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ORIGINAL CONTRIBUTIONS

Clinical, Endoscopic, and Histologic Findings at the Distal Esophagus and Stomach Before and Late (10.5 Years) After Laparoscopic Sleeve Gastrectomy: Results of a Prospective Study with 93% Follow-Up

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Abstract

Objective Perform a prospective study based on sequential clinical, endoscopic, and histologic evaluations of the foregut late after laparoscopic sleeve gastrectomy (LSG) in obese patients.

Summary After LSG, several studies have suggested an increase in the incidence of clinical gastroesophageal reflux (GERD) while others have reported an improvement but based mainly on clinical questionnaires.

Methods Prospective study of 104 consecutive patients submitted to LSG. Several postoperative endoscopic and histologic evaluations of the esophagogastric junction (EGJ) and the gastric tube (GT) were performed and correlated with symptomatic findings.

Results According to clinical preoperative findings, patients were divided into non-refluxers (Group I) and refluxers (Group II). Seven patients were unreachable, leaving 97 (93%) for late evaluation. Among Group I, 58.5% developed de novo GERD, while in Group II just 13.6% showed the disappearance of them. Endoscopic evaluations showed progressive deterioration of the EGJ in Group I, with the development of erosive esophagitis (EE), hiatal hernia (HH), and dilated cardia in a large proportion of them. In the GT, the presence of bile was seen in 40%, and an open immobile pylorus was detected in 82%. Short-segment Barrett's esophagus (BE) appeared in 4%.

Conclusions Patients submitted to LSG showed a significant and progressive increase in the presence of "de novo" GERD. Also, an increased duodenogastric reflux was seen through an open and immobile pylorus. Therefore, based on these results, it seems like LSG is a "pro-reflux" surgical procedure, which should be continuously evaluated late after surgery.

Keywords Sleeve gastrectomy · Endoscopic findings · Gastroesophageal reflux · Histology of EGJ

Introduction

Obesity alone is associated with an increase of up to 70% of gastroesophageal reflux disease (GERD) [1, 2]. Currently, two laparoscopic techniques are the most frequently employed procedures to treat obese patients: gastric bypass (LGB) and sleeve gastrectomy (LSG) [3]. Several clinical studies have suggested an increase of clinical GERD after LSG [4–6], while others point out an improvement [7, 8]. Several systematic reviews and meta-analysis have also mentioned conflicting results [9–13]. The conflicts in these reports are (a) short follow-up (1–2 years); (b) a small number of patients followed up, less than 80% from the original group; (c) only subjective evaluation of symptoms; (d) majority were retrospective studies; and (e) few mentions of late endoscopic evaluations of LSG effect on esophageal and gastric mucosa.

The purposes of this prospective study are to determine subjective and objective evaluations of GERD after LSG, accomplishing a late follow-up over 80% of the included patients.

Material and Methods

Patients Studied

This prospective study started in January 2006 and ended in December 2010, including all consecutive patients submitted to LSG at the Department of Surgery, University of Chile Hospital, Santiago, Chile. All clinical, endoscopic, and

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histologic evaluations before surgery were collected in a prospective database. Exclusion criteria corresponded to four patients with Barrett's esophagus (BE), two with prior bariatric surgery, and eight with type 2 diabetes and cases with a hiatal hernia (HH) over three cms. LSG was started in our institution in 2005. Therefore, we began this research after achieving our learning curve of 22 cases, plus extensive experience performing open gastrectomies for 25 years. According to clinical and endoscopic findings before surgery, subjects were divided into two groups:

1. Group I: The absence of GERD symptoms, with normal upper endoscopy (UE) findings.
2. Group II: The presence of GERD symptoms or abnormal UE such as HH, dilated cardia Type III or IV, or erosive esophagitis (EE) grades A to D.

Clinical Evaluation

For this study, all patients were personally interviewed and examined by the main author before, early, and late after surgery. None was interviewed indirectly, only "face to face" control. The following parameters were evaluated: (a) Body mass index (BMI) measured as Kg/m^2; (b) heartburn defined as a burning sensation in the middle chest which can extend up to the neck and worsens when bending or lying down; (c) regurgitation defined as a backward flowing of gastric content to the esophagus without any effort; (d) daily use of proton pump inhibitors (PPIs).

