2 Radiology in the Acute Bariatric Patient

Dustin R. Roberie and Thomas F. Murphy

Introduction

Obesity prevalence within the US adult population was calculated at 39.8% during 2015–2016 [1]. Furthermore, these data demonstrate a continuing upward trend from 30.5% in the year 2000. It is probable that obesity-related healthcare concerns will be increasingly commonplace.

The history of modern surgical management of obesity began in 1954 when Dr. Kremen et al. evaluated the role of intestinal absorption in dogs, subsequently leading to the practice of jejunoileal bypass [2]. This early technique proved successful for weight loss, though many patients experienced a host of complications related to malabsorption. In some cases, bacterial overgrowth within the excluded small bowel segment would culminate in liver failure. Ultimately, reversal of the procedure was sometimes required. This first attempt at weight loss surgery led to development of new techniques seeking to minimize complications.

Today a variety of surgical techniques are employed by bariatric surgeons relying upon various means of mechanical caloric restriction combined with the secondary effects of decreased absorption and hunger satisfaction. This chapter aims to provide a brief overview of the role radiology plays in the postsurgical complications of the most commonly performed bariatric procedures.

D. R. Roberie · T. F. Murphy (✉)
Department of Radiology, Tripler Army Medical Center, Honolulu, HI, USA

Abdominal Imaging

Imaging of the bariatric patient necessitates a multimodality approach with selection of specific diagnostic imaging studies determined by a variety of clinical factors. In the immediate postsurgical patient, there is concern for anastomotic leak. Patients not within the immediate postoperative period are more likely to develop complications as a result of their altered anatomy or surgical failure. These complications come in the form of bowel obstruction secondary to anastomotic stricture or internal hernia, gastrogastric fistula formation, or marginal ulcers at the gastrojejunal anastomosis.

Abdominal Radiographs

Evaluation of the acute abdomen often begins with plain abdominal radiographs, which may aid in the detection of bowel obstruction or perforation. Since abdominal radiographs are insensitive for most complications related to bariatric procedures, normal radiographs should not delay further workup.

R. Lim (ed.), *Multidisciplinary Approaches to Common Surgical Problems*,
https://doi.org/10.1007/978-3-030-12823-4_2

Upper GI

For evaluation of anastomotic leak or stricture, especially in the perioperative period, fluoroscopic upper gastrointestinal series (UGI) is the classic study of choice as it allows for dynamic assessment of the surgical anatomy. The specific imaging protocol for this procedure varies based upon the clinical question and time since surgery. If the patient is recently postoperative and there is suspicion for anastomotic leak, water-soluble contrast is substituted for barium. Water-soluble contrast avoids the risk of barium peritonitis should a leak be present. For this procedure, initial scout abdominal radiographs are obtained. The patient then consumes a small volume (<100cc) of contrast in the upright position, while the radiologist obtains fluoroscopic images in multiple projections. Prone and supine images are also obtained in multiple projections to visualize the surgical anatomy. After the fluoroscopic portion of the examination, overhead abdominal radiographs, which provide full coverage of the abdomen, should be obtained. Full abdominal coverage is imperative, as leaked intraperitoneal contrast material typically spreads in the peritoneal cavity to the dependent portions of the abdomen; a small field of view radiographs may exclude these collections.

Computed Tomography

Acutely, computed tomography (CT) is performed more often than UGI, as it is more readily available and more likely to provide an explanation for acute abdominal pain. Imaging protocols for abdomen and pelvis CT in post-bariatric surgery patients vary with the institution and the clinical question. For primary CT investigation of anastomotic leak, the patient is given at least 100 mL water-soluble contrast orally and then immediately scanned in order to best visualize the upper abdominal surgical anatomy and detect a leak. It is important to note that oral contrast used for CT is diluted, with an iodine concentration 2 orders of magnitude less than IV contrast. Should the patient drink undiluted contrast, the resultant artifacts may ruin the diagnostic value of the CT scan; therefore, properly diluted oral contrast should be obtained from the CT technologist. If the patient has a remote history of RYGB and presents with symptoms suggesting bowel obstruction, appendicitis, diverticulitis, or other acute abdominal process, then a larger volume of oral contrast (at least 500 mL) should be consumed, and CT of the abdomen and pelvis should be performed after only a 1-hour delay to allow better bowel opacification. In either case, IV contrast, unless contraindicated by allergy or renal failure, is helpful and should also be used. The use of CT to diagnose acute pulmonary embolism is discussed below.

