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ORIGINAL CONTRIBUTIONS

Impact of Extent of Antral Resection on Surgical Outcomes of Sleeve Gastrectomy for Morbid Obesity (A Prospective Randomized Study)

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Abstract
Background Laparoscopic sleeve gastrectomy (LSG) is a surgical technique that treats morbid obesity.
Methods Consecutive patients with morbid obesity treated by LSG at our department were evaluated. Patients enrolled in the study were randomized into group I (LSG begins the division 2 cm from the pylorus) and group II (LSG begins the division 6 cm from the pylorus). The primary outcome measure was the percent of excess weight loss (% EWL); secondary outcomes included postoperative morbidity and mortality and improvement of comorbidity.
Results One hundred five patients (79 (75.2 %) were females) were randomized into two groups of (GI) 52 patients and (GII) 53 patients. In group I, the mean % EWL was 51.8±13.9, 63.8 ±16.1 and 71.8±12; however, in group II, the mean % EWL was 38.3±10.9, 51.9±13.6 and 61±11.1 at 6, 12, and 24 months, respectively (P=0.0001, 0.0001, 0.003). There was weight regain after 2 years in five patients in group II and only one patient in group I (P=0.09). There was no significant difference between both group as regards gastric leakage, vomiting or GER. There was significant improvement in comorbidity after LSG in both groups, but no significant difference between them. Hospital mortality occurred in group II in one case as a result of gastric leakage.
Conclusions LSG is a safe and effective procedure with good short-term outcome. Increasing the size of the resected antrum is associated with better weight loss without increasing the rate of complications significantly.

Keywords Sleeve gastrectomy · Bariatric surgery · Weight loss · Obesity

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Background

Bariatric surgery is currently considered to efficiently produce long-term weight loss, improve comorbidities and improve quality of life for the morbidly obese patient [1]. Currently, there is much interest in restrictive procedures with their lower operative and nutritional risks compared to mixed and malabsorptive procedures [2].

Laparoscopic sleeve gastrectomy (LSG) in creating a narrow tube-like stomach is designed to decrease appetite by reducing the ability of the stomach to distend and producing the sensation of fullness with minimal oral intake [3]. LSG was initially conceived as a potential first step prior to a more complex procedure (Roux-en-Y gastric bypass or biliopancreatic diversion–duodenal switch) to reduce the overall operative risk in super-obese or high-risk patients [4]. Now, LSG is carried out more and more as a single and definitive bariatric procedure with promising short-term results [5]. Unfortunately, LSG has its own disadvantages as the potential complications of the relatively long staple line and the irreversibility of the procedure [6].

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LSG has been adopted by many surgeons [7–10]. In the last years, the number of LSG performed has risen dramatically. However, many points of controversy regarding the operative technique create a wide range of possibilities without well-designed randomized studies including the size of bougie caliber, the necessity of reinforcing the staple line, the routine use of intraoperative seal testing, the section at the oesophagogastric junction and the distance from the pylorus to beginning of antral resection [9–11]. All of these are matters that are debated among the most experienced surgeons.

The most conservative surgeons prefer to begin the resection at 6 cm from the pylorus with the aim of improving gastric emptying and decreasing intraluminal pressure, which allow early closure of gastric leak if occurred. Other surgeons performed the resection close to the pylorus and therefore achieve and maintain better results [11–13].

This prospective randomized study was designed to compare between the beginning of sleeve gastrectomy 2 cm vs. 6 cm from the pylorus with special regard to intraoperative problems, weight loss, improvement of comorbidities, postoperative complications and nutritional and elemental deficiencies.

Materials and Methods

Patients

Consecutive patients, who were treated for morbid obesity by laparoscopic sleeve gastrectomy (LSG) at the Department of General Surgery, Mansoura University, Egypt, during the period from January 2008 to January 2012, were eligible for the study. The exclusion criteria included patients above 60 or below 18 years old, history of upper laparotomy, unfit for anaesthesia or laparoscopy, major psychological instability and drug abuse.

