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ORIGINAL ARTICLE

Hiatal hernia recurrences after laparoscopic surgery: exploring the optimal technique

B. Akmaz[1] · A. Hameleers[1] · E. G. Boerma[1] · R. F. A. Vliegen[2] · J. W. M. Greve[1] · B. Meesters[1] · J. H. M. B. Stoot[1]

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Abstract

Introduction The recurrence rate of hiatal hernia (HH) after laparoscopic surgery with crural repair and Nissen or Toupet fundoplication is high (< 25–42%). HH repair can be reinforced with additional anterior sutures, vertical mesh strips (VMS) or mesh placement but the effect in the long-term (> 1 year) is still unclear. We determined the recurrence rate of HH after surgery and established whether the use of reinforcement techniques could reduce long-term recurrence rates.

Methods In this retrospective cohort study patients were included if they underwent a laparoscopic fundoplication in this hospital between 2012 and 2019. HH was measured with computed tomography and baseline patient characteristics and surgical details were collected. Primary outcomes were recurrence of symptoms and re-intervention, secondary outcome was effect of surgical reinforcement techniques. Statistical analyses comprised chi-square tests, Mann–Whitney U tests and uni- and multivariable logistic regression analyses.

Results In total, 307 patients were included, 206 women and 101 men. During primary surgery, 208 patients underwent a Toupet fundoplication and 97 patients underwent a Nissen fundoplication. Reinforcements consisted of anterior sutures in 132 patients, VMS in 89 patients and mesh in 17 patients. After primary surgery, recurrence of HH was diagnostically confirmed in 64 patients (20.8%). Use of VMS during primary surgery was significantly associated with fewer recurrences (OR = 0.34, $p = 0.048$), corrected for confounding factors. Secondary surgery was performed in 54 patients (17.6%) and tertiary surgery in five patients (1.6%). Mesh and VMS were used more during secondary and tertiary surgery.

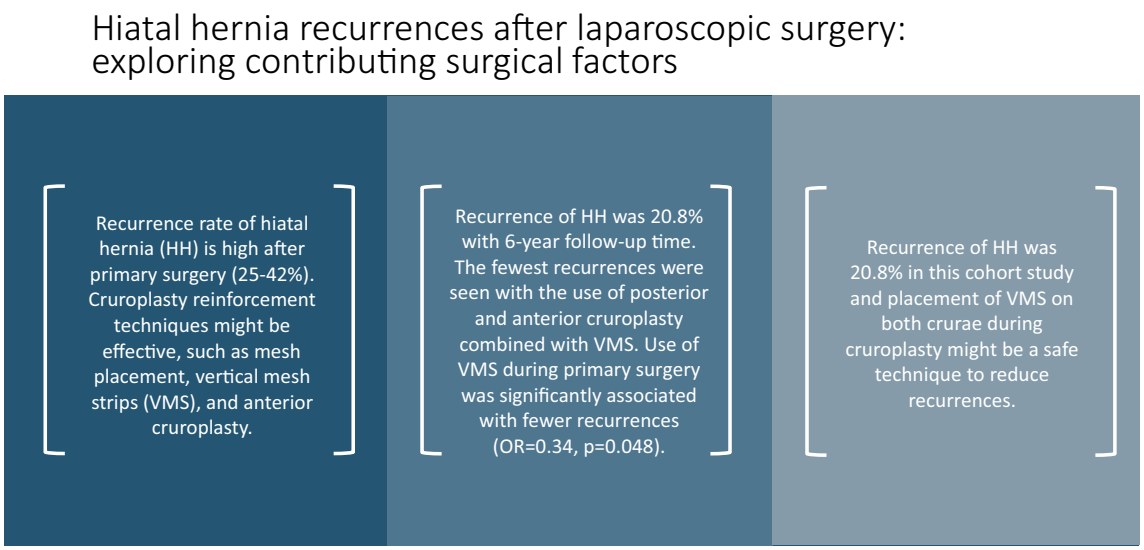
Conclusion The recurrence rate among HH patients in this cohort study was 20.8% with a mean follow-up time of 6 years. Secondary surgery was performed in 17.6% of the patients. In future, the use of VMS might lead to fewer recurrences after primary laparoscopic repair of HH.

✉ B. Akmaz
b.akmaz@outlook.com

[1] Department of Surgery, Zuyderland Medical Center, Henri Dunantstraat 5, 6419 PC Heerlen, The Netherlands

[2] Department of Radiology, Zuyderland Medical Center, Heerlen, The Netherlands

Graphical abstract



Keywords Fundoplication · Cruroplasty · Hiatal hernia · Mesh · Mesh strips · Recurrence

The recurrence rate of hiatal hernia (HH) after laparoscopic surgery with crural repair and Nissen, Toupet or Dor fundoplication for primary repair is demonstrated to be between 25 and 42% [1]. The causes of recurrences are reported to be multi-factorial and are associated with the type of cruroplasty performed, preexisting medical conditions and the size of the HH [2–5].

For many years, HH repair was conducted with primary sutured crural repair. Previous research has shown that recurrence rates after primary surgery can be reduced by means of various cruroplasty reinforcement techniques. Different techniques that have been developed over the years are mesh placement, pledget placement, gastropexy, relaxing incision and anterior cruroplasty [2, 3, 6]. The most well-known reinforcing technique is on-lay mesh placement. A recent meta-analysis has shown that mesh repair leads to lower recurrence rates in the short-term, compared to suture repair [2, 7]. The use of small mesh strips are suggested as an alternative for mesh due to a smaller surface causing less friction between prosthetics and viscera [8, 9]. No complications are reported yet after mesh strip use and recurrence rates are considered lower with mesh strip repair (1 × 3 cm) compared to suture cruroplasty [10]. Besides posterior cruroplasty, a method of reinforcing cruroplasty that is not routinely performed is the placement of additional anterior sutures. In the first place, anterior cruroplasty may avoid an unnatural angulation of the esophagus. Second, anterior cruroplasty might offer therapeutic benefit because the majority of recurrences are located anteriorly [3, 4]. Early HH recurrences are related to breakdown of posterior crural repair, whereas later recurrences are caused by progressive enlargement of the hiatus due to pressure gradients overwhelming the tensile strength of the hiatus [3].

