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ORIGINAL CONTRIBUTIONS

Measurement of Stomach Wall Thickness to Guide Staple Selection during Sleeve Gastrectomy

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Abstract

Background Sleeve gastrectomy has been considered a primary bariatric surgery; however, surgeons concerned with staple line leakage often query whether staples selected during stomach resection are of an appropriate size. This study aimed to measure gastric wall thickness using pathology laboratory measurements and to identify variables correlated with stomach wall thickness in patients who had undergone laparoscopic sleeve gastrectomy.

Methods We obtained fresh resected stomach wall specimens from 30 patients. Stomach wall thickness was immediately measured postoperatively, comprising the muscle layer of the antrum, body, and fundus. Results were correlated with body mass index (BMI), age, and sex and with diagnoses of presurgical diabetes, hypertension, hyperlipidemia, and fatty liver.

Results Stomach wall thickness ranged from 3.4 ± 4.3 mm to 1.0 ± 9.6 mm at the antrum. Except for the whole layer at the body wall, there was no significant correlation between wall thickness and other factors. At the body wall, whole layer wall thickness was found to positively correlate with age, sex, diabetes, and smoking ($r = 0.469$, -0.391, 0.396, and 0.349, respectively; $p < 0.05$ in all patients).

Conclusion Stomach wall thickness varied among patients who had undergone laparoscopic sleeve gastrectomy according to samples taken at three stomach wall sites. The range in wall thickness was normal, and thus, surgeons need not hesitate in selecting the staple height. Also, our study may be helpful to guide surgeon choice concerning the third or fourth staple around the body area when considering a patient's independent factors.

Keywords Stomach wall thickness · Laparoscopic sleeve gastrectomy · Staple height

Introduction

Laparoscopic sleeve gastrectomy (LSG) is emerging as a popular bariatric procedure and a stand-alone procedure for morbid obesity [1–3]. This procedure has been reported to have adequate outcomes concerning weight loss and changes to hormonal mechanisms [4], and there are many advantages with this simpler technique, such as the lack of gastrointestinal anastomosis and the prevention of internal hernia development [5]. LSG use has increased in Asia, where there is a high incidence of stomach cancer, and has the advantage of a possibility for remnant stomach evaluation through endoscopy.

However, some controversial aspects of LSG should also be considered. When vertical transection of the stomach is performed using an endoscopic linear stapler, prevention of major complications such as leakage and bleeding is most important. Surgeons have been required to select the correct staple height to reinforce sutures along the staple line [3, 6–8]. Previous studies have shown that the stomach wall's thickness may vary and that thickness at the fundus increases as it reaches the antrum, where it has been reported to be thickest [6–10]. Unlike previous studies, this study aimed to measure the thickness of excised stomach wall samples measured microscopically by a pathologist and to determine whether the thickness of the stomach wall correlated with patient characteristics and comorbidities. Our

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study findings could be helpful to surgeons deliberating over the choice of a suitable staple height when considering the thickness of the stomach wall.

Methods

Patients and Procedure

Data from thirty patients who had undergone LSG at the tertiary hospital from January 2019 to August 2019 were included in the analysis. All of the patients met the national insurance criteria and the Korea Society for Metabolic and Bariatric Surgery criteria, which considered the extent of the body mass index (BMI) and the presence of comorbidities. The national insurance criteria included patients with a BMI > 35 kg/m^2 with or without coexisting medical complications or with a BMI > 30 kg/m^2 with one or more obesity-induced comorbidities. This study was approved by an institutional review board (IRB No. 2019AN0326), and all participating patients provided their written informed consent prior to surgery. We routinely performed LSG using a 34 F bougie and a 4-port trocar. We marked a point 5 cm proximal to the pylorus and dissected between the stomach and the greater curvature of the omentum using an energy device. The first resection line was approximately 5 cm from the pylorus. We made a sleeve using about 7 or 8 cartridges of 60-mm-sized staples along the bougie. The final resection point was approximately 1 cm from the esophagogastric junction. Our procedures were performed with a mechanical stapling device which was reloaded with cartridges containing size-selected staples. We routinely selected the cartridge which was able to transect the thickest tissue at the first resection of antrum. Hemostasis such as coagulation and compression using the gauze were not routinely performed unless there was a bleed that puffs in the artery after stapling.

