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Pressure tolerance of newly constructed staple lines in sleeve gastrectomy and duodenal switch

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Abstract

BACKGROUND: Many bariatric surgeons elect to pressure test the newly constructed staple lines in sleeve gastrectomy and duodenal switch procedures as a means of intraoperatively detecting leaks. The pressure tolerance of these fresh staple lines has not been well studied in a clinical setting.

METHODS: This is a retrospective institutional review board–approved study that analyzed resected stomachs immediately after resection during a bariatric operation performed using sleeve gastrectomy or bilipancreatic diversion with duodenal switch. Resected stomachs were connected to a normal saline infusion and manometric pressure device for determining the maximum stomach capacity, the leak pressure, and the location of the first leak.

RESULTS: Thirty patients (9 underwent bilipancreatic diversion with duodenal switch and 21 underwent sleeve gastrectomy) met the inclusion criteria (mean age of 44.7 years, 63.3% female) with a mean body mass index of 44.1 that was higher with bilipancreatic diversion (51.3 vs 41.0, \( P = .001 \)) and a mean weight loss of 83 lb (a body mass index decrease of 13.4; median follow-up, 307 days). The leak volume of the resected stomach averaged 1,478 mL (range 1,100 to 2,200) with an average pressure of 25.6 cm H\(_2\)O (range 12 to 60). The volume and leak pressures were equivalent despite the operative approach (\( P = .79 \) and .32, respectively), and there was no difference in the location of the leak (staple line or intrinsic stomach) based on volume or pressure (\( P = .246 \) and .131, respectively), with 50% of leaks occurring on the staple lines.

CONCLUSIONS: The fresh staple lines in vertical sleeve gastrectomy and duodenal switch show burst strength well in excess of any intragastric pressures likely to be created by brief intraoperative leak checks via air instilled by an orogastric tube or intraoperative endoscopy. Leak testing is not likely to create iatrogenic damage to properly constructed fresh staple lines in these procedures.

Surgical options in bariatric surgery continue to evolve. Although the long-established Roux-en-y gastric bypass remains popular, in the last decade there has been increasing focus on 2 newer surgical procedures, lateral sleeve gastrectomy (LSG) and duodenal switch (DS), also known as bilipancreatic diversion with duodenal switch. Both LSG and DS involve major reductions in gastric capacity by resecting a large portion of the gastric body and fundus from the distal antrum to the angle of His.
This is achieved by serial applications of linear stapling devices, resulting in a tubularized stomach “sleeve” with a long lateral staple line seam. In the early postoperative period, the strength and integrity of this gastric staple line is of critical importance. A perioperative staple line leak after either LSG or DS is an obvious major complication, which can often lead to prolonged recovery or, rarely, a fatal outcome. The reported incidence of these leaks varies but may be as high as 2.4% in the average bariatric population and slightly higher in the super obese population (2.9%).

Staple devices used to tubularize the stomach in either LSG or DS have evolved over time. Current-generation linear stapling devices create 3 staggered rows of staples on each side of the tissue to be divided by the knife assembly. Many surgeons elect to further buttress gastric staple lines in LSG and DS with prosthetic strips. These have been shown to reduce staple line bleeding although their value for reducing the risk of leak remains unclear.

Intraoperatively, many surgeons also “leak test” newly constructed LSG or DS staple lines. The upper abdomen is filled with saline, and the newly constructed sleeve is then pressurized with air either via an orogastric tube or in the process of direct endoscopic inspection. Potential trouble spots are detected by air bubbles along the staple line.

There is theoretic concern that shear forces on these staple lines engendered by the leak testing process could result in perioperative staple line weakness. Although LSG and DS leak testing is common, we could not find any studies involving humans that addressed the burst strength of fresh staple lines in these procedures. The present study sought to address this issue by assessing the burst capacity of the freshly resected stomach specimen as a surrogate for the strength of the sleeve staple lines. A secondary area of investigation was to measure the actual capacity of the resected stomach specimens and to determine whether there was any correlation between this measured capacity and subsequent weight loss.

**Methods**

After obtaining institutional review board approval, we performed serial analysis of freshly resected gastric specimens obtained in the course of either LSG or DS. All procedures were performed at Madigan Army Medical Center, Tacoma, WA, as primary bariatric interventions by the senior author who operated with various resident surgeons. By practice preference, all procedures were performed with traditional open surgery via an upper midline approach. In both LSG and DS, the sleeve gastrectomy was formed by serial applications of a linear cutting stapler using 2 applications of green load staples for the antrum and gold load staples for the remaining proximal transection. All staple applications were buttressed with Seamguard (Gore Medical, Flagstaff, AZ) with the exception of the initial green load application to the thick distal antrum, for which an unbuttressed green load was used with Lembert inversion of this part of the staple line. After completing the operation, a small gastrotomy was created at the antral end of the fresh gastric specimen, and a 16F infusion catheter was inserted, securing a watertight seal with a purse-string suture over the flanged tip of the infusion catheter (Fig. 1). The specimen was then inflated with gravity-fed saline to an endpoint of the first grossly detectable leakage, at which point “leak pressure” and the specimen’s endpoint volume capacity were recorded. The anatomic site of leakage was also noted to include whether the leak occurred through the staple line seam or at some other site on the gastric specimen.