Although some reinforcement techniques have been advocated in literature, some controversies still exist regarding effectiveness on recurrence rates. First, even though mesh usage is endorsed in some studies, recent randomized clinical trials have shown that mesh reinforcement results in equal HH recurrence [1, 7, 11]. Besides, mesh use is associated with complications such as erosion and migration of the mesh. Additionally, it can lead to infection, oesophageal stenosis or dysphagia [12]. Since the use of prosthetic materials was advocated for hiatal reinforcement, mesh strips might be a safer alternative causing less complications. However, there are only few studies that have documented lower recurrence rates in the short term, and longer-term results (> 1 year) have yet to be established [1]. Additionally, despite knowledge that most recurrences occur anteriorly, no studies have examined yet the impact of anterior sutures on recurrence rates [3, 4].

The preliminary aim of this study was to determine the recurrence rate of HH after laparoscopic fundoplication in a high-volume teaching hospital. A second goal was to establish whether the use of mesh, mesh strips, and anterior sutures could reduce long-term recurrence rates.

Methods

Subjects

In this retrospective database study, patient records were analyzed of patients ≥ 18 years of age who were diagnosed with HH and were treated with laparoscopic surgery between 2012 and 2019 in Zuyderland Medical Center, locations Sittard and Heerlen. This research took place from November 2021 until June 2022. Patients were not included if they underwent surgery after December 2019 because we aimed to have follow-up data of at least 24 months. Patients were excluded if the follow-up time was shorter than 24 months due to death. Patients were also excluded if they had a history of esophagus resection, bariatric surgery and (partial) gastrectomy since these medical histories increase the risk for recurrence. Ethical approval was obtained from the medical ethics review committee Zuyd (METCZ20210112).

Surgical technique

All HH surgeries were carried out laparoscopically under general anesthesia. First, the intrathoracic content was carefully pulled back intraabdominally and stomach and intestines were repositioned. Both left and right crura were localized and released over the entire length. The right and left vagus nerves were identified and saved. Next, full excision of the hiatal hernia sac took place. The crural defect was routinely closed posteriorly with at least two posterior Goretex 2–0 sutures in cross shape. Posterior cruroplasty was supplemented by additional anterior sutures if needed to achieve an adequate closure. During surgery, the need for additional anterior sutures was determined by the surgeon based on their expertise. It is agreed in this hospital that patients with large HHs need additional anterior sutures to prevent an unnatural angle of the esophagus. This was defined as HH of at least 5–6 cm. The number of anterior and posterior sutures that are placed are also at the surgeon's discretion during surgery. To reinforce the HH cruroplasty further, the surgeon uses mesh or mesh strips. Mesh strips are small 1 × 3 cm strips that are cut out of mesh and placed bilateral vertically over each crural pillar. The aim of using these vertical mesh strips (VMS) is to strengthen weak crurae while suturing them for cruroplasty. Mesh strips were used in large hiatal hernias and/or when poor quality of the crurae was seen intraoperatively and this was at the surgeon's discretion. A large HH was again defined as a HH that was estimated to be 5–6 cm or more. In this study, most of the time light weight mesh (Ultrapro; Ethicon Inc., Somerville, NJ, USA) was used for mesh strips. Occasionally, other mesh brands were used for mesh strips such as Parietex Composite (Covidien, New Haven, CT, USA). While used more regularly in previous years, total mesh placement on the cruroplasty has become less common in recent years. Use of mesh was abandoned due to complications such as mentioned in the introduction and due to controversial statements regarding mesh use in literature. In the further writing of this article, anterior sutures, VMS and mesh are referred to as 'reinforcement technique'. All reinforcement techniques are additionally used besides conventionally placed posterior sutures. For a couple of years now, most fundoplications are performed as Toupet rather than Nissen in this hospital because the latter was proven to cause more postoperative complications such as dysphagia [13–16]. In Toupet fundoplication, the 270° wrap of the stomach is anchored to the esophagus with two to three stitches on both sides. The wrap is not sutured to both esophagus and crurae such as was initially described by Toupet in 1963 and later on also other authors [17–19]. In patients with a short esophagus a Collis gastroplasty is considered [20].

Data collection

Patient data were retrospectively collected in two ways: a data file of the business intelligence department was used which was supplemented and cross checked with the electronic patient file system of the hospital. The following patient data were extracted: age, gender, weight, length, Charlson Comorbidity Index (CCI), American Society of Anesthesiologists (ASA) classification, preoperative symptoms and preoperatively applied diagnostics. 14 independent surgical variables were defined a priori and investigated. The variables were: surgeon, perioperative complications, blood loss, surgery time, conversion, number of posterior sutures, anterior sutures use, number of anterior sutures, mesh use, mesh type, mesh shape, type of fundoplication, VMS use and surgical technique (meaning type of fundoplication and type of reinforcement). Postoperative variables were post-surgery complications following the Clavien–Dindo classification, length of stay, re-admission, postoperative diagnostics, recurrence of symptoms, time until recurrent symptoms, type of recurrence symptoms, actual recurrence (supported with diagnostics), mortality after surgery, date of death, secondary surgery, time until secondary surgery, tertiary surgery and time until tertiary surgery. The same surgical and postoperative variables were collected for secondary and tertiary surgery. There is no uniform and clear classification for recurrence of HH. In this study, HH recurrence was defined as any hiatal hernia that occurred after primary HH surgery, which was diagnostically confirmed with a computed tomography (CT) and/or barium swallow (BS).

Fig. 1 Transverse diameter measurement on a CT-scan, coronal plane

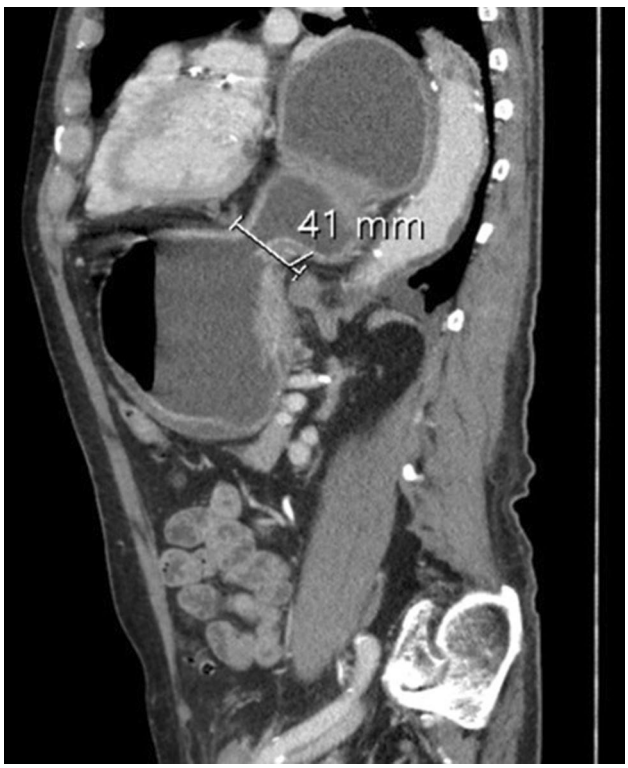


Fig. 2 Anterior–posterior diameter measurement on a CT-scan, sagittal plane

CT measurements

CTs were examined for each patient if available and not older than 2 years. The type of HH was initially defined with CTs and additionally with BS. If a CT was not conducted, HH type was only determined by means of BS.

