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PICTORIAL ESSAY

A guide to imaging in bariatric surgery

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Abstract There has been an increase in utilization of bariatric surgery and, as with any surgical procedure, the associated risk of complications. Many of the post bariatric surgical complications can be acute, necessitating an emergency room visit and imaging evaluation. Radiologists, especially in the emergency setting, need to be familiar with normal post-operative appearances and potential surgical complications. This review focuses on various bariatric surgical procedures that are performed, and illustrates normal and abnormal radiographic appearances seen on post-operative fluoroscopic upper GI studies and abdominal pelvis CT examinations.

Keywords Bariatric · Surgery · Obesity · Fluoroscopy · Computed tomography

Introduction

Obesity is a fast-growing public health problem in Western countries. Based on body mass index (BMI), more than 50 % of Americans are now overweight (BMI>25) or obese (BMI>30) [1]. There was a 74 % increase in obesity from 1991 to 2001 in the USA. Currently, approximately 36 % of US adults and 17 % of US children ages 2–17 are obese [2]. With the high prevalence of obesity, there is concomitant widespread utilization of bariatric surgery for weight reduction and control. From 1990 to 2000, the national annual rate of bariatric surgery increased nearly sixfold, from 2.4 to 14.1 persons per 100,000 with little change in morbidity and mortality [3], and the rate has continued to increase.

Routine radiologic evaluation following gastric bypass surgery involves a short-term post-operative fluoroscopic upper GI procedure, with either water-soluble iodinated or barium contrast, based on the preference of the ordering clinician (some clinicians prefer barium contrast material use for better visualization of complications, particularly small leaks) [4]. While routine inpatient evaluation is usually performed by an abdominal radiologist, it is not unusual to encounter these patients in an emergency room with potential early or late complications including leak, abscess, or bowel obstruction, making knowledge of the normal and abnormal postsurgical imaging findings crucial in arriving at the correct diagnosis of potential complications. We discuss various bariatric surgical procedures and illustrate radiographic appearances of normal postsurgical anatomy and potential early or late complications.

Technical Considerations

At the authors' institution emergent radiologic evaluation of patients with prior weight-loss surgery could include fluoroscopy, CT, or both. Fluoroscopy is preferred with cooperative patients and when the clinician strongly suspects a post-surgical etiology. In this case, both overhead and fluoroscopic spot "scout" images are performed prior to contrast ingestion as they are very helpful to use for comparison in evaluating for small and/or subtle leaks. Fluoroscopic monitoring is then performed while the patient takes sips of either water-soluble iodinated or barium contrast, depending on the clinician's preference, patient allergies to iodinated contrast, and risk of aspiration. Cine video clips are

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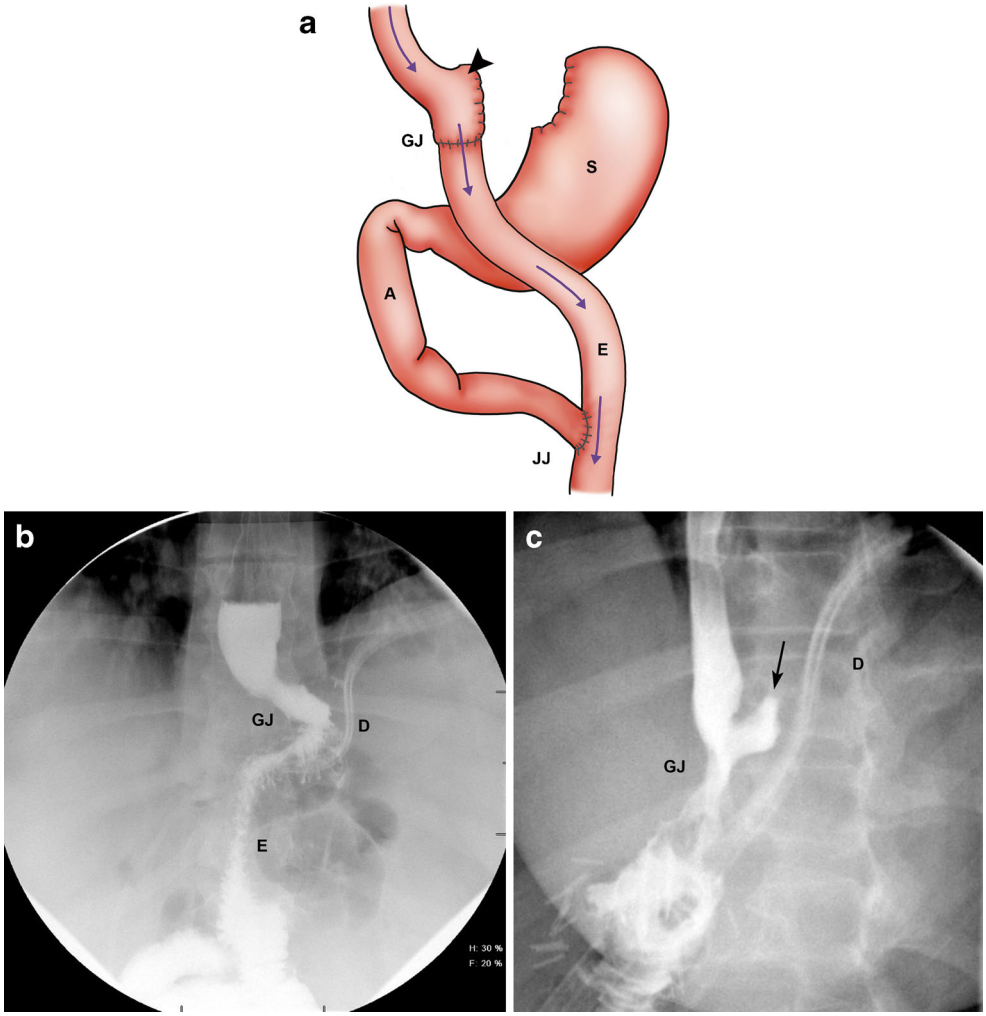

