



Laparoscopic posterior cruroplasty: a patient tailored approach

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Abstract

Background Different surgical variations have been described for laparoscopic crural repair however, the technique is not standardized and left to the surgeons' preference.

Objective The purpose of this study is to describe a standardized “patient tailored” approach for laparoscopic posterior cruroplasty in the setting of elective hiatal hernia repair.

Methods Retrospective single-center study was conducted (November 2015 to November 2019). The technical aspects of a standardized “patient tailored” laparoscopic posterior crural repair are described. Perioperative outcomes and patients' quality of life, measured with the disease specific Gastro-Esophageal Reflux Disease Health-Related Quality of Life (GERD-HRQL) and generic Short Form-36 (SF-36), were analyzed.

Results One hundred and forty-one patients were treated for symptomatic hiatal hernia according to the described “patient tailored” concept. Overall, 102 (72.3%) patients underwent simple suture repair while simple suture repair buttressed with biosynthetic resorbable U shaped mesh [Phasix ST[®]-Bard] was used in 39 (27.7%) patients. Toupet fundoplication was fashioned in all patients. The median operative time was 131 min (IQR 55–240). No intraoperative complications or conversion to open surgery occurred. The median postoperative stay was 1.8 days (range 1–7). The overall postoperative complication rate was 4.2%. The median follow-up was 21 months (IQR range 1–34) with 102 patients having a minimum follow-up of 6 months. Recurrent hernia was diagnosed in three patients (2.1%), but none required reoperation. No mesh-related complications occurred. Compared to baseline, the median GERD-HRQL ($p = 0.003$) and all SF-36 items ($p < 0.001$) were significantly improved.

Conclusion The application of a standardized “patient tailored” concept for laparoscopic posterior cruroplasty seems safe and effective in the medium-term follow-up with promising perioperative outcomes and quality of life improvement. This approach may be valuable to assure procedure reproducibility, standardization, and to uniformly interpret the outcomes.

Keywords Esophageal crura · Hiatus hernia · Recurrence · Gastroesophageal reflux disease (GERD) · “Patient tailored”

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Introduction

Hiatal hernia occurs when contents of the abdominal cavity protrude through the esophageal hiatus of the diaphragm. Factors that contribute to its development include enlargement of the hiatus, increased abdominal thoracic pressure gradient, depletion of elastic fibers in the phrenoesophageal membrane with aging and deterioration of the crura muscle fibers [1]. In addition, changes in spinal curvature may be an important pathogenic factors [2]. The stomach is the most commonly involved viscera and pathologic gastroesophageal reflux disease (GERD) may be associated.

Laparoscopic hiatal hernia repair with fundoplication has been shown to be a valuable option in symptomatic patients [3, 4]. Reconstruction of the diaphragmatic crura cannot exempt from a careful evaluation of the complex anatomical conformation of the esophageal hiatus [1]. Different techniques have been described for posterior cruroplasty ranging from simple suture repair to simple suture buttressed with mesh [5]. However, these techniques are not standardized and left to the surgeons' preference and "feeling" of weak crura [6].

In an attempt to overcome the limitations of a non-standardized repair, we describe and propose our standardized "patient tailored" approach for posterior cruroplasty in the treatment of hiatal hernia. In addition, we aimed to analyze the perioperative outcomes and disease specific quality of life.

Methods

This single center retrospective study was conducted from November 2015 to November 2019 including patients operated for hiatus hernia. Indications for surgery were in accordance with the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) 2010 Guidelines for Surgical Treatment of GERD [7]. All procedures were performed by three surgeons (DB, GS, and AA). The Institutional Review Board (IRB) approved the study and all

patients signed a written informed consent to participate in the study and follow-up. Inclusion criteria: (a) patients suffering from symptomatic hiatus hernia; (b) elective laparoscopic repair. Exclusion criteria (a) patients unfit for surgery; (b) previous resective gastric operations.

"Patient tailored" concept

A standardized "patient tailored" concept based on four parameters was introduced in accordance with literature evidence and surgeons experience:

Laparoscopic hiatus hernia classification (Table 1)

The type of hernia is stratified into Type I–II (1 point), Type IIIa (2 points), and Type IIIb–IV (3 points).

