unrelated reasons and 12 patients were lost to follow-up. Thus, 74 patients were included in the final analysis [Figure 1]. All procedures were performed in a standardized manner by two surgeons (D.B. and A.A.).

Among the 74 patients, 69% were female. The mean age was 65.9 years, and the mean preoperative BMI was 27.6 kg/m². The most common comorbidities were hypertension (51%), dyslipidemia (15%), and thyroid disease (10%). The main symptoms were heartburn (58%), regurgitation (39%), and epigastric pain (38%), while atypical symptoms were reported in a minority of patients [Table 1]. The mean HH size measured during UGI endoscopy was 6.5 cm, and esophagitis of any grade (according to the Los Angeles classification) was observed in about 14% of cases. HRM and pH-impedance testing were performed selectively as part of the diagnostic work-up.

The mean operative time was 126 min. According to the preoperative PTA score, 50% of patients with a score ≤ 5 underwent SS cruroplasty, while the remaining 50% received MB cruroplasty. The mean HSA was 6.2 cm². Concordance between HSA and PTA in indicating MB cruroplasty was 86%.

No intraoperative complications occurred, and no cases required conversion to open surgery. The 90-day postoperative complication rate was 5.4% (*n* = 4). Complications according to the Clavien-Dindo classification included: grade IIIa (pneumothorax, pleural effusion; *n* = 3) and grade IIIb (hydropneumothorax with pleural empyema; *n* = 1). No mortality (grade V) was observed.

Table 1. Demographic characteristics, preoperative, intraoperative, and postoperative data

			n = 74
Age, years (mean ± SD)			65.9 ± 10.3
Sex, female, n (%)			51 (69.0)
Follow-up, months, median (IQR)			38 (25-62)
BMI, kg/m ² (mean ± SD)	Pre		27.6 ± 3.8
	Post		26.2 ± 4.5
	P-value		0.10
Symptoms, n (%)	Heartburn		43 (58)
	Epigastric pain		28 (38)
	Regurgitation		29 (39)
	Cough		20 (27)
	Dysphagia		25 (34)
	Dyspepsia		19 (26)
EGDS	HH size, cm (mean ± SD)		6.5 ± 2.1
	Esophagitis, n (%)	L.A. A	4 (5.4)
		L.A. B	5 (6.8)
		L.A. C	0
		L.A. D	1 (1.4)
	Barrett's esophagus, n (%)		0
Surgical procedure	HH laparoscopic classification, n (%)	IIIA	47 (63)
		IIIB	16 (22)
		IV	11 (15)
	Hiatus diastasis, n (%)	< 2 cm	14 (18.9)
		≥ 2 and < 4 cm	53 (71.6)
		≥ 4 cm	7 (9.5)
	Pillars trophism, n (%)	≥ 5 mm	64 (86.5)
		< 5 mm	10 (13.5)
	Previous antireflux procedure, n (%)		10 (13.5)
	Mesh placement, n (%)		37 (50)
	OT, min (mean ± SD)		126 ± 39
	HSA, cm ² (mean ± SD)		6.2 ± 2.7
	Concordance rate between PTA and HSA, n (%) (n = 49)		42 (86)
PPI use, n (%)	Pre		55 (74.3)
	Post		35 (47.3)
	P-value		0.001
Quality of life	GERD-HRQL, median (IQR)	Pre	20 (6-35)
		Post	3 (0-19)
		P-value	0.004
	RSI, median (IQR)	Pre	14 (5-22)
		Post	6 (2-11)
		P-value	0.008
	SF-36, median (IQR)	Pre	63.5 (36.5-82.2)
		Post	72.3 (47-85.6)
		p-value	0.325
Recurrence, n (%)			7 (9.5)

SD: Standard deviation; IQR: interquartile range; BMI: body mass index; EGDS: esophago-gastro duodenoscopy; HH: hiatus hernia; OT: operative time; HSA: hiatal surface area; PTA: Patient-Tailored Algorithm; PPI: proton pump inhibitor; GERD-HRQL: GastroEsophageal Reflux Disease Health-Related Quality of Life; RSI: Reflux Symptom Index; SF-36: 36-Item Short Form Health Survey.