Measurement of the HH took place as described by Karatay et al. [21]. First, measurement of the transverse diameter of the HH in millimeters took place when a coronal reconstruction of the CT was available (Fig. 1) or could be reconstructed out of the available thin slices data set. Second, this was also the case for the sagittal plane measurements (Fig. 2). Due to the unavailability of thin slices CT data set in a substantial number of cases, multiplanar reconstruction (MPR) in an angulated coronal and sagittal plane according to the method of Karatay et al. could not be drawn and therefore no hiatal surface area (HSA) could be measured [21].

All measurements were made and saved by the primary researcher in the patient radiology system. The primary researcher was trained by a radiologist to be able to make HH measurements on CTs. The radiologist co-rated approximately 50% of the measured CTs.

Statistical analysis

Data were analyzed with IBM SPSS Statistics 28.0. Baseline patient- and surgery characteristics and recurrence data were analyzed using descriptive statistics. Descriptive statistics were also divided by outcome, in other words, performed for the recurrence group (RG) and non-recurrence group (NRG) separately. Skewness data and the Shapiro–Wilk test were used to examine the normality of all continuous patient and surgery data. Furthermore, a Kaplan–Meier analysis was performed to visualize the recurrence of HH over time during follow up. Chi-square tests were performed to statistically test the significance of the relationship between categorical patient- and surgery characteristics and the bivariate outcome 'actual recurrence'. Mann–Whitney U tests were used to test that relationship for continuous (non-parametric) patient- and surgery characteristics and actual recurrence.

Univariable logistic regression analyses were used to test the association between surgery technique and actual recurrence as outcome. A p-value of < 0.05 was considered significant. Age, gender, BMI, ASA, CCS, hernia size (transverse and anterior–posterior), type of HH, type of fundoplication and follow-up time were analyzed for confounding by means of multivariable logistic regression analyses for each variable, together with anterior sutures, VMS, mesh use and posterior sutures. ASA and CCS classifications were made categorical to create larger groups and examine for confounding. Posterior sutures were made categorical to create larger groups and be able to include the variable in the logistic

Table 1 Patient characteristics

Characteristic	Overall ($n=307$)	Recurrence ($n=64$)	No recurrence ($n=243$)	Missing *N*	*p*-value
Sex					
Female (*n*, %)	206 (67.1%)	44 (68.8%)	162 (66.7%)	0	0.75[a]
Male (*n*, %)	101 (32.9%)	20 (31.2%)	81 (33.3%)		
Age (median, IQR)	63 (54–71)	63.5 (54.3–71)	63 (54–72)	0	0.90[b]
BMI (median, IQR)	27.5 (24.5–30.9)	28 (24.2–31.6)	27.4 (24.6–30.8)	71	0.77[b]
Charlson comorbidity score (median, IQR)	2 (1–3)	2 (1–3)	2 (1–3)	0	0.53[a]
ASA classification (median, IQR)	2 (1–3)	2 (1–2)	2 (1–2)	82	0.26[a]
Symptom distribution					
Reflux	159	38	121	9	0.22[a]
Pain	138	29	109		0.96[a]
Passage problems	75	21	54		0.09[a]
Vomiting	67	13	54		0.69[a]
Nausea	52	12	40		0.71[a]
Dyspnea	36	8	28		0.87[a]
Regurgitation	33	7	26		0.99[a]
Dysphagia	31	10	21		0.11[a]
Cough	20	2	18		0.21[a]
Bloating	18	5	13		0.48[a]
Gastrointestinal bleeding	17	4	13		0.80[a]
Eructation	15	5	10		0.23[a]
Asymptomatic	8	0	8		0.14[a]
Type of HH (barium esophagogram/CT)					
Type I (*n*, %)	36 (11.7%)	11 (17.2%)	25 (10.3%)	96[c]	0.09[a]
Type II (*n*, %)	5 (1.6%)	0	5 (2%)		
Type III (*n*, %)	102 (33.2%)	28 (43.8%)	74 (30.5%)		
Type IV (*n*, %)	68 (22.1%)	10 (15.6%)	58 (23.9%)		
Transverse HH diameter					
Cm (median, IQR)	3.2 (2.7–4.0)	3.0 (2.5–3.6)	3.4 (2.7–4.1)	139[d]	0.12[b]
Slice thickness (median, IQR)	3 (3–3)	3 (3–3)	3 (3–3)		
Anterior–posterior HH diameter					
Cm (median, IQR)	3.6 (3.1–4.3)	3.7 (3.2–4.2)	3.6 (3.1–4.3)	215[e]	0.80[b]
Slice thickness (median, IQR)	3 (2–3)	3 (2–3)	3 (2–3)		
Follow-up time in months (min, max)	75 (12–120)	83.5 (27–115)	75 (25–120)	0	0.51[b]

HH hiatus hernia

IQR interquartile range

[a]Chi-square tests

[b]Mann-Whitney U tests

[c]Missing numbers due to missing CTs or BEs

[d]High missing numbers due to missing CTs

[e]High missing numbers due to missing sagittal CT planes

regression analyses. Categorical and dichotomous variables were analyzed as dummy variables in the logistic regression analysis. Confounding was defined as > 10% change in ORs of anterior sutures, VMS, mesh use and posterior sutures when the variable was added to the multivariable logistic regression analysis. Identified confounders were corrected for in the final multivariable logistic regression analysis with all reinforcement techniques. A *post-hoc* power analysis was performed using GPower 3.1.