Hiatus diastasis

After mediastinal and circumferential esophageal dissection, the transverse opening diameter of the hiatus is measured with a laparoscopic ruler just below the esophagus and classified as < 2 cm (1 point), > 2 and < 4 cm (2 points), > 4 cm (3 points).

Tropism of diaphragmatic pillars

Pillars were apriori categorized on the basis of the transverse length measured with a laparoscopic ruler. Pillars < 5 mm were defined hypoplastic while pillars > 5 mm were defined as normal. The presence of hypoplastic pillars (< 5 mm) is 3 points while the presence of normal pillars (> 5 mm) is 1 point.

Recurrence

The presence of recurrence gives two extra points.

Based on the final score the surgeon decided to repair the esophageal crura with simple suture technique (< 5 points) or simple suture buttressed with absorbable Phasix ST[®] mesh (> 5 pts) (Table 2).

Table 1 The Laparoscopic hiatal hernia classification

Hiatal hernia	Laparoscopic classification
Type I	Hiatal hernia with supra-diaphragmatic sliding of the cardia. "Sliding hiatal hernia"
Type II	Hiatal hernia with gastric fundus and greater curvature roll up through the diaphragm "Paraesophageal or rolling hernia"
Type IIIa	Combination of both Type I and Type II hernia with supra-diaphragmatic sliding of the cardia, gastric fundus, and gastric body (< 50%)
Type IIIb	Combination of both Type I and Type II hernia with supra-diaphragmatic sliding of the cardia, gastric fundus, and gastric body (> 50%)
Type IV	Hiatus hernia with associated supra-diaphragmatic sliding of other abdominal viscera (i.e., omentum, colon, etc.)

Table 2 The type of hernia was stratified into Type I–II (1 point), Type IIIa (2 points), and Type IIIb–IV (3 points)

Parameters	1 point	2 points	3 points
Laparoscopic classification	Type I–II	Type IIIa	Type IIIb–IV
Hiatus diastasis	< 2 cm	> 2–< 4 cm	> 4 cm
Hypotrophy of diaphragmatic pillars	Absent (> 5 mm)	//	Present (< 5 mm)

The opening of the hiatus was stratified as less than 3 cm (1 point), between 3 and 4 cm (2 points), more than 4 cm (3 points). The presence of hypoplastic pillars (< 5 mm) gives 3 points and the presence of normal pillars (> 5 mm) give 1 points. Finally, the presence of recurrence gives 2 extra points. Based on the final score the surgeon decided to place (> 5 pts) or not to place (< 5 pts) the reinforcement mesh



Fig. 1 After mediastinal dissection and circumferential downward esophageal mobilization, the opening diameter of the crura is measured just below the esophagus with a laparoscopic ruler

Surgical technique

The patient is placed in the reverse Trendelenburg position with the operating surgeon standing between the patient's legs. Five trocars are used and placed standard position for esophageal junctional procedures. The hiatus hernia classification is assigned. The gastrohepatic ligament is opened above the hepatic branch of the vagus nerve. By dividing the peritoneal reflection, the anterior aspect of the esophagogastric junction and the angle of his are exposed. The phrenoesophageal ligament is divided just lateral to its esophageal insertion. The avascular plane outside of the hernia sac is identified and dissected in a clockwise direction to reduce the herniated stomach. The mediastinal dissection and esophageal downward mobilization for at least 3 cm are completed. If present, the hernia sac and the lipoma are dissected free. Anterior and posterior branches of the vagus nerve are identified and preserved. The pneumoperitoneum is reduced to 8 mmHg to facilitate the recruitment of the left crus thus allowing a tension free closure. The wider opening diameter of the crura just below the esophagus and transverse diameter of the left and right pillars are measured with a laparoscopic ruler (Fig. 1).