Fig. 1 Normal post-operative appearance after Roux-en-Y gastric bypass surgery. **a** Graphic illustration, and **b** fluoroscopic upper GI contrast study show a small gastric pouch (*arrowhead*) leading into the efferent limb (*E*)through the gastro-jejunal anastomosis (*GJ*). Excluded stomach (*S*) is connected via the afferent limb (*A*) at the distal jejunojejunostomy (*JJ*). A surgical drain (*D*) is visible in **b**. **c** shows a variant of normal post-operative anatomy in which a small, blind outpouching is seen at the gastro-jejunal anastomotic site, also known as a "rabbit ear" (*arrow*) representing a small part of the efferent limb from end-to-side anastomosis with the gastric pouch

usually acquired during single swallows to evaluate for leak. Ideally images are acquired in the upright and semi-upright positions to fully evaluate the post-surgical anatomy. Another overhead scout image is obtained after the study to evaluate for any extraluminal contrast that collected during the procedure.

For patients with difficulty standing or with other potential etiologies for their illness such as small bowel obstruction, CT is favored [5]. In this case, the patient should drink either water-soluble or barium contrast 2 h before the exam; a small amount of oral contrast can be administered just before the scan so that contrast is seen in the proximal GI tract. Our institution acquires axial CT images and then performs coronal and sagittal reformats for every case.

Roux-en-Y gastric bypass

Roux-en-Y gastric bypass (RYGB) introduced by Griffen in 1977 is the most commonly performed weight-loss surgery in the USA. The procedure involves dividing the stomach to create a small 15–30-mL capacity gastric pouch just caudal to the esophagogastric junction [6]. The remainder of the stomach is then excluded from contact with food and liquid and is called the "remnant stomach." The jejunum is subsequently divided 30–40 cm distal to the ligament of Treitz and a segment isolated to create side-to-side gastrojejunostomy with the gastric pouch and a distal anastomosis with the small bowel 100–150 cm distal to pouch. This isolated limb is called the "Roux limb" or "efferent limb." The remnant excluded stomach remains connected to the proximal small bowel (termed the "afferent limb" or "biliary limb") in a normal fashion (Figs. 1 and 2). Sometimes a small, blind outpouching is seen at the gastro-jejunal anastomotic site, also known as a "rabbit ear" (Fig. 1), representing a small part of the efferent limb from end-to-side anastomosis with the gastric pouch. This could easily be confused with a leak during fluoroscopy, and direct fluoroscopic visualization focused to this area is helpful with

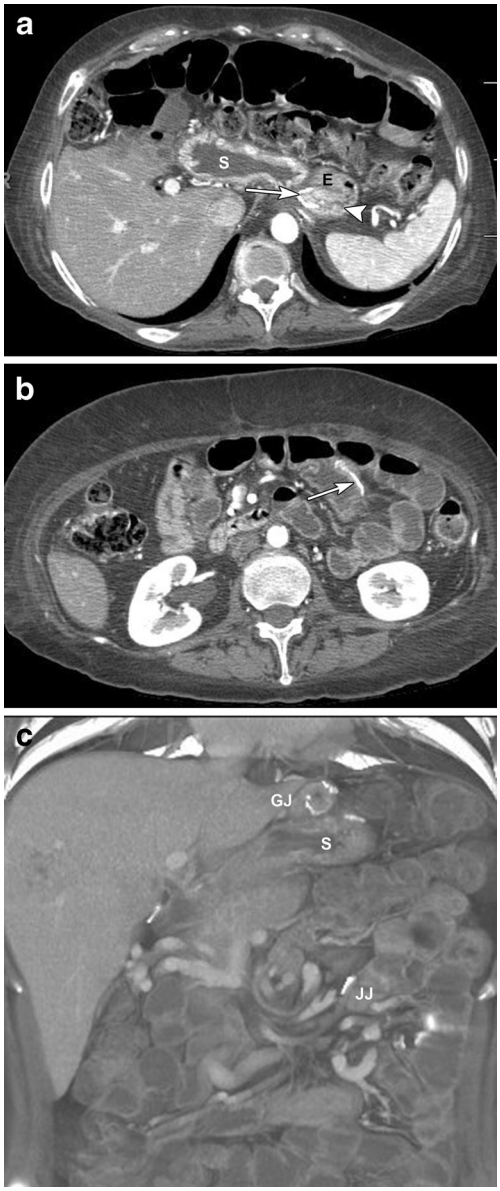

Fig. 2 Normal CT appearance of Roux-en-Y gastric bypass surgery. **a**, **b** Contrast-enhanced axial CT images at upper and mid-abdomen level, respectively. The gastric pouch (*arrowhead*) is separated from the remnant stomach (*S*) by staple line (*arrow* in **a**), and leads into the efferent limb (*E*). Jejunojejunostomy site is represented with staple line in left mid abdomen (*arrow* in **b**). **c** is a coronal reformatted 3D volumetric CT image. The proximal (*GJ*) and distal (*JJ*) anastomotic sites are recognized by the surgical suture lines; *S* represents the excluded stomach

