

Correct Evaluation of Gastric Wall Thickness May Support a Change in Staplers' Size When Performing Sleeve Gastrectomy

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ABSTRACT: **Background:** Leakage from the staple line is the most serious complication encountered after sleeve gastrectomy, occurring in 2.4% of surgeries. The use of inappropriately sized staplers, because of variability in stomach wall thickness, is a major cause of leakage.

Objectives: To measure stomach wall thickness across different stomach zones in order to identify variables correlating with thickness.

Methods: The study comprised 100 patients (52 females). Stomach wall thickness was measured immediately after surgery using a digital caliper at the antrum, body, and fundus. Results were correlated with body mass index (BMI), age, gender, and pre-surgical diagnosis of diabetes, hypertension, hyperlipidemia and fatty liver.

Results: Stomach wall thickness was found to be 5.1 ± 0.6 mm at the antrum, 4.1 ± 0.6 mm at the body, and 2.6 ± 0.5 mm at the fundus. No correlation was found between stomach wall thickness and BMI, gender, or co-morbidities.

Conclusions: Stomach wall thickness increases gradually from the fundus toward the antrum. Application of the correct staple height during sleeve gastrectomy is important and may, theoretically, prevent leaks. Staplers should be chosen according to the thickness of the tissue.

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KEY WORDS: sleeve gastrectomy, stomach wall, tissue thickness, staplers, bariatric surgery

Laparoscopic sleeve gastrectomy (SG) is gaining acceptance worldwide and has become a popular stand-alone bariatric procedure. Laparoscopic SG was initially used as a first-stage procedure in super obese patients to achieve some weight reduction before a bypass procedure. However, the weight loss and resolution of co-morbidities after SG were found to be satisfactory for most patients. Thus, given its relative simplicity and low risk, SG has become a popular stand-alone bariatric procedure. [1-4]. In procedures performed by the same surgeons, there were significantly fewer complications for SG patients (4.6%) compared to laparoscopic gastric bypass

(10.6%) or duodenal switch (39.3%) [5]. Leaks are reported to occur on average in 2.4% cases (up to 7%) of SG cases with a significantly higher leak rate in super obese patients (body mass index [BMI] > 50 kg/m²) [6]. Leaks occur predominantly at the proximal portion of the staple line, near the esophago-gastric junction, but have been reported along the entire length of the staple line [6]. The propensity of leaks in the upper staple line has been attributed to several factors, including poor blood supply to this area after division of the short gastric vessels, inadvertent thermal injury caused when dissecting the area of the left crus of the diaphragm and inappropriate staple height (either too small, causing ischemia or too big and not creating a sufficient seal).

Several studies have reported surgical methods to overcome these stapling problems. Bellanger and Greenway [7] used minimized pressure with a 50-French bougie at the incisura angularis and a 34-French bougie for the body and fundus. They also switched stapler cartridges from green at the antrum to blue at the body and fundus, taking into account differences in tissue thickness, and claimed that these techniques allowed them to avoid leaks in many of the procedures. If buttressing materials are used, an additional 1 mm thickness must be considered [8]. Huang and Gagner [9] claimed that since there are variations in stomach wall thickness in different areas and by genders, a singular method, in which the surgeon uses only one type of stapler cartridge (typically black) for the entire sleeve, is inappropriate and a thickness calibration device is needed to determine correct staple height.

A methodological analysis of the thickness of the human stomach wall was performed in a study comprising 50 patients undergoing SG [10]. The authors found that gender and location had a statistically significant influence on gastric specimen tissue thickness. The thickest tissue was found near the pylorus and the thinnest near the fundus, regardless of gender. Most male subjects (97.5%) had a tissue thickness of 4.9 mm or less near the pylorus, with the rest having thicker tissue. Only 5% of female subjects had a tissue thickness greater than 4.4 mm.

Ex vivo measurement of stomach tissue after bariatric surgery was performed on 50 patients [11]. Tissue thickness

was measured in different locations along the excision line, based on the number of staplers used. Tissue thickness was found to be significantly different at different locations, with values of 2.70, 2.33 and 1.97 mm at the antrum, midbody, and fundus, respectively. Thicker tissue at the antrum had a significant correlation with male gender and super obesity (BMI > 50 kg/m²).