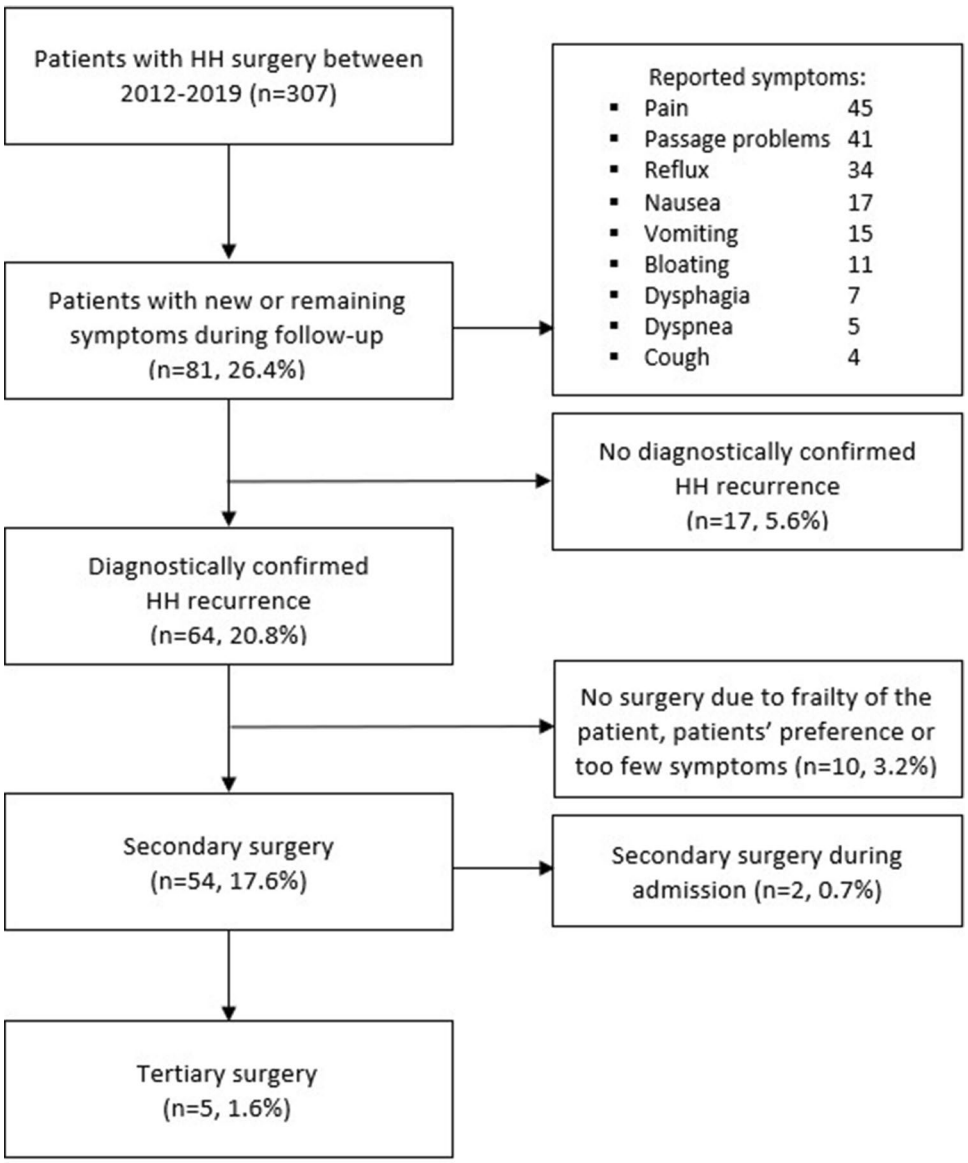


Fig. 3 Recurrence data of patients who underwent primary surgery

Results

Laparoscopic fundoplications were performed in 307 patients between 2012 and 2019, see Table 1. The median follow-up time was 75 months, thus approximately six years. The median age was 63 (51–71). Two thirds of the study population were female (206/101). The median BMI of 27.5 suggests mild obesity in the population. The most frequent symptoms that occurred were reflux ($n = 159$) and pain ($n = 138$). Pain was mostly mentioned as retrosternal pain and sometimes as upper abdominal pain. The most common HH types that were diagnosed were type III and type IV. For 96 patients, the type of HH was missing because they did not receive a CT or BE. Most recurrences occurred among type III HH patients (9.1%). The median transverse HH diameter was 3.2 cm and these were mostly measured on 3.0 slice thickness. Unfortunately, reconstructions of CTs in the sagittal plane were mostly missing and therefore few data of anterior–posterior HH diameters were included (missing $n = 215$). Normality tests showed that all variables were not normally distributed. Therefore, medians and interquartile ranges were used for all variables. No significant differences in patient variables were found between RG and NRG ($p > 0.05$).

Figure 3 shows that 81 of 307 patients (26.4%) suffered from symptoms after primary surgery. The most frequently experienced symptoms were pain, dysphagia and odynophagia. These findings led to further investigations to rule out recurrence. A recurrent HH was proven

