CT of Gastric Emergencies[1]

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Abbreviation: PUD = peptic ulcer disease

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Identify the CT appearances of emergent gastric pathologic conditions.
- Discuss clinical scenarios that may lead to development of disease.
- Describe how CT findings can guide treatment referral for emergent gastric pathologic conditions.

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Abdominal pain, nausea, and vomiting are common presenting symptoms among adult patients seeking care in the emergency department, and, with the increased use of computed tomography (CT) to image patients with these complaints, radiologists will more frequently encounter a variety of emergent gastric pathologic conditions on CT studies. Familiarity with the CT appearance of emergent gastric conditions is important, as the clinical presentation is often nonspecific and the radiologist may be the first to recognize gastric disease as the cause of a patient's symptoms. Although endoscopy and barium fluoroscopy remain important tools for evaluating patients with suspected gastric disease in the outpatient setting, compared with CT these modalities enable less comprehensive evaluation of patients with nonspecific complaints and are less readily available in the acute setting. Endoscopy is also more invasive than CT and has greater potential risks. Although the mucosal detail of CT is relatively poor compared with barium fluoroscopy or endoscopy, CT can be used with the appropriate imaging protocols to identify inflammatory conditions of the stomach ranging from gastritis to peptic ulcer disease. In addition, CT can readily demonstrate the various complications of gastric disease, including perforation, obstruction, and hemorrhage, which may direct further clinical, endoscopic, or surgical management. We will review the normal anatomy of the stomach and discuss emergent gastric disease with a focus on the usual clinical presentation, typical imaging appearance, and differentiating features, as well as potential imaging pitfalls.

Introduction

Gastric disease is a frequent but potentially overlooked cause of abdominal pain in patients presenting to the emergency room. The spectrum of acute gastric disease ranges from relatively self-limiting ailments, such as gastritis, to life-threatening conditions, including perforation, obstruction, and hemorrhage. Given its wide availability and capacity to rapidly enable a survey of the entire abdomen, computed tomography (CT) has largely replaced fluoroscopy in evaluating patients in the emergent setting who present with possible gastric disease. Although endoscopy remains an important tool for evaluating acute gastric disease, it is more invasive than and not as readily available as CT. This pictorial essay will review the key elements of evaluation with CT of gastric emergencies, including the relevant anatomy, protocol design, clinical presentation, and the spectrum of imaging features.

Anatomy

The stomach is divided into five segments: the cardia, fundus, body, antrum, and pylorus. The gastric cardia is the most proximal segment and surrounds the lower esophagus. The fundus is the second

TEACHING POINTS

- Inadequate gastric distention limits diagnostic evaluation of the stomach and poses a potential pitfall, as it may create a false appearance of thickening or, conversely, may obscure true disease. When evaluating abnormal gastric wall thickening in a nondistended stomach, supplementary findings can be helpful in identifying disease.
- The CT features of gastritis can overlap with malignancy. Certain features, such as the presence of mural stratification, favor inflammation, but when gastritis is focal or nodular in appearance, endoscopy and biopsy are often needed to exclude malignancy.
- Air in the gastric wall can be seen in a benign form of gastric emphysema, which can be encountered in the setting of a recent procedure and is typically asymptomatic. Patients with benign gastric emphysema demonstrate few clinical symptoms, whereas emphysematous gastritis causes patients to present with severe pain and potentially with sepsis and shock.
- The term *gastric volvulus* implies at least 180° rotation of the stomach and gastric outlet obstruction. Coronal reformatted images are particularly helpful in diagnosing gastric volvulus and often show these findings to greater advantage than axial images alone. Organoaxial or mesenteroaxial rotation of the stomach alone does not define volvulus.
- In all cases of penetrating trauma, it is crucial to identify the injury tract. The stomach often collapses around the site of injury, so that a defect is not visible at imaging, making the injury tract the only sign of gastric trauma.

portion of the stomach, and is the most superior portion of the stomach when the patient is upright and the most dependent portion when the patient is supine. The fundus accounts for the "stomach bubble" seen on upright radiographs and is the most common site for accumulation of intraluminal contents on CT, most notably blood products. The body of the stomach has what is known as the lesser curvature, located on axial images to the left and posteriorly, and the greater curvature, right and anteriorly. The gastric antrum is the most muscular segment of the stomach, exhibits the most peristalsis, and therefore is the thickest gastric segment (Fig 1). In normal patients, the antrum can display mural stratification on contrast-enhanced CT images (1). Between the gastric body and antrum is the incisura angularis, which marks the transition to antral-type mucosa. Because of this transition, the incisura is the most common site for gastric ulcers (2). Arterial supply to the stomach comes from all three branches of the celiac axis: the left gastric, common hepatic, and splenic arteries, forming two arterial arcades. Numerous anastomoses make the stomach relatively resistant to ischemia.