MRI and Ultrasound

There is no role for routine use of MRI or ultrasound in the acute bariatric patient. Neither modality reliably shows extraluminal leakage of contrast material, which is an abnormal finding of utmost importance. MRI and ultrasound are insensitive for the detection of bariatric surgical complications when compared to fluoroscopy and CT.

Surgical Procedures and Complications

Imaging of the bariatric patient requires knowledge of normal postsurgical anatomy. The different operations have distinctive radiographic manifestations. Some complications, such as intestinal leak and obstruction, are generic; others may be specific to particular procedures.

Roux-en-Y Gastric Bypass

Initially developed in the 1960s and gradually modified to its current form, Roux-en-Y gastric bypass (RYGB) has, up until very recently, been the most frequently performed bariatric procedure [3]. Given the historic prevalence, patients who have undergone RYGB are most commonly encountered.

Roux-en-Y gastric bypass entails partitioning the fundus to make a small gastric pouch, separated from a much larger excluded component of the stomach or "gastric remnant." The jejunum is divided distal to the ligament of Treitz, and the distal limb (variously called Roux, alimentary, or efferent limb) is brought cephalad and anastomosed to the gastric pouch. The proximal limb of divided jejunum (called either the biliopancreatic or afferent limb) is anastomosed to the small intestine 75–150 cm distal to the gastrojejunostomy.

Complications of RYGB

Imaging of complications post-RYGB is directed based upon a number of clinical presentation and time since surgery, with early and late complications varying in incidence.

Leak

Anastomotic leaks are one of the most feared complications in the perioperative patient with some studies quoting a rate of 1.9% [4]. Detection of a leak is of paramount clinical importance, as delayed diagnosis can have catastrophic consequences leading to peritonitis, sepsis, and eventually death. There are also medicolegal concerns, with leaks comprising a vast majority of malpractice claims [5].

Anastomotic leaks are most likely to occur at the gastrojejunal anastomosis where the distal portion of the gastric pouch joins the jejunal Roux limb [6]. Less frequently, leaks may also occur at the distal jejunojejunal anastomosis where the biliopancreatic limb joins the jejunum [6].

On UGI this will appear fluoroscopically as extraluminal linear arcs of enteric contrast extending separate from the gastric pouch or contrast accumulation adjacent to the anastomosis without luminal conformity or gradual clearing. Overhead abdominal radiographs may also reveal curvilinear pockets of contrast layering dependently within the peritoneal cavity (Fig. 2.1).

Evaluation of anastomotic leak on abdominal CT will demonstrate similar radiographic signs compared with UGI, but with greater anatomic detail. While the presence of a leak is confirmed by identifying extraluminal contrast, CT can be helpful in determining the location based on the higher contrast density in the vicinity of the leak. CT may also aid in detection of associated complications, such as intra-abdominal abscess formation (Figs. 2.2 and 2.3).

Fig. 2.1 UGI image demonstrating intraperitoneal contrast leak from the jejunum with amorphous radiodensity in the left upper abdomen

Fig. 2.2 CT from same patient demonstrating enteral contrast in the peritoneal cavity