Informed consent was obtained from all patients to be included in the study, after describing the operative and postoperative details and complications. The study was approved by the local ethical committee.

All patients were subjected to thorough history, clinical examination and laboratory investigations including basic preoperative investigations, lipid profile, thyroid and suprarenal hormonal evaluation. Abdominal ultrasound was done to exclude calcular cholecystitis and to evaluate the degree of fatty liver.

Reduction of fatty liver was done by putting all patients on low-calorie diet for 2 weeks. Deep vein thrombosis prophylaxis started 12 h before surgery with low molecular weight heparin subcutaneous injections.

Randomization

The randomization was obtained through Random Allocation Software (Version 1.0, May 2004). The patients were randomized into two groups: GI: gastric division started 2 cm from the pylorus and GII: gastric division started 6 cm from the pylorus.

Operative Techniques

The operation was done under general anaesthesia. Patient was in supine position with splitting of the operating X legs. The procedure started using Excel 12-mm optical trocar (Ethicon, USA) to enter the abdomen under direct vision about 20 cm below the xiphoid process and 2:3 cm to the left side of the midline. Pneumoperitoneum was achieved with carbon dioxide to 15 mmHg. Four additional ports were placed under direct vision.

The operating table was changed to steep reverse Trendelenburg position. Dissection started with opening of the greater omentum 1:6 cm proximal to the pylorus using 5 or 10 mm LigaSure (Valleylab, USA). The dissection then continued towards the gastroesophageal junction. The left crus was then completely freed of any attachments to avoid leaving a posterior pouch when constructing the sleeve in this region. Posterior attachments between the stomach and pancreas were then divided.

After insertion of 38 French gastric calibration tube (Obtech, Switzerland in cooperation with Ethicon, USA), gastric transection started 2 cm proximal to the pylorus using 60-mm green endo-stapler (Ethicon, USA) (GI) or 6 cm from the pylorus (GII). The following staplers were placed approximately 1 cm from the bougie in the direction of the gastroesophageal junction. The remaining staplers were 60-mm blue cartridges. After completing the transection, bleeding points were secured using 10-mm endoclips (Ethicon, USA) or vicryl 3/0 (Ethicon, USA) intracorporeal suture. We never oversew the staple line. The transected stomach was then removed through the 12-mm right midclavicular port. Methylene blue was injected into the stomach, and the staple line was inspected carefully for leak. The methylene blue was then removed from the stomach. Nasogastric tube was removed on the 2nd postoperative day, and abdominal drain on the 3rd postoperative day after the patient started oral feeding.

Postoperative Management

All patients were admitted in the intensive care unit (ICU) for at least 1 day before transfer to the ward. Outputs from operatively placed drains and nasogastric tube were recorded daily. Water-soluble contrast examination was performed on the first postoperative day only if there was clinical suspicion of leakage (e.g. tachycardia, fever). If there was no clinical or radiological suspicion of leakage, clear liquid diet was resumed. Patients were discharged except in the case of a morbidity resulting in prolongation of the hospital stay. Proton pump inhibitor was administrated for the first 3 months

postoperatively to reduce gastric acidity and avoid reflux symptoms.

Follow-Up

Follow-up was conducted 2 weeks, 3 months, 6 months, 1 year and 2 years postoperatively. Patients were also seen at outpatient clinic if they developed symptoms between their follow-up visits.

Assessments

The primary outcome was percent of excess weight loss (% EWL). The percent of EWL was calculated as follows: [(preoperative weight−follow up weight)/preoperative excess weight]×100.