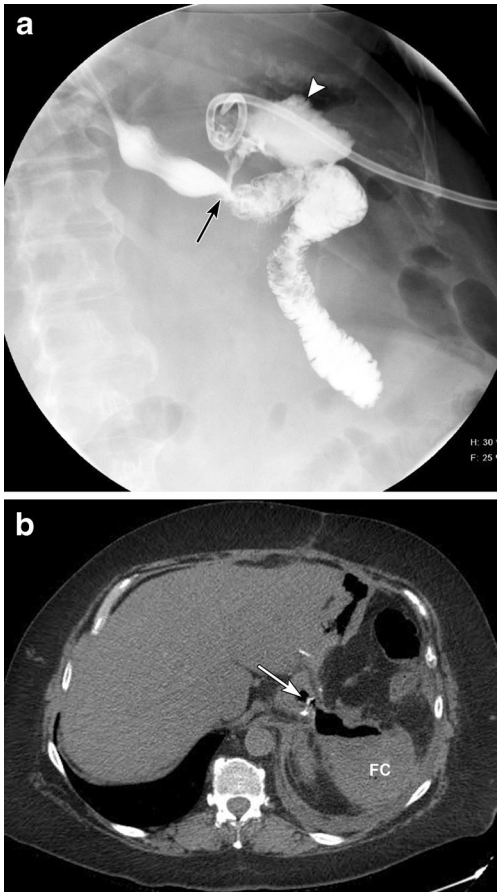

Fig. 3 Anastomotic leak following Roux-en-Y gastric bypass surgery. **a** Upper GI series using water-soluble non-ionic iodinated contrast performed early in the post-operative period, demonstrates extraluminal contrast material (*arrowhead*) adjacent to the gastrojejunal anastomotic site (*arrow*), consistent with an anastomotic leak; the pigtail drain seen in the image had been placed a week earlier for this same leak. **b** Correlative axial unenhanced CT image from the same patient as in A demonstrates a gas-containing fluid collection (*FC*) in the left upper quadrant. The site of the leak is noted next to the anastomotic site (*arrow*)

the "rabbit ear" showing filling and eventual emptying of the outpouching as the patient drinks the contrast, while in true leak will extraluminal contrast will remain consistent, increase or even disperse freely into the abdominal cavity.

The RYGB procedure utilizes both restrictive (small gastric pouch allows less food volume) and malabsorptive (altered bowel anatomy disrupts normal absorption) methods for weight loss, and in doing so achieves more permanent weight loss than other methods. Laparoscopic technique introduced in 1994 allows for quicker recovery. While perioperative complications remain higher in Roux-en-Y bypass (9 %) than is seen with some other methods discussed below, long-term re-operation rates are lower (16 %) [7].

Post-surgical complications after Roux-en-Y bypass can be divided into "early" and "late" categories. Leaks are the most important complication. Early leaks due to anastomotic or suture line disruption can be detected with fluoroscopic contrast upper GI studies (Fig. 3). Free extravasation of contrast is seen near the suture line and/or gastric pouch, with collection and subsequent dispersal of contrast in the peritoneal cavity; post-procedure scout images are especially

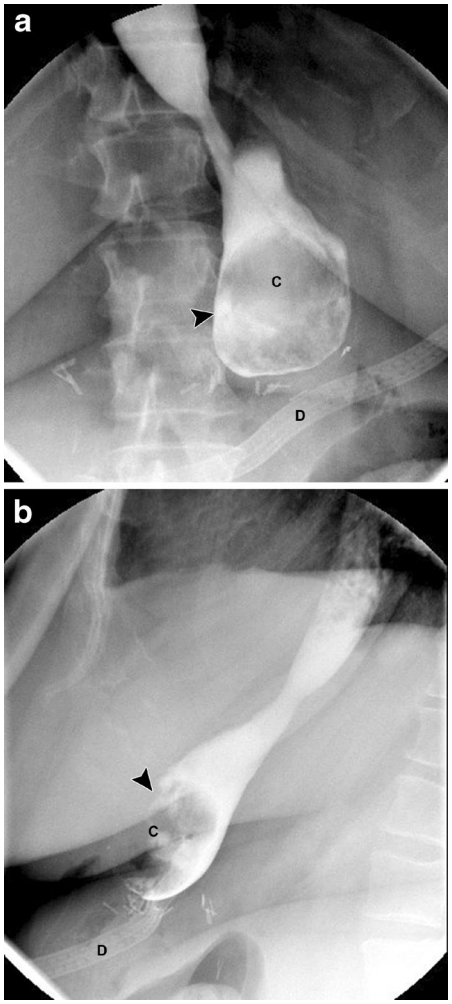

Fig. 4 Obstruction of gastric pouch following Roux-en-Y gastric bypass surgery. **a** Frontal and **b** right lateral images from an upper GI fluoroscopic image show hold-up of water-soluble iodinated contrast in the gastric pouch (*arrowheads*), with a large filling defect (*C* = confirmed as clot on endoscopy) and no discernible gastric emptying. *D* = surgical drain

Fig. 6 Disruption of staple line between gastric pouch and excluded stomach following Roux-en-Y gastric bypass surgery. Late postoperative upper GI fluoroscopic image shows filling of the excluded portion of the stomach (*S*) with orally administered contrast material, indicating abnormal communication between the gastric pouch (*GP*) and the excluded gastric remnant

helpful for finding leaks on fluoroscopy, while CT will show a collection of contrast outside of the bowel lumen. Another early complication is obstruction of the newly formed gastric pouch due to clot formation which can also be seen fluoroscopically as filling defects in oral contrast opacified gastric pouch, either on CT or fluoroscopy (Fig. 4).

Late complications include leaks due to perforated marginal ulcers, usually located close to the gastrojejunostomy (Fig. 5). Disruption of the staple line between the gastric pouch and remnant stomach can also occur, resulting in abnormal passage of administered oral contrast material into the excluded remnant stomach. This can be easily seen on fluoroscopy

Fig. 5 Marginal ulcer following Roux-en-Y gastric bypass surgery. Late post-operative upper GI fluoroscopic image shows extravasation of contrast (*arrow*) from the gastric pouch (*GP*) near the anastomotic site (*GJ*). Subsequent endoscopy showed a marginal ulcer with perforation

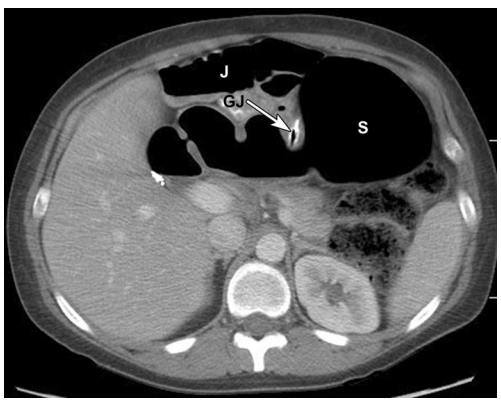

Fig. 7 Bowel obstruction after Roux-en-Y gastric bypass surgery. Late post-operative contrast-enhanced axial CT image of a patient with a distal small bowel obstruction past the jejunojejunal anastomosis (not pictured), causing upstream gaseous distension of duodenum and excluded stomach (*S*) and also the jejunum (*J*) anterior to gastrojejunostomy (*GJ*) with *arrow* indicating the white surgical suture material at the gastrojejunostomy