Similarly to other portions of the gastrointestinal tract, the stomach wall is composed of the mucosa, which enhances avidly; the submucosa, which is relatively low in attenuation; and the muscularis

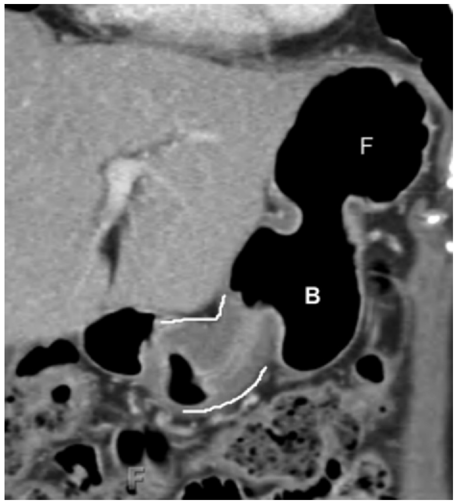


Figure 1. Gastric anatomy. Coronal CT image of the stomach with intravenous contrast material in an asymptomatic patient demonstrates gaseous distention of the gastric fundus *(F)* and body *(B)* with peristalsis of the antrum, resulting in apparent antral thickening (bounded by white lines). There are no ancillary findings to suggest gastritis.

propria and the serosa, which are high in attenuation. The degree of mucosal enhancement will vary with the phase of contrast, with more pronounced enhancement seen in the arterial phase than in later phases (3). The trilaminar appearance of the normal gastric wall is often altered in gastric disease (4).

When the stomach is collapsed, the gastric rugae or folds are prominent. With distention of the stomach, the folds become effaced and the gastric wall thins. Therefore, the degree of distention determines the thickness of the normal gastric wall and folds. In an adequately distended stomach, the normal nondependent gastric body is less than or equal to 5 mm in thickness. The antral wall, in contrast, may normally measure less than or equal to 12 mm in thickness (1). Inadequate gastric distention limits diagnostic evaluation of the stomach and poses a potential pitfall, as it may create a false appearance of thickening or, conversely, may obscure true disease. When evaluating abnormal gastric wall thickening in a nondistended stomach, supplementary findings can be helpful in identifying disease. Findings that should raise suspicion for gastric disease include focal or eccentric gastric wall thickening, low attenuation or nodularity of the gastric wall, mucosal hyperenhancement, and adjacent fat stranding (3,5).

CT Protocol

Although CT provides rapid evaluation of the stomach and simultaneous examination of other abdominal organs, it lacks the dynamic information and mucosal detail provided by fluoroscopy. To

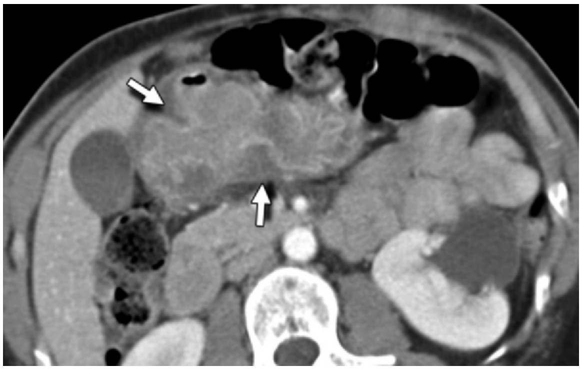


Figure 2. Gastritis in a patient who presented to the emergency department with abdominal pain and vomiting. Axial postcontrast CT image demonstrates diffuse gastric wall thickening and fold thickening with low attenuation of the gastric wall and mucosal enhancement (arrows).