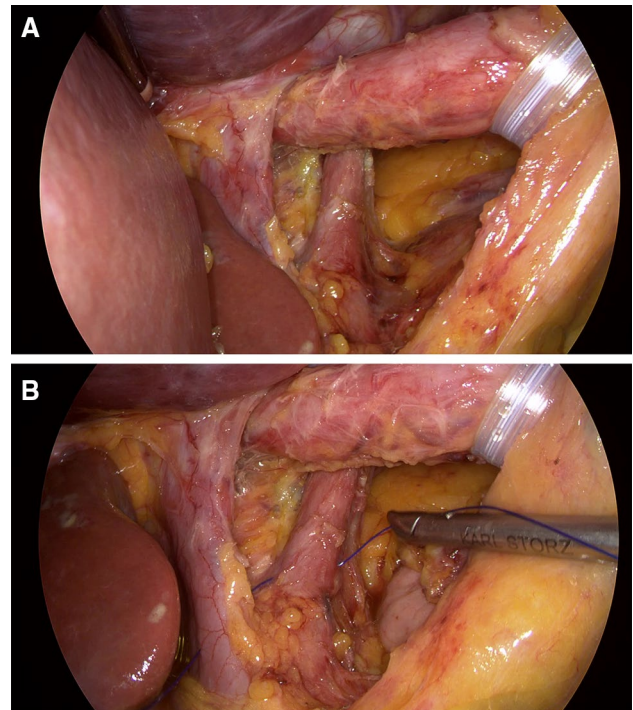


Fig. 2 a-b respecting the crura anatomy, the stitches of the hiatoplasty are passed from the left to the right diaphragmatic pillar by transfixing the left pillar 5 mm higher than the right

Cruroplasty with interrupted suture (score < 5)

The reconstruction of the diaphragmatic pillars is performed with interrupted non-resorbable sutures (Prolene® 2.0-Ethicon). Laparoscopic simple suture technique with extracorporeal knot ties is performed using round ½ curved needles. The hiatoplasty starts from the bottom extended upwards. With respect to the normal anatomy of the crura with an oblique insertion of the muscular bundles from left to right, the stitches are passed from the left to the right by transfixing the left pillar 5 mm higher than the right (Fig. 2a, b). Three or four stitches are needed to complete a posterior hiatoplasty reconstruction. The crura should not be excessively tight to leave a small 5 mm window from the highest stitch to the posterior esophageal wall since a laparoscopic instrument could be passed (Fig. 3).

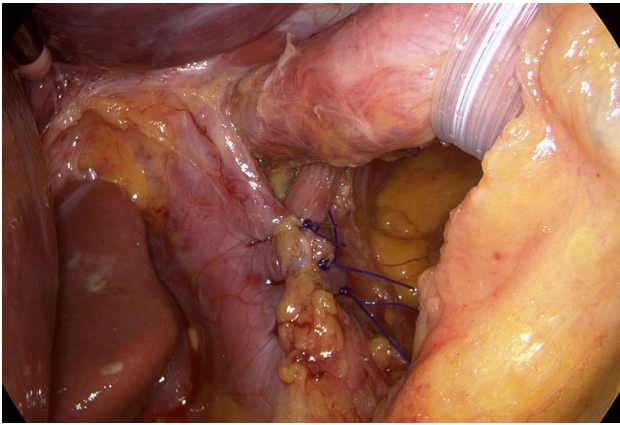


Fig. 3 Three stitches are usually needed to complete the laparoscopic posterior cruroplasty. The crura should not be excessively tight and a small 5 mm window is left from the highest stitch to the posterior esophageal wall

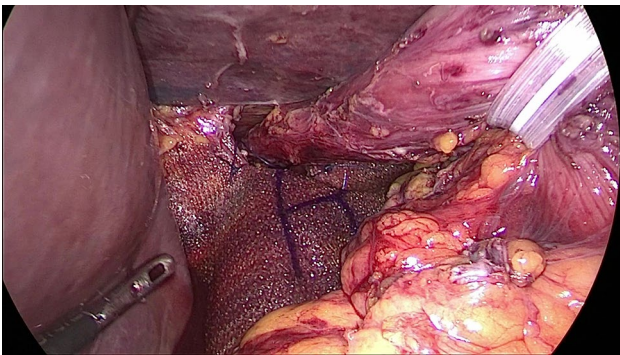


Fig. 4 The crura can be reinforced using 10×7 cm U shaped biosynthetic absorbable mesh (Phasix ST®-Poly-4-hydroxybutyrate (P4HB) with one-side hydrogel barrier

