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REVIEW

The New Interest of Bariatric Surgeons in the Old Ligamentum Teres Hepatis

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Abstract

The search for an operation that effectively prevents and treats intrathoracic gastric migration (ITGM) after bariatric surgery has revived a long-forgotten technique: ligamentum teres cardiopexy (LTC) by which a vascularized flap of the teres ligament is wrapped around the distal esophagus. The systematic search of publications in the English language revealed 4 studies (total number of patients 53) in the non-bariatric literature with an unsatisfactory resolution of GERD. There were 5 reports from the bariatric literature with small patient numbers (total 64) and a short follow-up (6–36 months). There were no objective signs of gastric remigration in 93% of investigated patients. Acknowledging the limitations of these preliminary reports, bariatric surgeons are encouraged to further investigate the potentials of LTC in their patients.

Keywords Ligamentum teres hepatis · Round ligament · Intrathoracic gastric migration · Hiatal hernia · GERD · Sleeve gastrectomy · Bariatric surgery

Abbreviations

LTC	Ligamentum teres cardiopexy
ITGM	Intrathoracic gastric migration
GERD	Gastroesophageal reflux disease
SG	Sleeve gastrectomy
RYGB	Roux-en-Y gastric bypass
OAGB	One anastomosis gastric bypass
BMI	Body mass index
LES	Lower esophageal sphincter

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Introduction

The ligamentum teres hepatis (also known as the round ligament of the liver) is the remnant of the umbilical vein, which once travelled from the placenta to the liver to deliver oxygenated and nutrient-rich blood to the fetal body circulation. The teres ligament is the free, inferior edge of the falciform ligament, which is a thin, sickle-shaped fibrous structure that connects the anterior part of the liver to the ventral wall of the abdomen [1]. The main arterial supply to the ligamentum teres hepatis is from the ligament branch of the middle hepatic artery which runs through the liver fissure [2] (Fig. 1a, b). This is the anatomical basis of the vascularized ligamentum teres hepatis pedicle flap [3].

The ligamentum teres hepatis has long been thought of as an insignificant embryological remnant; however, general surgeons increasingly use the ligamental flap for the closure of perforated duodenal ulcers [4], the repair and reconstruction of intraabdominal veins [5–8], the protection of the gastroduodenal artery stump after pancreaticoduodenectomy [9], the reconstruction of bile ducts [10], the augmentation of hepaticojejunostomy [11], the augmentation of

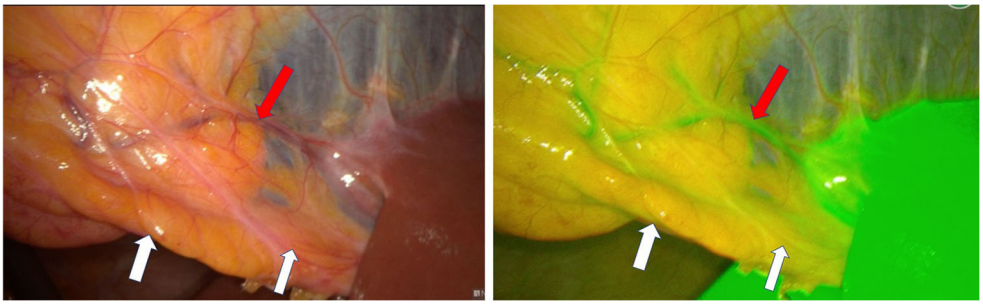

Fig. 1 Laparoscopic view of the base of the ligamentum teres hepatis from the left side (**a**) and near-infrared laparoscopy after ICG injection (**b**). The arterial blood supply is via a ligament branch of the middle hepatic artery. It runs through the liver fissure, leaves the liver margin (red arrow) and gives off branches which enter the teres and falciform ligament. ICG angiography visualizes a fine arterial plexus around the umbilical vein (white arrows)

pancreatojejunostomy [12], and the coverage of the pancreatic stump after distal pancreatectomy [13, 14]. The teres ligament flap was used for GERD and hiatal hernia repair in the past, which is discussed further below, and as a natural living gastric band for weight loss surgery [15]. The teres ligament was soon forgotten until recently, when bariatric surgeons rediscovered the flap for the treatment of intrathoracic gastric migration (ITGM) and gastroesophageal reflux (GERD). This review discusses the potentials of the ligament in bariatric surgery.