Data Collection and Analysis

Fresh excised specimens were sent immediately to the pathologist at the surgical pathology gross room after the surgeon had marked three points, namely, at the antrum, at the nearby angle of the body, and at the fundus (Fig. 1, 1b). After staple line removal, the pathologist pinned the specimen to a cork board prior to fixation to prevent shrinkage during fixation. Three representative parts of the fundus, body, and antrum were cut vertically, and tissue blocks were made and embedded in paraffin. The pathologist reviewed the hematoxylin-eosin stained slides of three specimens that had been selected at each point. The thickness of the stomach wall was measured microscopically using two measurements at areas without gastric rugae. One measurement involved the whole layer (WL) of the stomach wall, comprising a measurement from the mucosa to the serosa. The other measurement comprised the muscle layer (ML) and included the muscularis propria (Fig. 1c). The three WL specimens and the three ML specimens at each point were measured, and the longest distance among each of the three values was recorded. All continuous variables are presented as mean and standard deviation (SD), and categorical variables are presented as counts and percentages. Categorical variables were compared using a chi-square test or Fisher's exact test, and continuous variables were compared using a t test. Pearson's correlation coefficient analysis was used to analyze the correlations between patient characteristics and stomach wall thickness. A two-sided p value < 0.05 was considered statistically significant.

Results

Baseline Characteristics and Postoperative Complications after 30 Days

Baseline patient characteristics are shown in Table 1. Of 30 patients who had undergone LSG, 21 (70%) were female. The mean age was 40.4 ± 12.9 years, the mean initial BMI was 38.8 ± 5.0 kg/m^2, and 19 patients (63%) had been previously diagnosed with diabetes mellitus (DM). The thickness of the stomach wall differed at each measurement site, namely, at the fundus, the body, and the antrum. When measuring the ML, the wall thickness at the antrum and fundus were 1688.6 ± 649.0 mm and 1573.8 ± 604.6 mm, respectively. The WL wall thickness of the antrum and the fundus was 3697.8 ± 986.7 mm and 3379.8 ± 866.5 mm, respectively. In terms of the WL and ML, the wall increased in thickness from the fundus to the antrum. Table 2 shows the mean stomach wall thickness at each measurement point.

Among the 30 study patients, there were no deaths or leakage reported. Intra-abdominal bleeding was the only major complication to occur in one patient due to omental artery hemorrhage, which was resolved through performing angiographic coilization. Another patient, a male smoker with diabetes mellitus, developed bleeding and peripheral tissue tearing at a staple site. The stomach wall thickness of the stomach body area in this patient was thicker than that of the other patients. The bleeding was managed conservatively by using coagulants including tranexamic acid and vitamin K. Complications that occurred within 30 days post-LSG are listed in Table 3.

A Comparison of Patient Demographics and Stomach Wall Thickness between Males and Females

Of the 30 participants, 70% were female. Male and female patients were compared to determine whether there were significant differences in their baseline characteristics. The mean