Cruroplasty with interrupted suture reinforced with mesh (score > 5)

The posterior hiatoplasty is reinforced using a 10×7 cm U shaped biosynthetic absorbable mesh [Phasix ST®-Poly-4-hydroxybutyrate (P4HB)-Bard] with one-side hydrogel barrier (Fig. 4). This mesh has a full reabsorption time ranging from 12 to 18 months [8]. The mesh is placed over the hiatoplasty and fixed with two intracorporeal resorbable braided sutures (Vycril® 2.0-Ethicon) to the right and left diaphragmatic pillar. The right portion of the mesh is placed over the right crus below the caudate lobe of the liver. On the other side the larger left portion placed on the left pillar until it lodges on the diaphragm posteriorly to the spleen. The biosynthetic mesh is gradually reabsorbed and replaced by vascularized soft tissue.

Toupet fundoplication

The fundus is rotated anticlockwise through the retrosophageal window. A “shoe-shine” maneuver allows to tailor the wrap ensuring that there is no radial tension. Incremental adjustments of the fundus may be required until it lies posteriorly without tension. Toupet 270° posterior fundoplication is fashioned according to the previously described “critical view” concept [9].

Follow-up

Perioperative complications were defined in accordance with the modified Clavien–Demartines–Dindo classification [10]. Outpatient follow-up visits were scheduled at 1, 6, and 12 months after operation, and then yearly. Both barium swallow study and/or upper gastrointestinal endoscopy were performed between 6 and 12 months after surgery, and repeated every year or at any time the patient complained of symptoms. Disease specific Gastro-Esophageal Reflux Disease Health-Related Quality of Life (GERD-HRQL) and generic Short Form-36 (SF-36) were used to assess patients’ quality of life at baseline and during follow-up [11]. Hernia recurrence was defined as recurrent GERD symptoms with > 2 cm of gastric tissue above the diaphragmatic impression evidenced at follow-up upper endoscopy and/or swallow study [12].

Statistical analysis

Continuous data are reported as mean ± standard deviation or median and interquartile range (IQR), as appropriate. Categorical data are reported using frequencies and proportions. Wilcoxon signed rank for paired data was performed as appropriate. Two-sided *p* values were computed. Statistical significance was considered when *p* value was equal or less than 0.05. All analyses and figures were carried out using R version 3.2.2 software [13].

Results

Overall, 141 patients underwent laparoscopic hiatus hernia repair and Toupet fundoplication during the study period and were managed according to the described “patient tailored” concept. Demographics of the patient population are shown in Table 3.

Type I–II hiatus hernia (57.4%) were the most commonly diagnosed hernias, followed by type IIIa (24.1%), and type IIIb–IV (18.5%). Overall, 86 patients (61.2%) were measured with hiatus diastases < 2 cm while 16 patients (11.3%) had a hiatus diastasis > 4 cm. Pillars were hypoplastic in 30 patients (21.3%) (Table 4). Overall, 102 (72.3%) patients

Table 3 Demographic and preoperative characteristics of the patient population

	<i>n</i> = 141
Age, years (mean ± SD)	65.1 ± 13.7
Sex, female, <i>n</i> (%)	76 (53.9)
BMI, kg/m ² , (mean ± SD)	26.7 ± 4.2
ASA score > 3, <i>n</i> (%)	23 (16.3)
Comorbidities, <i>n</i> (%)	
Hypertension	73 (51.8)
Smoke	35 (24.8)
Kyphosis	21 (14.9)
CAD	20 (14.2)
COPD	11 (8.1)
Symptoms, <i>n</i> (%)	
Heartburn	89 (63.1)
Regurgitation	36 (25.5)
Chest pain	34 (24.1)
Nausea/vomiting	21 (14.9)
Anemia/previous blood transfusion	18 (12.7)
Esophagitis, <i>n</i> (%)	32 (22.7)
Barrett's esophagus, <i>n</i> (%)	10 (6.9)