Methods

Due to the limited amount of literature on the use of ligamentum teres hepatis in surgery, the authors conducted a narrative review. The literature was scanned on PubMed up to March 2020. The search terms (number of items) that were used included "ligamentum teres hepatis" OR" "teres ligament" AND "surgery" (28), "ligamentum teres" AND "hiatal" (15), "ligamentum teres" AND "reflux" (19), "pexis" AND "round ligament" (3), and "teres cardiopexy" (12). Twenty-eight potentially relevant articles were identified by screening titles and abstracts. Criteria for the inclusion in the review were articles published in English, full text available, and articles that included patients that had undergone ligamental flap surgery. Duplicates were removed.

Results

Twenty-four potentially relevant articles were published before 2008; they concerned the nonbariatric population. Four of these articles met the inclusion criteria for this review, and 20 articles were excluded (Fig. 2). The summaries of the excluded citations were analyzed in order to avoid a potential language bias. Seven references were duplicates and another 7 were without an abstract or clinical data leaving 6 references with some valuable information about the clinical outcome. Of these 6 abstracts, 3 were from Spain, 2 from Germany, and

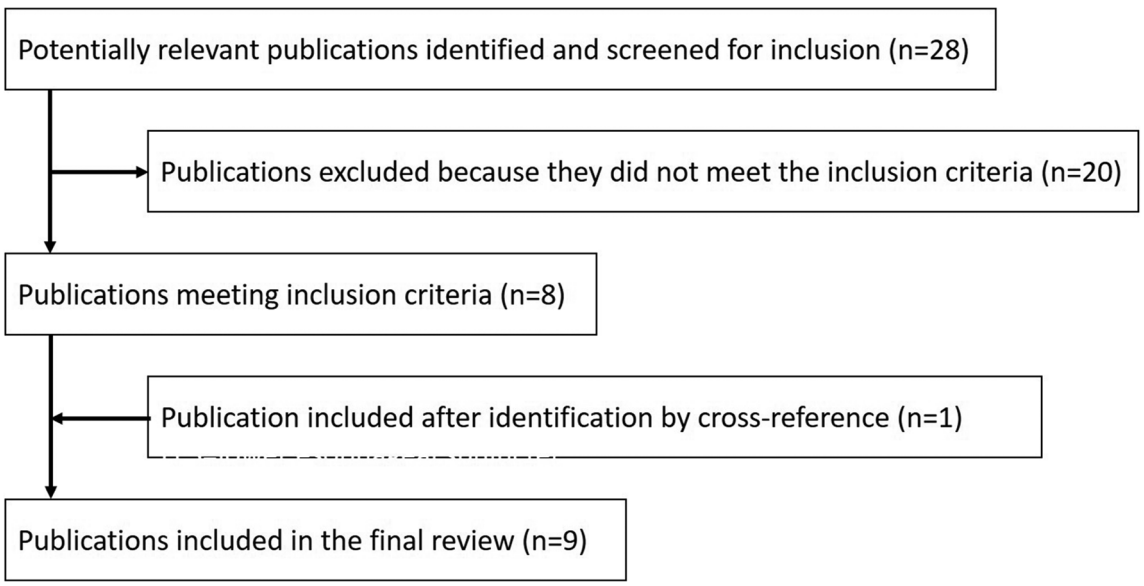

Fig. 2 Flowchart describing the number of articles found, excluded, and retained during the review process

1 from France. These articles are mentioned in this review for the purpose of a historical perspective.

There were no citations between 2008 and 2015. All 5 articles since then are included in this review. They all concerned the application of the teres ligament in the bariatric population. One additional reference was included which was identified by cross-reference.