In this article we describe a similar approach based on 100 SG procedures, in which we measured tissue thickness at three anatomical locations with anterior and posterior tissue evaluation at each measuring point. The purpose of this study was to establish differences in stomach tissue thickness along the SG surgical path to provide a more informed methodology for the use of staplers during the procedure.

PATIENTS AND METHODS

The study design was a single-center, prospective study of patients undergoing SG in a bariatric surgery center in Tel Aviv, Israel. All patients were evaluated by a multidisciplinary team including a surgeon, a dietician, and a psychologist. All patients participating in the study signed an informed consent and gave their permission to perform measurement on the excised stomach tissue. The study was approved by the institutional review board and was registered on the National Institutes of Health website with the study identifier NCT02068014.

The study comprised 100 patients (52 female, 48 male) with an average age of 43.9 years (range 19–68), and an average BMI of 41.7 (range 35–52). SG was the primary surgery for all the patients participating in the study. The surgical procedure used was not modified and we used a 34-French bougie for all cases. The stomach was cut using Endo GIA™ 60 mm black and purple staplers and cartridges (Covidien-Medtronic, New Haven, CN, USA), and the staple line was reinforced in all cases with Peri-Strips Dry® with Veritas (Baxter Healthcare Corporation, Minneapolis, MN, USA). All surgeries were performed by the same experienced surgeon, starting with black cartridges on the antrum and switching to purple cartridges according to the tactile feel of the stomach tissue. The

excised tissue, with two different types of staplers, is shown in Figure 1.

To allow us to assess any relationship between stomach wall thickness and the patient's co-morbidities, we recorded several major patient co-morbidities including diabetes, hyperlipidemia, hypertension, and fatty liver. We also recorded the number and type of staples and cartridges used.

Excised stomach specimens were measured in the operating room by the same member of the team immediately after excision. Tissue thickness was measured using a 6 inch electronic digital caliper (Delcast Engineering Corp. Estancia Del Lago, Caguas, Puerto Rico) with an accuracy of 0.02 mm and a resolution of 0.01 mm. Each location had two separate measurements, one at the anterior and one at the posterior part of the excised tissue.

STATISTICS

Pearson's correlation coefficient was used to test for relationships between stomach wall thickness, BMI, and number of staplers. The two-sample *t*-test for independent samples was used to test for differences in stomach wall thickness among categories (gender, diabetes, hyperlipidemia, and fatty liver). The paired *t*-test was used to test for differences in stomach wall thickness across the different locations (antrum, body, and fundus). A linear regression model was used to test the relations between stomach wall thickness and explanatory variables.

RESULTS

Our study comprised 100 patients (52 female and 48 male), mean age of 43.88 years (range 19–68 years). Of these, 95 patients presented with co-morbidities: 33 patients had type 2 diabetes, 37 had hypertension, 51 had hyperlipidemia, and 55 had fatty liver [Table 1]. Other co-morbidities included obstructive sleep apnea, asthma, osteoarthritis, snoring, gastroesophageal reflux disease, and infertility. None of the patients had postsurgical leaks or bleeding.

Stomach wall thicknesses were 5.1 ± 0.6 mm for the antrum, 4.1 ± 0.6 mm for the body, and 2.6 ± 0.5 mm for the fundus. The anterior part was thicker than the posterior

Figure 1. Stapler line: [A] black tri-staplers 60 mm long (5 mm); [A1] stapler line has bad closure on the antrum; [B] purple tri-stapler 60 mm long (4 mm); [B1] third row of staplers are too loose on the fundus