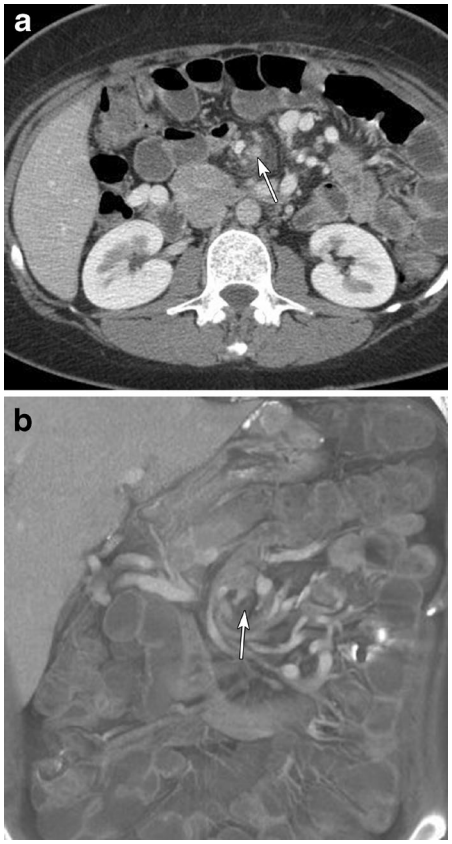

Fig. 8 Petersen's hernia following Roux-en-Y gastric bypass surgery. Axial (**a**) and coronal reformatted (**b**) contrast-enhanced CT images in a patient with prior Roux-en-Y bypass. The mid-superior mesenteric vein (*arrow*) becomes narrowed with swirling of the mesenteric vessels and multiple dilated collateral venous channels. Surgery confirmed internal hernia of the efferent limb through Petersen's space, causing chronic SMV occlusion

(Fig. 6) or CT. If there is no associated extraluminal leak, the patient may have minimal symptoms, only experiencing nausea and bloating due to increased drainage through the afferent limb.

Small bowel obstruction following Roux-en-Y bypass has been described with an overall incidence of up to 4.4 % [8]. Although thought to be a late complication, bowel obstruction can occur at any time [9]. Most of these small bowel obstructions are due to abdominal adhesions. The obstruction can be detected on conventional abdominal radiographs, upper GI series, and on CT (Fig. 7), using similar criteria as for any bowel obstruction with dilated bowel loops and possibly a transition point. Because imaging findings of the small bowel obstruction will be nonspecific, it is the clinical history and knowledge of post-operative anatomy that guide the radiologist to the diagnosis.

Internal hernias are another late complication and occur due to the creation of a mesenteric potential space after the gastrojejunostomy; these may develop in either the antecolic or retrocolic position of the efferent limb. In a so-called Petersen's hernia, small bowel moves into a potential space (Petersen's space) between the caudal surface of the transverse mesocolon and the mesentery of the Roux limb (Fig. 8) [10]. Imaging findings include displacement of mesenteric vessels and potentially dilated bowel that has herniated through the mesentery. Sometimes these internal hernias cause small bowel obstruction, which can be evaluated with CT [11].

Laparoscopic adjustable gastric banding

Laparoscopic adjustable gastric banding was developed as a means for better patient management during long-term weight loss, and though it is more popular in Europe, it has been increasingly utilized in the USA [12]. This method is the least invasive of the weight loss surgeries, as no cutting or re-routing of bowel is necessary. This procedure is also reversible

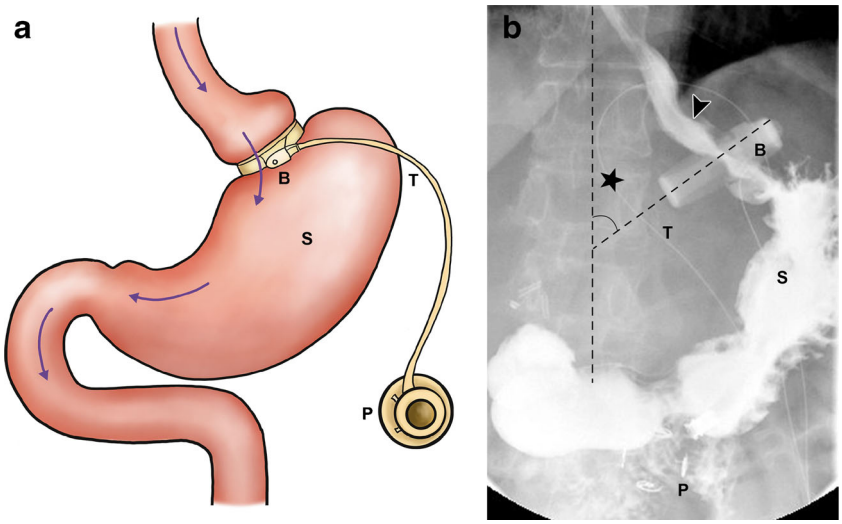

Fig. 9 Normal post-operative appearance after gastric banding. **a** Graphic illustration and **b** upper GI fluoroscopic spot image show the adjustable gastric band (*b*) creating a small gastric pouch (*arrowhead*), which empties into the remainder of the stomach (*S*). The band is composed of an inflatable balloon, which is attached via tubing (*T*) to a subcutaneous port (P). The *star* indicates the phi angle, which is measured from the angle of the band compared to a vertical line, as pictured. This phi angle is 49°, which is within normal range

(i.e., the band can be removed). Gastric banding involves placement of an adjustable silicon band with an internal inflatable balloon around the proximal stomach, thereby creating a small gastric pouch (3–4 cm) with an entrance whose diameter can be altered, but which is preferably about 3–4 mm in diameter [13, 14]. The balloon is inflated or deflated by injecting or aspirating saline from a subcutaneous port, which is attached to the balloon via kink-resistant tubing (Figs. 9 and 10) [15]. Measurement of the "phi angle", which defines the angle between the spinal column (or a vertical line, if the spine has curvature) and the long axis of the gastric band, can help determine whether the band is in the appropriate position. A normal phi angle ranges from 4° to 58° (Fig. 9) [16].