The included articles were divided into three themes which are used to organize the results: reinforcement of hiatoplasty (1 article), antireflux cardiopexy in the nonbariatric population (3 articles), and antireflux cardiopexy in the bariatric population (5 articles) (Table 1).

Ligamentum Teres Flap for Reinforcing the Hiatoplasty

One article was included in this theme [16]. Varga et al. used the teres ligament to reinforce the hiatal closure during Nissen-DeMeester fundoplication. The technique was described in an earlier paper: the mobilized ligamentum teres was pulled through the gap between the repaired hiatus and the esophagus; the ligament was then sutured to the left and right crus with nonabsorbable stitches at the level of the esophagus creating a U-shaped reinforcement of the hiatus [25]. The authors reported their experience in 26 patients during 2003–2007 [16]. The follow-up period was 35 months on average (17–50 months). All patients were regularly interviewed and underwent a barium swallow. Additional functional foregut testing was performed when symptoms developed. Two patients complained about reflux postoperatively at 1 and 2 years, respectively, but there was no evidence of abnormal acid exposure and anatomical recurrence. Recurrent hernia was diagnosed in 4 patients, 1 patient with severe postprandial pain 18 months after the operation, 1 patient with mild dysphagia 24 months postoperatively, and another 2 asymptomatic patients diagnosed at 12 months after the operation. Among 21 patients with a hiatal diameter of 6–9 cm, the hernia recurred in 1 patient (4.7%). Of the 5 patients who had a hiatus greater than 9 cm in diameter, 3 (60%) had an anatomic recurrence. The authors concluded that ligamental reinforcement was safe and effective except for extremely large hiatal hernias.

Ligament Teres Flap for Antireflux Cardiopexy in the Nonbariatric Population

Three articles were selected for this theme [17–19]. Non-English literature was added for the historical perspective. The ligamentum teres cardiopexy (LTC) is a sling-shaped wrap of the ligament around the distal esophagus. It pulls the gastroesophageal junction forward, downward, and toward the right. According to Galvez [20], the technique was developed by Rampal [26] in France in 1964 and Narbona-Arnau [27] in Spain in 1972. Teres cardioplasty, teres plasty, and Narbona technique are other names for this procedure [28–30]. The largest series was published in the French literature by Narbona and colleagues from Valencia, Spain, who reported remarkable results after more than 3.000 LTCs [27]. They carefully reviewed 100 consecutive cases operated 15 years earlier or more. The results were classified as normal or occasional disorders (81%), functional disorders without recurrence (12%), and recurrence (6%). The authors concluded that "a 15-min operation cures 94% of the patients without recurrence after 15 years and more," Another Spanish report of a retrospective analysis of 47 LTCs with an average follow-up of 5 years showed a high success rate of 95% [31]. In this paper, cardiopexy was performed as a standalone procedure (61%) or in combination with crural repair (39%).

The selected articles in English language reported far less favorable results. One prospective randomized trial from the Netherlands compared the LTC with Nissen fundoplication [17]. Concomitant crural repair was performed in 2 of 10 patients with cardiopexy and in 5 of 10 patients with fundoplication. At 1 year, 16 patients (9 cardiopexy, 7 fundoplication) consented to evaluation by endoscopy. Esophagitis was found in 8 patients after cardiopexy and in only 1 patient after fundoplication. After 1 year, 6 of the 10 patients with cardiopexy versus 1 of 10 patients with fundoplication required a second antireflux procedure because of severe reflux that did not respond to conservative treatment. The authors concluded that cardiopexy was significantly less effective than fundoplication. The disappointing outcome at 1 year after LTC led to discontinuation of the trial. The differences between the Spanish and Dutch results were remarkable and difficult to understand. The authors speculated that technical aspects might have played a role although training experience was obtained from the Spanish surgeon during the pilot study (30 patients).

