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ORIGINAL CONTRIBUTIONS

Effect of Resection Distance from Pylorus on Weight Loss Outcomes in Laparoscopic Sleeve Gastrectomy

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Abstract

Background Despite the established efficacy and safety of laparoscopic sleeve gastrectomy (LSG), controversy still exists on optimal operative technique, the resection distance from pylorus (DP) being among the most controversial issues. This study aimed to examine the effect of resection distance from pylorus on % excess weight loss (EWL) during postoperative period, in patients who underwent LSG for morbid obesity.

Methods A total of 390 patients who underwent laparoscopic sleeve gastrectomy for morbid obesity were included in this retrospective study. Patients were allocated into one of the two groups based on the distance between antrum resection margin and pylorus: group A, ≤ 3 cm and group B, > 3 cm. Follow-up data for %EWS and nausea/vomiting as well as demographical and perioperative data were retrospectively reviewed and logistic regression analysis was done.

Results Follow-up data up to 12 months were available for all patients, whereas 199 patients had follow-up data at 24 months. Shorter distance from pylorus was associated with higher %EWL throughout the treatment period ($p < 0.001$), evident from the first postoperative month ($p = 0.013$ for the first month, $p < 0.001$ for all other time points). The benefit extended up to 24 months in ≤ 3 cm group. However, nausea/vomiting was more frequent in the ≤ 3 cm group only at 1-month visit (15% vs. 4%, $p < 0.001$). In multivariate evaluations, while %EWL variable was taken as a dependent variable, time variable with DP × time interaction was statistically significant in the model.

Conclusions Our findings indicate that a short distance between resection margin and pylorus is associated with better and sustained %EWL in LSG. However, these patients seem to be more prone to nausea and vomiting in the early postoperative period. Further prospective large studies would help to define an optimal resection distance.

Keywords Sleeve gastrectomy · % excess weight loss (%EWS) · Resection margin · Residual antrum size · Nausea

Introduction

Bariatric surgery is an effective therapy for morbid obesity, with sleeve gastrectomy being the most commonly performed procedure comprising 58.1% of all bariatric procedures [1]. Sleeve gastrectomy is mostly performed laparoscopically, and currently, a large body of evidence supports the efficacy and safety of laparoscopic sleeve gastrectomy (LSG) as well as its benefits in terms of improving obesity-related comorbidities [2–5].

Despite its established efficacy and safety, controversy still exists on the optimal operative technique for LSG; bougie size, distance of resection margin from the pylorus, the shape of section at the gastroesophageal junction, staple line reinforcement, and intraoperative leak testing are among the most controversial issues [6]. Regarding the resection distance from the pylorus, different authors have adopted a resection distance from the pylorus ranging between 2 and 6–7 cm [6].

In more conservative techniques, the section is performed at a higher distance to improve gastric emptying, preserve function, and to prevent distal stenosis, as well as to decrease

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pressure, thereby supporting wound closure without leak [7–10]. On the other hand, LSG is a restrictive approach aiming to substantially reduce gastric volume by removing mainly body and fundus part. Such a small size would reduce distensibility and increase intragastric pressure, which in turn would result in satiety with less oral intake. Therefore, in more restrictive techniques, distance from the pylorus is kept shorter to reduce gastric remnant in an attempt to achieve better clinical outcomes [11, 12]. To date, several studies have examined the effect of resection distance from pylorus on clinical outcomes; however, they provided inconsistent results [13–22].

This retrospective study aimed to examine the effect of resection distance from pylorus on % excess weight loss (%EWL) during postoperative period, in patients that underwent LSG for morbid obesity.

Materials and Methods

Patients

A total of 390 patients that underwent contemporaneously laparoscopic sleeve gastrectomy between May 2015 and May 2017 for morbid obesity were included in this retrospective study. Medical records were reviewed, and patients were allocated into one of the two groups based on the distance between the pylorus and the resection margin: group A, ≤ 3 cm and group B, > 3 cm. In addition to demographical and perioperative data, follow-up data were extracted. The study protocol was approved by the local ethics committee for clinical trials and the study was conducted in accordance with Declaration of Helsinki.