Secondary outcomes were operative time, length of postoperative stay, hospital mortality, nutritional status, improvement of comorbidity, reexploration, BMI, weight regain and postoperative complications including gastric leakage, internal haemorrhage and pulmonary complications. Complications were graded according to their severity on a validated five-point scale using Clavien–Dindo complication classification system into grades I, II, IIIa–b, IVa–b, and V: grade I, no need for specific intervention; grade II, with a need for drug therapy such as antibiotics, blood transfusion, total parenteral nutrition; grade IIIa–b, with a need for invasive therapy, radiological, endoscopic or surgical; grade IVa–b, organ dysfunction requiring ICU stay and management; and grade V, death [14]. The complications higher than Clavien–Dindo grade III were considered to be major complications.

Significant weight regain was defined as an increase of body weight of more than 10 kg from the nadir. Clinically significant reflux was defined as the necessity to take antiacid drugs, chronically. Resolution of comorbidity was considered if the disease is controlled without any medications.

The investigator who reordered weight loss and resolution of comorbidity was blinded about patient's group

Data Collected

Preoperative data included age, gender, initial weight, initial body mass index (BMI), obesity comorbidities and treatment medications used (chest problems, diabetes, arterial hypertension and cardiac ischaemia, hyperlipidaemia, obstructive sleep apnea syndrome (OSAS) using STOP-Bang score [15], cholecystolithiasis, urinary stress incontinence, joint pain, depression, infertility and heart burn).

Operative data included operating time, intraoperative complications (bleeding, splenic injury, oesophageal injury, liver tears and specimen retrieval problems) and stapler malfunction.

Postoperative data included hospital stay, early postoperative complications during the first month (e.g. fever, collection, bleeding, vomiting, leak and port site problems) by Clavien score [14]. Long-term complications more than 1 month after surgery (e.g. nausea, vomiting, reflux, stricture, leak, anaemia, calcium deficiency, vitamin B12 deficiency and adhesive small-bowel obstruction), excess weight loss and BMI were collected.

Statistical Analysis

Statistical analysis in this study was performed using SPSS software, version 17. Analysis of data was by intention-to-treat. Categorical variables were reported using percentages. For continuous variables, descriptive statistics were calculated and were described as mean±standard deviation (SD). Chi-square test was used for categorical variables, and Student's *t* test was used to detect differences in the means of continuous variables. *P* values <0.05 were considered to be significant. Significance was two tailed.

Results

Patients' Characteristics

The study flow chart is shown in Fig. 1. Of 112 consecutive patients with morbid obesity seen during the study period, 105 patients (79 (75.2 %) were females and 26 (24.8 %) were males) were eligible and included in the study. Mean preoperative body weight was 142.6±23 kg (range 104–184), mean preoperative BMI was 51.7±7.5 kg/m^2 (range 39–66.9), and mean excess weight was 73.4±20.5 kg (range 38.4–115.2) (Table 1). The patients were randomized into two groups of (GI) 52 patients and (GII) 53 patients. Preoperative data were comparable in both groups as regards age, sex, BMI and comorbidity. The characteristics of the two randomized groups are presented in Table 1.

Intraoperative Data

The mean total operative time was 137.96±30.39 min in group 1 vs. 132.36±28.72 min in group 2 (*P*=0.33) (Table 1). In group 1, there were two cases of intraoperative bleeding from short gastric vessels (bleeding was controlled in both cases; laparoscopically in one case and after conversion through upper midline incision in the other case). All cases were completed laparoscopically except this case. There was no significant difference between both groups as regards the number of stapler used.

Bleeding from staple line was noticed in 85 cases in both groups; in the first 45 cases, haemostasis was achieved using ligaclips until we faced 1 case of postoperative bleeding due to