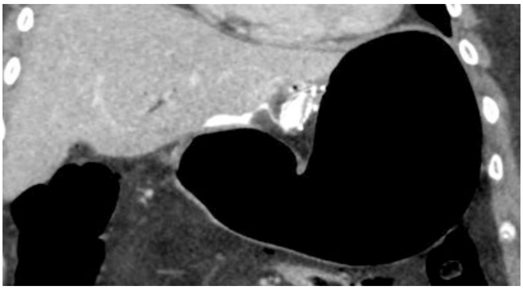


Fig. 2.3 Coronal CT image post RYGB demonstrating anastomotic leak

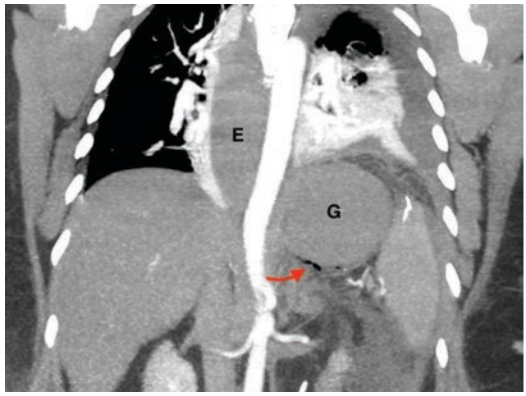


Fig. 2.4 Coronal CT pulmonary angiogram image from a recently post-RNYGB patient. CT demonstrates severe distension of the gastric pouch (G) with consequent gastric wall pneumatosis (arrow) in addition to massive esophageal distension (E) of refluxed enteric contrast. Findings proved secondary to gastric outlet obstruction at the gastrojejunal anastomosis with subsequent development of aspiration pneumonia

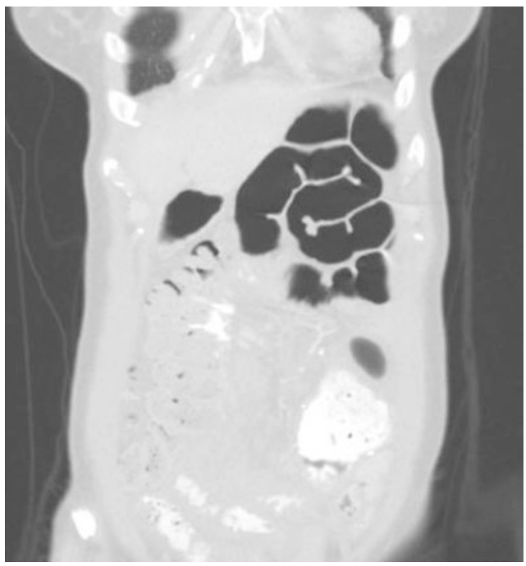


Fig. 2.5 Coronal CT image in lung window of a remotely post-RNYGB patient. CT demonstrates dilated loops of air-filled small bowel within the left upper abdomen secondary to internal hernia

Bowel Obstruction

Small bowel obstruction is another complication of Roux-en-Y gastric bypass, occurring in up to 4% of patients [7]. Causes for small bowel obstruction are variable and can be placed into two main categories. Early obstructions in the perioperative period are more likely secondary to technical complications with the Roux limb and may require revision [8]. Whereas, later complications are more likely the result of internal hernias, Roux limb compression, or formation of adhesions [7] (Fig. 2.4).

Internal hernias can be both congenital and iatrogenic due to any abdominal surgery. Internal hernias occurring following gastric bypass may occur through a surgical defect in the transverse mesocolon if the Roux limb has a retrocolic passage, at the enteroenterostomy, or posterior to the Roux limb within Petersen's space [9]. Clinical diagnosis of internal hernia can be challenging, owing to vague symptoms. Radiographic diagnosis of an internal hernia can also be troublesome, as detection of the mesenteric defect relies upon the presence of secondary signs. The most useful signs of internal hernia are visualization of small bowel loops outside of their expected location. Swirling of the mesenteric fat and vessels on CT, in addition to a "mushroom" shape of the mesenteric root, is also a useful sign for internal hernia [9] (Figs. 2.5 and 2.6).

A less common complication of gastric bypass is the development of a bezoar in the gastric pouch. Most commonly, phytobezoars (bezoars composed of plant-derived material) can form in the gastric pouch as a consequence of diminished mechanical digestion. Under normal physiologic circumstances, the muscular wall of the gastric body helps grind food into a fine paste for nutrient absorption. If this ability is impaired, fibrous plant material is at greater risk of forming an indigestible and immobile mass (Fig. 2.7).

Often, the bezoar will remain within the gastric pouch where it may contribute to symptoms of

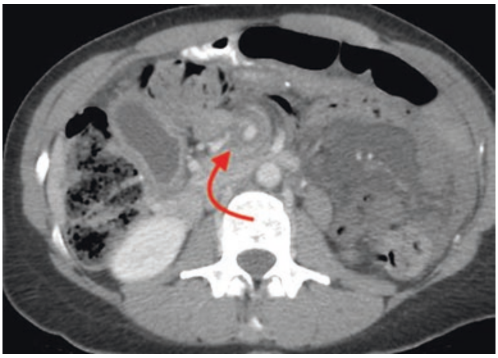


Fig. 2.6 Axial CT image from same patient demonstrating swirling of the mesenteric vasculature

Fig. 2.7 Axial CT image from a post-RYGB patient with a bezoar in the gastric pouch

gastric outlet obstruction such as nausea or vomiting [10]. Small bowel obstruction may occur should the bezoar pass distally into the Roux limb.