Surgical Technique

Patients were operated in "French" position. First, a 10-mm trocar was placed 2 cm left to the midline above the umbilicus, for optical view. Then, four other trocars were placed in the following order: a 15-mm trocar into the right mid-clavicular line, a 5-mm trocar into the left mid-clavicular line, a 5-mm trocar into the sub-xiphoid area (liver retractor), and a 5-mm trocar into the left subcostal area (to pull the stomach). Beginning from the line of the incisura angularis, the stomach was completely mobilized from the greater omentum side using LigaSure™ (Covidien, USA). Proximal dissection was performed up to the angle of His and the distal dissection was performed until the pylorus. Then, a 36-F bougie was inserted by the anesthesiology team along the lesser curvature of the stomach. Antral resection was started 2–6 cm from the pylorus and continued up to 0.5–1 cm medial to the angle of His (one-two Endo GIA, Covidien USA; 60 mm black and three-five medium thick tissues Endo GIA, Covidien USA; 60 mm purple were used). Antral resection was started 2 cm from the pylorus in group A and 5 cm from the pylorus in group B according to the surgeon preference. Hemostasis was provided by Endoclips™ (Covidien, USA) or Fibrin Sealant (Tisseel), where appropriate. Methylene blue solution (in saline) was given through the bougie to check any leakage.

Intraoperative Measurements

After removal of the gastric material, saline was injected into the gastric antrum with a 100 cc syringe and the filling volume was measured to estimate the volume of the removed part of the stomach. For the measurement of remaining gastric volume, pylorus was clamped with an intestinal clamp; the remaining stomach and the bougie were filled with methylene blue solution up to a certain mark on the bougie. Then, the bougie volume was subtracted from the total filling volume to estimate the remaining stomach volume. The distance between the pylorus and resection line was measured using a centimeter scale marked on the intestinal clamp.

Follow-Up

Patients were invited for follow-up visits at 1, 3, 6, 12, 24, and 36 months postoperatively for %EWL measurements. In addition, the presence of nausea was questioned during the first 6 months.

Statistical Analysis

SPSS version 21.0 was used for the analysis of data. Descriptive data were presented as mean ± standard deviation or frequency (percentage), where appropriate. Categorical data were compared using Pearson's chi-square test or Fisher's exact test. Student's *t* test for independent samples was used for the comparison of continuous variables. A two-way analysis of variance for repeated measurements, with time (within-subject variable) and resection distance from pylorus (between-subject variable) as factors, was used to examine the effects on %EWL. Post-operative comparisons of %EWL at different time points were done by a *t* test for paired samples with the Bonferroni correction. Comparisons of the two groups at each time point were done by a *t* test for independent samples. Type 2 diabetes, obstructive sleep apnea, hypertension, degenerative joint disease variables (between-subject variable), resection distance from the pylorus, and time (within-subject variable) %EWL variable to test for the presence of 7 different models (generalized linear mixed model) were created. The models were included as an EWL-dependent variable, whereas resection distance from pylorus (DP), type 2 diabetes (DM), obstructive sleep apnea (OSA), hypertension (HT), degenerative joint disease (DJD), gender, and age were included as arguments, respectively. In the multivariate evaluations, the variables which have effects on %EWL in univariate evaluations were included in the model and re-analyzed. Post hoc analysis, with the Bonferroni correction, has significant results at the multivariate analysis. A p value < 0.05 was considered an indication of statistical significance.

Results

Table 1 shows the comparison of the two groups regarding patient characteristics and perioperative variables. The two groups did not differ regarding age, gender, body mass index (BMI), duration of operation, or duration of postoperative hospitalization. In addition, the remaining gastric volume and removed gastric volume were similar across the two groups.