For late clinical evaluation, a modified Visick gradation was employed, with the following criteria [14, 15]:

- Visick I**:** asymptomatic;
- Visick II: mild or episodic symptoms controlled easily with medical treatment or diet adjustment, with no need for permanent medication; endoscopic findings of esophagitis grade A without reflux symptoms were also included;
- Visick III**:** frequent or daily symptoms requiring permanent medical treatment;
- Visick IV**:** severe symptoms causing daily incapacity and requiring reoperation.

For final evaluations, patients with Visick ratings of I and II were considered a surgical success and Visick ratings of III and IV as a failure. We employed this scale because it was designed for the evaluation of subjects submitted to a partial gastrectomy.

Radiological Evaluation

This examination was performed in all patients two to three days after surgery, employing water-soluble contrast medium, taking 8 to 10 films in a different position in order to evaluate at baseline the residual gastric tube (GT) anatomy and the gastric emptying to the duodenum and to discard a GT narrowing or twisting of the mid-portion.

Endoscopic Evaluation

Endoscopic procedures were performed employing the Olympus GIFX-type V endoscope (Tokyo, Japan). After a 12-h overnight fast, with the patient in a supine lateral position, the macroscopic aspect of the distal esophageal mucosa was examined, and the EE presence was described according to the Los Angeles classification [16]. If present, the length of the columnar-lined mucosa at the distal esophagus (CLM) was measured as the distance between the squamous-columnar junction (SCJ) and the endoscopically located lower esophageal sphincter (LES), which is the point where the proximal extent of the gastric folds met with the tubular esophagus [17]. The esophagogastric junction (EGJ) or cardia was defined as the place where the proximal rugal folds join the tubular esophagus with the stomach decompressed. HH was defined as the presence of a sack-like structure distal to the tubular esophagus and containing gastric rugal folds. The macroscopic aspect of the gastroesophageal flap or cardia was classified into four types during the endoscopic procedure in retroflection according to Hill's classification [18].

After surgery, the length of the GT between the EGJ and the pylorus was measured in cm. The presence of bile or duodenal content at the GT was also inspected and recorded either in the fundus or antrum. The pylorus ring was observed, for 2 min, whether there was a contraction of the pylorus together with the terminal antral contraction (TAC) or remained open and immobile because TAC time is three per minute [19–21]. Before surgery, UE was performed in all subjects. After surgery, a total of 170 endoscopies were performed in Group I: 3.2 endoscopies per patient (U.E./pt.), while in Group II 156 endoscopies were performed (3.5 UE/pt.).

Histologic Analysis

In all endoscopic procedures, biopsy specimens were taken at two main sites: (a) Gastric antrum to detect the presence of *Helicobacter pylori* (HP) = two samples and (b) Juxtacardial (JC) biopsies 5 mm distal to the SCJ. Three to four samples were taken to detect the presence of intestinal metaplasia (IM) or carditis. In the presence of a CLM, the Seattle biopsy protocol was applied. [22] All samples were immediately submerged in a 10% formalin solution and sent for histologic examination. They were stained with hematoxylin-eosin and Alcian blue stain at pH 2.5. The type of epithelium lining the distal esophagus was classified as follows:

(a) Fundic mucosa named by the presence of parietal and chief cells at the deep glandular layer and funditis, when chronic inflammatory cells were present.
(b) Cardiac mucosa was identified by the presence of mucus-secreting columnar cells and carditis when inflammatory cells were present.
(c) Specialized IM characterized by the appearance of well-defined goblet cells and confirmed by positive staining with Alcian blue. After surgery, 3.7 samples per patient were taken from the JC area.

Preoperative Evaluation

All patients had a complete multidisciplinary evaluation, which included UE, abdominal ultrasound, hematological parameters, nutritional and psychological evaluations, and EKG.

Follow-Up

All patients had a UE one month after surgery; it was repeated one to two years (mean 1.6) after and performed once again in all cases 10.5 years after surgery. The follow-up was closed in December 2018.