Values are expressed as mean ± standard deviation or numbers (%)

BMI Body Mass Index, *ASA* American society of anesthesiologists classification, *CAD* coronary artery disease, *COPD* chronic obstructive pulmonary disease

Table 4 Intraoperative characteristics of the patient population (*n* = 141)

Laparoscopic hiatus hernia classification, <i>n</i> (%)	
Type I–II	81 (57.4)
Type IIIa	34 (24.1)
Type IIIb–IV	26 (18.5)
Hiatus diastase, <i>n</i> (%)	
< 2	86 (61.2)
> 2–< 4 cm	39 (27.5)
> 4 cm	16 (11.3)
Atrophy of the pillars, <i>n</i> (%)	
No (> 5)	111 (78.7)
Yes (< 5)	30 (21.3)
Recurrence, <i>n</i> (%)	
No	125 (88.6)
Yes	16 (11.4)

Values are expressed as numbers (%)

underwent simple suture crura repair (score < 5) while bio-synthetic *U* shaped mesh was used for crura reinforcement in 39 (27.7%) patients (score > 5). Toupet fundoplication was fashioned in all patients. Posterior cruroplasty was fashioned with 3 interrupted sutures in 120 patients (85.1%) while cruroplasty with 4 interrupted sutures was completed

in 21 patients (14.9%). Additional anterior hiatoplasty was required in 13 patients (9.2%). The median operative time was 131 min (range 55–240). There were no conversions to open procedure. No intraoperative complications occurred and the median blood loss was 80 ml (range 45–170). The median postoperative stay was 1.8 days (range 1–7). The overall postoperative complication rate was 4.2% (*n* = 6). The distribution of complications according to the modified Clavien classification was Grade II 0.7% (pneumonia; *n* = 1), grade IIIa in 2.1% (pneumothorax; *n* = 2 and transient gastric distension treated with nasogastric tube decompression; *n* = 1), grade IIIb in 0.7% (pleural empyema; *n* = 1), and grade IV in 0.7% (pulmonary embolism; *n* = 1) of the patients. There was no mortality (Clavien V).

The median follow-up was 21 months (IQR 1–34) with 112 patients (79.4%) having a minimum follow-up of 6 months. Hernia recurrence was diagnosed in three patients (2.1%), all managed with PPI. Postoperative dysphagia was diagnosed in two patients (1.4%) and successfully treated with endoscopic balloon dilatation. Overall, 86% of the patients were off PPI with 11% taking daily or occasional PPI for residual symptoms. Other 3% of the patients were on PPI because other medical reasons. Gas bloat symptoms were recorded in 22.3% of the patients (*n* = 31) while ability to vomit and ability to belch were preserved in 83.5–91.3% of the patients, respectively. Both the GERD-HRQL (14.4 ± 6.8 vs. 3.9 ± 3.2 ; $p = 0.003$) (Fig. 5) and all SF-36 items were significantly improved ($p < 0.001$) (Table 5) compared to baseline.

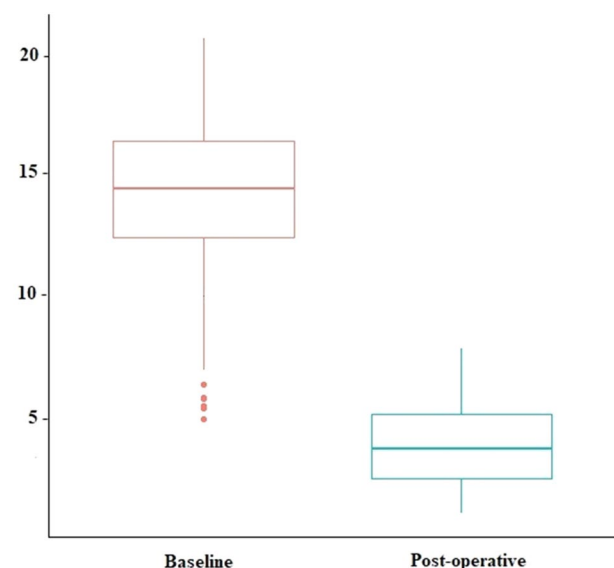


Fig. 5 Baseline and post-operative box plot showing results for the disease specific Gastro-Esophageal Reflux Disease Health-Related Quality of Life (GERD-HRQL) (14.4 ± 6.8 vs. 3.9 ± 3.2 ; $p = 0.003$)