Changes in Percent Excess Weight Loss, Percent of Total Body Weight Loss, Percent of Body Mass Index Loss

Figure 1 shows comparison of the groups for change in %EWL, percent of total body weight loss (%TBWL), and percent of body mass index loss (%BMIL) during follow-up. There was a significant interaction between time and study group; ≤ 3-cm distance from pylorus was associated with higher %EWL throughout the treatment period ($p < 0.001$). The difference between the two groups was evident from the first postoperative month ($p = 0.013$ for the first month, $p < 0.001$ for all other time points) (Table 2, Fig. 1). In the ≤ 3 cm group, there was a significant and gradual increase in %EWL ($p < 0.001$ for each pairwise comparisons). In the > 3 cm group, there was a significant and gradual increase in %EWL only until 12 months ($p < 0.001$ for each pairwise comparisons); however, the difference between 12-month and 24-month assessments was not significant ($p = 0.271$). There was a significant interaction between time and study group; ≤ 3-cm distance from pylorus was associated with higher %TBWL and %BMIL throughout the treatment period ($p < 0.001$). The difference between the two groups was evident from the first postoperative month ($p = 0.029$ for the first month, $p = 0.005$ for the 36th month and $p < 0.001$ for all other time points) (Table 2). Follow-up data up to 12 months were available for all patients, whereas 199 (101 in group ≤ 3 cm, 98 in group > 3) patients had follow-up data at 24 months and 120 (63 in group ≤ 3 cm, 57 in group > 3) patients had follow-up data at 36 months.

Prevalence of Nausea and Vomiting

Nausea and vomiting were more frequent in the ≤ 3 cm group at 1-month visit (14.2% vs. 2.8%, $p < 0.001$) (Table 3). At 3-month follow-up, the difference between the groups was not significant (2% vs. 0.7%, $p = 0.418$). At 6 months, none of the patients reported nausea/vomiting.

Univariate Analyzes on the Dependent Variables %EWL and %TBWL and Multivariate Analysis on the Dependent Variable %EWL

In univariate evaluations, 7 different models (generalized linear mixed model) were created in order to test the effect of DP, DM, OSA, HT, DJD, gender, and age variables on the change in the %EWL value and in the %TBWL over time. The models were included as a %EWL-dependent variable, whereas DP, DM, OSA, HT, DJD, gender, and age were included as arguments, respectively. In the models created using DM,

Table 1 Patients characteristics and perioperative variables

Characteristics	All patients ($n = 390$)	Group A (≤ 3 cm) ($n = 247$)	Group B (> 3 cm) ($n = 143$)	p
Demographics				
Age (years)	33.9 ± 10.4	34.4 ± 10.7	33.3 ± 9.5	0.32
Female gender, n (%)	245 (62.8%)	154 (62.3%)	91 (63.6%)	0.89
BMI (kg/m^2)	43.2 ± 5.2	43.2 ± 5.4	43.1 ± 4.9	0.88
Perioperative variables				
Duration of operation (min)	40.0 ± 13.1	39.5 ± 11.7	40.8 ± 15.2	0.35
Duration of postoperative stay (h)	46.5 ± 6.4	46.1 ± 7.1	47.2 ± 4.9	0.06
Remaining gastric volume (ml)	47.4 ± 11.2	47.1 ± 11.6	48.3 ± 10.4	0.213
Removed gastric volume (ml)	1191.6 ± 388.7	1160.2 ± 316.6	1244.1 ± 483.3	0.060

Unless otherwise stated, data presented as mean ± standard deviation. *BMI*, body mass index