Cushieri's group was the first to describe the laparoscopic technique of LTC in detail [32]. Their technical paper focused on the perioperative course of 5 patients. A later article included 9 cases [18]. All patients were assessed symptomatically and by endoscopy, 24 h pHmetry, manometry, and esophageal transit up to 18 months. One patient developed recurrence of heartburn 4 months after surgery and had endoscopically proven esophagitis and a duodenal ulcer. The authors announced a subsequent paper with the full details, but unfortunately, this was not found in the available database.

Poor results were communicated by Meyer et al. from France in a letter responding to the Dutch RCT in 1994 [19]. The authors followed 8 patients after laparoscopic LTC including clinical evaluation, 24-h pHmetry, and manometry. Symptoms were abolished by 3 months but recurred within 12 months in all patients. There were no real improvements on manometry and pHmetry at 3 months. The objective findings deteriorated by 12 months. The reoperation in 2 patients

Table 1 Summary table of the included studies. LTC = ligamentum teres cardiopexy, SG = sleeve gastrectomy, LES = lower esophageal sphincter, RCT = randomized controlled trial

Citation	Year	Country	Study design	Indication	Surgical technique	Number of patients	Concomitant crural repair (number of patients)	Follow-up period	Outcome in percent of patients
Varga et al. [16]	2008	Hungary	Prospective	Hiatal hernia	Laparoscopic crural reinforcement with teres ligament	26	26	Average 35 months (17–50)	81% asymptomatic; 19% recurrent hiatal hernia
Janssen et al. [17]	1993	Netherlands	RCT	GERD	Open LTC	10	2	12 months	40% asymptomatic; 60% with recurrent symptoms requiring conversion to fundoplication
Cushieri [18]	1993	UK	Prospective	GERD	Laparoscopic LTC	9	Not reported	< 18 months	89% asymptomatic; 11% symptomatic with recurrence
Meyer et al. [19]	1994	France	Prospective	GERD	Laparoscopic LTC	8	Not reported	12 months	50% asymptomatic; 50% symptomatic requiring conversion to fundoplication
Gálvez-Valdovinos et al. [20]	2015	Mexico	Prospective	GERD after SG	Laparoscopic LTC	15	15	6 months	87% asymptomatic with normal function tests; 13% persistence of symptoms with low LES pressure; no recurrence of hiatal hernia on endoscopy
Al-Sabah et al. [21]	2017	Kuwait	Prospective	GERD after SG	Laparoscopic LTC	2	2	6 months	Both asymptomatic with normalized LES pressure
Vilallonga et al. [22]	2019	Spain	Prospective	GERD after SG	Laparoscopic LTC	1	1	6 months	Asymptomatic with normalized LES pressure
Hutopila & Copaescu [23]	2019	Rumania	Prospective	GERD and hiatal hernia after SG	Laparoscopic LTC	28	28	36 months	67% asymptomatic, 62% normalization of pHmetry, no recurrent hernia, 4% requiring conversion to RYGB after 2 years
Huang et al. [24]	2018	Taiwan, Philippines	Prospective	Prevention of GERD	Laparoscopic LTC concomitant with SG	18	11	6 months	100% asymptomatic

revealed a complete loosening of the cardiopexy and lengthening of the round ligament. Two further patients awaited reoperation at the time of publication.

The overall results were in favor of fundoplication, and after its adoption by most laparoscopic surgeons as the standard procedure for reflux disease in the early 1990s of the last century, LTC fell into oblivion.

Ligament Teres Flap for Antireflux Cardiopexy in the Bariatric Population

Three publications and 1 abstract were selected for this theme. They dealt with GERD after sleeve gastrectomy (SG).

Gálvez-Valdovinos et al. from Mexico were the first to propose LTC for GERD after sleeve gastrectomy in 2015 [20]. They applied the original technique described by Narbona-Aarau [27]. Fifteen patients were included in the study. The interval between sleeve gastrectomy and LTC was 30 months on average. The BMI had fallen from 45 ± 5 to 22 ± 2 kg/m^2. Pre-LTC manometry revealed a low esophageal sphincter pressure (9.3 ± 1.3 mmHg), and endoscopy showed esophagitis grade A in 13 patients and grade B in 2 patients. All patients had a hiatal hernia measuring 3–5 cm. Six months after the operation, signs and symptoms of GERD resolved in 13 patients. None of them required medication. Endoscopy confirmed a normal anatomy in these patients, and manometry demonstrated an increase of the esophageal sphincter pressure above 12 mmHg. LTC was considered unsuccessful in two patients (13.3%) both of whom required occasional proton pump inhibitors. The pressures of the lower esophageal sphincter were 13 mmHg and 14.9 mmHg, respectively. Both the symptomatic patients experienced mild erosive esophagitis grade A without a hiatal hernia recurrence.