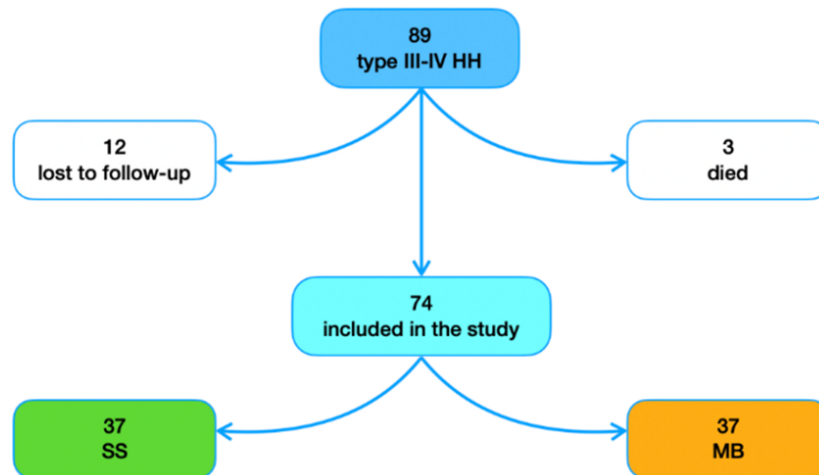


Figure 1. Patient population. SS: Simple suture cruroplasty; MB: mesh-buttressed cruroplasty.

The median follow-up was 38 months (range, 12-98). Compared to baseline, there was a significant reduction in postoperative PPI use (74% vs. 47%; $P = 0.001$) and significant improvements in quality of life, as measured by both GERD-HRQL (20 vs. 3; $P = 0.004$) and RSI (14 vs. 6; $P = 0.008$). Overall, seven patients (9.5%) were diagnosed with HH recurrence; none required redo surgery. No mesh-related complications were reported during follow-up.

Patients were stratified into SS and MB groups. Demographic, preoperative, intraoperative, and postoperative characteristics are reported in Table 2. Compared with SS cruroplasty, MB cruroplasty showed a trend toward lower HH recurrence (10.8% vs. 8.8%). Notably, both GERD-HRQL (2 vs. 7; $P = 0.048$) and RSI (3 vs. 10; $P = 0.008$) were significantly improved in the MB group compared with SS. Trends toward improved SF-36 scores and reduced PPI use were also observed with MB cruroplasty. Multivariate logistic regression, adjusting for relevant covariates, did not identify significant factors associated with HH recurrence [Table 3]. The recurrence-free probability for mesh vs. no mesh repair was as follows: at 12 months, 1.00 vs. 0.95; at 24 months, 0.94 vs. 0.95; at 36 months, 0.94 vs. 0.94; at 48 months, 0.86 vs. 0.91; and at 72 months, 0.86 vs. 0.83 [Figure 2].

DISCUSSION

This study shows a promising effect of MB PTA-guided cruroplasty in patients with symptomatic type III-IV HH. Compared to SS cruroplasty, MB cruroplasty was associated with a trend toward lower medium-term HH recurrence and reduced PPI use, along with significant improvements in patient quality of life.

Laparoscopic posterior cruroplasty is a crucial step in HH repair. The choice of technique largely depends on the surgeon's subjective assessment of crural weakness, as there is currently no standardized, objective method for crura repair. The use of mesh to reinforce diaphragmatic closure and reduce recurrence risk remains controversial due to the lack of clear guidelines. Conflicting evidence in the literature contributes to this uncertainty. Studies comparing MB cruroplasty with SS cruroplasty report heterogeneous outcomes, with some suggesting benefits in recurrence reduction and others showing no significant effect. For instance, a 2022 meta-analysis by Clapp *et al.*, including 21 studies, reported a significantly lower recurrence rate in the bioabsorbable mesh group compared to the non-mesh group (8% vs. 18%, pooled P -value < 0.0001) with a median follow-up of 27 months^[26]. Similarly, Hanna *et al.* (2024) found that mesh placement

Table 2. Demographic characteristics, preoperative, intraoperative, and postoperative data of patients divided into SS and MB groups