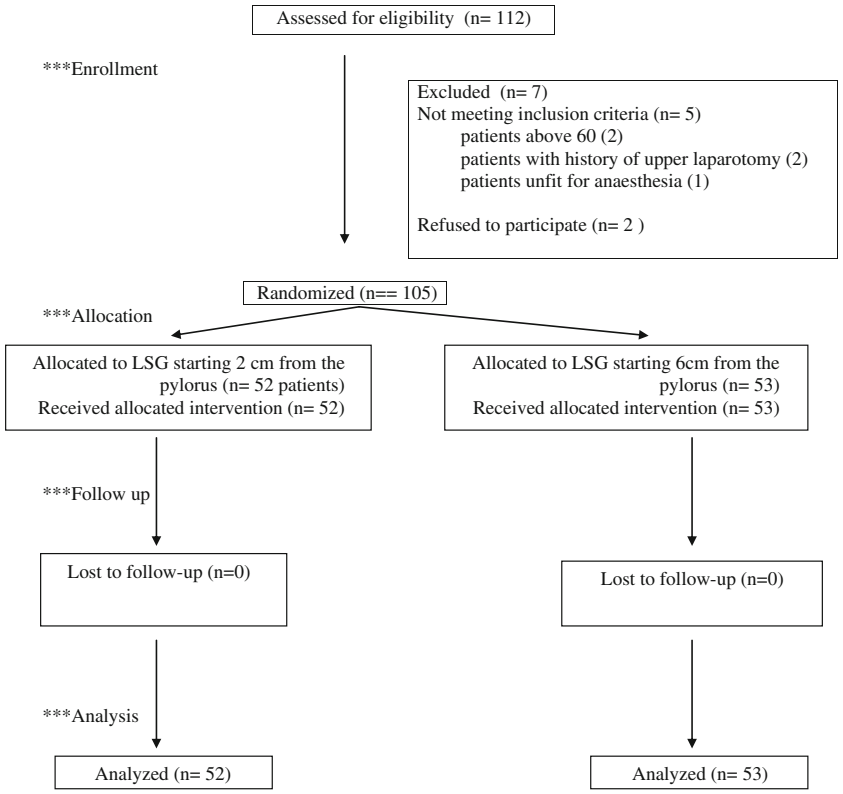

Fig. 1 Flow Diagram of the progress through the phases of a randomized trial (i.e. enrollment, intervention allocation, follow-up and data analysis)

slipped clip over spurting vessel, then haemostasis was done through intracorporeal suturing of bleeding points. We never oversew the staple line. The staple line failed in two cases (one in each group), where oversewing of the risky part of the staple line was done by a running polypropylene suture, and no postoperative leakage was detected.

A minor injury of the left lobe of the liver was observed in 15 patients but did not require any management and stopped spontaneously.

Cholecystectomy was done in only two patients with symptomatic gallstone disease, after completion of sleeve gastrectomy.

Postoperative

Postoperative Courses

The nasogastric tube was removed on the first postoperative day in all cases. There was no significant difference in both groups as regards the mean length of hospital stay (76.26± 78.28 h vs. 62±59.91, P=0.29).

The postoperative complication rates were 22 in 11 patients in group I and 21 in 12 patients in group II (P=0.68). The details of these complications are shown in Table 2. There was one case of postoperative bleeding (relaparoscopy was done

Table 1 Demographic and peri-operative data in both groups

Variables	Total, 105 patients	2 cm from the pylorus (52)	6 cm from the pylorus (53)	*P* value
Gender				
Male	26 (24.8 %)	14 (26.9 %)	12 (22.6 %)	0.61
Female	78 (74.3 %)	38 (73.1 %)	41 (77.4 %)	
Age	29.9±7.4	29.19±6.62	30.64±8.15	0.32
Medical comorbidities	74 (70.5 %)	35 (67.3 %)	39 (73.6 %)	0.48
Comorbidity medication	46 (43.8 %)	21 (40.4 %)	25 (47.2 %)	0.48
Preoperative BMI	51.7±7.5	51.79±8.49	51.57±6.51	0.88
Preoperative excess weight	73.4±20.5	73.15±21.65	73.59±19.52	0.91
Duration of operation (min)	135±29.5	137.96±30.39	132.36±28.72	0.33
Hospital stay (h)	69±69.57	76.26±78.28	62±59.91	0.29