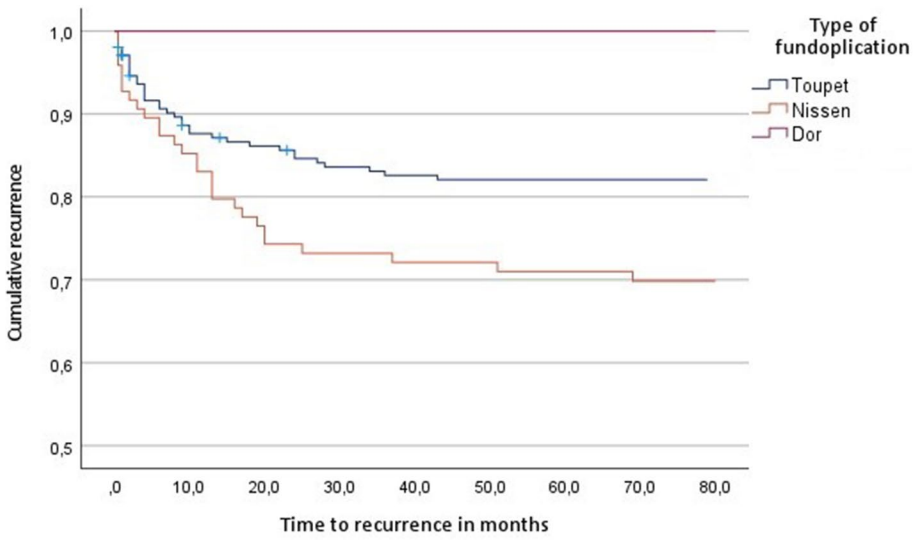


Fig. 4 Time until recurrence of symptoms, in months

Table 2 Primary OR details, Toupet fundoplication

	Overall ($n=208$)	Recurrence ($n=36$)	No recurrence ($n=172$)	Missing *n*	*p*-value
Perioperative complications (*n*, %)	1	0	1	0	0.65[a]
Blood loss in cc (median, IQR)	10 (0–30)	10 (0–23.8)	10 (0–30)	17	0.67[b]
OR time in min (median, IQR)	104(85–126)	108 (82–120)	104 (85–127.5)	27	0.79[b]
Hiatal repair					
Posterior (*n*, %)	100 (48.1%)	21 (58.3%)	79 (45.9%)	0	–
Posterior + anterior (*n*, %)	108 (51.9%)	15 (41.7%)	93 (54.1%)	0	0.176[a]
Number of hiatal sutures					
Posterior (median, IQR)	2 (2–3)	2 (2–3)	2 (2–3)	3	0.27[b]
Anterior (median, IQR)	1 (0–1)	0 (0–1)	1 (0–1)	0	0.11[b]
Use of pledgets VMS (*n*, %)	77 (37%)	12 (33.3%)	65 (37.8%)	0	0.61[a]
Mesh use (*n*, %)	10 (4.8%)	1 (2.8%)	9 (5.2%)	0	0.53[a]
Mesh brand					
Parietex (*n*, %)	1 (0.5%)	0	1 (0.6%)	0	0.76[a]
Permacol (*n*, %)	1 (0.5%)	0	1 (0.6%)	0	
Crurasoft (Bard) (*n*, %)	1 (0.5%)	0	1 (0.6%)	0	
Fasix (*n*, %)	1 (0.5%)	0	1 (0.6%)	0	
Ultrapro (*n*, %)	3 (1.4%)	0	3 (1.7%)	0	
Anterioright (*n*, %)	3 (1.4%)	1 (2.8%)	2 (1.2%)	0	
Mesh shape					
Heart shape (*n*, %)	5 (2.4%)	0	5 (2.9%)	0	0.22[a]
Oval (*n*, %)	2 (1%)	1 (2.8%)	1 (0.6%)	0	
V shape (*n*, %)	1 (0.5%)	0	1 (0.6%)	0	
Unknown (*n*, %)	2 (1%)	0	2 (1.2%)	0	
Length of stay (median, IQR)	2 (1–3)	3 (1–4)	2 (1–3)	0	0.08[b]

[a]Chi-square tests

[b]Mann-Whitney U tests

VMS vertical mesh strips

IQR interquartile range

Table 3 Primary OR details, Nissen fundoplication

	Overall ($n=97$)	Recurrence ($n=28$)	No recurrence ($n=69$)	Missing n	p-value
Perioperative complications	0	0	0	0	–
Blood loss in cc (median, IQR)	10 (5–40)	5 (5–40)	10 (3.5–40)	7	0.53[b]
OR time in min (median, IQR)	90 (66–120)	94 (65–120)	90 (66.5–120)	16	0.92[b]
Hiatal repair					
Posterior (n, %)	75 (77.3%)	19 (67.9%)	56 (81.2%)	0	–
Posterior + anterior (n, %)	22 (22.7%)	9 (32.1%)	13 (18.8%)	0	0.156[a]
Number of hiatal sutures					
Posterior (median, IQR)	2 (2–3)	1 (1–1)	1 (1–1)	15	0.51[b]
Anterior (median, IQR)	0 (0–0)	0 (0–1)	0 (0–0)	0	0.14[b]
Pledgets useUse of VMS	11 (11.3%)	3 (10.7%)	8 (11.6%)	0	0.90[a]
Mesh use (n, %)	7 (7.2%)	2 (7.1%)	5 (7.2%)	0	0.99[a]
Mesh brand					
Parietex (n, %)	4 (4.1%)	1 (3.6%)	3 (4.3%)	0	0.81[a]
Permacol (n, %)	3 (3.1%)	1 (3.6%)	2 (2.9%)	0	
Mesh shape					
Heart shape (n, %)	4 (4.1%)	2 (7.1%)	2 (2.9%)	0	0.15[a]
Unknown (n, %)	3 (3.1%)	0	3 (4.3%)	0	
Length of stay (median, IQR)	2 (1–3)	2 (1–3)	2 (1–3)	0	0.26[b]

[a]Chi-square tests

[b]Mann-Whitney U tests

VMS vertical mesh strips

IQR interquartile range

with CTs and BS for 64 patients out of 81 patients that presented with these symptoms, which is 20.8% from the total number of patients that underwent primary surgery ($n=307$). Thus, 17 patients experienced symptoms that could be stated as side effects of surgery. Secondary surgery was required in 54 patients (17.6%), and two surgeries already took place during admission. The other ten patients did not undergo surgery due to few symptoms or because the patients were too frail to undergo reoperation. Of the 54 patients that underwent secondary surgery, five patients had a second recurrence and underwent tertiary surgery, which is 1.6% of the total number of patients.

Figure 4 shows a Kaplan–Meier plot of the recurrences that took place over time, given in months. In total 64 recurrences took place in 69 months. The mean follow-up time in this study was 73 months (Table 1). It is visible in Fig. 4 that most recurrences took place in approximately 24 months. Some patients immediately suffered from recurrence and had secondary surgery during admission. The mean time until recurrence was 11.3 months.

Surgery details of the RG versus the NRG are compared in Tables 2 and 3, separately for Toupet fundoplication and Nissen fundoplication. All surgeries were performed laparoscopically and no patient was converted to an open procedure. Within the Toupet fundoplication group, the NRG received more anterior sutures (54.1% vs. 41.7%), more VMS placements (37.8% vs 33.3%) and more mesh placements (5.2% vs. 2.8%) compared to the RG (Table 2). The median length of stay was 2 days overall and shorter for the NRG compared to the RG. However, all these differences were not shown to be statistically significant ($p>0.05$).

Table 3 shows that no complications occurred during Nissen fundoplication. Only 22.7% of the total Nissen population received anterior cruroplasty, which is substantially less than the Toupet group. The NRG comprised more VMS placements (11.6% vs 10.7%) and an equal number of mesh placements (7.2%) compared to the RG. The table also shows that VMS were used more in combination with Toupet fundoplication (37%) compared to Nissen fundoplication (11.3%). The median length of stay was two and equal for both groups. Additionally, two patients had a Dor fundoplication, these were not shown in both tables.

Figure 5 shows the surgical reinforcement techniques that were used besides posterior cruroplasty during primary surgery in the RG and NRG. The combination of anterior sutures and VMS use led to the lowest recurrence rate (14%) compared to other techniques. However, statistical analysis showed no significant differences in surgery technique regarding recurrence rate ($p=0.688$).