Surgical Procedure

The details of our surgical technique have been published elsewhere [23]. Three surgeons performed all operations. Briefly, we start two to three cm from the pylorus, because it has been demonstrated to have a better weight loss compared if the distance is over six cm [24]. The mobilization of the greater curvature extended up to the hiatus zone, dissecting the posterior gastric wall, and visualizing the left crura in order to avoid the development of a "neo-fundus". Neither the phrenoesophageal ligament was taken down nor the EGJ was dissected and mobilized during sleeve surgery. A 38-Fr calibration bougie is used, and the gastric section is made using two green cartridges for the antrum and four to five blue cartridges for the rest (Medtronic®, USA). In all, a methylene blue test was used to identify leaks. Two to three days after the operation, a radiological examination was performed in all patients. In nine patients with a small HH, the distal esophagus was dissected, and the hiatus was closed with three nonabsorbable sutures.

Statistical Analysis

For the calculation of statistical significance, the chi-square test and the Fisher exact test were used, considering $p < 0.05$ as significant. All results are expressed as mean ± standard deviation.

Results

One hundred and four patients fulfilled the inclusion criteria and were submitted to LSG. After surgery, two patients developed a leak which was treated conservatively. None has bled, and no mortality was seen. Radiological evaluation two to three days after the surgery showed a narrow gastric tube and rapid emptying of contrast medium in all, except one patient who showed a mid-stricture which needed several endoscopic dilatations. Figure 1 shows the flow diagram of patients concerning the follow-up. The clinical features of the whole group according to the presence of GERD symptoms are shown in Table 1. There were no significant differences in any parameter in both groups. The mean follow-up was 10.5 years. A similar loss of weight was seen in both groups ($p > 0.7$).

Table 2 demonstrates the preoperative and postoperative endoscopic findings. Before surgery, EE grade A or B was observed in 32% of Group II patients. The macroscopic aspect of the cardia was normal (types I and II) in 100% of Group I, while 75% of Group II had a cardia of type III or IV ($p < 0.001$). One month after LSG, Group I showed a type III cardia in nearly one-half of the subjects, a significantly higher number compared with preoperative values ($p < 0.001$). One and a half year after surgery, the finding of a type III cardia showed a significant increase ($p < 0.02$) compared with preoperative values in both groups. The presence of a small HH was seen in two patients in both groups. EE appeared in both groups in 15 and 18%, respectively ($p > 0.8$). At late control, several changes were documented: (a) a significant increase in EE appearance among Group I, almost two times higher compared with early control ($p < 0.01$) but not significant among Group II ($p > 0.64$); (b) a significant increase in HH, usually three cms in length, in both groups ($p < 0.02$ in Group I; $p < 0.0001$ in Group II); (c) a significant decrease of normal cardia in Group I ($p < 0.013$); (d) the presence of fasting bile at the GT increased parallel to the follow-up length. This increment was significant comparing values 1 month and late (10.5 years) after the surgery in both groups ($p < 0.0001$); (e) GT length grew significantly in both groups, up to 3.8 cm and 3.4 cm respectively ($p < 0.0001$). An open and adynamic pylorus was seen in over 80%, as early as 1 month after the procedure and persisted late on control.

Before LSG, histologic findings at the EGJ showed normal fundic mucosa in 92% of Group I compared with 68% in Group II ($p < 0.006$). At the antrum, the infection due to HP was similar. All patients were treated with eradication therapy before surgery (Table 3). Late after surgery, biopsy samples at the antrum revealed two cases with HP in each group. At the EGJ, the finding of normal fundic mucosa decreased significantly in Group I, parallel to the increase in carditis or funditis ($p < 0.001$). The same occurred in Group II ($p < 0.0002$). Short-segment BE appeared in four cases, showing all of them