Gastric banding has been promoted as a safe, less invasive alternative to Roux-en-Y bypass, with shorter operating room time and shorter hospital stay during the procedure, as well as a lower rate of peri-operative complications, but with decreased weight loss in comparison to RGYB. Postsurgical radiologic study involves evaluation of the position and function of the gastric band. One of the most common post-operative complications is overtightening of the band. The band should not obstruct the flow of contrast, an abnormality which can be identified on a fluoroscopic upper GI study as prolonged hold-up of contrast proximal to the band (Fig. 11). Conversely, a band that is too loose may be difficult to identify on a radiologic study. The best indicator of a loose band is a history of difficulty with weight loss, which suggests that the band is not restricting intake sufficiently.

Band slippage, another common complication, can occur in both the acute and chronic setting and can be seen in up to 15–20 % of patients, most frequently occurring distally (Fig. 12). The phi angle can be best measured on a fluoroscopic image or on a CT scout image as a line parallel

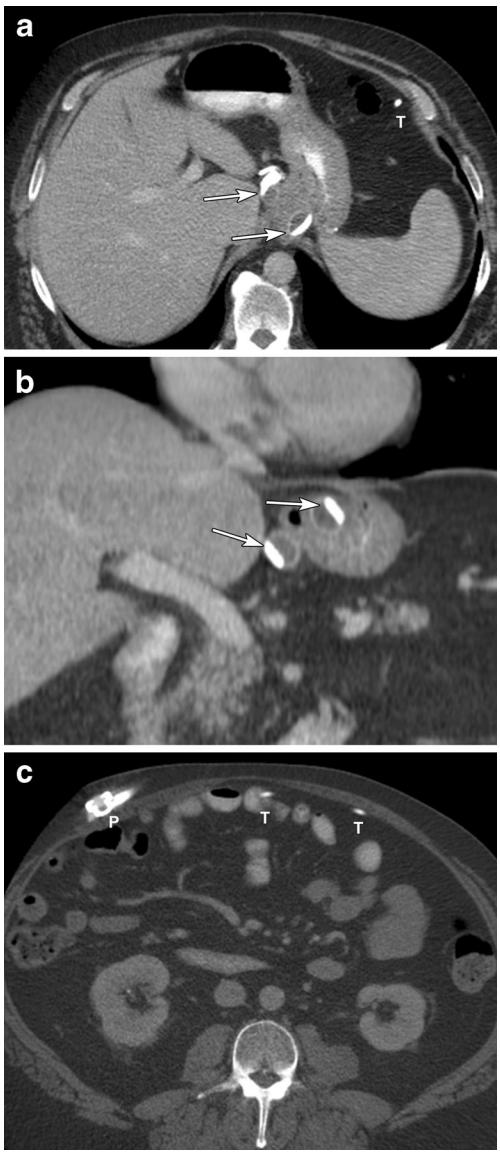

Fig. 10 Normal post-operative appearance after gastric banding. Axial (**a**, **c**) and coronal reformatted (**b**) CT images demonstrate normal anatomy after gastric band placement. The high attenuation band (*arrows*) creates an area of narrowing at the outlet of the gastric pouch. The fluid-attenuation inflatable balloon is visible inside the band. The tubing (*T*) is seen connecting the balloon to the subcutaneous port (*P*)

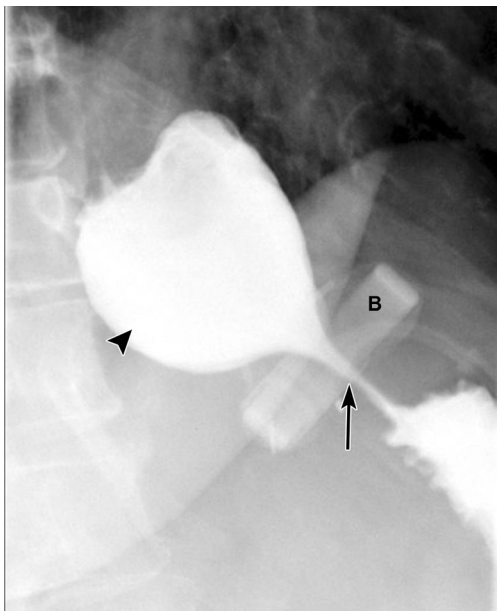

Fig. 11 Over-tightening of the gastric band. Late post-operative upper GI fluoroscopic image shows persistent hold-up of contrast material in the gastric pouch (*arrowhead*) with very slow emptying into the remainder of the stomach through the narrowed outlet (*arrow*). The narrowed outlet never widened during fluoroscopic monitoring over approximately 20 min