On CT, a bezoar will appear as a rounded heterogeneous and nonenhancing intraluminal mass with mottled internal foci of air. A bezoar with gas bubbles should not be confused with an abscess, which will be extraluminal, and demonstrate an enhancing rim with internal fluid density, in addition to air.

Marginal Ulcer

Marginal ulceration following Roux-en-Y gastric bypass varies widely with reported incidence reaching as high as 16% [11]. Smoking and diabetes have been described as risk factors for ulcer formation, in addition to large gastric pouch size and prior history of peptic ulcer disease [12]. Some studies also implicate nonsteroidal anti-inflammatory drugs (NSAIDs) as an associated risk factor [13].

Marginal ulcers most commonly arise at the gastrojejunal anastomosis or more distally within the jejunum [14]. Following gastric bypass, the jejunum is exposed to acidic secretions from the gastric pouch while lacking the buffering ability of bicarbonate production which normally occurs within the duodenum (Figs. 2.8 and 2.9).

Radiographically, ulcers will be seen as mucosal pits on UGI, with internal pooling of contrast when viewed from the appropriate dependent projection. Similarly, CT will demonstrate a variably sized mucosal contour defect with pooling of luminal contrast.

Figs. 2.8 and 2.9 UGI images post-RYGB demonstrating a posterior gastric pouch ulcer (arrows). Enteric contrast can be seen pooling within the mucosal defect

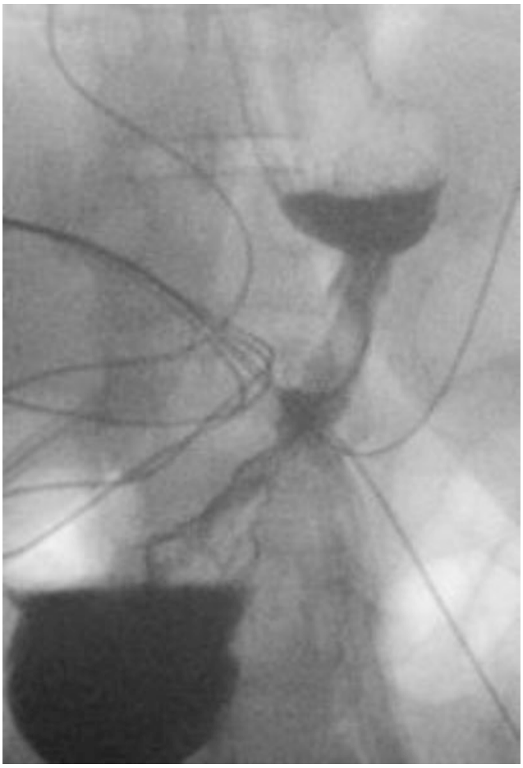


Fig. 2.10 UGI image demonstrating normal anatomic appearance following sleeve gastrectomy

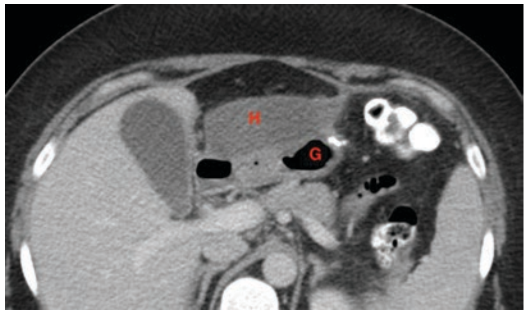


Fig. 2.11 Axial CT image post sleeve gastrectomy demonstrating a hematoma (H) anterior to the gastric lumen (G)

Sleeve Gastrectomy

An alternative to gastric bypass is the sleeve gastrectomy which was initially performed in association with biliopancreatic diversion and duodenal switch procedures in 1988 and first performed laparoscopically in 1999 [15]. According to procedure data published in 2016, incidence of sleeve gastrectomy has sharply increased in recent years, now surpassing Roux-en-Y gastric bypass as the most commonly performed bariatric procedure encompassing 58% of bariatric procedures in 2016 [3] (Fig. 2.10).