Figure 3. Gastric cancer in a patient with abdominal pain, nausea, and vomiting. Axial postcontrast CT image shows more focal gastric wall thickening without mural stratification (arrow), which was thought to represent either gastritis or gastric cancer. Endoscopy was recommended, which demonstrated diffuse infiltrating gastric adenocarcinoma.

optimize sensitivity and specificity, protocols for CT should be tailored to best address the patient's clinical history. Variable parameters include use of oral or intravenous contrast material, number of imaging phases, extent of anatomic coverage, collimation, and acquisition of isotropic voxel datasets.

At our institution, a routine examination of the abdomen consists of axial multidetector CT images obtained with 3-mm-thick sections at 2-mm intervals. Scans are generally performed after intravenous administration of the iodinated contrast agent, ioversol injection 74% (Optiray 350; Mallinckrodt, St Louis, Mo), at a rate of 1–3 mL/sec, with a fixed delay ranging from 60 to 100 seconds depending on the injection rate. When gastric disease is suggested by patient history, negative contrast material (water) is given to the patient immediately before scanning. Although positive contrast material is often used to evaluate the gastrointestinal tract, it can mask mucosal enhancement and preclude assessment for intraluminal bleeding. Therefore, negative contrast material is favored for gastric distention. Intravenous contrast material is necessary to fully evaluate neoplastic or inflammatory conditions of the stomach, and is helpful in assessment of ischemic compromise. Multiphase contrast examinations are not routinely performed in patients with suspected gastric disease, but a CT angiographic protocol that includes precontrast, arterial, and portal venous phases is used for patients with suspected acute gastrointestinal bleeding. Isotropic datasets are routinely obtained to allow multiplanar reformatting.

Emergent Gastric Conditions

Inflammation

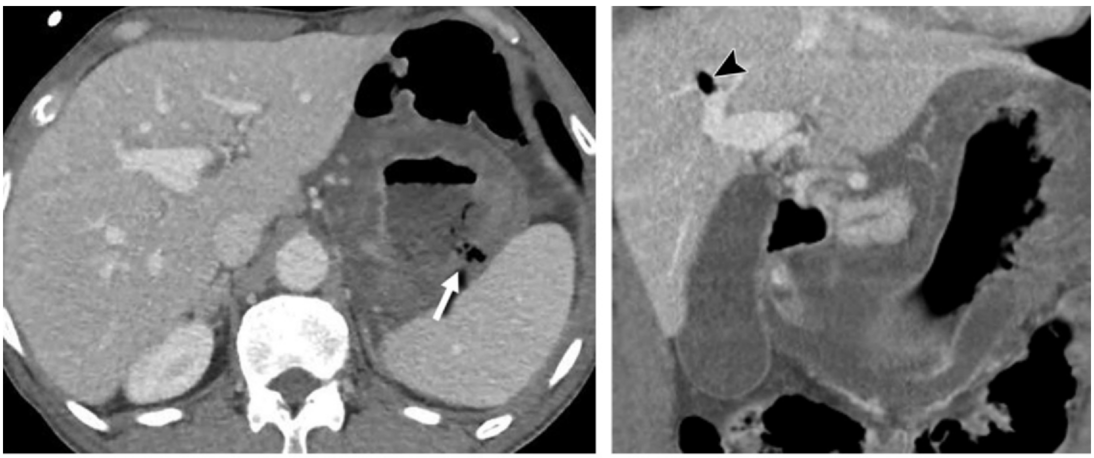
Gastritis.—Gastritis, or gastric mucosal inflammation, is a common condition that often results in submucosal edema and hyperplasia of the gastric mucosa (6) (Table). Gastritis is most frequently secondary to *Helicobacter pylori* infection, nonsteroidal anti-inflammatory drugs (NSAIDs), alcohol, or systemic illness (2). Patients with gastritis may present with epigastric pain, nausea, vomiting, or loss of appetite. Although CT, given its poor mucosal detail, is not the preferred modality for assessing gastritis, it is often the first study performed in patients with acute symptoms and may suggest the diagnosis. Gastric wall or fold thickening is the most common CT finding in gastritis and, as previously discussed, is best appreciated when the stomach is distended (5). Gastritis or gastric edema can manifest as diffuse submucosal low attenuation and/or mucosal hyperemia (Fig 2). The combination of mucosal hyperemia with submucosal edema results in the appearance described as mural stratification, which is most pronounced at arterial phase imaging. Gastritis may be focal, segmental, or diffuse (5). Gastritis due to *H pylori* infection can have a variety of manifestations, including circumferential antral wall thickening and focal thickening along the greater curvature (6).

