Laparoscopic sleeve gastrectomy: Imaging of normal anatomic features and postoperative gastrointestinal complications

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**Abstract** Morbid obesity is a public health problem in the United States and Europe and its prevalence is on the increase. Despite certain progress the efficacy of medical treatment remains limited. Bariatric surgery has consequently become an effective alternative for patients with morbid obesity. The bariatric operations most frequently performed are laparoscopic adjustable gastric banding (LAGB) and Roux-en-Y gastric bypass (LGB), but laparoscopic sleeve gastrectomy (LSG) is increasingly popular with both bariatric surgeons and patients due to its simplicity, rapidity and decreased morbidity. The purpose of this pictorial essay is to familiarize radiologists with the normal postoperative anatomic features and the imaging findings of postoperative gastrointestinal complications of laparoscopic sleeve gastrectomy because little literature exists on this subject.

Obesity is a serious, multifactorial, chronic illness affecting patients of all ages. Its prevalence is continuing to increase at an alarming rate \cite{1}. Each year, 300,000 deaths in the United States \cite{2} are attributed to obesity. In the OBEPI 2009, 31.5\% of French adults over 18 years are overweight and 14.5\% are obese \cite{3}. Over the past 10 years, the treatment of severe obesity has radically changed through the benefits of bariatric surgery not only on weight loss significant and lasting, but also on reducing mortality, correction of metabolic disorders, reduction of cardiovascular risk and improving the quality of life \cite{4}. Surgery has been shown to be more effective in the management of morbid obesity than diet and lifestyle modifications. The two procedures most frequently performed are laparoscopic...
adjustable gastric band (LAGB) and laparoscopic gastric bypass (LGB), but laparoscopic sleeve gastrectomy is an increasingly used bariatric surgical procedure. Sleeve gastrectomy has gained popularity among bariatric surgeons and patients, mainly due to its relatively simple technique and its lower risk profile [5,6].

To ensure accurate evaluation, radiologists must understand the surgical technique, particularly as postoperative anatomy and surgery-specific complications can sometimes make interpretation difficult. In addition, radiologists often participate in the management of these complications (endoscopic stent placement, glue injection, percutaneous drainage).

In this pictorial review, we describe and illustrate the laparoscopic sleeve gastrectomy procedure, depict the normal postoperative findings on both fluoroscopic and CT images, and reviews the radiologic signs of complications.

Surgical technique

LSG, a restrictive operation, consists of vertical gastrectomy including the entire greater curvature of the stomach (Fig. 1). Operations are performed laparoscopically under general anesthesia. While the surgeon exposes the greater curvature, a 34 French bougie (the size varies according to the surgical team, ranging from 16 F to 60 F) [7] is introduced by the anesthesiologist into the stomach. The surgeon advances the bougie along the lesser curvature into the pyloric canal and duodenal bulb. The stapler is applied alongside this bougie strictly positioned against the lesser curve to avoid stenosis and to obtain a narrow gastric tube. Stapling starts 6 cm proximal to the pylorus [7,8] and is continued as far as the angle of His by applying traction on the fundus and antrum. If stapling is started too close to the pylorus, the antral pumping mechanism will be weakened, resulting in poor emptying of the antrum responsible for nausea [7,9]. The greater curvature, including all of the fundus and most of the corpus and antrum, is resected from the antrum. At the end of the procedure, a methylene blue test (blue fluid is introduced via a nasogastric tube, while constricting the pylorus with forceps) is performed to exclude staple line leakage [8]. The nasogastric tube is left in place at the end of the operation. Water-soluble contrast swallow studies are usually performed, 1 to 2 days after surgery, primarily to rule out staple line leaks and sleeve obstruction before removing the nasogastric tube and resuming oral intake [8,10].