Table 2 Postoperative complications related to distance from the pylorus

Variables	Total, 105 patients	2 cm from the pylorus (52)	6 cm from the pylorus (53)	*P* value
Gastric leak	3 (2.9 %)	2 (3.8 %)	1 (1.9 %)	0.53
Late vomiting (>1 month)	10 (9.5 %)	7 (13.5 %)	3 (5.7 %)	0.17
Reflux symptoms de novo	5 (4.8 %)	3 (5.8 %)	2 (3.8 %)	0.67
Reflux				
Preoperative	10 (9.5 %)	4 (7.7 %)	6 (11.3 %)	0.52
Improvement	2 (1.9 %)	1 (1.9 %)	1 (1.9 %)	0.67
Resolution	7 (6.7 %)	3 (5.8 %)	4 (7.5 %)	
Anaemia	11 (10.5 %)	5 (9.6 %)	6 (11.3 %)	0.77
DVT	1 (0.95 %)	1 (1.9 %)	0	0.31
Pulmonary embolism	1 (0.95 %)	1 (1.9 %)	0	0.31
Hypocalcaemia	16 (15.2 %)	9 (17.3 %)	7 (13.2 %)	0.59
Vitamin B12 deficiency	7 (6.7 %)	5 (9.6 %)	2 (3.8 %)	0.23
Clavien score				
0	63 (60 %)	30 (57.7 %)	33 (62.3 %)	0.68
1	29 (27.6 %)	15 (28.8 %)	14 (26.4 %)	
2	9 (8.6 %)	5 (9.6 %)	4 (7.5 %)	
3a	1(0.95 %)	1 (1.9 %)	0	
3b	2 (1.9 %)	1 (1.9 %)	1 (1.9 %)	
4	0	0	0	
5	1	0	1 (1.9 %)	

6 h postoperative where spurting vessel was sutured due to slipped clip).

Three patients developed gastric leak (two cases in group I and one case in group II). In group I, the first case had low-output fistula; drain was left, and oral feeding stopped for 2 weeks. Fortunately, leakage stopped after these 2 weeks of conservative treatment. The 2nd case was treated by relaparoscopy and wide-pore drainage in the 4th postoperative day, then fully covered Mega^{TM} Esophageal stent insertion (Teawong Medical, Korea) in the 8th postoperative day, and then oral feeding started in the next day after oral contrast study revealed no leakage. Stent was removed 1.5 months later, and contrast study was normal. In group II, one case was treated by laparotomy in the 5th postoperative day, where suturing of the fistula site and wide pore drainage was done, and the patient developed leakage again, then multiorgan failure and died.

In group I, there was only one case of DVT and pulmonary embolism which was successfully treated by low molecular weight heparin and thrombolytic therapy.

Seven (13.5 %) patients had persistent attacks of vomiting for more than 1 month in group I and three (5.7 %) patients in group II (P=0.17). Oral gastrografin study and endoscope were normal, and vomiting frequency decreased gradually in all cases after 3 months. They were successfully managed conservatively by IV fluids and antiemetics.

Increased antral resection did not cause an increase in GERD complaints (Table 2).

There was no significant difference in both groups as regards hypocalcaemia and vitamin B12 deficiency (Table 2). All patients had normal laboratory results after intake of oral iron and calcium supplementation and oral (or IM) vitamin B12 supplementation.

Weight Loss

In group I, the mean % EWL was 51.8±13.9, 63.8±16.1 and 71.8±12 at 6, 12 and 24 months, respectively; however, in group II, the mean % EWL was 38.3±10.9, 51.9±13.6 and 61 ±11.1 at 6, 12 and 24 months, respectively (Table 3). Patients with the first staple line started 2 cm from the pylorus had significantly better weight loss than those started 6 cm without significant increase in the complication rate (Tables 2 and 3).

Comorbidity

There was significant improvement in comorbidity after LSG in both groups, but no significant difference between them. The best result of comorbidity improvement or resolution was noticed in hypertension, where 88 % of patients resolved and 12 % improved in one year (Table 4).