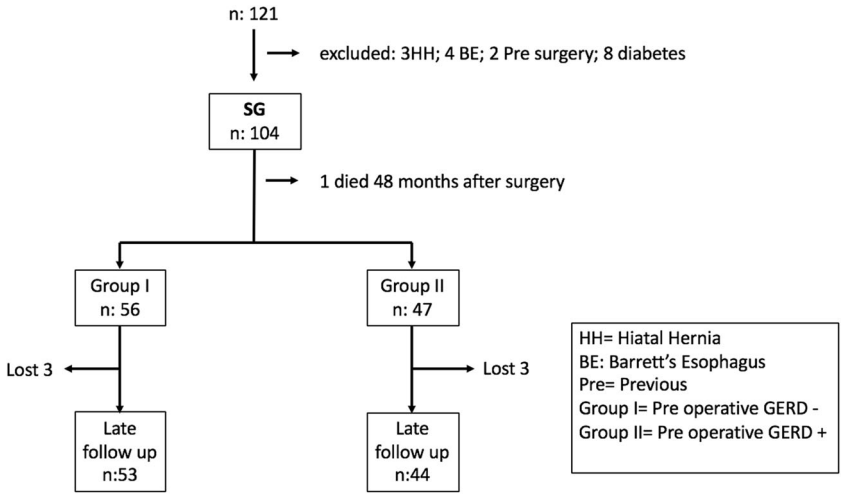

Fig. 1 Patients flow diagram concerning follow-up of all patients submitted to laparoscopic sleeve gastrectomy

to have a fundic mucosa before surgery. The appearance of IM occurred at 98–114—78 and 90 months after surgery, finding bile at GT in three of them (75%).

Table 4 summarizes all clinical, endoscopic, and histologic findings before and late after LSG. New onset GERD symptoms appeared in 58.5% of Group I and needed daily intake of PPIs. In 13.6% of Group II, symptoms disappeared late after surgery, and the rest of the cases were daily dependent on PPIs. Different abnormal endoscopic findings in GERD subjects increased significantly in Group I cases after LSG, as well as the presence of carditis at the EGJ. Short-segment BE developed in 4%. Group II subjects showed late after surgery a significant increase of the presence of a dilated cardia types III-IV ($p < 0.006$), likewise the development of carditis at the EGJ. The other endoscopic parameter showed no significant differences. The Visick gradation showed grades I and II in 39.8% of Group I and 22.8% of Group II. Up to now, six patients have been converted to gastric bypass due to intractable reflux (three in each group corresponding to Visick IV).

Table 1 Clinical characteristics of patients with obesity submitted to laparoscopic sleeve gastrectomy ($N = 97$)

Parameters	Group I $N = 53$	Group II $N = 44$	p
Age (years)	38.6 ± 9.1 (19–62)	38.0 ± 10.2 (18–60)	> 0.48
Gender			
Women	38	36	> 0.8
Men	15	8	
BMI preop (Kg/m^2)	38.6 ± 2.9	37.4 ± 5	> 0.33
BMI late after surgery	28.6 ± 3.4	2.9 ± 5.0	> 0.72
Follow-up (months)	126 ± 19	124 ± 22	> 0.9

Discussion

The effect of LSG on GERD appearance remains controversial [10], many existing reports evaluating it subjectively early after surgery [5, 6, 25]. Nowadays, there are at least five systematic reviews or meta-analyses regarding this topic [9–13]. Most of them concluded that GERD is not resolved after LSG, and new onset GERD is seen in a significant number of patients. Also, the daily use of PPIs to control reflux symptoms increases significantly. Nevertheless, some recent reviews mention GERD symptom improvement after LSG. Oor [10] evaluated 16 studies reporting an increase of reflux symptoms after sleeve, while twelve reports mention the opposite. Stenard [12] commented 13 articles reporting a negative influence on GERD and 12 with a positive impact. Hayat [26] analyzed 12 studies showing an increase of postoperative GERD and 12 reporting a decrease.

Few articles mention results later than 60 months after surgery. Sieber [27] published persistence of GERD symptoms in 44% of cases, and Catheline [28] reported 33% of reflux 5 years after LSG. The group of Himpens [29] stated the most extended issued follow-up (11 years), showing 22% of de novo GERD. Our group [19] previously described new onset of GERD in 10 to 23% and Mandeville [30] in 50% after LSG at 8.4 years of follow-up.