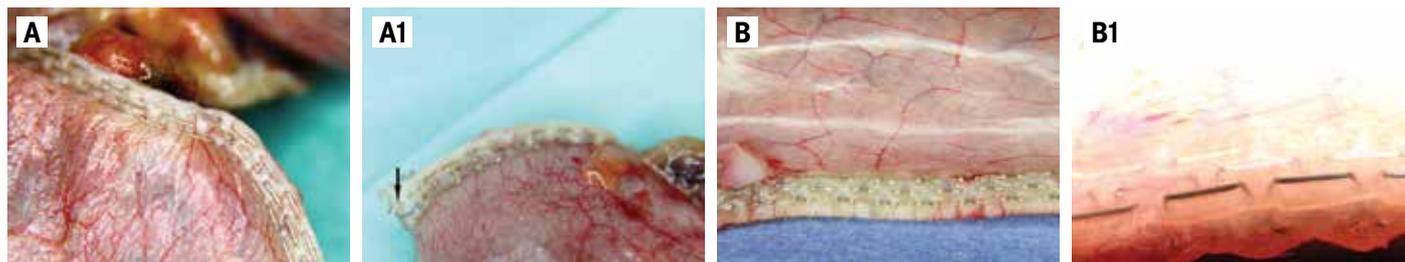
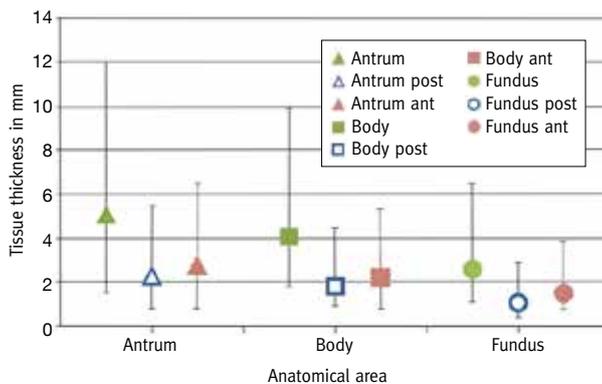


Table 1. Descriptive statistics of background variables (N=100)

	Mean	STD	Min	Median	Max
Age (years)	43.9	11.3	19.0	44.0	68.0
Height (cm)	169.4	10.2	147.0	170.0	189.0
Weight (kg)	120.4	18.8	88.0	116.8	180.0
BMI	41.7	4.2	34.0	42.0	52.0
Gender	Female 52%		Male 48%		
Co-morbidities					
Diabetes	33%				
Hypertension	37%				
Hyperlipidemia	51%				
Fatty liver	55%				

N = number of patients, STD = standard deviation, Min = minimum, Max = maximum

Figure 2. Stomach wall thickness in different zones: The anterior part is thicker than the posterior part in all stomach zones. Antrum is thicker than fundus

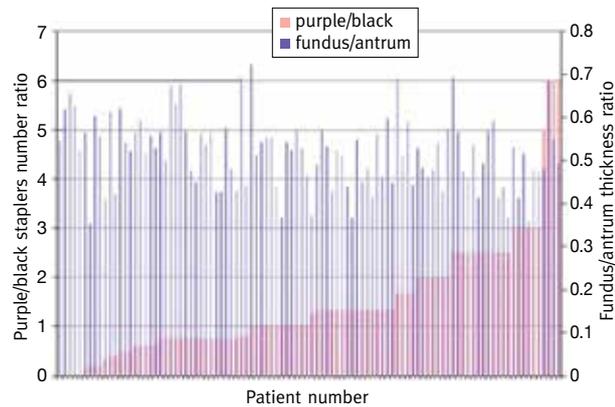


for all zones ($P < 0.0001$) [Figure 2]. The stomach wall was thicker at the antrum and decreased progressively toward the fundus, which was 51.67% thinner than the antrum.

Male gender was positively correlated with thicker a stomach wall; both for the tissue fold measurements and for posterior/anterior measurements. Mean stomach wall thicknesses were 5.154 (male) and 5.008 mm (female) for the antrum ($P = 0.2119$); 4.199 (male) and 3.921 mm (female) for the body ($P = 0.0237$); and 2.667 (male) and 2.580 mm (female) for the fundus ($P = 0.3511$). No correlation was found between BMI and tissue thickness. No correlation was found between tissue thickness and any of the co-morbidities tested.