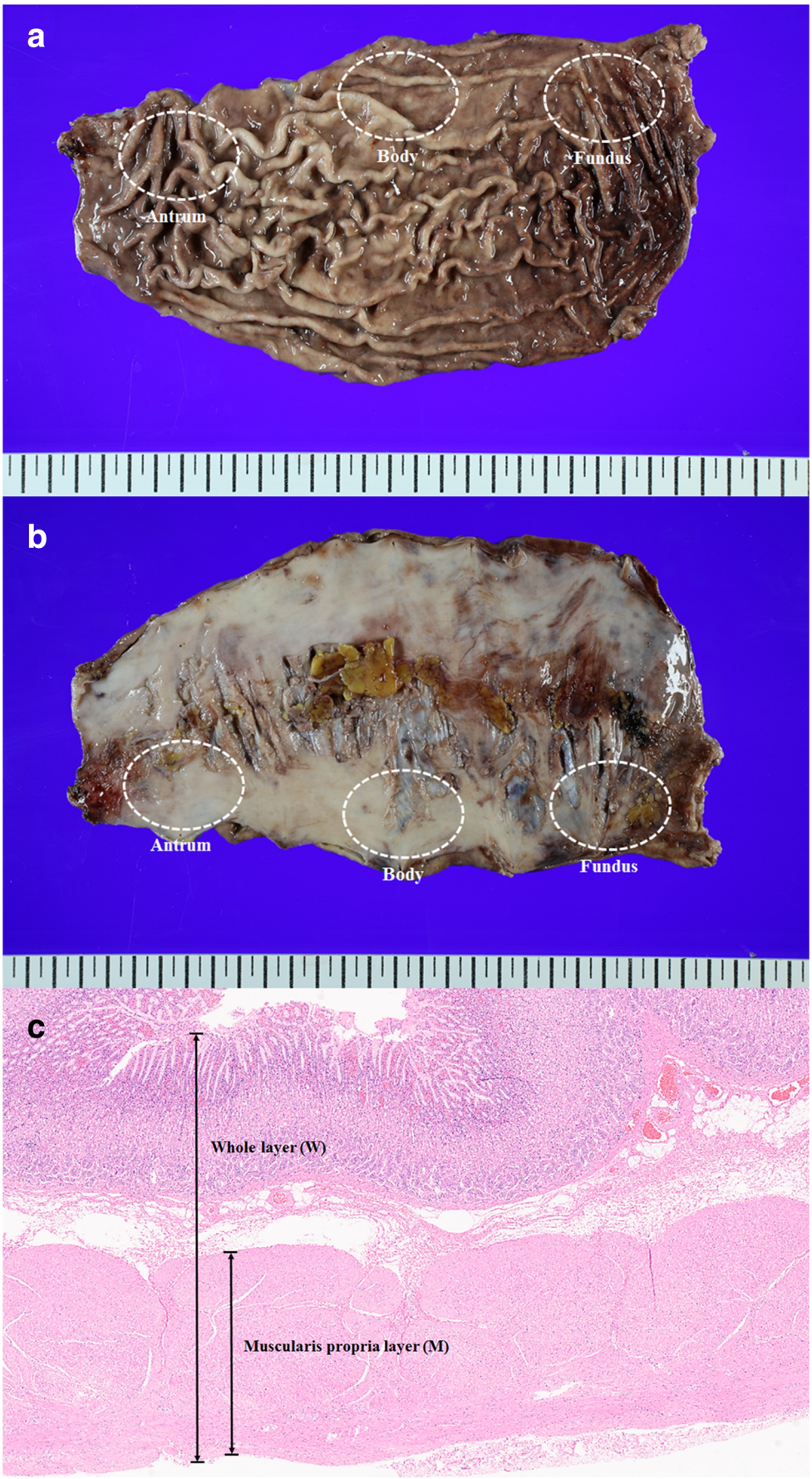

Fig. 1 **a** The representative gross appearance of sleeve gastrectomy specimen. **b** The thickness of stomach wall from fundus, body, and antrum near the stapler area were evaluated. **c** Microscopic examination of stomach wall for evaluating stomach wall thickness (hematoxylin-eosin staining, original magnification × 100)

Table 1 Baseline characteristics

	Sleeve gastrectomy ($N = 30$)	Range
Age (mean)	40.4 ± 12.9	20.0–65.0
Sex	9 (30%)	
Male	21 (70%)	
Female		
Smoking	10 (33.3%)	
Yes	5 (16.7%)	
ASA score	17(56.7%)	
1	8 (26.6%)	
2	19 (63.3%)	
3	19 (63.3%)	
Comorbidity	20 (66.7%)	
DM	5 (16.7%)	
HTN	9 (30%)	
Dyslipidemia		
Osteoarthritis		
OSAS		
BMI	8 (26.7%)	
30.0–34.9	12 (73.3%)	
> 35		
Preoperative Weight (kg)	107.8 ± 19.0	81.3–156.3
Preoperative BMI (kg/m^2)	38.8 ± 5.0	31.5–49.9

ASA score, American Society of Anesthesiologists score; BMI, body mass index; DM, diabetes mellitus; HTN, hypertension, OSAS, obstructive sleep apnea syndrome

BMI prior to surgery was significantly higher in men (42.2 kg/m^2) than in women (36.9 kg/m^2) ($p = 0.046$). However, there were no significant differences in terms of comorbidity, smoking, and mean age. Stomach wall thickness differed by sex and the WL of the body wall was significantly thicker in males ($p = 0.036$) (Table 4).