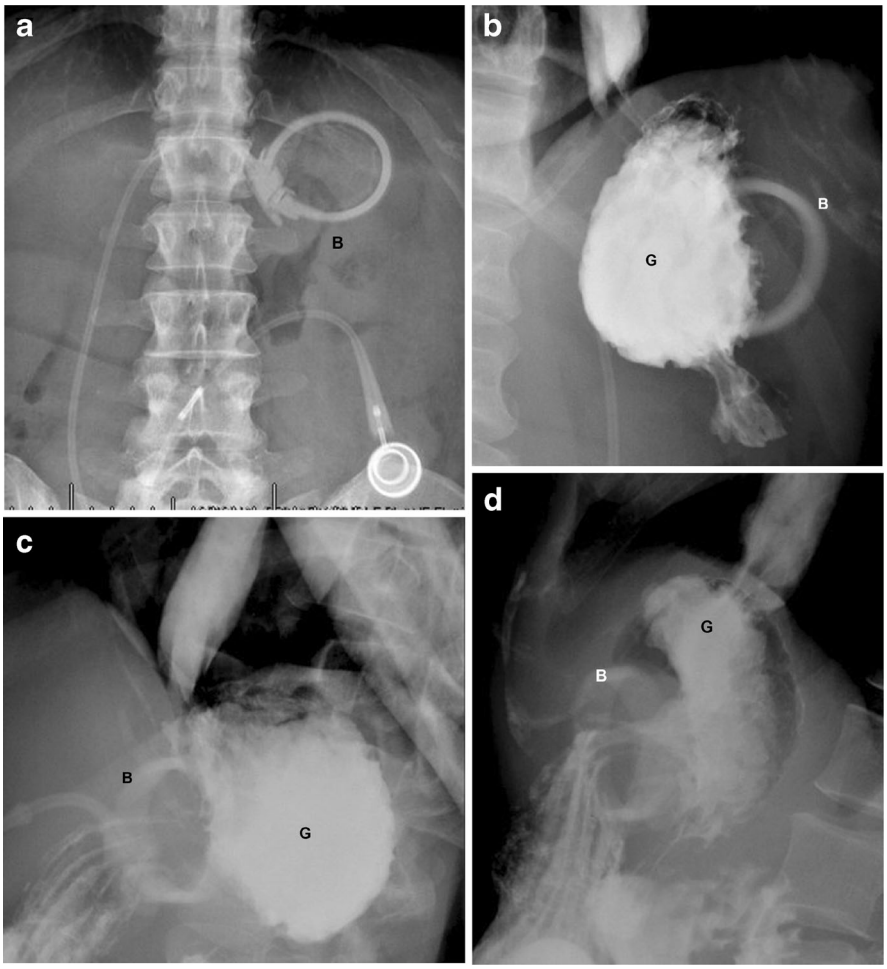

Fig. 12 Slippage of gastric band demonstrated on an upper GI series. **a** Scout radiograph shows the abnormal en face, vertical orientation of the band (*B*) with altered phi angle. **b**, **c**, **d** Upper GI fluoroscopic spot images demonstrate near complete filling of the now-enlarged gastric pouch (*G*) with orally administered contrast material. The band (*B*) has moved too far inferiorly and is no longer constricting the superior portion of the stomach into a small pouch. Patients with this complication may present with slowed or absent weight loss after initial success

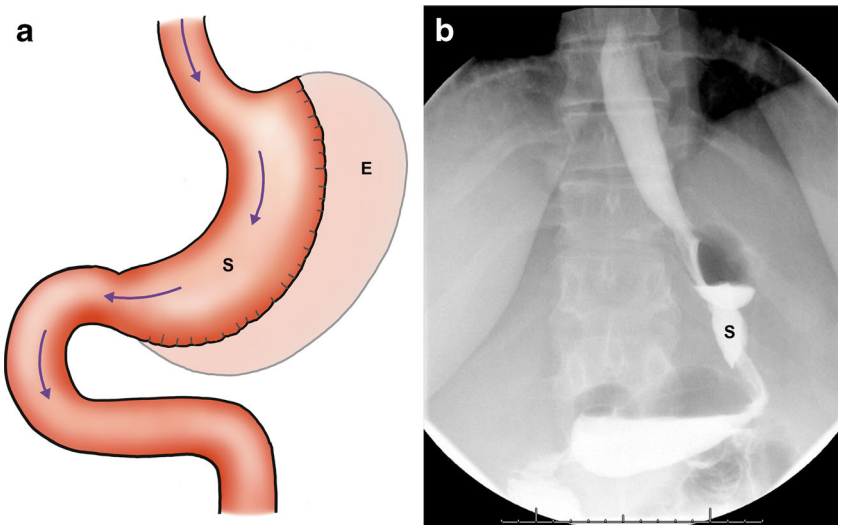

Fig. 13 Normal post-operative appearance after sleeve gastrectomy. **a** Graphic illustration and **b** image from an upper GI fluorosopy demonstrate the normal post-operative appearance following sleeve gastrectomy. The elongated staple line forms a thin gastric "sleeve" (*S*) of low capacity along the lesser curvature of the stomach. The excluded portion of stomach (*E*) is removed. The distal connection of the stomach to small bowel is preserved

to the gastric band and vertical/spinal line as mentioned above [8]. Any deviation from the phi angle from the normal range, or abnormal band position or eccentric pouch dilation, should suggest band slippage [14]. An oval or O-shaped appearance of the band ("en face") has been suggested a radiographic feature of band slippage, usually posteriorly [17].

Other complications after gastric banding include chronic pouch dilation, which can occur due to excessive food intake, and leakage from or migration of the port in the subcutaneous tissues.

A large pouch can be seen either on fluoroscopy or CT, and comparison with early post-operative studies is most helpful in this situation. Migration of the port can be assessed with plain radiography or might be noticed during fluoroscopy or CT.

Sleeve gastrectomy

Sleeve gastrectomy was originally developed as bridge to a Roux-en-Y bypass surgery, but because patients lost significant weight after this "first step" procedure, it is now also used as stand-alone surgery. The procedure itself is essentially a greater curve gastrectomy using a line of staples (Figs. 13 and 14 show normal anatomy). Sleeve gastrectomy utilizes restrictive gastric size and resulting hormonal alterations and malabsorptive properties to produce weight loss. Overall, the average excess weight loss following this procedure is 61 %, with a morbidity and mortality comparable to that of adjustable gastric banding [18].

Complications after sleeve gastrectomy include staple line bleeding, leak, stricture, and fistula formation. Leaks along the staple line are the most feared complication of this procedure believed to be due to heat ischemia of the gastric wall during electrocautery [4]. Similar to other procedures, leaks are seen either on fluoroscopy or CT and free or loculated extraluminal contrast, and attention should be paid to the staple line as a site of contrast extravasation. Strictures can occur somewhat later in the post-operative course, and a fluoroscopic upper GI study can illustrate the abnormally narrowed gastric sleeve in patients who develop this complication (Fig. 15).