For the study population, we also obtained data on sex, age, and body mass index. Follow-up analysis compared short-term weight loss with the measured capacity of the sleeve specimen. Categoric variables were represented as percentages with a chi-square statistical analysis, and continuous variables were represented as mean ± standard deviation and range (low to high) with analysis using the Student t test. All data analysis was performed using PASW 19.0 (SPSS Inc, Chicago, IL); statistical significance for this study was set at α = .05.

**Results**

Thirty resected sleeves were studied: 21 from patients who underwent LSD and 9 who had the duodenal switch procedure (mean age = 44.7 ± 11.8 years, 63.3% female, mean preoperative body mass index = 44.1 ± 9.3 kg/m², DS = 51.3 ± 10.1 kg/m² and LSG 41.0 ± 6.1 kg/m²). The leak volume of the resected stomach averaged 1,478 ± 287 mL (range 1,100 to 2,200 mL). The average pressure at the time of the first leak was 25.6 ± 10.6 cm H₂O (range 12 to 60 cm H₂O). The volume and leak pressures were similar in the LSG and DS groups (P = .79 and .32, respectively). There was no correlation between specimen capacity or leak pressure and whether the first leak occurred in the staple line or elsewhere on the gastric specimen (P = .246 and .131, respectively). There was no clear correlation between specimen capacity or leak pressure and subsequent short-term weight control (Fig. 2). In the majority of cases in this study, leaks in the specimen staple lines occurred at junction points between sequential staple applications. In cases in which the first leakage occurred separate from the staple lines (ie, in the wall of the gastric specimen itself), they were invariably in the proximal half of the specimen. In these cases, the leak was often a sudden “blowout,” precluding accurate measurement of the intragastric pressure at the time of this event. Observationally, however, the specimens in these cases all appeared to be under very tight distention before the leak occurred. Thus, it is reasonable to infer that burst pressures in these cases were at the high end of the measured ranges in the study.
Comments

With good reason, leaks are one of the most feared perioperative complications in bariatric surgery, often leading to severe clinical consequences. In both LSG and DS, long staple lines are created to form a much smaller tubularized stomach, thus achieving greatly reduced prepyloric gastric capacity. These extensive staple lines are of particular interest as possible leak sites, but even in “standard” Roux-en-Y gastric bypass, lengthy staple lines are created on the remnant stomach, which can be at risk as a leak site if the remnant stomach becomes acutely distended from obstruction of the biliopancreatic channel. Thus, the mechanical integrity of newly constructed staple lines is of paramount interest. We found few experimental studies in human subjects addressing the stress strength of new gastric staple lines. Because the staple seams in LSG and DS are identical on the sleeve itself and on the resected stomach, this study uses the bursting pressure of the resected gastric specimen as a surrogate for pressure effects on the newly created gastric sleeve. This study found that the pressure required to create a leak at the staple line on the specimen was much higher than the pressures likely created in the sleeve by most air leak testing methods. The pressure on the new sleeve, which can be achieved by standard air leak testing, is likely

Figure 1  (A and B) A resected gastric specimen before burst testing and just before bursting. Note the 16F infusion catheter inserted on the left (pyloric) side of the resected lateral stomach. (C) The lateral stomach after saline infusion at maximal capacity. (D) The stomach at maximal capacity showing the first leak.

Figure 2  Plots of body mass index change (BMI) versus (A) capacity and (B) bursting pressure.
limited by venting into the esophagus. The pressure in a stented lower esophageal sphincter is typically 15.4 to 20.8 cm H₂O.⁴,⁵ Furthermore, LES pressure decreases with gastric distention by 1.1 mm Hg/1 mm Hg of fundal pressure rise.⁶,⁷ The average volume of a gastric sleeve is about 100 mL.⁸ In our study, the observed volume of the gastric specimens was about 1,500 mL at the time of the leak. By inference, air leak testing is in all likelihood safe with insufflation of less than 150 mL air. This volume would be much greater than the usual air volumes instilled by the bariatric surgeons in our institution (usually 40 to 70 mL). In our study, the gastric specimens were subjected to continuously increasing pressures as the specimen was distended. Leaks most often occurred only after several minutes of obvious tight distention of the specimen. The observed leak pressures in our study likely well exceed actual intragastric sleeve pressures generated with the described brief intraoperative testing.

As previously mentioned, leaks not infrequently occurred as gastric wall “blowouts” separate from the staple line itself. This attests to the excellent holding power of accurately placed buttressed staples. Because all the procedures in this study were performed with open surgery, our data have not been confounded by possible weakening of the specimen and staple lines, which could result in the process of laparoscopic specimen extraction through a tight port.

A secondary area of interest in our study was the capacity of the resected stomach. Previous studies have shown that typical sleeve gastrectomy has a volume of 100 mL.⁸ We found that the capacity of the gastric specimens varied widely but was on average about 50% larger than some prior reports of stomach volume in obese patients.⁹,¹⁰ Thus, it is worth emphasizing that the restrictive aspects of LSG and DS reduce effective gastric capacity by over 90%. This may reduce the risk of dumping and allow patients more normal postsurgical eating patterns.