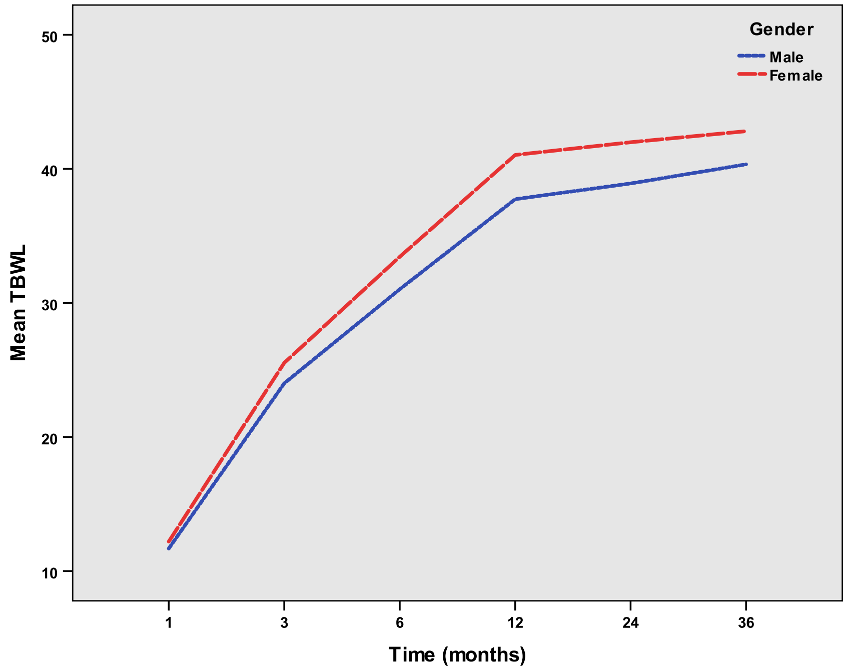

Fig. 1 Comparison of the groups for change in % excess weight loss during follow-up

OSA, HT, gender, and age variables (model 1, model 2, model 3, model 6, model 7), the interaction of the time variable with the related variable was not significant. There were statistically significant effects of DJD (model 4) and DP (model 5) variables on the change of %EWL over time ($p = 0.108$, $p < 0.001$, respectively).

In multivariate evaluations (model 8), while the %EWL variable was taken as a dependent variable, DJD and DP variables which had significant effects on univariate evaluations were included as independent factors with time factor. The result of the analysis was found to be statistically significant (F, 1307.206; $p < 0.001$). The main effect of time variable with DP × time interaction was statistically significant in the model. In this context, post hoc evaluation results were examined in order to test the source of the significance of DP × time dual interaction (Table 4).

In univariate evaluations, the change in the %TBWL over time which used the same parameters as on the change in the %EWL DP (model 5) and gender (model 6) was statistically significant (F, 754.006, $p < 0.001$). The main effects of time variable with DP × time interaction and gender × time interaction were statistically significant in the model. In this context, post hoc evaluation results were examined in order to test the source of the significance of DP × time dual interaction and gender × time dual interaction (Table 4).

Complications and Comorbid Factors

Table 5 shows the comparison of the two groups regarding complications and comorbid factors. The two groups did not differ regarding concomitant operations, bleeding, leakage, hypertension, and degenerative joint disease. OSA was found to be significantly higher in group B than in group A (in group A, $n = 26$, 10.5%; in group B, $n = 36$, 25.1%; $p < 0.001$) and DM was found to be significantly higher in group A than in group B (in group A, $n = 103$, 41.7%; in group B, $n = 43$, 30%; $p = 0.001$).

Discussion

This study examined the potential role of resection distance from pylorus on weight loss outcomes in a relatively large cohort of patients that underwent LSG. To the best of our knowledge, this is the first study to compare the groups with different resection distances from pylorus in terms of %EWL changes over time in such detail.