These discrepancies may be due to many reasons: (1) evaluation of symptoms is subjective and reviewer-dependent and is an inadequate way to determine the actual reflux disease after LSG; symptom control does not guarantee an absence of pathologic reflux to esophagus [31, 32]; (2) an inadequate short follow-up period (< 24 months) and less than 80% of the original group, which undermine results and conclusions; (3) several retrospectives publications; (4) no studies have separated patients before LSG into refluxers and non-refluxers, therefore mixing them into one assemblage may lead to erroneous conclusions.

Table 2 Endoscopic findings at the distal esophagus before surgery at 1 month, 1.5 years, and 10.5 years after laparoscopic sleeve gastrectomy ($N = 97$)

Parameters	Group I $N = 53$	Group II $N = 44$	p
Before surgery			
Esophagitis	0	14 (31.8%)	
Hiatal hernia	0	9 (20.4%)	
Cardia type I	39 (73.6%)	2 (4.5%)	< 0.01
Type II	14 (26.4%)	9 (20.4%)	> 0.4
Type III	0	24 (54.5%)	
Type IV	0	9 (20.4%)	< 0.001
1 months A.S			
Esophagitis	0	7 (15.9%)	
Hiatal hernia	0	0	
Cardia type I	26 (49%)	5 (11.4%)	< 0.002
Type II	2 (3.8%)	5 (11.4%)	> 0.15
Type III	25 (47.2%)	34 (77.2%)	< 0.008
Bile (+) GT	1 (1.9%)	1 (2.2%)	> 0.46
Adynamic pylorus	42 (79.2%)	36 (81.8%)	> 0.7
Length—stomach (cm)	15.8 ± 2.8	15.7 ± 3.2	> 0.89
1.5 years A.S			
Esophagitis	8 (15.1%)	8 (18.2%)	> 0.8
Hiatal hernia	2 (3.8%)	2 (4.5%)	> 0.8
Cardia type I	16 (30.2%)	3 (6.8%)	< 0.04
Type II	0	2 (4.5%)	
Type III	35 (66.0%)	37 (84%)	> 0.67
Type IV	2 (3.8%)	2 (4.5%)	> 0.8
10.5 years A.S			
Esophagitis	16 (36.2%)	17 (38.5%)	> 0.3
Hiatal hernia	10 (18.9%)	14 (31.8%)	> 0.15
Cardia type I	5 (9.4%)	2 (4.5%)	> 0.5
Type II	0	0	
Type III	38 (71.7%)	28 (63.6%)	> 0.09
Type IV	10 (18.9%)	14 (31.8%)	> 0.015
Bile (+) GT	22 (41.5%)	16 (36.4%)	> 0.5
Adynamic pylorus	43 (81%)	39 (88.6%)	> 0.8
Length—stomach (cm)	19.6 ± 3.7	19.1 ± 3.4	> 0.58

A.S., after surgery; *GT*, gastric tube

Table 3 Histologic findings before and late (10.5 years) after laparoscopic sleeve gastrectomy ($N = 97$)

Parameters	Group I $N = 53$	Group II $N = 44$	p
Before surgery			
a. Juxtacardial area			
Fundic mucosa	49 (92.4%)	30 (68.2%)	< 0.006
Funditis	2 (3.7%)	9 (20.4%)	< 0.03
Carditis	2 (3.7%)	5 (11.4%)	> 0.1
b. Antrum			
H. pylori (+)	10 (18.9%)	9 (20.4%)	> 0.7
Late after surgery			
a. Juxtacardial area			
Fundic mucosa	27 (50.9%)	11 (25%)	< 0.01
Funditis	13 (24.5%)	11 (25%)	> 0.8
Carditis	11 (20.7%)	20 (45.4%)	< 0.01
Intestinal metaplasia	2 (3.8%)	2 (4.5%)	> 0.65
b. Antrum			
H. pylori (+)	2 (3.8%)	2 (4.5%)	> 0.8

In the beginning, we believed (as many surgeons) that an 80% reduction of parietal cell mass [19] will result in a significant drop of gastric acid secretion, producing a decrease of postoperative pathologic reflux. However, this theoretical action did not occur, and 58% of non-refluxers developed de novo GERD, while 86% of refluxers maintained this state, and only 14% showed an absence. We [19] and Nadaleto [4] have reviewed the different pathophysiological changes that occur at the EGJ in the GT. To date, there are nine studies concerning the use of 24-h pH meter before and after LSG [33–41]. Eight of them claimed an increase of abnormal acid reflux into the esophagus 3 to 12 months after surgery. Only one [37] reported a decrease of pathologic reflux after LSG. There is also a scintigraphic examination evaluating GERD before and after LSG, demonstrating the presence of postoperative reflux in 75% of the cases [42].