Table 3 Surgical outcomes

Variables	Total, 105 patients	2 cm from the pylorus	6 cm from the pylorus	*P* value
% EWL, 6 months	44.8±14.1	51.8±13.9	38.3±10.9	0.0001
% EWL, 12 months	57.8±16	63.8±16.1	51.9±13.6	0.0001
% EWL, 24 months	66.5±12.7	71.8±12	61±11.1	0.003
Weight regain	6 (5.7 %)	1 (1.9 %)	5 (9.4 %)	0.09

Discussion

Despite the lack of long-term follow-up data, sleeve gastrectomy has gained an enormous popularity as sole bariatric procedure in the last years based on the encouraging short- and intermediate-term results [16]. LSG is not technically challenging and achieves satisfactory weight loss and resolution of comorbidities comparable to RYGB and better than LAGB [17]. Many publications have documented significant weight loss in spite of difference in many variables such as bougie size, antral resection, stapling flush with the bougie and cuff of tissue left at the gastrooesophageal junction [18]. However, these points of controversy regarding the operative technique create a wide range of possibilities without well-designed randomized studies [9–11]. This prospective randomized study was designed to compare between the beginning of sleeve gastrectomy 2 cm vs. 6 cm from the pylorus as regards surgical outcome, postoperative complications, improvement of comorbidity and nutritional status.

Mognol et al. [12] and Baltasar et al. [19] begin the antral resection 2 cm from the pylorus; they reported that there were no postoperative complications or mortality. The median hospital stay was 7.2 days. Average % EWL and BMI at 1 year were 51 % and 23 kg/m^2, respectively. All patients tolerate food in small amounts. Other surgeons begin the resection at 6 cm from the pylorus in order to preserve the antrum and

Table 4 The value of distance from the pylorus

Variables	Total, 105 patients (%)	2 cm from the pylorus (%)	6 cm from the pylorus (%)	*P* value
Medical comorbidities	74/105 (70.5)	35/52 (67.3)	39/53 (73.6)	0.48
Comorbidity medication	46/105 (43.8)	21/52 (40.4)	25/53 (47.2)	0.48
DM				
Preoperative	16/105 (15.2)	5/52 (9.6)	11/53 (20.8)	0.11
Improvement	7/16 (43.7)	1/5 (20)	6/11 (54.5)	0.02
Resolution	8/16 (50)	4/5 (80)	4/11 (36.4)	
Hypertension				
Preoperative	25/105 (23.8)	12/52 (23.1)	13/53 (24.5)	0.86
Improvement	3/25 (12)	1/12 (8.3)	2/13 (15.4)	0.58
Resolution	22/25 (88)	11/12 (91.7)	11/13 (84.6)	
Hyperlipidaemia				
Preoperative	60/105 (57.1)	29/52 (55.8)	31/53 (58.5)	0.77
Improvement	15/60 (25)	4/29 (13.8)	11/31 (35.5)	
Resolution	35/60 (58.3)	22/29 (75.9)	13/31 (41.9)	0.02
Joint pain				
Preoperative	52/105 (49.5)	24/52 (46.2)	28/53 (53.8)	0.49
Improvement	30/52 (57.7)	17/24 (70.8)	13/28 (46.4)	0.07
Resolution	18/52 (34.6)	7/24 (29.2)	11/28 (39.3)	
Sleep apnea				
Preoperative	55/105 (52.4)	24/52 (46.2)	31/53 (58.5)	0.20
Improvement	15/55 (27.3)	4/24 (16.7)	11/31 (35.5)	0.12
Resolution	40/55 (72.7)	20/24 (83.3)	20/31 (64.5)	
Back pain				
Preoperative	59/105 (56.2)	33/52 (63.5)	26/53 (49.1)	0.13
Improvement	14/59 (23.7)	8/33 (24.2)	6/26 (23)	0.75
Resolution	30/59 (50.8)	23/33 (69.7)	17/26 (65.4)	