In recent years, three randomized studies directly examined the effect of resection distance from pylorus on weight loss outcomes. In the most recent randomized study, patients were allocated either into an antrum resection group (antrum resection 2 cm from the pylorus) or an antrum preservation group (antrum resection 5 cm from the pylorus) [17]. Although there were an accelerated gastric emptying and higher antral volume in the antral preservation group as evaluated by multi-slice computerized tomography, the two groups did not differ in terms of %EWL at 1 year. However, the sample size was relatively low in that study. In another earlier prospective randomized study with larger sample size, where again 2-cm vs 6-cm resection distances were compared, no difference could be found between the two groups in terms of %EWL at 1 year as well as quality of life and improvements in comorbidities;

Table 2 Comparison of the groups for changes in %EWL, %TBWL, and %BMIL throughout the follow-up period ($n = 390$)

	Postoperative time	Group A (≤ 3 cm) ($n = 254$)	Group B (> 3 cm) ($n = 151$)	p
%EWL	Month 1	24.7 ± 5.6	23.3 ± 6.7	0.013
	Month 3	52.7 ± 11.5	45.4 ± 9.1	< 0.001
	Month 6	68.4 ± 6.7	60.5 ± 7.9	< 0.001
	Month 12	82.3 ± 4.8	7598 ± 6.1	< 0.001
	Month 24[a]	86.1 ± 3.7	77.1 ± 5.1	< 0.001
	Month 36[b]	85.9 ± 4.0	77.8 ± 3.6	< 0.001
%TBWL	Month 1	12.3 ± 3.1	11.6 ± 5.5	0.029
	Month 3	26.3 ± 7	22.6 ± 5.4	< 0.001
	Month 6	33.9 ± 5.7	30.1 ± 6	< 0.001
	Month 12	41.0 ± 5.8	37.8 ± 5.9	< 0.001
	Month 24[a]	43.0 ± 6.1	38.6 ± 5.6	< 0.001
	Month 36[b]	43.1 ± 6.3	40 ± 3.6	0.005
%BMIL	Month 1	12.3 ± 3.1	11.6 ± 5.5	0.029
	Month 3	26.3 ± 7.0	22.6 ± 5.4	< 0.001
	Month 6	33.9 ± 5.7	30.1 ± 6.0	< 0.001
	Month 12	41.0 ± 5.8	37.8 ± 5.9	< 0.001
	Month 24[a]	43.0 ± 6.1	38.6 ± 5.6	< 0.001
	Month 36[b]	43.1 ± 6.3	40.0 ± 0	0.005

Data presented as mean ± standard deviation

[a] 24-month follow-up data was only available in 199 (101 in group A, 98 in group B) patients

[b] 36-month follow-up data was only available in 120 (63 in group A, 57 in group B) patients

however, weight loss was greater in the 2 cm group at 6 months [16]. In contrast, in a 2014 randomized study, a shorter resection distance from pylorus was associated with increased %EWL at 6, 12, and 24 months and the groups did not differ in terms of gastric leakage, vomiting, or GER [14]. Similarly, in a recent retrospective study with relatively large number of patients, 6-cm vs 2-cm resection distance from pylorus was compared in terms of weight loss and reflux [22], and a short resection distance from pylorus was associated with better weight loss; however, a short distance was associated with slightly increased symptoms of gastroesophageal reflux disease although the two groups were similar in terms of complications. In addition, several studies examined the predictors of weight loss in large cohorts, with conflicting results regarding the independent role of resection distance from the pylorus. Some identified resection distance from the pylorus as an independent significant predictor of weight loss or obtained findings supporting its association with better weight loss outcomes; however, in some studies, no such a benefit could be identified [13, 15, 18, 19]. In this study, a significantly better weight loss was evident in the short resection margin group, starting from the first month, and weight loss was more sustained in this group extending to the 24th month. Although detailed data for side effects and postoperative complaints was not available for analysis, available data for postoperative nausea and vomiting showed that these complaints were limited to only the early postoperative periods, and they are more common in the group with short resection margin at the first month.