Endoscopy plus biopsy samples which were taken at the EGJ represent (a) a fast and easy objective evaluation of esophageal and gastric mucosa injury produced by gastric and duodenal refluxate; (b) a visualization of mucosal changes and surgical complications which may increase GERD (like gastric stenosis or twisting) [43]; (c) an opportunity to detect IM presence taking samples at five mm distal of SCJ [44]; (d) an examination of bile presence at GT, motility of the antrum-pylorus and allows for measurement of its length.

Up to now, there are no motility studies before and after LSG. In most publications, there is no reference to endoscopic evaluations, and none have mentioned routine histological analysis. Table 5 shows a summary of seven published endoscopic findings after LSG [40, 42, 45–49]. These studies have the following characteristics: (a) few patients (less than 100) were evaluated in 4 studies [40, 42, 45, 47]; (b) the follow-up in five is less than 60 months [42, 45–48]; (c) the percent of followed-up subjects is low in four publications [45–47, 49] (d) a UE was done just once after surgery and in some cases only. They mention the development of EE in 7 to 67%, as well as the appearance of a HH in 2 to 27%.

In our study, we performed at least three endoscopic procedures in each patient after surgery: (a) at the first month, which was not mentioned before; (b) at 1.5 years; (c) at 10.5 years similar to Felsenreich [40], who pointed a follow-up of 129 months. With these thorough examinations, we

Table 4 Summary of clinical, endoscopic and histologic findings before and late (10.5 years) after sleeve gastrectomy (%)

Parameter	Group I (n: 53)			Group II (n:44)		
	Preop	Postop	*p*	Preop	Postop	*p*
Symptoms of GERD	0	58.5%	–	100%	86.4%	> 0.7
EE	0	30.2%	–	31.8%	38.6%	> 0.5
Cardia type III-IV	0	90.6%	–	74.9%	95.5%	< 0.006
HH	0	18.9%	–	20.4%	31.8%	> 0.2
Bile present GT	–	41.5%	–		36.4%	–
Carditis	1.9%	20.7%	< 0.007	9.0%	45.4%	< 0.0001
BE	0	3.8%	–	0	4.5%	–
Visick I		36%			11.4%	
Visick II		3.8%			11.4%	
Visick III		54.7%			77%	
Visick IV		5.6%			6.8%	

GERD, gastroesophageal reflux disease; EE, erosive esophagitis; HH, hiatal hernia; GT, gastric tube; BE, Barrett's esophagus

found a new onset EE in 30% of Group I and development of HH of three cms size in 19%. These anatomic alterations appear late after surgery as seen in Table 2, with an increase of HH diagnosis from 4% early after surgery to 19% late in Group I and from 4 to 32% in Group II. These findings were reported by Hayat [33], examining only GERD symptoms and postulating that there is a second peak of the disease five to seven years after surgery, with an increased risk of BE development. The other crucial anatomic finding is the presence of a dilated cardia as early as one month after surgery in a high proportion of Group I (47%), and an increase from 55 to 77% in Group II after LSG. This cardia dilatation is probably due to a partial section of the sling fibers which are located on the left side of the EGJ and insert at the antrum [19] as well as to the greater curvature of the fundus. This can be measured by determining the resting LES pressure [50], which is hypotensive and incompetent after the operation.

An unprecedented finding was the HP determination late after LSG. Only Felsenreich [40] mentions HP infection higher (15%) than our encountered values (4%). All patients with a positive HP test before LSG were submitted to eradication therapy and this low rate after surgery is probably due to a new infection.