For this technique, the stomach is divided along the greater curvature with resection of a longitudinal portion of the gastric fundus and body. The result is a stomach with a tubular appearance.

In the early postoperative period, hemorrhage is a serious acute complication of sleeve gastrectomy with reported incidence between 1% and 6% [16]. Intermediate to high density intraabdominal fluid exhibiting a mean Hounsfield unit density higher than water density fluid which should have an average density close to 0 HU (Fig. 2.11).

Extraluminal leak is another serious acute complication of sleeve gastrectomy. Leaks may occur at any point along the surgical staple line. On UGI, extraluminal extravasation of water-soluble contrast media will be seen typically within the vicinity of the leak or layering dependently if discovered on post-fluoroscopic overhead radiographs. Abdominal CT may demonstrate thin linear projections of extravasated extraluminal contrast. CT imaging can aid in detection of other complications, such as abscess formation (Figs. 2.12 and 2.13).

Laparoscopic Adjustable Gastric Band

The least prevalent option of the three most commonly encountered bariatric procedures is the adjustable gastric band. The gastric band functions to limit gastric volume through inflation of a laparoscopically placed band encircling the proximal stomach. Similar to gastric bypass, this effectively creates a gastric pouch. The size of the pouch can be adjusted through the addition or removal of saline from within the gastric band, by way of a subcutaneous access port (Fig. 2.14a, b).

Complications of gastric banding can be categorized as those occurring early or late following surgery. Early complications include misplacement of the band or gastric perforation as a result of surgical trauma [17]. Surgical misplacement is rare but may result in development

Fig. 2.12 UGI image demonstrating leak along the proximal gastric staple line following sleeve gastrectomy with contrast pooling along the left abdominal wall

of gastric outlet obstruction if the band is placed around the lower portion of the stomach [17] (Figs. 2.15 and 2.16).

Late complications of gastric banding include migration of the band over time, termed band slippage. Or, complications may also arise due to gradual failure of the hardware components

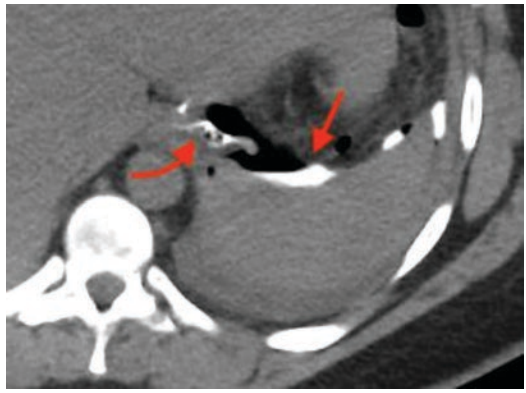


Fig. 2.13 Axial CT image from the same patient demonstrating site of gastric staple line leak near the gastro-esophageal junction