A possibly interesting finding of this study may be regarded as the lack of difference between the two groups in terms of remaining/resected gastric volumes. Since there is a difference in distance from the pylorus, a difference in the remaining volume at least may be expected. In fact, the differences in resection margins are expected to be reflected as the differences in remaining antral volume. Therefore, the remaining gastric volume may not always give an accurate idea on the remaining antral volume, for which postoperative

Table 3 Comparison of the groups for nausea/vomiting frequency

Postoperative follow-up	Group A (< 3 cm) ($n = 247$)	Group B (> 3 cm) ($n = 143$)	p
At 1 month	35 (14.2%)	4 (2.8%)	< 0.001
At 3 months	5 (2.0%)	1 (0.7%)	0.418
At 6 months	0 (0%)	0 (0%)	

Data presented as n (%)

Table 4 Univariate analysis on the dependent variables %EWL and %TBWL and multivariate analysis on the dependent variable %EWL

	Model	Dependent variable, %EWL			Dependent variable, %TBWL		
		Source	*F*	*p*	Source	*F*	*p*
Univariate	1	Corrected model	2274.449	< 0.001	Corrected model	1378.482	< 0.001
		DM	11.594	0.001	DM	4.684	0.031
		Time	4632.309	< 0.001	Time	2811.036	< 0.001
		DM × time	0.387	0.858	DM × time	0.340	0.889
	2	Corrected model	2267.997	< 0.001	Corrected model	1383.661	< 0.001
		OSA	3.805	0.051	OSA	3.735	0.053
		Time	2741.096	< 0.001	Time	1661.716	< 0.001
		OSA × time	0.522	0.760	OSA × time	0.956	0.444
	3	Corrected model	2266.506	< 0.001	Corrected model	1377.562	< 0.001
		HT	0.079	0.779	HT	0.079	0.779
		Time	3380.970	< 0.001	Time	2053.013	< 0.001
		HT × time	1.224	0.295	HT × time	1.042	0.391
	4	Corrected model	2300.208	< 0.001	Corrected model	1382.847	< 0.001
		DJD	1487.763	< 0.001	DJD	0.754	0.385
		Time	5.786	0.016	Time	920.444	< 0.001
		DJD × time	1.808	0.108	DJD × time	0.778	0.566
	5	Corrected model	2707.838	< 0.001	Corrected model	1489.339	< 0.001
		DP	5437.503	< 0.001	DP	31.729	< 0.001
		Time	185.105	< 0.001	Time	3014.825	< 0.001
		DP × time	29.332	< 0.001	DP × time	18.531	< 0.001
	6	Corrected model	2272.498	< 0.001	Corrected model	1446.286	< 0.001
		Gender	4665.646	< 0.001	Gender	15.200	< 0.001
		Time	0.043	0.836	Time	2901.436	< 0.001
		Gender × time	0.847	0.516	Gender × time	7.625	< 0.001
	7	Corrected model	2268.410	< 0.001	Corrected model	1383.365	< 0.001
		Age	426.275	< 0.001	Age	5.294	0.022
		Time	5.039	0.025	Time	243.561	< 0.001
		Age × time	0.849	0.515	Age × time	1.384	0.227
Multivariate	8	Corrected model	1307.206	< 0.001	Corrected model	754.006	< 0.001
		DP	64.892	< 0.001	Gender	16.456	< 0.001
		DJD	1.323	0.250	DP	32.554	< 0.001
		Time	1691.184	< 0.001	Time	2871.799	< 0.001
		DP × DJD	0.585	0.444	Gender × DP	0.021	0.884
		DP × time	12.215	< 0.001	Gender × time	9.116	< 0.001
		DJD × time	0.609	0.693	DP × time	18.745	< 0.001
		DP × DJD × time	1.521	0.180	Gender × DP × time	0.672	0.644

Dm, type 2 diabetes; *OSA*, obstructive sleep apnea; *HT*, hypertension; *DJD*, degenerative joint disease; *DP*, resection distance from the pylorus

antral volume measurements would be more relevant. This may be one explanation for the lack of differences. Another explanation may be the low accuracy and reliability of the intraoperative measurement technique, which could well be affected by for example filling pressure. A more precise and relevant, probably postoperative, remaining antral volume measurement modality would be more informative.