Figure 2 shows the summary of different endoscopic aspects of LSG patients which we have detected late after surgery, dividing them into three different types: (A) normal endoscopic findings with cardia type I or II and absence of EE, HH, and duodenal reflux; (B) presence of cardia type III without HH divided into two subtypes: (B1) absence of EE and (B2) presence of EE; (C) appearance of a HH divided in two subtypes: (C1) absence of EE and (C2) presence of EE. This simple classification could be useful for future endoscopic investigations after LSG.

Table 5 Endoscopic reports after laparoscopic sleeve gastrectomy

Author	*N*	Follow-up (months)	% follow-up	Esophagitis	HH	New onset GERD
Braghetto (2011)	167	60	30	15.5%	1.2%	27.5%
Tai (2013)	66	12	69	66.7%	27.3%	?
Sharma (2014)	35	6	100	25%	25%	75%
Mion (2016)	42	11	81	7.1%	7.1%	?
Felsenreich (2017)	24	129	100	30%	4.5% BE 15%	
Genco (2017)	110	58	69	32%	BE 17%	
Soricelli (2018)	219	66	66	60%	BE 13%	36%
Csendes (2019)	97	126	93	32%	HH 24.7% BE 4.1%	58.5%

HH, hiatal hernia; *GERD*, gastroesophageal reflux disease; *BE*, Barrett's esophagus

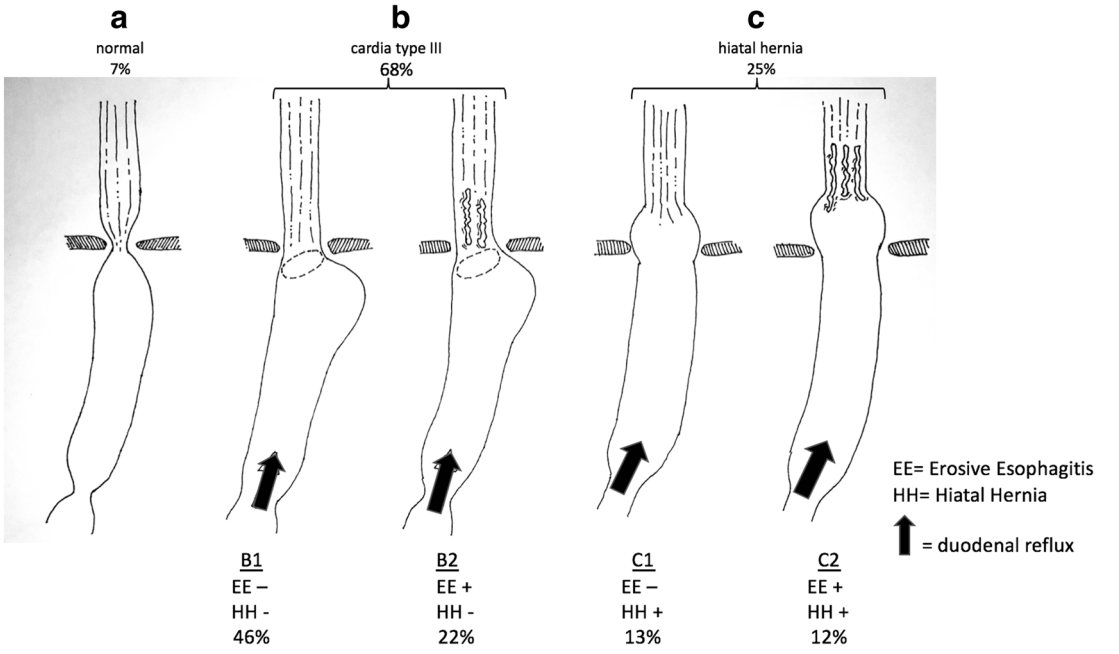

Fig. 2 Summary of different endoscopic findings late after sleeve gastrectomy

An essential hallmark of our study was to incorporate the histologic analysis of biopsy samples at the EGJ before and late after surgery in every patient included in this research (100%). Carditis is an excellent histologic marker of chronic GERD presence [44]. In both groups, carditis increased from 2 to 21% in Group I and from 9 to 45% in Group II. A similar behavior was seen evaluating funditis, which is also a marker for chronic reflux.