The CT features of gastritis can overlap with malignancy. Certain features, such as the presence of mural stratification, favor inflammation, but when gastritis is focal or nodular in appearance, endoscopy and biopsy are often needed to exclude malignancy (Fig 3) (7).

Emphysematous Gastritis.—Emphysematous gastritis is an uncommon condition with a high mortality rate and is caused by mucosal disruption and invasion of microorganisms into the gastric wall, producing intramural gas. Causative microorganisms reported in the literature include both aerobic and anaerobic bacteria as well as fungal species.

CT Findings in Emergent Gastric Conditions

Condition	Potential Findings at CT
Inflammation	Wall or fold thickening, edema
Emphysematous gastritis	+ intramural gas, venous gas
Peptic ulcer disease	+ luminal outpouching and perigastric fat stranding
Marginal ulcer	+ ulceration, usually at the jejunal side of a gastrojejunal anastomosis
Obstruction	Dilated stomach or pouch/remnant
Gastric volvulus	+ abnormal location of the gastropyloric junction or gastric antrum, wall thickening, and adjacent fluid or fat stranding.
Peptic ulcer disease	+ gastric wall edema or stricture
Malignancy	+ masslike or nodular or enhancing wall thickening, replacement of submucosa with soft tissue, lymphadenopathy, or metastases
Bezoar	+ mottled material
Bouveret syndrome	+ obstructing ectopic gallstone in the distal stomach or duodenum, air in the gallbladder or biliary tree
Slipped gastric band	+ increased φ angle (normal 4°–58°)
Vertical band gastroplasty	+ distended gastric remnant with fibrosis or food impaction at the stoma
Perforation	Free intraperitoneal air or fluid, extraluminal contrast material, wall discontinuity
Peptic ulcer disease	+ ulcer, wall thickening, edema
Malignancy	+ masslike or nodular or enhancing wall thickening, replacement of submucosa with soft tissue, lymphadenopathy, or metastases
Gastric banding	+ air or oral contrast material outlining the band, abscess or fat stranding
Penetrating trauma	+ tract and adjacent organ injuries
Hemorrhage	Contrast blush or hyperattenuating clot
Ischemia	Ulceration, wall thickening, intramural gas, gastric dilatation



a. b.

Figure 4. Emphysematous gastritis in a patient with abdominal pain and lung cancer after chemoradiation therapy. **(a)** Axial CT image shows typical CT findings of emphysematous gastritis with diffuse wall thickening, low attenuation of the gastric wall, and foci of gas within the gastric wall (arrow). **(b)** Coronal CT image shows diffuse gastric wall thickening and portal venous gas (arrowhead).

Frequently isolated organisms include *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter* species, *Pseudomonas aeruginosa*, and *Candida* species (8). Patients generally present with severe symptoms. The CT appearance includes features of gastritis, such as wall thickening and edema, in combination with intramural gas that may dissect into the draining gastric veins and portal venous system (Fig 4) (9,10). Similar imaging features can also be seen in the rare settings of gastric ischemia or caustic ingestion. Air in the gastric wall can be seen in a benign form of gastric emphysema, which can be encountered in the setting of a recent procedure and is typically asymptomatic. Patients with benign gastric emphysema demonstrate few clinical symptoms, whereas emphysematous gastritis causes patients to present with severe pain and potentially with sepsis and shock (9,11). In addition to obtaining an appropriate history, absence of gastric wall edema is helpful in diagnosing benign gastric emphysema

Figure 5. Gastric emphysema in an asymptomatic patient with recent gastrostomy tube placement. Coronal CT image demonstrates air (arrows) in the gastric wall and a gastrostomy tube balloon. Note the lack of gastric wall thickening.