Many factors may contribute to weight loss after sleeve gastrectomy, including the degree of restriction (extent of resection), gastric motility change, hormonal effects (particularly decreased ghrelin due to the removal of ghrelin-secreting gastric tissue), and changes in eating habits due to the new structural and functional characteristics of the stomach. Better weight loss results with a short resection distance from pylorus may be mainly explained by the more restrictive nature of the technique. A restrictive technique will leave a small but functional stomach, with a smaller antrum, allowing only a small amount of food consumption at each meal due to early satiety.

Table 5 Comparison of the groups for complications and comorbid factors

		All patients ($n = 390$)	Group A ($n = 247$)	Group B ($n = 143$)	p
Concomitant operation	No	383 (98.2)	243 (98.4)	140 (97.9)	0.504
	Cholecystectomy	7 (1.8)	4 (1.6)	3 (2)	
Bleeding	No	373 (95.6)	240 (97.2)	133 (93.0)	0.060
	Yes	17 (4.4)	7 (2.8)	10 (7.0)	
Bleeding	No	373 (95.6)	240 (97.2)	133 (93.0)	0.270
	Medical follow-up	5 (1.3)	2 (0.8)	3 (2)	
	Blood Tx	6 (1.5)	3 (1.2)	3 (2)	
	Re-laparoscopy	6 (1.5)	2 (0.8)	4 (2.8)	
Leak		0 (0)	0 (0)	0 (0)	–
Comorbidities		289 (74.1)	167 (67.6)	122 (85.3)	0.001
DM		146 (37.4)	103 (41.7)	43 (30)	0.015
HT		85 (21.8)	50 (20.2)	35 (24.5)	0.256
OSA		62 (15.9)	26 (10.5)	36 (25.1)	< 0.001
DJD		33 (8.5)	18 (7.3)	15 (10.5)	0.762

Data presented as *n* (%). *Tx*, transfusion; *Dm*; type 2 diabetes; *OSA*, obstructive sleep apnea, *HT*, hypertension; *DJD*, degenerative joint disease

Usually, the remaining gastric volume is around 50 cc (47.4 ml in the present study). Another potential factor may be the rate of gastric emptying. In a more restricted stomach with a smaller antrum, gastric emptying may not be accelerated after LSG as much as in a stomach with a larger antrum remnant [17]. These all help explain the findings in favor of a short resection distance in this study, although hormonal and functional changes following the two different techniques deserve further investigation. However, there are conflicting results in previous studies regarding the role of distance from the pylorus in improving weight loss outcomes. We believe that the differences in the other aspects of the surgical techniques, heterogeneity of patient characteristics and surgical experience, and timing of %ESW measurements may all contribute to the variability of the results. Nevertheless, large studies with standardized techniques allowing corrections for different patient groups and studies with long-term follow-up results are warranted.

Although the sample size of the present study is relatively large, its main limitation is its retrospective design, which did not allow to compare adverse postoperative symptoms over time in detail, including GERD. Another limitation is the low reliability of intraoperative remaining/resected gastric volume measurements, which precludes firm conclusions regarding the remaining/antral volume and its potential role on improved weight loss results. A detailed antral volume measurement after LSG, probably using CT or MRI, would be informative. And the last limitation is the follow-up time, which is only 36 months in 120 patients.

The findings of this study support the benefits of adoption, a technique using a small resection margin from pylorus in LSG in terms of sustained weight loss. This benefit seems to be associated with acceptable postoperative discomfort in terms of nausea/vomiting. Further large prospective studies allowing comparison of different patient subgroups and different time points are warranted.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Ethical Approval All procedures performed in this study were in accordance with the ethical standards of the local ethics committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the local ethics committee.

Informed Consent Formal consent is not required for this retrospective study.

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