Table 5 Baseline and postoperative results of the Short Form-36 (SF-36) Questionnaire

SF-36 domain	Baseline score	Post-operative score	<i>p</i> value
Physical function (PF)	46.8 ± 17.5	79.7 ± 17.9	< 0.001
Role physical (RP)	28.4 ± 16.7	82.1 ± 19.8	< 0.001
Bodily pain (BP)	54.3 ± 20.7	78.5 ± 21.8	< 0.001
General health (GH)	40.6 ± 19.3	66.7 ± 19.1	< 0.001
Vitality (VT)	49.7 ± 11.8	65.1 ± 16.4	0.001
Social function (SF)	45.2 ± 17.7	74.9 ± 19.2	< 0.001
Role emotional (RE)	53.1 ± 28.7	86.2 ± 26.4	< 0.001
Mental health (MH)	61.8 ± 15.7	78.3 ± 18.6	< 0.001
Component summary (CS) (orthogonal rotation weight)			
Physical (PCS)	45.7 ± 17.8	75.9 ± 18.4	< 0.001
Mental (MCS)	54.9 ± 19.4	79.6 ± 18.2	< 0.001

Values are expressed as mean ± standard deviation

PF physical function, *RP* role physical, *BP* bodily pain, *GH* general health, *VT* vitality, *SF* social function, *RE* role emotional, *MH* mental health, *PCS* physical component summary, *MCS* mental component summary

Discussion

Laparoscopic posterior cruroplasty represents a cardinal step in the treatment of hiatal hernia. The most appropriate technique for hiatus repair is left to the surgeons' preference and "feeling" of weak crura while an objective and standardized method for crura repair is lacking. This introduces a significant interstudy heterogeneity because of different surgeons' capabilities and expertise. In an attempt to overcome these limitations, we propose a standardized "patient tailored" concept for crura repair with the intent to improve procedure reproducibility, standardization, and uniformly interpret outcomes.

When Andre Toupet first described his technique in 1963, the hiatus closure was recommended only in case of large defects [14]. By contrast, the modern notion of fundoplication encompasses the concept of hiatus closure in attempt to reduce recurrences and improve reflux [15]. However, there also remains a debate regarding the best way to close the crura while different non-standardized techniques have been described ranging from simple suture to simple suture reinforced with mesh [16–19]. A 2006 randomized controlled trial compared primary repair vs. primary repair reinforced with biological mesh in the setting of paraesophageal hernias. The authors found a statistically significant reduced 6 months recurrence rate for mesh repair (9% vs. 24%, $p = 0.04$) with no statistically significant differences in the long-term (5-year) [20]. Similarly, recent systematic reviews and meta-analyses showed statistically significant reduced recurrence rate for laparoscopic mesh-reinforced crura repair [21–23]. Up to date, no definitive evidence exists to strongly

recommend mesh augmentation for large hiatal hernia repair because of the low "quality of evidence" related to the data heterogeneity, inconsistency of hernia definition, hernia recurrence, and technical variations [24]. Moreover, mesh-related complications such as infection, migration, shrinkage, and esophageal erosion should be considered [25, 26].