There are limitations to our study. First, the study assumes that staple line stresses to distention are similar along the sleeve gastrectomy and the resected stomach. We believe that this is reasonable because modern bariatric staplers have 6 rows of staples with a blade dividing the rows into identical groups of 3. Both in the study and in our general bariatric practice, larger staples are chosen for the distal stomach, where the gastric wall is thickest. We do not think this additional variable affects the study validity. Another limitation was that we did not perform continuous intragastric pressure tracings as the specimens were inflated. More refined data could be obtained in a further study.

Conclusions

The fresh staple lines in LSG and DS gastric specimens show burst strength well in excess of any intragastric pressure or volume commonly used for intraoperative air leak testing of fresh gastric sleeves. Leak testing is unlikely to cause iatrogenic damage to properly constructed fresh staple vertical gastric staple lines. We found no meaningful correlation between resected stomach capacity and subsequent short-term weight control.

References


Discussion

Mathew Rawlins, M.D. (Spokane, WA): LSG and DS procedures entail uniquely long continuous staple lines, typically measuring around 30 cm in length. The procedures also produce a healthy specimen with a staple line that is nearly identical to the staple line being left behind. The authors use these specimens as surrogates for the gastric sleeve as they conduct experiments on staple line pressure tolerance. The following clinical question in this study is important: does intraoperative pressure testing result in intraluminal pressures high enough to disrupt a staple line and thereby pose a risk of leak to the sleeve? There is relatively little information in the literature regarding direct pressure testing of staple lines. In 2004, Baker et al.¹¹ presented similar experiments on porcine stomachs and cadaveric fresh frozen human stomachs. Their model attempted to mimic staple lines used in gastric bypass and used a small pouch incorporating only 2 fires of the stapler with a single staple line junction.
They found mean leak pressures of 6.8 cm H$_2$O on unbut- 
tressed and 13.7 cm H$_2$O on buttressed staple lines. Dr 
Causey et al’s current data using fresh human specimens 
and sequential staple lines likely provide more meaningful 
pressure tolerance data than we have ever had relative to 
sleeve gastrectomy and, in fact, showed significantly 
higher strength with an average leak pressure of 25.6 to 
10.6 cm H$_2$O (range 12 to 60 cm H$_2$O). In the article, 
the authors propose that this is much higher than pressures 
likely to be encountered within the sleeve during most air 
leak testing methods although the intrasleeve pressures 
during air leak testing have not been measured. Citing 
that the pressure in a stented lower esophageal sphincter 
is typically 15.4 to 20.8 cm H$_2$O, they reason that this 
would set an upper limit of pressure within a new sleeve 
during pressure testing because of venting into the esop-
aghagus. Does lower esophageal sphincter pressure in unoper-
ated stomachs accurately predict the maximal intraluminal 
pressure in a sleeve gastrectomy during endoscopy? If we 
accept that it does, then we must acknowledge that the 
range and variance of the pressures at which your speci-
mens leaked (12 to 60 cm H$_2$O, mean $= 25 \pm 10$ cm 
H$_2$O) shows that some of the surrogate staple lines failed 
at or below this predicted threshold used to estimate intra-
sleeve pressures. What was the nature of the these few 
leaks in the specimen staple lines that occurred at lower 
pressures? What do you believe is the clinical significance 
of these low pressure leaks? Did they correlate with the 
leaks on the sleeve during leak testing? If they were not 
clinically significant, do they reflect a weakness in the 
model? Could direct measurement of intraluminal pres-
sure within the sleeve during pressure testing be safely 
done, and would it offer a more direct comparison with 
the leak pressure in the surrogate specimen? The authors 
also reasoned that because surrogates leaked at volumes 
about 50% higher than their resting nonpressurized vol-
umes, that a $<50\%$ increase in volume would be safe in 
the sleeve. However, it is generally understood that the 
most distensible part of the stomach is the fundus. I would 
propose that a 50% increase in volume in the sleeve would 
require a higher pressure than that which would cause the 
same percentage of distension of the specimen that con-
tains the entire fundus. This study does show that a 
well-formed staple line has strength approaching that of 
the tissue it is coapting. It also confirms clinical reports 
that leaks most often occur at the junctions of staple lines 
or in the upper part of the stomach. Most sleeve gastrec-
tomies in North America are performed laparoscopically, 
and the process of removing the specimen through a trocar 
site inevitably damages the specimen. The authors’ prac-
tice preference of the open approach gives them a rare 
source of uncorrupted sleeve gastrectomy specimens. 
This provides an opportunity to test the strength of the 
other common approaches to staple line reinforcement. 
The clinical literature on sleeve gastrectomy has been try-
ing to sort out, for example, the role of buttressing versus 
no buttressing and continuous oversew versus oversew of 
only staple line junctions versus no oversew. Bench test-
ing of these techniques on their surrogate stomachs may 
lead to better comparison and understanding of the vari-
ous techniques. I enjoyed this article and hope to see 
this model used for more testing.

Reference