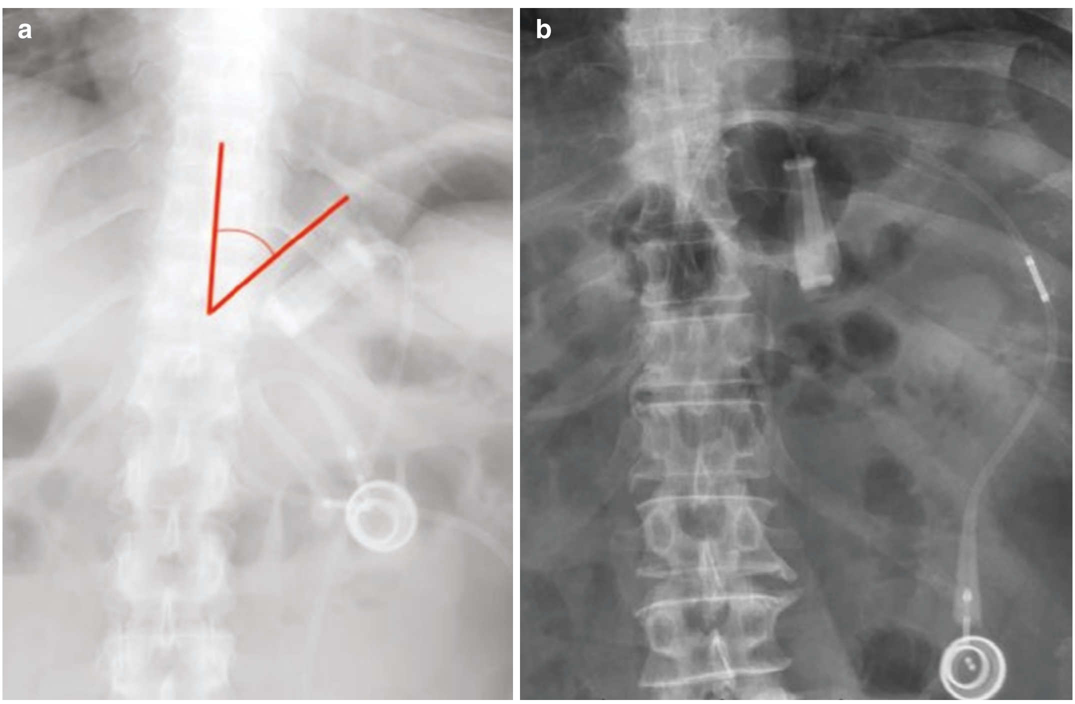
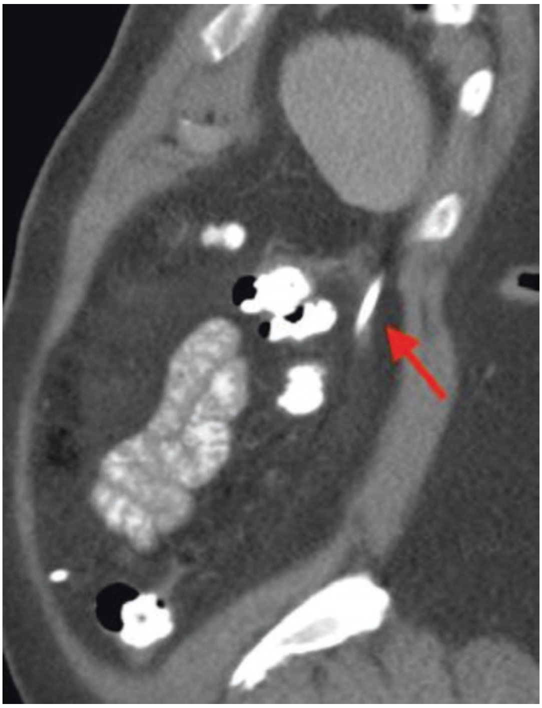
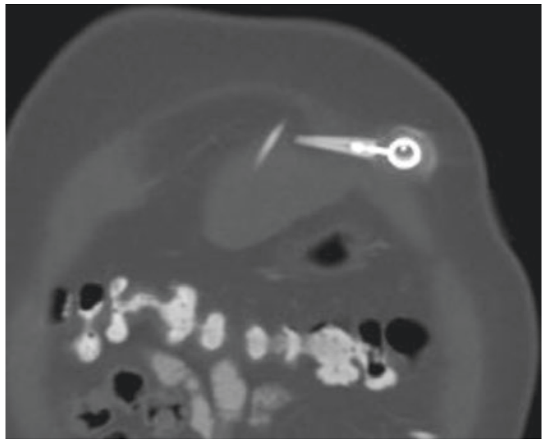


Fig. 2.14 (**a**) Frontal abdominal radiograph demonstrating normal gastric band orientation. (**b**) Frontal abdominal radiograph demonstrating abnormal acute angulation of the gastric band indicating band slippage





Figs. 2.15 and 2.16 Sagittal and coronal CT images demonstrating fractured gastric band tubing (arrow)

themselves, such as in the case of fractured port tubing.

Initial imaging evaluation for gastric band complications involves conventional radiographs of the abdomen. Abdominal radiographs allow for gross visual assessment of hardware integrity. Discontinuity of the port tubing should be readily identifiable on plain films, as is malpositioning of the band or access port. Normal angulation of the gastric band, relative to a vertical line drawn through the vertebral column, is between 4° and 58°, a measurement known as the phi angle [17]. An abnormal phi angle may be the first indication of gastric band malposition and can be confirmed by UGI or CT if clinically warranted.

Pulmonary Embolism

Patients undergoing bariatric procedures are also at increased risk for development of pulmonary venous thromboembolism (PE) with incidence varying between 0.2% and 1.3% at 30 days following surgery [18]. The classic chief complaint is that of acute dyspnea with pleuritic chest pain, often in addition to tachycardia. Multiple evidence-based models exist for the purposes of risk stratification and may help dictate the necessity for further imaging.