			SS group	MB group	P-value
<i>n</i>			37	37	
Age, years (mean \pm SD)			65 \pm 11	67 \pm 10	0.301
Sex, female, <i>n</i> (%)			26 (70)	25 (68)	1.000
Follow-up, months, median (IQR)			59 (23-68)	33 (27-49)	0.081
BMI, kg/m ² (mean \pm SD)		Pre	28 \pm 4	26 \pm 4	0.109
		Post	27 \pm 5	25 \pm 4	0.260
Symptoms, <i>n</i> (%)		Heartburn	25 (68)	18 (49)	0.157
		Epigastric pain	14 (38)	14 (38)	1.000
		Regurgitation	18 (49)	11 (30)	0.153
		Cough	13 (35)	7 (19)	0.190
		Dysphagia	12 (32)	7 (19)	0.287
		Dyspepsia	12 (32)	13 (35)	1.000
EGDS	HH size, cm (mean \pm SD)		6 \pm 2	7 \pm 2	0.072
Surgical procedure	HH laparoscopic classification, <i>n</i> (%)	IIIA	32 (87)	15 (41)	0.000
		IIIB	3 (8)	13 (35)	0.010
		IV	2 (5)	9 (24)	0.046
	Hiatus diastasis, <i>n</i> (%)	< 2 cm	13 (35)	1 (3)	0.001
		\geq 2 and < 4 cm	24 (65)	29 (78)	0.302
		\geq 4 cm	0	7 (19)	0.011
	Pillars trophism, <i>n</i> (%)	\geq 5 mm	37 (100)	27 (73)	0.001
		< 5 mm	0	10 (27)	
	Previous antireflux procedure, <i>n</i> (%)		1 (3)	9 (24)	0.014
	Score, <i>n</i> (%)	\leq 5	35 (95)	0	0.000
		> 5	2 (5)	37 (100)	
	OT, min (mean \pm SD)		107 \pm 31	145 \pm 36	< 0.0001
	HSA, cm ² (mean \pm SD)		4.3 \pm 1.4	7.4 \pm 2.7	< 0.0001
	HSA concordance (%)		42/49 (86)		
Recurrence, <i>n</i> (%)			4 (10.8)	3 (8.1)	1.000
Time from surgery to recurrence, months, median (IQR)			25 (10-45)	19 (17-32)	0.829
PPI use, <i>n</i> (%)		Pre	32 (86.5)	23 (62.1)	0.032
		Post	21 (56.8)	14 (37.8)	0.162
Quality of life	GERD-HRQL, median (IQR)	Pre	20 (5-35)	23 (10-34)	0.774
		Post	7 (0-25)	2 (0-13)	0.048
	RSI, median (IQR)	Pre	15 (5-22)	10 (5-17)	0.731
		Post	10 (4-18)	3 (1-8)	0.003
	SF-36, median (IQR)	Pre	31 (19-59)	73 (64-79)	0.321
		Post	65 (40-89)	77 (61-84)	0.140

SS: Simple suture; MB: mesh-buttressed; SD: standard deviation; IQR: interquartile range; BMI: body mass index; EGDS: esophago-gastro duodenoscopy; HH: hiatus hernia; OT: operative time; HSA: hiatal surface area; PPI: proton pump inhibitor; GERD-HRQL: GastroEsophageal Reflux Disease Health-Related Quality of Life; RSI: Reflux Symptom Index; SF-36: 36-Item Short Form Health Survey.

during primary HH repair reduced early recurrences but did not affect late recurrences, complications, or postoperative symptoms^[27]. Conversely, Petric *et al.*, in a meta-analysis of randomized control trials (RCTs) comparing sutured vs. mesh-augmented HH repair, found no significant differences in short-term recurrence (6-12 months, 10.1% mesh vs. 15.5% sutured, *P*-value = 0.22), long-term recurrence (3-5 years, 30.7% mesh vs. 31.3% sutured, *P*-value = 0.69), functional outcomes, or patient satisfaction^[28]. Latorre-Rodríguez *et al.* similarly reported no difference in recurrence rates between absorbable mesh and suture repair