Correlation between Stomach Wall Thickness and Patient Characteristics

Table 5 shows the Spearman correlation coefficients (r) and the p values for each measure of stomach wall thickness as a multivariable comparison between patient variables and wall thickness at each measurement site. Except for the WL at the body wall, there was no significant correlation between wall thickness and other factors. At the body wall, WL wall thickness was found to be significantly positively correlated with age, sex, DM, and smoking (r = 0.469, − 0.391, 0.396, and 0.349, respectively). Concerning the WL at the body wall, the older the patient, the thicker the WL, and the WL was thinner females than in males. There was a statistically significant correlation between stomach wall thickness at the body wall and a diagnosis of DM and a history smoking. We found no statistically significant correlations with measurements taken at the antrum and the fundus.

Table 2 Stomach wall thickness

	Sleeve gastrectomy ($N = 30$)	Range
Thickness of muscle layer		
Fundus	1573.8 ± 604.6	385.0–2842.0
Body	1633.4 ± 589.4	381.0–3212.0
Antrum	1688.6 ± 649.0	510.0–3121.0
Thickness of whole layer		
Fundus	3379.8 ± 866.5	1729.0–5107.0
Body	3564.1 ± 908.9	2043.0–5685.0
Antrum	3697.8 ± 986.7	2192.0–6321.0

Discussion

Since 2014, LSG has been reported to be the preferred procedure worldwide, and its use has increased considerably [11]. Although LSG is a simple surgical procedure, complications concerning leakage and staple-line bleeding have been reported. When performing LSG, surgeons are required to select an average of four to seven staple cartridges [6]. Some studies have reported a correlation between stomach wall thickness and leakage. Gagner [12] suggested that, to prevent leakage at the staple line, the most appropriately sized staple cartridges should be selected. Using gross measurements, Rawlins et al. [13] reported that the thickness of the stomach decreased from the antrum to the fundus. Huang et al. [7] showed that using a calibration device to measure tissue thickness was necessary to prevent staple line leakage. One recently published study [6] and other previous studies [7, 12, 13] that have examined the thickness of the stomach wall all showed that stomach wall thickness tends to decrease from the antrum to the fundus and that stomach wall thickness varies between patients, depending on factors such as BMI and sex. However, these studies were limited in that only gross measurements had been taken and most of the study participants were super obese.

Assessing variations in stomach wall thickness at differing sites using microscopic measurements was a strength of this study. Moreover, there have been no previous reports of results concerning the measurement of stomach wall thickness in patients with a mean initial BMI < 40 kg/m^2. Study limitations included the small size of our study and the absence of an intraoperative device prior to selection of the cartridges. Although the study was a single-center study with a limited sample size, measurements taken by the pathologist and the measurement method were unbiased. Also, despite the small sample size, we identified some statistically significant associations between patient characteristics and stomach wall thickness. There was a significant correlation between individual factors such as being male, having a history of DM and smoking, and stomach wall thickness in the body wall only. The number of LSG surgeries is increasing rapidly. The results of this study may help surgeons to select the appropriate staple

Table 3 Postoperative complications

Complication	Sleeve gastrectomy ($N = 30$)	Complication management
Major	0 (0%)	Angiography–omental artery coiling
Leakage	1 (3.3%)	
Bleeding		
Minor	1 (3.3%)	Endoscopy
Dysphagia	0 (0%)	Coagulant applied
Intraluminal bleeding	1 (3.3%)	Skin re-suture
Bleeding staple line	2 (6.7%)	Conservative management
Wound infection	0 (0%)	
Pneumonia	1 (3.3%)	
Phlebitis	1 (3.3%)	
Clavien-Dindo Grade	2 (6.7%)	
I	2 (6.7%)	
II	0 (0%)	
III		
IV		
Total: *N* (%)	5 (16.6%)	

height and may be especially helpful for beginner bariatric surgeons and surgeons operating on patients with a BMI < 40 kg/m^2. Further research of a larger number of patients by means of multicenter studies, which include patients with an initial BMI > 40 kg/m^2, and development of intraoperative device that can be selected prior to the selection of cartridges will be necessary.