Normal anatomy

In our institution, an upper gastrointestinal (UGI) series is performed 24 h after surgery with up to 250 mL of watersoluble contrast material given via a straw. As the patient swallows, one-per-second rapid sequence images of the stomach are obtained in the frontal projection, then in shallow oblique and lateral projections and finally in the reverse Trendelenburg position. The reverse Trendelenburg position can reveal a leak at the upper part of the stomach not visible on the previous views due to rapid passage of contrast material in this region and can also demonstrate reflux. A completely normal postoperative examination shows a regular sleeve around the nasogastric tube (Fig. 2) without delayed passage of contrast material and without any additional images. The staple line is sometimes not visible on the plain radiograph. In our experience, delayed passage of contrast material is often observed during the early postoperative state, presumably due to secondary edema of the pylorus and remaining stomach. The sleeve does not have a uniform shape and sometimes presents a filiform pattern, presumably due to spasm, while other sleeves may have a more "relaxed" appearance, but no correlation has been demonstrated between this appearance and the contrast passage time [10]. Sometimes the pylorus of the sleeve is also larger than expected (Fig. 3), presumably due to a wider prepyloric shape, even though resection is consistently started 6 cm from the pylorus in our institution. Another normal anatomic variant after LSG is a regular pouch at the upper part of the stomach (Fig. 3) with regular emptying [11]. This finding is due to an irregular staple line, as the upper part of the stomach is more difficult to expose and access laparoscopically than the antrypyloric region. Another hypothesis is that the surgeon applied less traction on the fundus to avoid a postoperative leak, which is the most common complication of LSG in the upper part of the stomach [8].

CT is performed only when a complication is suspected. Unenhanced CT is performed to detect hemorrhage, and a sequence is then performed after oral intake of contrast material to detect a leak or fistula and finally contrast-enhanced CT is performed to identify an abscess. These are the three main complications of LSG. CT can also be used to perform a therapeutic procedure at the same time (percutaneous drainage, glue injection). Normal postoperative CT shows a sleeve with a clearly visible staple line adjacent to the stomach with no contrast material leak or abscess in contact with the staple line. The normal

Figure 1. Diagram of sleeve gastrectomy. The greater curvature, including all of the fundus and most of the corpus and antrum is resected (curved black arrow). Staple line (white arrowhead).
variants depicted on fluoroscopy may also be observed on CT series.

Complications
Published complication rates range from 0% to 24% [8], with an overall reported mortality rate of 0.1 ± 0.3% [5].

Leak
A postoperative leak has been observed in the upper part of the sleeve in 1.3% [5] of cases and in the lower part in 0.5% of cases [5,7]. Etiologies of leaks have been divided into mechanical or technical errors for leaks occurring within 48 h and ischemic (tension, poor wound healing) for leaks occurring 5–7 days after surgery. In both instances, the intraluminal pressure exceeds the strength of the tissue and the staple line, resulting in a leak [12–15]. The leak is usually located just below the esophagogastric junction, possibly related to the high intragastric pressure with impaired peristaltic activity and ischemia, and is sometimes located in the antrum [15]. The two main consequences are abscess and fistula. UGI images may be normal [16], particularly when the leak is situated in the upper part of the sleeve due to rapid passage of contrast material. However, contrast leak usually outside the pouch along the staple line and in the subphrenic area. This preferential site could be explained by mobilization of the greater curvature of the

Figure 2. Sleeve gastrectomy anatomy. a: plain antero posterior (AP) x-ray of the abdomen showing a nasogastric tube (white arrow) and a drain (empty arrow) in contact with the staple line (black arrow); b: UGI series after LSG showing a regular sleeve around the nasogastric tube without delayed passage of contrast material; c: axial CT of upper abdomen showing a regular sleeve without leak adjacent to the staple line (black arrow).
stomach after transection of gastrocolic and gastroplenic ligaments, establishing a communication between the lesser sac and the left subphrenic space. Transient postoperative serum collection and abscess therefore also tend to form in this surgical compartment between the lesser sac and the left subphrenic and gastroplenic spaces [17].

In addition, in the presence of a high clinical suspicion of leak, and even when postoperative UGI images are normal, CT is performed to look for other associated complications such as abscess and fistula (Fig. 4), as a localized fluid collection or abscess may be the only sign of a leak and must be distinguished from transient postoperative serum collection, which is not always easy. CT can also provide other important data by showing pneumoperitoneum or extraluminal accumulation of oral contrast material. However, pneumoperitoneum alone is an extremely common postoperative finding, and extravasation of oral contrast material is rarely seen in the case of a small leak (Fig. 5).