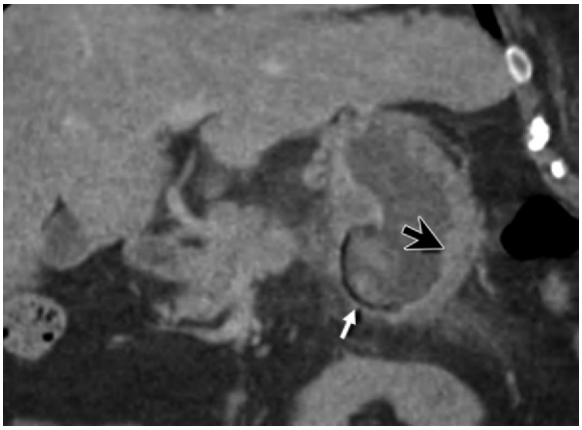


Figure 6. Peptic ulcer in a patient with abdominal pain, nausea, and vomiting. Coronal CT image of the abdomen demonstrates a large ulcer (white arrow) arising from the lesser curvature at the incisura angularis, with adjacent fat stranding. There is irregular thickening of the gastric wall (black arrow) consistent with gastritis.

(Fig 5). The appearance of the intramural gas in benign gastric emphysema is often linear.

Peptic Ulcer Disease.—Peptic ulcer disease (PUD) is an inflammatory condition of the mucosa caused by an acid imbalance in the stomach, resulting in inflammation, superficial erosions, and eventually ulceration. Because they are usually isolated to the gastric mucosa, many gastric ulcers are not visible at CT, even when large. However, deep ulcers and penetrating ulcers may be visible at CT, and are characterized by findings of gastritis in conjunction with a luminal outpouching or "ulcer crater"

a. **b.**

Figure 7. Marginal ulcer in a patient who had Roux-en-Y gastric bypass 3 years prior, who presented with abdominal pain to the emergency department. Coronal **(a)** and axial **(b)** CT images show postoperative changes of Roux-en-Y gastric bypass with a large outpouching (*) from the jejunal side of the gastrojejunostomy, consistent with a marginal ulcer. There is adjacent fat stranding, as well as edema within the liver parenchyma.

and perigastric fat stranding (Fig 6) (5). Multiplanar reconstructions can be a useful tool in evaluating gastric ulcers, as many ulcers are more readily visible on sagittal or coronal reconstructions. Occasionally, antral diverticula (acquired outpouchings from the antral greater curvature) can be mistaken for gastric ulcers. Antral diverticula, however, are not associated with secondary features of gastritis (12).

Marginal Ulcers.—Marginal ulcers are a subset of ulcers seen at the suture line in postoperative patients, and specifically in patients who have undergone gastrojejunostomy and Roux-en-Y gastric bypass. Patients may present with epigastric pain or gastrointestinal bleeding, the latter of which can be life-threatening (13). The ulcer usually occurs on the jejunal side of the gastrojejunal anastomosis (14). Altered postoperative anatomy can make detection of marginal ulcers challenging, but multiplanar reconstructions and identification of adjacent inflammatory changes can be helpful, as with other gastric ulcers (Fig 7). Complications of marginal ulcers include stomal stenosis, hemorrhage, and perforation. Marginal ulceration is the most common cause of early and late upper gastrointestinal bleeding following Roux-en-Y gastric bypass (13).