Table 4 provides an overview of the relation between the reinforcement techniques during primary surgery and recurrence. BMI, hernia size (transverse diameter) and type of

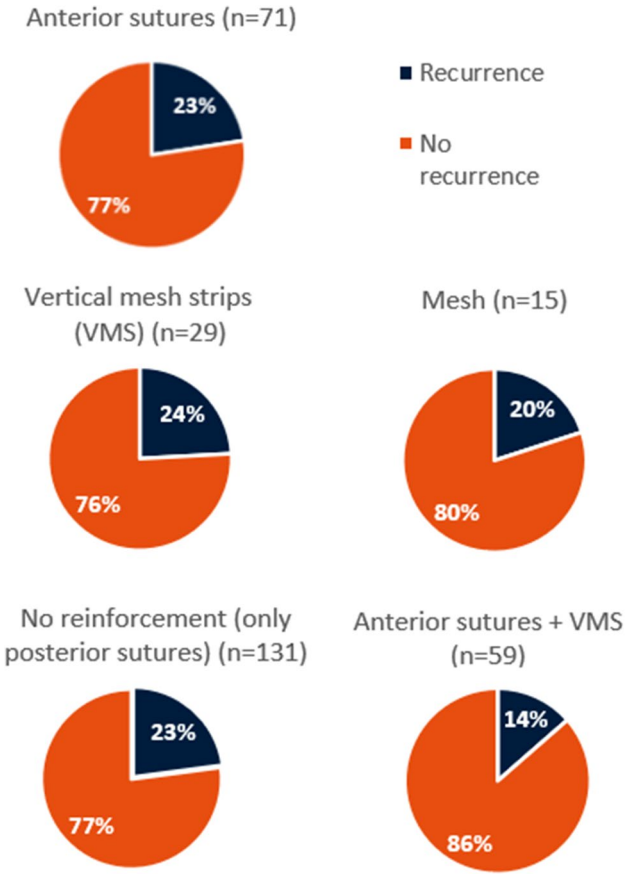


Fig. 5 Reinforcement techniques, all used in addition to posterior cruroplasty

HH were identified as confounders in separate multivariable analyses, which are not shown here. Important to note from the data presented in Table 4 is that the use of VMS during surgery is significantly associated with less recurrences when corrected for confounders (OR = 0.34, $p = 0.048$). Other reinforcement techniques did not lead to significantly less recurrences.

Secondary surgery was performed in 54 patients (17.6%) and tertiary surgery in five patients (1.6%) (Table 5). The most recurrent HH fundoplications were redo Toupet fundoplications (35.2%) or conversions from Nissen to Toupet fundoplications (27.8%) but in several cases revision of the fundoplication was not conducted (22.2%). Additional posterior sutures or anterior sutures were made when the existing fundoplication was still sufficient. New or additional anterior sutures were used in 30 patients (56.6%), mesh was used in eight patients (14.8%), VMS were used in 24 patients (44.4%).

During tertiary surgery, one patient received a Dor fundoplication. Four patients received anterior sutures and VMS. No patients received additional mesh. It can be seen that mesh is used more often during secondary surgery (14.8%) compared to total mesh use during primary surgery (5.5%). Also, VMS are used more often in secondary surgery compared to primary surgery (44.4% vs 24%). Additionally, post-hoc power analyses were done and no sufficient power was found in this study.

Discussion

Summary of evidence

The aim of this 8-year retrospective cohort study was to determine the recurrence rate of HH after laparoscopic fundoplication in this teaching hospital and to establish whether lower recurrence can be achieved with anterior cruroplasty, VMS or mesh hiatoplasty. We present, to the best of our knowledge, the first long-term retrospective cohort study establishing the recurrence rates of patients who underwent laparoscopic fundoplication with one or more of these reinforcement techniques.

Table 4 The influence of reinforcement techniques on recurrence, bivariate outcome, logistic regression

Reinforcement	Univariable analysis[a]		Multivariable analysis (adjusted)[b]	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Anterior sutures use	0.75 (0.43–1.32)	0.319	0.76 (0.32–1.8)	0.535
PledgetsVertical mesh strips	0.70 (0.37–1.32)	0.273	0.34 (0.12–0.99)	0.048*
Mesh	0.80 (0.22–2.89)	0.739	0.79 (0.07–8.9)	0.851
Number of posterior sutures	0.72 (0.41–1.26)	0.242	0.50 (0.20–1.24)	0.134

OR odds ratio

CI confidence interval

[a]Analysis of the individual relationship between each reinforcement technique and recurrence

[b]Analysis of the relationship between each reinforcement technique and recurrence, corrected for other reinforcement techniques and for confounders. Confounders were BMI, hernia size (transverse diameter) and type of HH

Table 5 Secondary and tertiary OR details

	Secondary OR details ($n=54$)	Tertiary OR details ($n=5$)
Perioperative complications	0	0
Blood loss in cc (median, IQR)	20 (6.3–50)	0 (0–35)
OR time in min (median, IQR)	111.5 (90–155.5)	87 (69–188)
Fundoplication		
None (*n*, %)	12 (22.2%)	4 (80%)
Redo Toupet (*n*, %)	19 (35.2%)	0
Redo Nissen (*n*, %)	3 (5.6%)	0
Conversion to Toupet (*n*, %)	15 (27.8%)	0
Conversion to Nissen (*n*, %)	2 (3.7%)	0
Conversion to Dor (*n*, %)	2 (3.7%)	1 (20%)
Use of posterior sutures (*n*, %)	46 (86.8%)	2 (40%)
Posterior sutures (median, IQR)	1 (1–1)	1 (1–1)
Use of anterior sutures (*n*, %)	30 (56.6%)	4 (80%)
Anterior sutures (median, IQR)	1 (0–1)	1 (1–1)
Mesh use (*n*, %)	8 (14.8%)	0
Mesh brand		
Parietex (*n*, %)	4 (7.4%)	0
Permacol (*n*, %)	1 (1.9%)	0
Ultrapro (*n*, %)	2 (3.7%)	0
Unknown (*n*, %)	1 (1.9%)	0
Mesh shape		
Semi-circular (*n*, %)	1 (1.9%)	0
Cut to size (*n*, %)	4 (7.4%)	0
Unknown (*n*, %)	3 (5.6%)	0
Pledgets useUse of VMS (*n*, %)	24 (44.4%)	4 (80%)

OR surgery

IQR interquartile range

VMS vertical mesh strips

This study showed an HH recurrence rate of 20.8%. Secondary surgery was done in 17.6% of the patients. Recurrence rates differed amongst subgroups of reinforcement techniques, though not significantly, which is probably caused by insufficient group sizes. The lowest recurrence rate was shown in the group with posterior and anterior cruroplasty in combination with VMS (14%). No significant differences were found between the RG and NRG regarding baseline characteristics or surgical characteristics. An important finding was that the use of VMS during primary HH repair seemed to reduce recurrence rates (OR = 0.34, CI 0.12–0.99, $p=0.048$). In other words, the odds for recurrence in the VMS group were 66% lower than in the patient group without VMS, with the true population effect between 1 and 88%. This result was statistically significant, although with a quite broad confidence interval.