Table 3. Univariate vs. multivariate analysis

	Non-recurrence group (n = 67)	Recurrence group (n = 7)	Univariate analysis P-value	Multivariate analysis	
				P-value	OR (95%CI)
Age					
< 65	26	3	1.00	0.94	1.07 (0.21; 5.53)
≥ 65	41	4			
HH laparoscopic classification					
IIIA	42	5	1.00	0.99	0.99 (0.12; 8.11)
IIIB-IV	25	2			
Diastasis					
< 2 cm	13	1	1.00	0.61	1.90 (0.17; 21.58)
≥ 2 and < 4 cm	47	6			
≥ 4 cm	7	0			
Pillars trophism					
≥ 5 mm	58	6	1.00	0.98	0.97 (0.07; 13.52)
< 5 mm	9	1			
Mesh placement					
No	33	4	1.00	0.83	0.78 (0.08; 7.34)
Yes	34	3			

OR: Odds ratio; CI: confidence interval; HH: hiatus hernia.

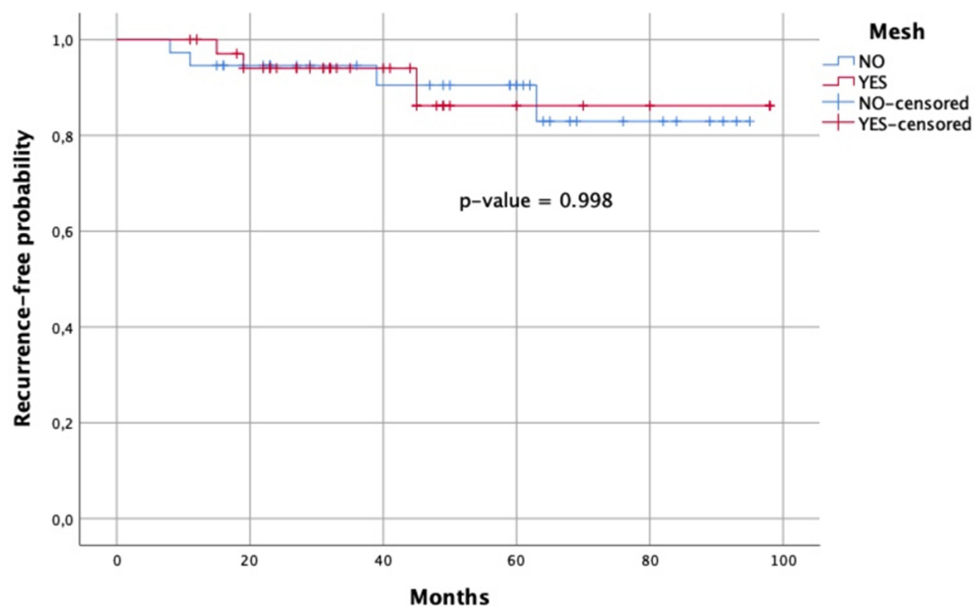


Figure 2. Kaplan-Meier survival curve of patients treated with mesh (red line) vs. no mesh (blue line). The x-axis represents time in months, and the y-axis represents recurrence-free probability.

(20.6% vs. 20.8%)^[29]. Another 2022 RCT meta-analysis also found comparable early [relative risk (RR) = 0.74, P -value = 0.46] and late (RR = 0.75, P -value = 0.48) recurrence rates regardless of mesh use. However, heterogeneous definitions of HH recurrence and inclusion of patients lost to follow-up limited these conclusions. By reanalyzing the same RCTs with a more uniform definition of recurrence (both anatomic and symptomatic), excluding patients lost to follow-up, and performing sensitivity analysis, Aiolfi *et al.*

found a significant reduction in HH recurrence ($RR = 0.35$; P -value = 0.02), supporting mesh use for crural augmentation^[30]. Nevertheless, it remains essential to weigh the potential benefits against possible mesh-related complications. Absorbable meshes are preferred, as the inflammation associated with implantation promotes native tissue strengthening and scar formation without causing the serious complications seen with non-resorbable meshes, such as erosion, migration, adhesions, infection, strictures, dysphagia, or chest pain^[31-33].