The correlation between relative stomach wall thicknesses at the fundus and antrum and the ratio of purple and black staple cartridges used is shown in Figure 3. Although the ratio of tissue thickness shows small variations, the purple–black stapler ratio has large variations. Thus, there is discordance between the surgeon’s tactile feeling used for selecting the stapler size and the true measurement of the gastric thick-

Figure 3. Correlation between the relative stomach wall thicknesses at the fundus and antrum and the ratio between the numbers of purple and black stapler cartridges in all patients. There is discordance between the surgeon’s tactile feeling in selecting the stapler size and the true measurement of the gastric thickness



ness. This result indicates that the surgeon’s tactile feeling is inaccurate in most cases.

DISCUSSION

One of the most significant complications of the SG procedure is leak. Approximately 90% of leaks occur proximal to the cutting edge [12], making them difficult to treat effectively. Treatment approaches for these leaks include clips [13], stents [14], sealing materials [15] and re-operation [16], with no sufficiently positive solution.

Potential reasons for leaks following SG as local ischemia are diverse and include the diameter of the bougie [17], the increase of the intra-gastric pressure [18] or malfunction of the staplers, among others. Based on our findings, we propose that a mismatch between the type of stapler used and the thickness of the tissue can account for a large proportion of leaks.

Our data establish the differences in stomach tissue thickness across different stomach zones. The antrum is the thickest (5.1 ± 0.6 mm), and the fundus is approximately half this thickness (2.6 ± 0.5 mm). These data are in line with measurements of tissue excised during SG: 2.7 mm at the antrum, 2.33 mm at the mid-body and 1.97 mm at the fundus [11]. Our data did not show any correlation with age or BMI, as found by previous studies. It is important to note that Rawlins and co-authors [11] established a significant correlation between antrum thickness and BMI > 50 . Our patient population consisted of only two patients with such a high BMI, and therefore this parameter could not be compared. The gender correlation in our study is consistent with previous studies [10,11], showing thicker stomach wall for men.

It is interesting to note that our data is in line with measurements of the human stomach wall thickness made by other methods. The gastric antrum was found to be 2.9 ± 0.8 mm thick when measured using ultrasound [19]. Using multidetector CT, Pickhardt and Asher [20] found the antrum to be 5.1 ± 1.6 mm thick and the body 2.0 ± 0.4 mm. similar differences between antrum and fundus were reported by the same group on cadaveric tissue.

A comparison of ratio of tissue thickness to the ratio of purple and black staplers suggests that the most appropriate staplers are not always used. Surgeons use different staplers sizes based on differences in stomach wall thickness across different zones (thicker antrum, thinner fundus) and according to their tactile feeling. Figure 3 shows that, in practice, the number and type of staplers do not correlate with tissue thickness. This discrepancy can lead to staples that are too loose at the fundus and/or staples that are too small at the antrum, resulting in leaks. This incongruity is consistent with the higher frequency of leaks in SG at the gastroesophageal junction area [21]. None of the patients of this study had leaks.

Patient gender is an additional factor to be considered. In our population BMI < 50, age and co-morbidities had no influence on stomach wall thickness.

Potential limitations of this study include the relatively small sample sizes and the fact that most patients had a BMI below 50.

CONCLUSIONS

Based on our data, we recommend that surgeons carefully consider stomach wall thickness and stapler selection during SG, especially when moving from the antrum to the fundus. Correct decisions about when to change cartridges can diminish the risk of leak. In the fundus, vascular cartridges with smaller clips are likely to be appropriate.

Staplers that can estimate tissue thickness during the procedure would be advantageous and should be prioritized for development.

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“If you see what needs to be repaired and how to repair it, then you have found a piece of the world that G-d has left for you to complete. But if you only see what is wrong and how ugly it is, then it is you yourself that needs repair”

Rabbi Menachem Mendel Schneerson, (1902–1994) leader of the Chabad-Lubavich movement and the last Lubavitcher Rebbe

“We have come to a point where it is loyalty to resist, and treason to submit”

Carl Schurz (1829-1906), German revolutionary, American statesman and reformer