preserve its contractile function and to decrease intraluminal pressure combined with low gastric tube compliance. They suspected that it decreases the risk of distal (outlet) stricture and proximal leaks and allows early closure of postoperative gastric fistula [13, 20, 21]. Sanchez-Santos et al. found that the groups which begin LSG nearest to the pylorus achieve better weight loss results in the follow-up [22]. The success of LSG when done as sole and definitive bariatric procedure might be limited by weight regain or insufficient weight loss which ranges from 1.3 to 15 % [23]. In our study, weight loss was satisfactory, and this was significantly higher when starting antral resection 2 cm from the pylorus without significant increase in the complication rate suggesting that more antral resection is associated with better weight loss. Five patients had significant weight regain after the LSG started 6 cm from the pylorus, and fortunately, they were satisfied by the amount of weight loss suggesting that SG is a valid and definitive option to achieve stable weight loss.

The rate of complications is varied between authors with bleeding ranging from 0 to 16 % and gastric leak from 0 to 5.5 % [18–23]. Leak is considered as the major cause of mortality which ranged from 0:1.7 % [19–23]. In our study, postoperative gastric fistula developed in three cases (2.9 %): two cases in group I and one case in group II. Some authors believe that starting >5 cm from the pylorus will improve gastric emptying through antral preservation and reduce intraluminal pressure (and potentially decrease leak). Others believe that there is no difference in leak rate or weight loss based on this factor [11, 24]. Narrowing the sleeve too much at the incisura may be the main contributing factor to develop GERD or fistula at gastroesophageal junction after LSG [19, 24].

There is a strong association between morbid obesity and GERD [25–29]. LSG tends to reduce reflux by reducing intraabdominal pressure due to decreased body weight, reduced acid productions and accelerated gastric emptying [30–33]. However, many postoperative factors may increase GERD after LSG including technical error, lack of gastric compliance, intact pylorus, increased intraluminal pressure and decreased pressure in the lower oesophageal sphincter [27, 28, 32, 33]. In our study, there was no significant impact of extent of antral resection on GERD complaints as the fundus was removed completely in all cases, and there was no outlet stricture especially opposite the incisura.

In our study, the comorbid conditions, including hypertension, diabetes and sleep apnea which are life-threatening diseases, can be either significantly improved or resolved with weight loss after LSG. The rates of improvement and resolution of these comorbidities in our study are consistent with data reported in a systematic review of many LSG studies [34, 35], with more antral resection associated with better rates of improvement and resolution of these comorbidities. Lakdawala et al. [24] reported 98 % resolution of diabetes, 91 % resolution of hypertension, 75 % resolution of dyslipidemia, 97 % resolution of joint pain and 100 % resolution of sleep apnea at 1 year. In our study, hypertension showed the best resolution rate (88 %) followed by OSAS (72 %), and the lowest was joint pain (34 %). Brethauer et al. reported that the overall remission rate of diabetes was 56 % with additional 37 % demonstrating improvement, hypertension improved or resolved in 78 % of patients, and 93 % of patients had improvement or resolution of obstructive sleep apnea after LSG [35, 36].

The current study has two limitations: firstly, the difference in complication rate between both groups is questionable as the study is not powered to detect this. Secondly, five surgeons performed the operations, which may be a source of bias. However, they have almost equal experience in a trial to overcome this. However, further prospective randomized studies with larger sample size are needed to confirm these results.

Conclusion

LSG is a safe and effective procedure with good short-term outcome. Increasing the size of the resected antrum is associated with better weight loss without increasing the rate of complications significantly. However, long-term follow-up studies are mandatory to assess the durability of this achieved weight loss and the persistence of remission of comorbidities.

Clinical Trials gov. ID: NCT01974388

Conflict of Interest There was no financial support received. The authors declare no conflict of interest.

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