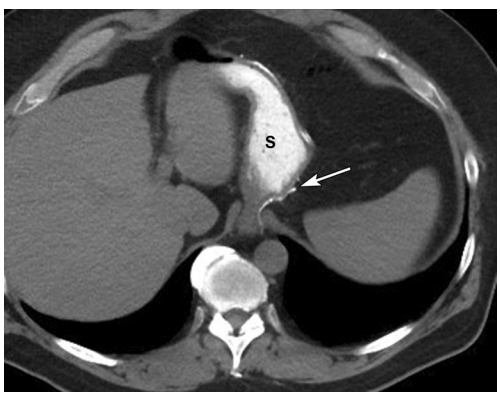

Fig. 14 Normal post-operative appearance after sleeve gastrectomy. Axial unenhanced CT image through gastric level demonstrates the elongated staple line (*arrow*), which again creates a narrowed stomach lumen "sleeve" (*S*) along the lesser curvature

Vertical banded gastroplasty

Vertical banded gastroplasty (VBG) is a relatively older procedure that was developed to create a small gastric pouch as a means for food restriction. Mason started using VBG in 1980, followed by Chua and Mendiola who first performed VBG laparoscopically in 1995 [19]. The surgery involves creation of a small gastric pouch along the lesser curve, with exclusion of the remainder of the stomach and placement of a band around the exit window from the pouch (Fig. 16).

Early post-operative complications after VBG include leak, bleeding from the staple line, and abscess formation [12]. Leak is well-evaluated on a fluoroscopic upper GI study, but bleeding from the staple line and abscess can be seen better on CT than fluoroscopy. Later complications include stricture and/or stomal narrowing, pouch enlargement, food impaction, and disruption of the staple line. Radiologic evaluation with fluoroscopic upper GI studies can evaluate patients for these complications. Figure 17 shows the delayed complication of

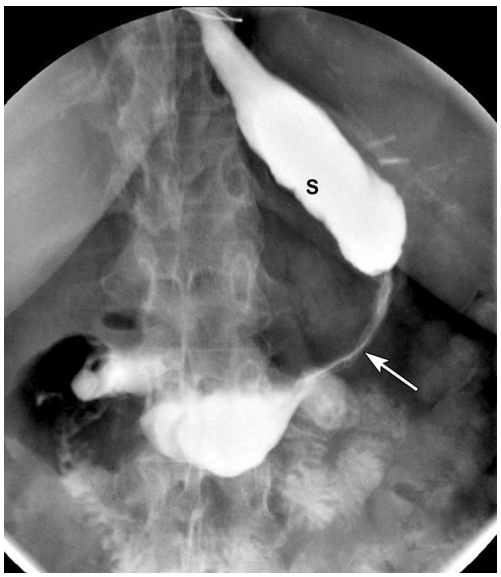

Fig. 15 Stricture formation after sleeve gastrectomy. Frontal view of an upper GI fluoroscopic study shows a normal proximal portion of the gastric sleeve (*S*). More distally, the sleeve is substantially narrowed (*arrow*). This was a persistent finding consistent with a "tight sleeve" configuration, an abnormality which was confirmed during surgery

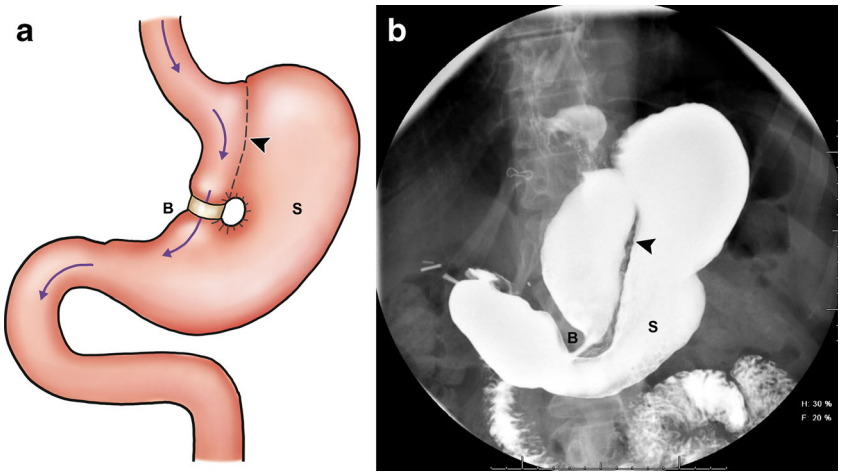

Fig. 16 Normal post-operative appearance after vertical banded gastroplasty. **a** Graphic illustration and **b** upper GI fluoroscopic image. The vertical staple line along the long axis of the stomach (*arrowheads*) creates a narrowed entrance to the stomach, and the gastric band (*B*) creates a narrow outlet. The remainder of the stomach (*S*) is left in place and is connected distally to the pouch via the gastric band

stricturing at the outlet of the gastric pouch causing proximal dilation and obstruction.

Jejunoileal bypass

Jejunoileal bypass was one of the first weight loss surgeries to be performed, having been reported in the published literature by Kremen in 1954 [20]. This procedure involves creating an end-to-side anastomosis of the proximal 35 cm of jejunum to the terminal ileum, located 10 cm from the ileocecal valve. The majority of the small bowel is therefore excluded (Fig. 18).