Fistulas

The terms of fistula and leakage are often confused in most surgical series so we do not have true frequency of occurrence of this complication. Fistulas are abnormal communications between the stomach and the skin, or another organ allowing passage of fluids and secretions. The pathogenesis of fistula is more or less obvious. Typically, the subphrenic infectious process, usually due to a staple line leak, causes gastrocutaneous fistula, pleural effusion and lung infection. However, several cases of gastrobronchial fistula have been reported after bariatric surgery. Gastrocutaneous fistula (Fig. 6) and gastrobronchial fistula (Fig. 7) are two of the most serious complications. UGI studies may show passage of contrast material onto the skin or into the bronchial tree. The site of the fistulous track may be difficult to detect on UGI studies, but is more clearly visualized by CT. CT also shows mediastinal, pulmonary and subphrenic abscesses, recurrent pneumonia, and an associated pleural effusion.

Abscess

Abscess is usually secondary to leak and their frequency is not specified in large surgical series. As with all abscesses, these abscesses demonstrate rim enhancement and often contain both gas and fluid. The presence of contrast material within the abscess after oral ingestion of contrast material confirms its origin. CT is the main imaging modality

Figure 3. Normal variants. a: UGI series showing a wider than expected pylorus; b: UGI series showing a regular pouch in the upper part of the stomach with regular emptying.

Figure 4. Common site of leak. UGI series showing a leak just below the esophagogastric junction.
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Figure 5. Common site of abscess with no contrast leak visualized. a: axial CT of upper abdomen after swallowing contrast material showing an abscess (white arrow) adjacent to the upper part of the staple line (black arrow) with no contrast material leak; b: coronal CT of the upper abdomen showing the abscess in the subphrenic area extending towards the splenic hilum.

Figure 6. Gastrocutaneous fistula. a: sagittal CT of upper abdomen after LSG showing a gastrocutaneous fistula demonstrated by a track of gas bubbles (white arrow) extending as far as the upper part of the staple line; b: axial CT showing a large leak at the upper part of the staple line, responsible for this fistula.

Hemorrhage, hematoma

Postoperative hemorrhage has been observed in 1.1% of cases [7]. It may be due to inadequate vascular ligation or hemostasis, torn spleen, ulcer, or gastritis, but the main etiology is bleeding from the staple line (Fig. 9). Bleeding during the first 72 h after surgery is usually due to bleeding from the staple lines or suture lines; the blood pressure of vessels within the cut tissues is not adequately compressed by staple lines or sutures. Chronic bleeding may due to gastritis, ulcer and mostly fistula (Fig. 10). On CT, hematoma has high attenuation values (40–60 HU) at the acute stage. Chronic hematoma may be difficult to distinguish from other fluid collections or abscess, especially when the hematoma is infected.

Gastric dilatation

The incidence of gastric dilatation appears to be low, but long-term results are not yet available [18–20], as LSG is a relatively recent procedure. Gastric dilatation may be due to an excessively large pouch created during the initial phase of the operation due to missed posterior gastric folds [19].
Another hypothesis is that an excessive pressure against the pouch wall by large meals, repeated vomiting or distal obstruction, may lead to pouch dilatation [19]. In the rare reported cases, the patient presented with weight regain after successful weight reduction and upper Gl series showed a dilated gastric sleeve without any stricture or obstacle to explain this dilatation (Fig. 11).

**Stricture**

A long gastric sleeve could become stenotic, especially in the case of tight construction at the incisura angularis [9]. Delayed stenosis has been observed in 0.9% of cases according to the most recent consensus conference [7]. Strictures may occur early, within a few days, secondary to ischemia or edema, or may occur later, usually as a result of fibrosis. This fibrosis can also develop at the site of a previous leak or fistula. Fluoroscopy shows narrowing, which is responsible for expansion of the gastric pouch, and delayed transit of contrast material (Fig. 12).

**Splenic injuries**

Splenic injury occurred in 0.1% of cases [7]. Splenic injury has been reported after various operations involving dissection in the left upper quadrant [21,22]. The most common type of injury observed in our institution, based on CT findings, was splenic infarction. Other injuries, including subcapsular hematoma and laceration, are less common. Splenic infarction is due to injury or occlusion of peripheral splenic arterial branches when the surgeon exposes the greater curvature and separately coagulates the short gastric vessels close to the spleen. Contrast-enhanced CT shows a well-demarcated, peripheral, low-density triangular area (Fig. 13). Contrast-enhanced CT sometimes shows a crescent-shaped fluid collection, flattening the underlying lateral aspect of the spleen corresponding to a subcapsular collection and more rarely shows a separated low-density area in the spleen corresponding to laceration.