Bariatric surgeons who perform LSG may experience tissue tears and crushed tissue when applying equipment or cartridges less suitable for thicker tissue such as the antrum wall. Previous studies have reported that the thickest part of the stomach wall is the wall of the antrum. Most surgeons use the thickest "biteable" cartridge for the first staple and sometimes for the second staple. The stomach wall tends to become thinner from the antrum to the fundus; therefore, the third or fourth staples selected by a surgeon should involve thinner cartridges than the first or second staples used, as the area to be stapled with the third or fourth staples is located at the angle of the body area. Our results showed that body wall thickness differed significantly according to individual factors. Our study results are consistent with the results of previous studies that have shown that stomach wall thickness tends to decrease

Table 4 A comparison of patient demographics and stomach wall thickness between males and females

	Male ($N = 9$)	Female ($N = 21$)	*p* value
Age (mean)	37.7 ± 10.0	41.5 ± 14.0	0.461
Preoperative BMI	42.2 [37.3;43.4]	36.9 [34.2;40.7]	0.046
Comorbidity	7 (77.8%)	12 (57.1%)	0.508
DM	7 (77.8%)	9 (45.0%)	0.261
HTN			
Preoperative	1122.6 ± 14.5	97.3 ± 15.0	< 0.001
Weight (kg)			
Thickness of muscle layer			
Fundus	1658.3 ± 598.2	1537.6 ± 618.3	0.625
Body	1640.4 ± 596.6	1630.4 ± 601.1	0.967
Antrum	1848.2 ± 257.0	1620.2 ± 753.6	0.229
Thickness of whole layer			
Fundus	3390.4 ± 1022.2	3375.3 ± 818.9	0.966
Body	4089.8 ± 1086.8	3338.9 ± 740.1	0.036
Antrum	3723.0 [3480;4098.0]	3178.0 [2958.0;4320.0]	0.326

BMI, body mass index; DM, diabetes mellitus; HTN, hypertension

Table 5 An analysis of the correlation between patients and stomach wall thickness

Correlation coefficients *r* (*p* value)	Age	Sex	BMI	Comorbidities	DM	Smoking
Thickness of muscle layer						
Fundus	0.085 (0.654)	− 0.097 (0.611)	0.283 (0.130)	0.057 (0.765)	0.052 (0.785)	0.276 (0.140)
Body	0.462 (0.010)	0.029 (0.877)	0.063 (0.739)	0.315 (0.090)	0.164 (0.387)	0.348 (0.060)
Antrum	0.215 (0.254)	− 0.294 (0.115)	− 0.010 (0.957)	0.109 (0.568)	0.012 (0.950)	0.184 (0.331)
Thickness of whole layer						
Fundus	0.258 (0.168)	0.021 (0.912)	0.225 (0.232)	0.140 (0.462)	0.164 (0.387)	0.260 (0.166)
Body	0.469 (0.009)	− 0.391 (0.033)	0.306 (0.100)	0.439 (0.015)	0.396 (0.030)	0.349 (0.047)
Antrum	0.164 (0.387)	− 0.189 (0.317)	0.055 (0.772)	0.005 (0.978)	− 0.012 (0.950)	0.164 (0.387)

BMI, body mass index; DM, diabetes mellitus

from the antrum to the fundus. It is thought that the thick part was not different between patients because everyone was thick at antrum. The thin part did not make a significant difference because it was thin at fundus in everyone. Where surgeons might not be routinely selecting the thinner third or fourth staples, they do not need to hesitate while choosing the thinner third or fourth staples according to our results.

Conclusion

In terms of microscopic measurement, the stomach wall thickness varied according to individual and according to the location within the stomach. Most surgeons are aware that the antrum wall is the thickest part of the wall; however, previous studies have not addressed the association between stomach wall thickness and individual patient factors. Our results may motivate surgeons to take individual factors into account and thus, by selecting appropriate size staples, help to prevent leakage and tissue injury such as tearing in the area of the resection of the body. In patients who had the factors such as more advanced age, male sex, DM, and smoking, surgeons need to choose larger cartridges for stapling the resection of body area considering that patients with these characteristics tend to have thicker tissues of body area than patients who do not. In conclusion, our study may be helpful to guide surgeons' choice of the third or fourth staples used around the body area by taking individual patient factors into account.

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Compliance with Ethical Standards

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

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Statement of Informed Consent Informed consent was obtained from all individual participants included in the study.

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