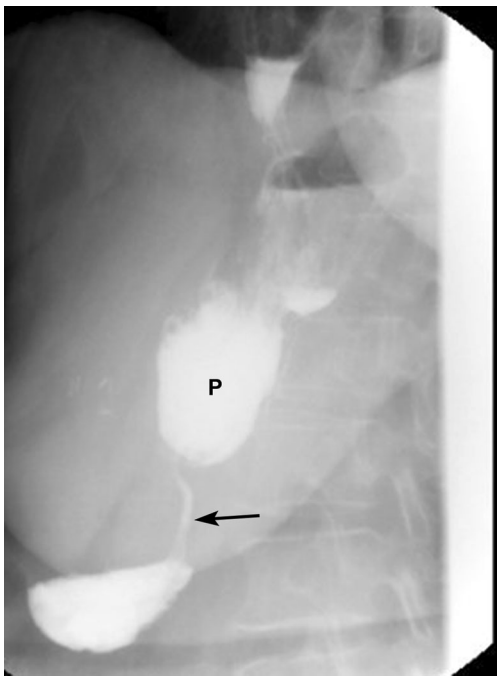

Fig. 17 Stricture at gastric pouch outlet following vertical banded gastroplasty. Fluoroscopic spot image of an upper GI study late after vertical-banded gastroplasty shows orally administered contrast material and gas within the vertical gastric pouch (*P*) with a severely narrowed outlet (*arrow*), which was persistent during the entire fluoroscopic study. This narrowed area represents a high-grade stricture at the level of the gastric band

The jejunoileal bypass procedure is no longer in use due to the severe side effects that have been encountered, including liver disease and liver failure, malnutrition, electrolyte imbalance, renal stones, and gallstones, and a nearly 50 % hospital re-admission rate [21]. Nevertheless, many patients who underwent this operation still present for clinical care, and, therefore, knowledge of the radiographic appearance in patients who have had jejunoileal bypass surgery is important for this reason.

On small bowel follow-through examinations performed in patients who have had these procedures only a small portion of small bowel will be opacified with enteric contrast material. It is important to obtain the correct clinical history in order to distinguish changes from a jejunoileal bypass from those after small bowel resection on barium studies, although CT can help clearly identify the difference. One of the important late complications following jejunoileal bypass surgery is small bowel obstruction at the anastomosis (Fig. 19). This has similar imaging findings as any small bowel obstruction, but the post-surgical changes including the absence of long segment of small bowel and the distal anastomosis can suggest the etiology.

Conclusion

Bariatric surgeries are increasing in frequency due to the increasing prevalence of obesity in Western society. While some bariatric surgeries are currently favored, including Roux-en-Y bypass surgery and adjustable gastric banding,

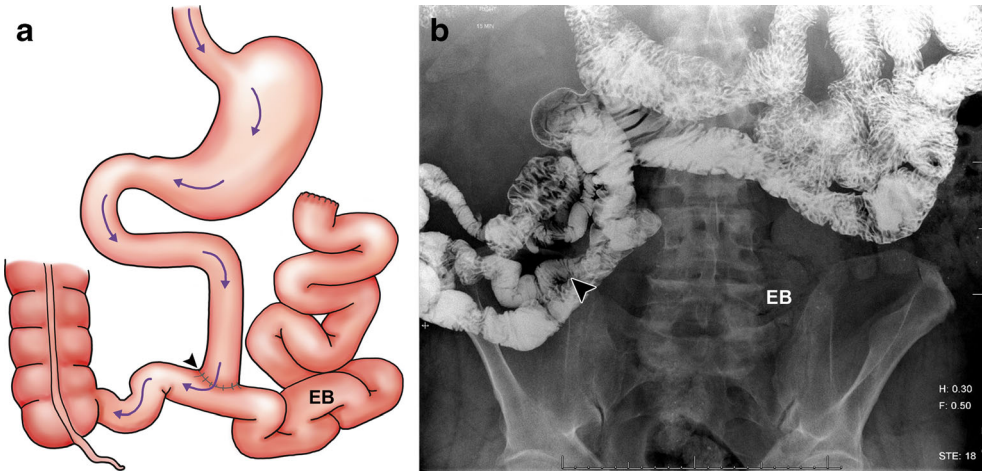

Fig. 18 Normal post-operative appearance after jejunoileal bypass. **a** Graphic illustration and **b** spot image from small bowel follow-through study illustrate the normal appearance after jejunoileal bypass surgery. The anastomosis of the proximal jejunum to the distal ileum can be identified on both images (*arrowheads*). The extensive excluded small bowel (EB) is not opacified with the orally administered contrast material on the fluoroscopic study (**b**)

others, such as sleeve gastrectomy and vertical-banded gastroplasty, are less commonly performed but may be encountered in patients presenting to the emergency room. Knowledge of expected normal postoperative appearance with the resulting altered anatomy and of the appearance of both short-term and long-term complications on upper GI studies and computed tomography is crucial to patient management.

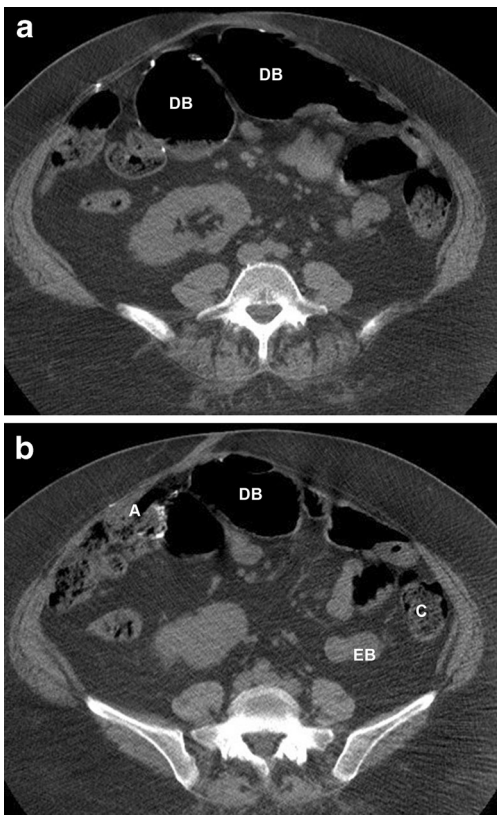

Fig. 19 Bowel obstruction after jejunoileal bypass surgery. Axial unenhanced CT images through the mid abdomen at two different levels in a patient with prior jejunoileal bypass shows multiple loops of dilated anteriorly located small bowel (*DB*) due to an anastomotic stricture. There is no dilatation of the excluded small bowel (*EB*) and also the colon (*C*). The clinical history and timeframe are key to suggesting this diagnosis; mechanical bowel obstruction should be considered in patients with prior jejunoileal bypass and a transition point at the anastomotic site

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Conflict of interest The authors declare that they have no conflict of interest.

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