A "surgeon-at-work" publication from Kuwait presented 2 cases in 2017 [21]. Both patients had developed severely symptomatic GERD after SG. Their BMI had dropped from 44 to 22 kg/m^2 and from 47 to 24 kg/m^2, respectively. A hiatal hernia was present in both cases. The postoperative barium swallow was regular. Six months after the operation, both patients were asymptomatic without medication. Manometry demonstrated pressures of the lower esophageal sphincter above 12 mmHg in both patients.

A recent "brief communication" from Barcelona presented a 56-year-old female patient after initial RYGB [22]. Severe hypoglycemia was the reason for conversion into SG. A preexisting hiatal hernia was not repaired. Postoperatively, she experienced severe GERD and regurgitation which was unresponsive to medical treatment and endoscopic dilation of the gastrogastric anastomosis. A standalone hiatoplasty for severe GERD was performed but did not relieve the symptoms. The patient underwent laparoscopic revision, esophageal mobilization, anterior cruroplasty, and LTC. She experienced resolution of GERD without proton pump inhibitors and a manometric measurement of over 12 mmHg at 6 months.

Hutopila and Copaescu presented the Bukarest experience of the LTC for the control of GERD after SG at the 27th International Congress of the European Association for Endoscopic Surgery. The data were available as an abstract only and reconfirmed by personal communication with the principal author [23]. The procedure was performed on 28 patients with hiatal hernia and GERD after SG since 2014. One patient was converted to RYGB because of intractable reflux after 2 years. Of the remaining patients, 66.7% were without symptoms and without medication 3 years later. Imaging examinations showed no signs of hiatal hernia recurrence.

One article ("video submission") by authors from Taiwan and the Philippines explored the option of a prophylactic *LTC for the prevention of post-SG GERD*. The hiatal area was repaired in cases with preexisting hiatal hernias. Eighteen patients were recruited over a 2-month period whose ligamentum teres was estimated long enough for a 360° wrap [24]. Preoperative endoscopy had showed 8 patients with GERD A, 1 with GERD B, and 5 with hiatal hernias. All patients underwent SG, five with concomitant proximal jejunal bypass and two with duodenojejunal bypass. Eleven patients also had hiatal hernia repair. LTC was performed in all 18 patients. At 6-month follow-up, the mean percent excess weight loss was 56%. No patient required proton pump inhibitors at that time. No further investigations were performed.

Discussion

Vascularized flaps of the ligamentum teres hepatis were used by surgeons of the last century for the treatment of GERD. It is an easy, quick, and low-risk procedure by open and laparoscopic access. The ligament is dissected from its insertion at the umbilicus and from the anterior abdominal wall up to the falciform ligament. The dissection proceeds between the two vascular arcades (hepatic and diaphragmatic) down to the anterior liver margin preserving the hepatic arterial branch. The ligamental flap, pediculated at the liver, is passed through a window behind the gastroesophageal junction from right to left. Rampal fixed the cardia on both sides to the ligament which was then wrapped around the esophagus in an anticlockwise fashion and fixed on itself by nonresorbable sutures [26]. Nabona's technique of LTC, which was adopted by most surgeons, is a 270° wrap based on concerns about a slippage of the cardia through the sling causing an obstructive dysphagia [27].