Due to the heterogeneity in overall recurrence rates in literature, we would like to focus on recurrence rates per reinforcement technique. This study has shown a recurrence rate of 24% for patients with *posterior cruroplasty and VMS* and a rate of 14% when *posterior cruroplasty and VMS were combined with anterior cruroplasty*. However, VMS placement as conducted in this study is rarely found in literature because other studies use horizontally placed mesh strips on the crurae or use Teflon or polytetrafluoroethylene (PTFE) pledgets. The study group of Granderath et al. used horizontally placed 1 × 3 cm polypropylene strips and found significant differences in terms of less intrathoracic wrap migration and postoperative dysphagia in the mesh strip group compared to the non-mesh group, who had simple hiatoplasty. All patients received a Nissen fundoplication in the studies of Granderath et al. [10, 22]. Van den Dop et al. also used horizontal polypropylene mesh strip placement and reported a recurrence rate of 8.1%, which is not in line with our result of 24%. However, the follow-up time in their research was only seven months and might be an explanation for the difference found since the current study had a mean follow-up time of 6 years [8]. Few studies describe Teflon or PTFE pledgets, which are only partially comparable with this study due to the different material and size of pledgets compared to lightweight VMS. However, pledgets have the same purpose as VMS placement. Studies using multiple interrupted Teflon pledgets on both crurae reported recurrence rates varying from 10.8 to 23% [23, 24]. Unfortunately, no odds ratios were presented by any other study to represent the association between mesh strip use and recurrence.

In one of the most recent meta-analyses looking into *mesh* use and recurrence rate Sathasivam et al. found heterogeneous studies regarding the reduction in HH recurrence with mesh. However, their meta-analysis showed a significant reduction of recurrence after mesh repair compared to suture repair of HH (OR 0.48, $P<0.05$), which is not similar to the present study because no significant difference in recurrence for this mesh patient population was found (OR 0.80, $P=0.739$). Sathasivam et al. included multiple studies that used both absorbable and non-absorbable mesh, while only the latter is used in the present study [7]. The most recent studies analyzing only non-absorbable mesh were done by Oor et al. and Watson et al., who found that non-absorbable mesh did not result in improved recurrence rates compared to suture cruroplasty. Their findings confirm the results of the current study, although the current study shows a broad confidence interval, indicating low reliability due to the low power of the mesh patient population group [11, 25]. The decision to use mesh during surgery was mostly made according to the size of the hiatal defect [26]. Surprisingly, no standard method has yet been described to calculate the HH size, although Granderath et al. offer recommendations for optimal hiatal surface area (HSA) measurements [9].

Additionally, this study showed a recurrence rate of 23% for patients with *posterior and anterior cruroplasty*. No

significant association was found between anterior cruroplasty and recurrence rate. This result is in line with the results of the studies of Gibson et al., who showed a recurrence rate of 25% in the posterior and anterior cruroplasty group after a 24-month follow-up period. Gibson et al. initially reported a recurrence rate of 9% in a first report [27, 28]. This increase in recurrence rate also shows the importance of sufficient follow-up time. The present study has shown that most recurrences take place in 24 months and the mean follow-up time in the present study was 73 months.

Implications

This study is the first one to describe the use of mesh strips in a vertical position on each crural pillar. The use of VMS such as in the present study seems to have a protective effect to reduce recurrences. Furthermore, the findings in this study show that the lowest recurrence rate was achieved with the use of a combination of anterior sutures and VMS. This finding could be due to the protective effect of VMS on weak crurae and the reinforcement of the HH anteriorly. Mesh-related complications are probably caused by direct contact of mesh with viscera and we have not seen any of these late complications for VMS in this large cohort study with 6 years of follow-up time. The probability that VMS cause the same complications might therefore be lower as reported for mesh in literature due to the significantly smaller size of VMS. Based on our clinical experience it is recommended to use mesh strips in type III and IV HH patients due to its size and the type of HH. A total mesh placement remains controversial, as previous studies showed contradictory results on whether the use of mesh was significantly associated with recurrence. Furthermore, many studies have reported various complications due to the use of mesh [12]. The current study was not able to reject or confirm these different findings regarding mesh in literature.

Limitations of the study

A potential drawback of this study is its retrospective design, which may have caused us to miss some patients who experienced recurrent symptoms without our knowledge. Due to the retrospective design, it was not possible to ask patients about recurrences of symptoms. Moreover, if patients went to other hospitals with recurrent symptoms without reporting back to this hospital, these patients might be lost to follow-up. Nonetheless, we expect these patients to be few since the patients in this study area tend to be loyal to their physician, and not many other hospitals provide these services in the area. Besides, the retrospective design of this study also led to less available CTs because CTs were not made regularly in the past. Less available CTs and a substantial number of CTs with older techniques (thick slices) or unavailability of the thin slices data set and therefore reconstruction in multiple planes was not possible. The number of missing CTs might also be the explanation that no association was found between hiatal size and recurrence. Furthermore, the recurrence number might also be underestimated due to the different follow-up times of the patients. However, most recurrences were shown to occur within 24 months, and this study had a mean follow-up time of 73 months. Hence, we believe different follow-up times did not limit the reliability of our findings.

Although 307 patients were included in this patient population, post-hoc power calculations showed insufficient power, especially for the patient group with only mesh. Therefore, surgical technique groups could not be compared in a regression analysis, only reinforcement techniques were compared in a logistic regression. This low power might explain the broad confidence intervals of the multivariable logistic regression analysis and therefore the results should be interpreted cautiously.

Recommendations for further research

This exploratory study has shown the possible implications of the use of reinforcement techniques for HH surgery. In future research, it is recommended to examine these research questions in a prospective multicenter research setting. Prospective research would allow to determine recurrence symptoms for every patient by means of questionnaires or patient consultations. A multicenter study will make it possible to include sufficient patients for enough power in the study.

Conclusion

In conclusion, this study demonstrated a recurrence rate of 20.8% with a mean follow-up time of 6 years. Secondary surgery was performed in 17.6% of the patients and tertiary surgery in 1.6%. VMS are suitable for reinforcement of weak crura and may be safer than total mesh placement because they are associated with fewer mesh-related complications due to a smaller surface. The vertical placement of mesh strips on both crurae during cruroplasty appears to be a safe technique to reduce recurrences. The combination of VMS with anterior sutures might be the optimal technique to lower recurrence rates, though this needs further investigation.