A special mention of our investigation refers to BE development after LSG. Previously, we reported BE development in three cases (1.3%) from 231 patients submitted to LSG [51]. Felsenreich [40] found 15% of BE in a small group of followed-up subjects for 10 years; however, no mention is given concerning preoperative biopsy samples. Genco [48] performed a unique histologic analysis before and five years after surgery. He encountered in the previous study a 17% de novo BE and one year later, 13% in the latter report [49]. We do not know whether they systematically took biopsy samples in all patients at the EGJ. In our protocol, taking biopsies before and 10.5 years after the procedure, we determined the occurrence of short-segment BE in 4% of the cases.

There were two new aspects in our article which have not been mentioned before: duodenal reflux presence in the GT and the measurement of its length (not width) after LSG. In respect to the first point, it is known that bile together with acid reflux is deleterious to the distal esophagus and may induce the development of BE [52, 53], as well as the appearance of adenocarcinoma at the distal esophagus [54, 55]. Recently, this finding was reported five years after LSG [56]. In our study, three out of four BE patients showed bile presence at the GT. Furthermore, bile reflux is also promoted by the loss of contraction capacity of the residual antrum (TAC), and therefore, the pylorus remains open and immobile, as seen in 82% of the patients [19]. Gastric intrinsic myogenic activity is controlled by a pacemaker located in the mid-portion of greater curvature composed by interstitial cells of Cajal [20, 21]. This pacemaker originates an electrical activity at a rate of three cycles per minute, generating contractile motor activity at the same rate. It is resected after LSG, eliminating TAC, and consequently, the pylorus remains open and immobile. Besides gastric hypomotility, an increase in intragastric pressure associated with an incompetent LES allows a swift bile reflux to the distal esophagus, creating conditions for EE and BE [53]. Our investigation displayed a 39% of bile presence at GT late after surgery; while Soricelli [49] described it in 68%, but not pointing the exact time when the endoscopic evaluation was performed.

In regard to the length of the sleeve, some radiological examinations have been focused on the transverse dilatation of the residual fundus, which was called "neo-fundus" by Himpens [29], but no one has measured the length from the EGJ to the pyloric ring. It is known that the greater curvature is almost entirely resected during LSG if surgeons start two to three cms from the pylorus [57, 58]. When performing the LSG, a new "mid-curvature" is created. We measured the average length of the lesser and greater curvature before [59], which is 18 and 38 cm respectively. One month after surgery, the GT length is around 16 cm, a value which increases significantly by four cms late after surgery.

The limitations of the present research are as follows: (a) neither 24 h-pH meter determinations nor esophageal manometry were performed; (b) no control group is incorporated; (c) it is not a randomized study; (d) low volume of patients.

Conclusions

Our prospective clinical, endoscopic, and histologic evaluations of patients without reflux symptoms and normal endoscopy submitted to LSG show that there is a clear and progressive increase in the presence of de novo reflux (58%). This may be induced by a sleeve adverse effect on the function of the antireflux barrier, and therefore, the abnormal acid and duodenal reflux to the distal esophagus is mainly allowed by an incompetent LES rather than to the loss and regain of weight and or increased intragastric pressure [19]. This adverse effect of LSG on the antireflux barrier can be seen as early as one month after surgery. Further endoscopic evaluations can demonstrate the development of GERD hallmarks like EE, HH, and BE In patients with preoperative GERD symptoms or altered endoscopy, pathologic reflux persists in 86% and endoscopic parameters showed a progressive worsening. Therefore, we propose to all bariatric surgeons to perform a UE on a regular basis in order to detect associated GERD complications. Lastly, our outcomes show that LSG is a "pro-reflux" surgical procedure if patients are appropriately examined at a delayed follow-up.

Compliance with Ethical Standards

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

Informed Consent All patients gave their written informed consent to be included in this study, unique identifying registration number 3744.

Ethical Approval All procedures in human participants were conducted following the Institution and Ministerial Committee and with the 1961 Helsinki declaration and its later amendments or comparable ethical standards.

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