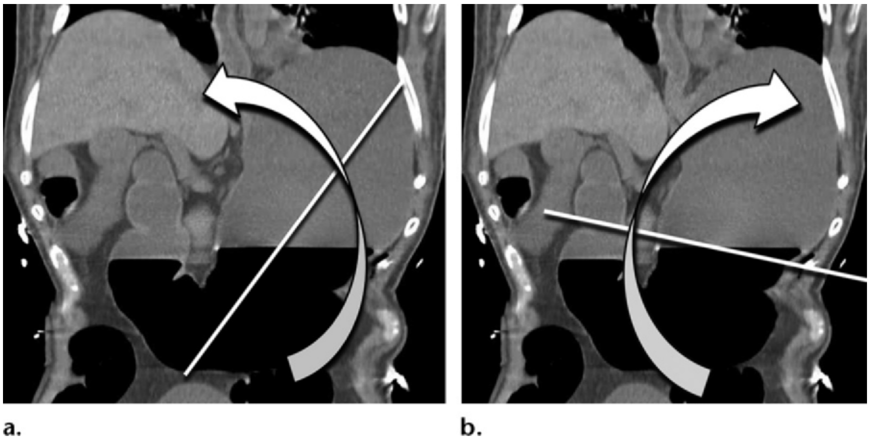
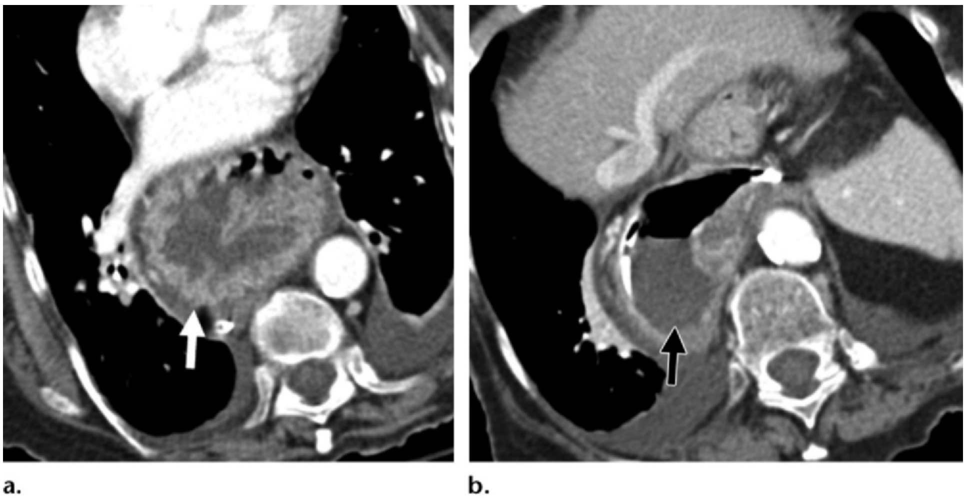
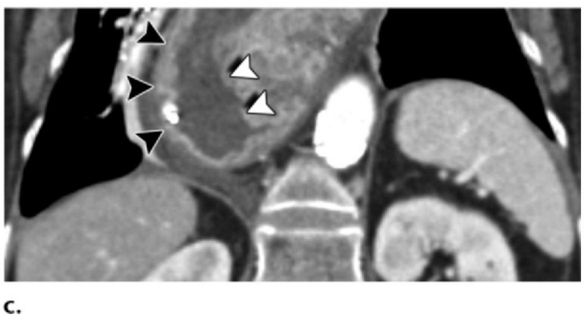


Figure 8. Coronal CT images showing axis (line) and direction (arrow) of rotation of the stomach in **(a)** organoaxial volvulus and **(b)** mesenteroaxial volvulus.

Figure 9. Organoaxial volvulus in a patient with intractable vomiting. **(a)** Axial CT image shows a hiatal hernia with the gastric body (arrow) located superiorly. **(b)** Axial CT image, in a different section, shows that the fundus (arrow) is located inferiorly to the gastric body. **(c)** Coronal CT image shows the greater curvature (black arrowheads) superior and to the right of the lesser curvature (white arrowheads), compatible with organoaxial gastric volvulus.



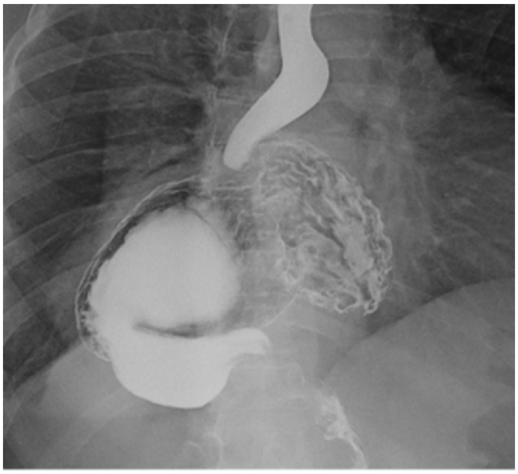


Obstruction

Gastric Volvulus.—Gastric volvulus is twisting of the stomach resulting in gastric outlet obstruction, and can result in ischemia or perforation. Patients classically present with sudden epigastric pain, intractable retching, and inability to pass a nasogastric tube (the Borchardt triad) (15). Volvulus occurs most often in elderly patients with a hiatal hernia and may be acute or chronic-recurrent. Paraesophageal hernias, particularly large type III hernias, are at greater risk of gastric volvulus (16). Because of the potential for ischemia and perforation, acute gastric volvulus has high morbidity and mortality if not treated rapidly with decompression of the stomach, reduction of the volvulus, and correction of the underlying cause.