Given their often acute presentation, imaging of patients with suspected PE frequently begins with PA and lateral chest radiographs in order to rule out other readily identifiable causes for chest pain such as pneumonia or pneumothorax. The classic plain film radiographic signs of PE are Westermark's sign or presence of a Hampton's hump. Westermark's sign refers to a peripheral wedge-shaped segment of relative oligemia compared with other pulmonary segments as a result of decreased pulmonary perfusion. Hampton's hump refers to the presence of pulmonary infarcts manifested as peripheral wedge-shaped opacities. However, neither of these signs are a sensitive indicator for PE (Fig. 2.17).

CT pulmonary angiography (CTPA) is the study of choice in diagnosing PE as result of its ready availability, high sensitivity, and specificity, as well as its demonstration of anatomic detail. CTPA technique requires rapid IV injection of contrast material, a typical rate is 5 mL/s. A timing

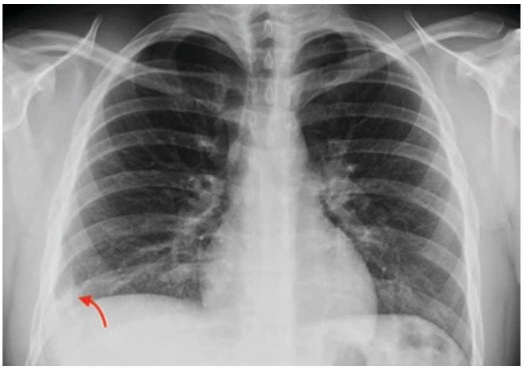


Fig. 2.17 Frontal chest radiograph demonstrating asymmetric blunting of the right costophrenic angle (arrow) subsequently revealed to represent pulmonary infarct on CTPA

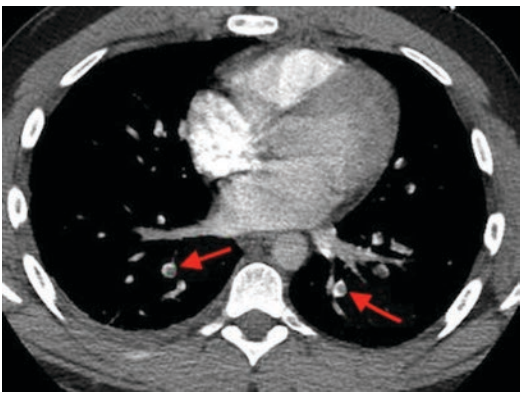


Fig. 2.18 Axial CT pulmonary angiogram image demonstrating extensive bilateral pulmonary emboli (arrows)

bolus, and bolus tracking software, helps to ensure optimal opacification of the pulmonary arteries.

On CT angiography, acute emboli will appear as low-density central filling defects within the pulmonary arterial system. These findings are best appreciated in a soft tissue window, similar to one used for evaluating the mediastinum. Care should be taken not to misidentify non-opacified pulmonary veins as extensive PE (Fig. 2.18).

Aside from detection of pulmonary embolus, CTPA allows for recognition of right heart strain through the presence of leftward bowing of the interventricular septum. Under normal physiologic conditions, pressures are greater within the left ventricle causing slight rightward septal deviation. In the setting of right heart strain, elevated right ventricular pressure results in the opposite effect. Similarly, passive hepatic congestion of intravenous contrast may be seen within the hepatic veins and inferior vena cava, as a consequence of heart strain.

In the immediate postoperative period, a bariatric surgery patient presenting with tachycardia and respiratory distress should have both a CTPA to exclude pulmonary embolism and abdominal CT to rule out a leak. In patients who have a contraindication to iodinated contrast material, ventilation/perfusion scintigraphy (V/Q scan) is an alternative imaging method to exclude pulmonary embolism.

Conclusion

Understanding the capability of imaging studies to reveal the surgically altered anatomy is key to recognizing complications of bariatric surgery. This knowledge, in conjunction with clinical factors such as symptomatology and time since surgery, can assist in the prompt diagnosis and effective management of postsurgical complications.