**Wound complications**

Laparoscopy is associated with a lower wound complication rate, but these complications can still occur. Gas bubbles or mild stranding are usually observed in the closed trocar incision. Wound infection is often diagnosed clinically, but CT can facilitate early detection by demonstrating small fluid or gas collections deep within the closed trocar incision and neighboring tissues. Another type of wound complication is strangulated hernia through the trocar orifice, which
Figure 8. Abscess at the lower part of the staple line due to a leak. a: axial CT of the upper part of the abdomen showing a large collection with a fluid level (white arrow) containing contrast material adjacent to the staple line; b: coronal CT showing the leak between two staples and the abscess (black arrow); c: axial CT showing resolution of the abscess after drainage.

Figure 9. Early hemorrhage. a: unenhanced coronal CT showing a significant hemoperitoneum (white arrow); b: enhanced axial CT showing an early leak of contrast material at the arterial phase (black arrow) adjacent to the lower part of the staple line related to bleeding from the gastroepiploic artery confirmed and treated surgically.
Figure 10. Hemorrhage in a woman with history of leak at the upper part of the stomach after LSG treated by prosthesis and percutaneous drainage. a: unenhanced axial CT showing the prosthesis in the stomach to treat a leak at the upper part of the staple line without hemoperitoneum; b: enhanced axial CT showing early leak of contrast material at the arterial phase (white arrow) due to arterial bleeding confirmed and treated during endoscopic exploration.

is usually diagnosed clinically, but the diagnosis of Richter’s hernia may require CT. Richter’s hernia is a protrusion and/or strangulation, of only part of the antimesenteric wall of the intestine through a small, rigid defect of the abdominal wall, often accompanied by necrosis [23]. An abdominal wall hematoma may rarely occur over the trocar insertion site, secondary to slipped ligatures or postoperative coagulation disorders. Unenhanced CT shows asymmetric enlargement and increased attenuation of the abdominal wall muscles (Fig. 14).

Figure 11. Secondary dilatation. a: UGI series performed 2 days after surgery showing a regular sleeve; b: UGI series performed 1 year after surgery in a context of weight gain showing a dilated gastric sleeve without any stricture or obstacle to explain this dilatation.
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Figure 12. Early stenosis. a: UGI series, oblique view; b: UGI series, antero posterior (AP) view. UGI series performed 2 days after surgery showing stenosis of the remaining stomach and dilatation of the esophagus due to postoperative edema (white arrow).

Figure 13. Splenic infarction. a: coronal CT of the upper abdomen after LSG showing a regular, peripherally-based low-attenuation triangular area corresponding to splenic infarction (white arrow); b: axial CT showing major pneumoperitoneum due to the leak at the upper part of the staple line.
Figure 14. Abdominal wall hematoma over the trocar incision. a: axial CT of the upper abdomen showing a spontaneous high attenuation subcutaneous collection over the trocar incision (white arrow); b: sagittal CT of the upper abdomen showing the subcutaneous hematoma (white arrow) and infiltration of the splenic hilum related to recent surgery (arrowhead).

Conclusion

As LSG is performed increasingly frequently, it is essential for radiologists to understand the normal postoperative anatomy and recognize the complications of this procedure, as a good knowledge of the surgical procedure avoids confusing normal postoperative anatomy with complications (Fig. 15). In most of the centres UGI studies remain the first-line imaging modality for follow-up and detection of complications and CT is performed as a second-line procedure to ensure accurate diagnosis or in the case of mismatch between symptoms and imaging. Now it seems that CT can substitute for UGI as the first-line imaging before any suspected complications of sleeve gastrectomy because UGI is often few contributing: it does not detect abscesses, hematomas and small leak. Moreover, CT allows to diagnose complications but also to adapt the therapeutic strategy.
Figure 15. Nasogastric tube cut and stapled in the remaining stomach. a: axial CT showing a small part of nasogastric tube in the stomach (white arrow); b: maximum intensity projection (MIP) reconstruction showing a small part of the nasogastric tube that has been stapled in the stomach (black arrow); c: MIP reconstruction after swallowing contrast material does not show any leak.

Disclosure of interest
The authors declare that they have no conflicts of interest concerning this article.

References