Because of the different techniques, cruroplasty is prone to extreme variability and such heterogeneity may introduce a significant interstudy background bias related to surgeons' experience and preference. In an attempt to reduce this heterogeneity, based on the literature data and senior surgeon's experience (DB), four parameters (laparoscopic hiatal hernia classification, hiatus diastasis, tropism of the crural pillar, and recurrence) were identified and considered for this standardized "patient tailored" concept. As previously reported, type III–IV hiatal hernia and an increased cranio-caudal height have been shown to be associated with the augmented risk of postoperative hernia recurrence [27, 28]. Endzinas and colleagues described a cohort of 381 patients treated for small (grade 1 and 2; $n = 272$) and large (grade 3 and 4; $n = 109$) hiatus hernia. The authors found a statistically significant higher recurrence rate in patients diagnosed with large hiatus hernia (10.1% vs. 2.58%; $p < 0.05$) [29]. The larger hiatus diastasis yields crura approximation at increased tension with a presumed high risk of stitch detachment. This concept was proposed by Granderath and colleagues who first introduced the idea of the Hiatal Surface Area (HSA). Overall, 55 patients underwent laparoscopic antireflux surgery (Nissen = 47.2% and Toupet = 52.8%) for GERD. Thirty-two patients (58.2%) with a smaller hiatal defect (mean HSA = 3.8 cm²) underwent hiatal closure with simple sutures, 12 patients (21.8%) with a mean HSA of 7.1 cm² underwent hiatal closure with simple sutures reinforced with polypropylene mesh, five patients (mean HSA = 6.7 cm²) underwent hiatal closure with Parietex mesh®, and six patients (mean HSA = 8.4 cm²), underwent hiatus closure with BARD Crurasoft mesh®. The authors concluded that tailoring of the hiatal closure by measurement of the HSA is effective to prevent recurrence [30]. Limitations of this study was the narrow patients' cohort and follow-up (6.3 months). Therefore, another study published in 2013 seems to support the validity of the HSA in the long term (28 months) [31]. Finally, the presence of hypoplastic crura with deterioration of muscle fibers and the consequent loss of tissue elasticity may constitute the "Achilles heel" of pillars approximation [1, 32, 33].

Due to the lack of a comparison group, the proposed "patient tailored" concept should not be intended as superior to other non-standardized approaches, though it demonstrates its utility as a suitable scoring system to characterize the hiatal hernia and lead treatment. Results were promising in terms of overall morbidity (4.1%) and hernia recurrence (2.1%) and all are documented in patients with large type

IIIb–IV hernia [6, 14, 34]. Interestingly, the postoperative prevalence of gas bloat symptoms, ability to vomit, ability to belch and disease specific patients' quality of life improvement seems equivalent to previous studies [4–6, 35].

We believe that the proposed standardized concept encompasses and broadens the study by Granderath et al. and Grubnik et al., strengthening the need for a simple, clear, and readily available “patient tailored” approach valuable to guide the intraoperative decision making. Despite the HSA notion show to be a valid and effective method to guide appropriate crural repair, its calculation is complex and not immediately available. Our results should be interpreted with caution because the retrospective design, the possible patient selection bias, different follow-up, mesh/fundoplication type, and surgeons experience. Irrespective of the baseline motility pattern, in our center we prefer to perform Toupet fundoplication rather than Nissen fundoplication. This is in accordance with the recently published studies that showed comparable results in term of reflux control and disease specific quality of life with reduced dysphagia, gas bloat, and inability to belch for Toupet fundoplication [36, 37]. The lack of comparison with non-standardized techniques may constitute a study limitation. However, the primary purpose of the study was to describe a standardized approach for posterior cruroplasty and sustain the importance of “patient tailored” repair valuable for a practical intraoperative surgery guidance. Comparison with non-standardized approaches was beyond the aim of the paper, statistically unsuitable and underpowered because of the limited number of recurrences and complications.

The application of a standardized “patient tailored” concept for posterior cruroplasty, seems promising and may be valuable to increase intra- and inter-individual reproducibility and uniformly interpret outcomes. Further trials are necessary to validate the effect of this “patient tailored” approach and explore the comparison with other non-standardized techniques. Finally, an expert panel consensus would be beneficial to discuss the state of the art and identify universally validated criteria to endorse a standardized esophageal crura repair.

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Author contributions AA, AS, and GB did the literature search. AA and DB formed the study design. Data collection done by AA, MC and GC. AA, AS, and GS analysed the data. AA, GS, GM and DB interpreted the data and AA, GC and DB critically reviewed the manuscript.

Compliance with ethical standards

Conflict of interest DB, MC, GS, AS, GB, GM, GC and AA declare that they have no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the insti-

tutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Informed consent Informed consent was obtained from all patients prior to all surgical procedures.

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