References

1. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015–2016. NCHS data brief, no 288. Hyattsville, MD: National Center for Health Statistics; 2017.
2. Kremen AJ, Linner JH, Nelson CH. An experimental evaluation of the nutritional importance of proximal and distal small intestine. Ann Surg. 1954;140(3):439.
3. Estimate of Bariatric Surgery Numbers, 2011–2016. (n.d.). Retrieved April 10, 2018, from https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers.
4. Zellmer JD, Mathiason MA, Kallies KJ, Kothari SN. Is laparoscopic sleeve gastrectomy a lower risk bariatric procedure compared with laparoscopic Roux-en-Y gastric bypass? A meta-analysis. Am J Surg. 2014;208(6):903–10. https://doi.org/10.1016/j.amjsurg.2014.08.002.
5. Cottam D, Lord J, Dallal RM, Wolfe B, Higa K, Mccauley K, Schauer P. Medicolegal analysis of 100 malpractice claims against bariatric surgeons. Surg Obes Relat Dis. 2007;3(1):60–6. https://doi.org/10.1016/j.soard.2006.10.008.
6. Marshall JS. Roux-en-Y gastric bypass leak complications. Arch Surg. 2003;138(5):520. https://doi.org/10.1001/archsurg.138.5.520.

7. Husain S. Small-bowel obstruction after laparoscopic Roux-en-Y gastric bypass. Arch Surg. 2007;142(10):988. https://doi.org/10.1001/archsurg.142.10.988.
8. Shimizu H, Maia M, Schauer PR, Kroh M, Brethauer SA. Surgical management of early small bowel obstruction after laparoscopic Roux-en-Y gastric bypass. Surg Obes Relat Dis. 2013;9(5):718–24.
9. Lockhart ME, Tessler FN, Canon CL, Smith JK, Larrison MC, Fineberg NS, et al. Internal hernia after gastric bypass: sensitivity and specificity of seven CT signs with surgical correlation and controls. Am J Roentgenol. 2007;188(3):745–50. https://doi.org/10.2214/ajr.06.0541.
10. Eng K, Kay M. Gastrointestinal bezoars: history and current treatment paradigms. Gastroenterol Hepatol (NY). 2012;8(11):776–8.
11. Adduci AJ, Phillips CH, Harvin H. Prospective diagnosis of marginal ulceration following Roux-en-Y gastric bypass with computed tomography. Radiol Case Rep. 2015;10(2):1063. https://doi.org/10.2484/rcr.v10i2.1063.
12. Sverdén E, Mattsson F, Sondén A, Leinsköld T, Tao W, Lu Y, Lagergren J. Risk factors for marginal ulcer after gastric bypass surgery for obesity. Ann Surg. 2016;263(4):733–7. https://doi.org/10.1097/sla.0000000000001300.
13. Coblijn UK, Lagarde SM, Castro SM, Kuiken SD, Wagensveld BA. Symptomatic marginal ulcer disease after Roux-en-Y gastric bypass: incidence, risk factors and management. Obes Surg. 2014;25(5):805–11. https://doi.org/10.1007/s11695-014-1482-9.
14. Azagury D, Dayyeh BA, Greenwalt I, Thompson C. Marginal ulceration after Roux-en-Y gastric bypass surgery: characteristics, risk factors, treatment, and outcomes. Endoscopy. 2011;43(11):950–4. https://doi.org/10.1055/s-0030-1256951.
15. Gumbs AA, Gagner M, Dakin G, et al. Obes Surg. 2007;17:962. https://doi.org/10.1007/s11695-007-9151-x.
16. Sarkhosh K, Birch DW, Sharma A, Karmali S. Complications associated with laparoscopic sleeve gastrectomy for morbid obesity: a surgeon's guide. Can J Surg. 2013;56(5):347–52. https://doi.org/10.1503/cjs.033511.
17. Mehanna MJ, Birjawi G, Moukaddam HA, Khoury G, Hussein M, Al-Kutoubi A. Complications of adjustable gastric banding, a radiological pictorial review. Am J Roentgenol. 2006;186(2):522–34. https://doi.org/10.2214/ajr.04.0655.
18. Froehling DA, Daniels PR, Mauck KF, Collazo-Clavell ML, Ashrani AA, Sarr MG, et al. Incidence of venous thromboembolism after bariatric surgery: a population-based cohort study. Obes Surg. 2013;23(11):1874–9. https://doi.org/10.1007/s11695-013-1073-1.