The cardiopexy was superseded by fundoplication during the early 1990s through the rise of laparoscopy. Since then, the ligamental flap has been increasingly used to cover intraabdominal wounds and surfaces but there have been no more citations in the nonbariatric literature

regarding the control of GERD. Varga, a surgeon from Hungary, used the teres ligament as an inexpensive substitute for mesh reinforcement of hiatoplasty rather than for its antireflux capacity [16, 25]. Due to the noncomparative design of the study, the proof of superiority over other techniques of hiatal hernia repair is missing.

Bariatric surgeons have recently rediscovered and revived LTC while searching for a durable anchor for the gastric sleeve [20–24]. The case series have the limitations of low numbers and a short follow-up period, but their results are similar: high rates of reflux resolution and low rates of intrathoracic remigration of the gastric sleeve. Bariatric surgeons are taking notice of these data because they are faced with a rising tide of gastroesophageal reflux. Of all bariatric operations, SG is at highest risk.

When hiatal hernia preexists, hiatoplasty concomitant with sleeve gastrectomy is a consented procedure [33]. However, clinical results are inconsistent. Failure of the suture hiatoplasty with sleeve remigration was recorded in 18.4% of 47 patients 5 years postoperatively [34]. In other studies, hiatoplasty did not resolve or prevent GERD at all [35, 36]. New techniques including mesh or buttress reinforcement, phrenicopexy, or Nissen/sleeve indicate the dissatisfaction with suture hiatoplasty. In this situation of preventive hiatoplasty, the concomitant augmentation with LTC is a new concept, but systematic anatomical and functional investigations are lacking [24].

When ITGM is detected after SG, the role of standalone hiatoplasty is unclear and simultaneous conversion to RYGB is generally recommended. For those patients who do not accept the conversion, LTC may be an alternative method.

ITGM occurs not only after SG but also after RYGB and OAGB, but the prevalence is unknown. There are no published results of hiatal repair after gastric bypass surgery. Theoretically, LTC may also have advantages in this clinical setting.

Bariatric surgeons preferred Rampal's 360° sling over Narbona's 270° sling, yet a reason for this preference is unknown. Galvez et al. [20], El Sabath et al. [21], and Huang et al. [24] passed the ligament posteriorly around the gastroesophageal junction, whereas Vilallonga et al. [22] preferred the anterior clockwise position of the ligament. The ligament was sutured on both sides of the cardia. Huang et al. fixed the ligament also to the left diaphragmatic crus and then over itself with 4 to 6 stitches, forming a 360° necktie cardiopexy [24].

It is unclear why LTC should work in bariatric patients when it was unsuccessful in nonbariatric patients. One may speculate whether this discrepancy is caused by a difference in the pathogenesis of GERD between the two populations. Another explanation could be that the LTC was used for GERD in nonbariatric patients even without a hiatal hernia. In addition, the esophageal stretching after fundoplication could be more efficient than after LTC.

Bariatric surgeons do not have the option of restoring the antireflux capability of the gastroesophageal junction. Whether the right downward traction by the teres ligament affects the junction directly or indirectly by assuring a long intraabdominal segment of the esophagus remains to be clarified. Vilallonga and his coauthors thought that LTC creates an artificial valve and restores the angle of His [22]. El Sabath speculated that securing the cardia with the left lobe of the liver provides mobility with hepatic movements, which occur when breathing and with diaphragmatic contraction and displacement [21]. The strength of the ligament can eventually subside [19]. The long-term stability is most likely provided by adhesions around the ligament and by the bolster effect for the hiatal closure. The durability, however, needs to be addressed in further studies.

Conclusion

A flap of the ligamentum teres hepatis was used for the treatment of gastroesophageal reflux disease and for the reinforcement of hiatal hernia repair in the past. Recent publications dealt with the ligamentum teres cardiopexy in patients with SG for the correction and prevention of intrathoracic gastric migration. This new interest is fuelled by the increasing number of bariatric patients with intrathoracic gastric migration, reflux, and metaplasia. The published results are preliminary, but the lack of therapeutic alternatives gives the old ligamentum teres cardiopexy a new chance that should be explored and researched by bariatric surgeons.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Statement The article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent Informed consent does not apply.

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