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Declarations

Disclosures Drs Berdel Akmaz, Amber Hameleers, Dr Evert-Jan G Boerma, Dr Roy FA Vliegen, Prof Dr Jan Willem M Greve, Drs Berry Meesters and Dr Jan HMB Stoot have no conflicts of interest or financial ties to disclose.

References

1. Westcott LZ, Ward M (2020) Techniques for closing the hiatus: mesh, pledgets and suture techniques. Ann Laparosc Endosc Surg 5:16
2. Kohn GP, Price RR, DeMeester SR, Zehetner J, Muensterer OJ, Awad Z et al (2013) Guidelines for the management of hiatal hernia. Surg Endosc 27(12):4409–4428
3. Saad AR, Velanovich V (2020) Anatomic observation of recurrent hiatal hernia: recurrence or disease progression? J Am Coll Surg 230(6):999–1007
4. Zaman JA, Lidor AO (2016) The optimal approach to symptomatic paraesophageal hernia repair: important technical considerations. Curr Gastroenterol Rep 18(10):53
5. Lidor AO, Steele KE, Stem M, Fleming RM, Schweitzer MA, Marohn MR (2015) Long-term quality of life and risk factors for recurrence after laparoscopic repair of paraesophageal hernia. JAMA Surg 150(5):424–431
6. Acosta MA, Cuesta MA, Bruna M (2021) Atlas of minimally invasive techniques in upper gastrointestinal surgery. Springer, Cham
7. Sathasivam R, Bussa G, Viswanath Y, Obuobi R-B, Gill T, Reddy A et al (2019) 'Mesh hiatal hernioplasty' versus 'suture cruroplasty' in laparoscopic para-oesophageal hernia surgery; a systematic review and meta-analysis. Asian J Surg 42(1):53–60
8. Van Den Dop LM, De Smet GHJ, Mamound A, Lange J, Wijnhoven BPL, Hueting W (2021) Use of polypropylene strips for reinforcement of the cruroplasty in laparoscopic paraesophageal hernia repair: a retrospective cohort study. Dig Surg 38(4):290–299
9. Granderath FA, Schweiger UM, Pointner R (2007) Laparoscopic antireflux surgery: tailoring the hiatal closure to the size of hiatal surface area. Surg Endosc 21(4):542–548
10. 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(1):40–48
11. Oor JE, Roks DJ, Koetje JH, Broeders JA, van Westreenen HL, Nieuwenhuijs VB et al (2018) Randomized clinical trial comparing laparoscopic hiatal hernia repair using sutures versus sutures reinforced with non-absorbable mesh. Surg Endosc 32(11):4579–4589
12. Stadlhuber RJ, Sherif AE, Mittal SK, Fitzgibbons RJ Jr, Michael Brunt L, Hunter JG et al (2009) Mesh complications after prosthetic reinforcement of hiatal closure: a 28-case series. Surg Endosc 23(6):1219–1226
13. Nissen R (1956) A simple operation for control of reflux esophagitis. Schweizerische medizinische Wochenschrift 86(Suppl 20):590–592
14. Dallemagne B, Weerts JM, Jehaes C, Markiewicz S, Lombard R (1991) Laparoscopic Nissen fundoplication: preliminary report. Surg Laparosc Endosc 1(3):138–143
15. Tian Z-c, Wang B, Shan C-x, Zhang W, Jiang D-z, Qiu M (2015) A meta-analysis of randomized controlled trials to compare long-term outcomes of Nissen and Toupet fundoplication for gastroesophageal reflux Disease. PLoS ONE 10(6):e0127627
16. Broeders JAJL, Mauritz FA, Ahmed Ali U, Draaisma WA, Ruurda JP, Gooszen HG et al (2010) Systematic review and meta-analysis of laparoscopic Nissen (posterior total) versus Toupet (posterior partial) fundoplication for gastro-oesophageal reflux disease. Br J Surg 97(9):1318–1330
17. Toupet AC (1963) Technique d'oesophago-gastroplastie avec phréno-gastropexie appliquée dans la cure radicale des hernies hiatales et comme complément de l'opération de Heller dans les cardiospasmes. Mem Acad Chir 89:394–399
18. Watson DI, Jamieson GG, Pike GK, Davies N, Richardson M, Devitt PG (1999) Prospective randomized double-blind trial between laparoscopic Nissen fundoplication and anterior partial fundoplication. Br J Surg 86(1):123–130
19. Bell RC, Hanna P, Mills MR, Bowrey D (1999) Patterns of success and failure with laparoscopic Toupet fundoplication. Surg Endosc 13(12):1189–1194
20. Collis JL (1957) An operation for hiatus hernia with short oesophagus. Thorax 12(3):181–188
21. Karatay E, Gok MA, Javadov M (2021) Measurement of hiatal surface area and other hiatus oesophageal diameters at computed tomography imaging in patients with gastroesophageal reflux disease and its relationship with hiatal hernia. J Minim Access Surg 17(4):537–541
22. Granderath FA, Schweiger UM, Kamolz T, Pasiut M, Haas CF, Pointner R (2002) Laparoscopic antireflux surgery with routine mesh-hiatoplasty in the treatment of gastroesophageal reflux disease. J Gastrointest Surg 6(3):347–353
23. Kang T, Urrego H, Gridley A, Richardson WS (2014) Pledgeted repair of giant hiatal hernia provides excellent long-term results. J Laparoendosc Adv Surg Tech A 24(10):684–687
24. Weitzendorfer M, Pfandner R, Antoniou SA, Schwaiger-Hengstschläger C, Emmanuel K, Koch OO (2019) Short-term results after laparoscopic repair of giant hiatal hernias with pledgeted sutures: a retrospective analysis. Hernia 23(2):397–401
25. Watson DI, Thompson SK, Devitt PG, Smith L, Woods SD, Aly A et al (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
26. Frantzides CT, Carlson MA, Loizides S, Papafili A, Luu M, Roberts J et al (2010) Hiatal hernia repair with mesh: a survey of SAGES members. Surg Endosc 24(5):1017–1024
27. Gibson SC, Wong SK, Dixon AC, Falk GL (2013) Laparoscopic repair of giant hiatus hernia: prosthesis is not required for successful outcome. Surg Endosc 27(2):618–623
28. Furtado RV, Vivian SJ, van der Wall H, Falk GL (2016) Medium-term durability of giant hiatus hernia repair without mesh. Ann R Coll Surg Engl 98(7):450–455