As noted, there is no standardized method for posterior cruroplasty, and techniques vary according to surgeon experience, contributing to outcome heterogeneity. An early attempt at standardization was proposed by Granderath *et al.* (2007), who introduced the HSA calculation via a complex trigonometric formula^[21]. They recommended mesh placement when HSA exceeded 4 cm². To simplify decision-making, we developed the PTA, a tool based on easily assessable intraoperative features without complex computations. The PTA provides a simpler, reproducible, and direct method for guiding cruroplasty, demonstrating promising outcomes in improving quality of life and reducing HH recurrence^[23]. Compared to HSA, the PTA is more accessible intraoperatively, with a high concordance rate exceeding 85%, and accounts for factors such as HH recurrence risk and crural frailty, which HSA does not.

In our study, the overall recurrence rate was 9.5%, lower than many reported rates. However, the lack of a uniform definition of recurrence contributes to such variability and makes robust comparisons difficult^[9,34,35]. Surgeons at our center are part of a specialized referral unit for GERD surgery, which may also contribute to lower recurrence and complication rates. The use of Phasix-ST®, a biosynthetic absorbable mesh composed of P4HB with Sepra Technology (ST) coating, may further reduce complications. This mesh degrades over 12-18 months, acting as a scaffold to reinforce the hiatus^[12], while the ST coating - composed of sodium hyaluronate and carboxymethylcellulose - minimizes visceral adhesions. This type of mesh demonstrates a favorable short- and medium-term safety and efficacy profile, preventing early recurrences while avoiding long-term complications. In our study, a trend toward lower HH recurrence was observed for MB *vs.* SS cruroplasty (8.8% *vs.* 10.8%), although the difference did not reach statistical significance, likely due to the small number of recurrences. Multivariate analysis suggested a possible clinical trend (point estimation 0.78), but the 95%CI included the null value. Increasing age was linearly associated with HH prevalence, though statistical significance was limited by the sample size^[36,37]. Clinically, postoperative PPI use tended to be lower in the mesh group (37.8% *vs.* 56.8%, P -value = 0.16). MB cruroplasty was also associated with improved GERD-HRQL and RSI scores compared to SS, an important finding given that, according to the 2024 SAGES guidelines, HH repair primarily aims to improve quality of life^[13].

Limitations of this study include its retrospective design, which may introduce attrition and selection bias. Variable follow-up durations could underestimate recurrence rates. The limited number of patients and recurrences restricted robust multivariate analysis. Additionally, as a tertiary referral center study, generalizability may be limited. Prospective, multicenter studies with larger samples are required to validate these preliminary findings.

In conclusion, MB cruroplasty using a biosynthetic absorbable mesh appears safe and promising for reducing HH recurrence, improving quality of life, and potentially decreasing PPI use. Careful patient selection is essential to optimize outcomes. The PTA offers a practical, reproducible approach to standardize type III-IV cruroplasty, reducing reliance on subjective surgical judgment.

DECLARATIONS

Authors' contributions

Conceptualization, investigation, analysis, writing - original draft, review, and editing: Aiolfi A
Conceptualization, investigation, writing - original draft, review, and editing, supervision: Bona D
Data analysis, writing - review and editing: Cammarata F
Conceptualization, investigation, writing - review and editing, supervision: Campanelli G
Conceptualization, investigation, writing - original draft, review, and editing, supervision: Bonavina L
Writing - review and editing: Cavalli M
Data collection, writing - review and editing: Manara M, Bonavina G
Data collection, analysis, writing - original draft, review, and editing: De Bernardi S
All authors contributed to data interpretation, critical revisions and approved the final version of the manuscript.

Availability of data and materials

All data are available from the corresponding author upon reasonable request.

Financial support and sponsorship

None.

Conflicts of interest

Aiolfi A and Bona D are Editorial Board members of *Mini-invasive Surgery*. Bonavina L and Aiolfi A served as Guest Editors for the Special Issue *Minimally Invasive Techniques for Repair of Hiatal Hernia*. Aiolfi A, Bona D, and Bonavina L were not involved in any stage of the editorial process, including reviewer selection, manuscript handling, or decision making. The other authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

The study was approved by the Comitato Etico Territoriale Lombardia 1 (protocol number: OGSA#2025-00151) and was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all patients prior to surgery during preoperative counseling.

Consent for publication

Not applicable.

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