Gastric volvulus is divided into two subtypes, organoaxial and mesenteroaxial, based on the axis of rotation (17) (Fig 8). Organoaxial volvulus is obstruction of the stomach due to rotation around the long axis of the stomach, resulting in the antrum moving anterosuperiorly and the fundus rotating posteroinferiorly, so that the greater curvature lies superior to the lesser curvature (Fig 9). In mesenteroaxial volvulus, the stomach rotates around its short axis, such that the antrum moves above the gastroesophageal junction, twisting its vascular supply (Fig 10). Organoaxial volvulus is more common than mesenteroaxial volvulus, accounting for approximately two-thirds of cases, and is commonly associated with congenital and

Figure 10. Mesenteroaxial gastric volvulus. Coronal CT image shows gastric obstruction secondary to mesenteroaxial volvulus with the gastric antrum (arrowhead) located superior to the gastroesophageal junction (arrow) within the paraesophageal hernia sac.



a.

b.

Figure 12. Re-descent of the gastric fundus in a patient with acute onset abdominal pain and vomiting. **(a)** Image from a prior upper gastrointestinal examination shows an intrathoracic stomach. **(b)** Subsequent coronal CT image at the time of emergent presentation shows re-descent of the gastric fundus into the abdomen, resulting in obstruction.

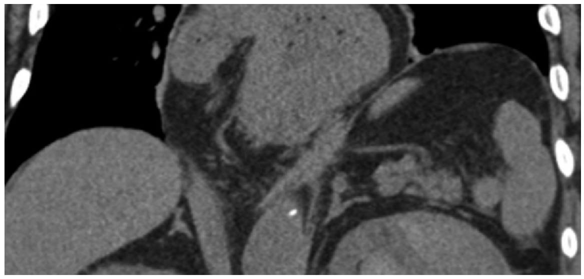


Figure 11. Organoaxial rotation without volvulus in an asymptomatic patient. Coronal CT image shows a hiatal hernia with organoaxial position of the stomach, but no obstruction.

acquired diaphragmatic defects. Many cases may have overlapping features of organoaxial and mesenteroaxial volvulus and indeed may be due to a combination of these two entities.

Imaging features of gastric volvulus include obstruction of the gastric outlet associated with abnormal location of the gastric outlet, nonpassage of enteric contrast material, wall thickening, and adjacent fluid or fat stranding. The term *gastric volvulus* implies at least 180° rotation of the stomach and gastric outlet obstruction. Coronal reformatted images are particularly helpful in diagnosing gastric volvulus and often show these findings to greater advantage than axial images alone. Organoaxial or mesenteroaxial rotation of the stomach alone does not define volvulus. In patients who present with similar abnormal positioning of the stomach yet are not obstructed, it is more appropriate to report this as organoaxial or mesenteroaxial rotation rather than volvulus (17) (Fig 11). Related entities resulting in gastric obstruction include incarcerated hiatal hernias and re-descent of the fundus, in which the majority of the stomach is intrathoracic, but the fundus herniates into the abdomen, causing obstruction of the stomach mouth (Fig 12) (17,18).

Obstruction and PUD.—PUD was once the most common cause of adult gastric outlet obstruction. As the prevalence of PUD of the duodenum and pyloric channel has significantly decreased over the last 30 years due to advances in diagnosis and treatment, the prevalence of gastric outlet obstruction has also decreased (19). Gastric outlet obstruction related to PUD is usually secondary to gastric wall edema or spasm in the acute setting or fibrotic stricture in the chronic setting (Fig 13). The imaging appearance of PUD resulting in outlet obstruction may overlap with malignancy, and therefore direct visualization and biopsy is often necessary (7).

Obstruction and Malignancy.—Malignancy is the most common cause of gastric outlet obstruction in adults since the widespread use of H2 blockers (20). Gastric and pancreatic adenocarcinomas,

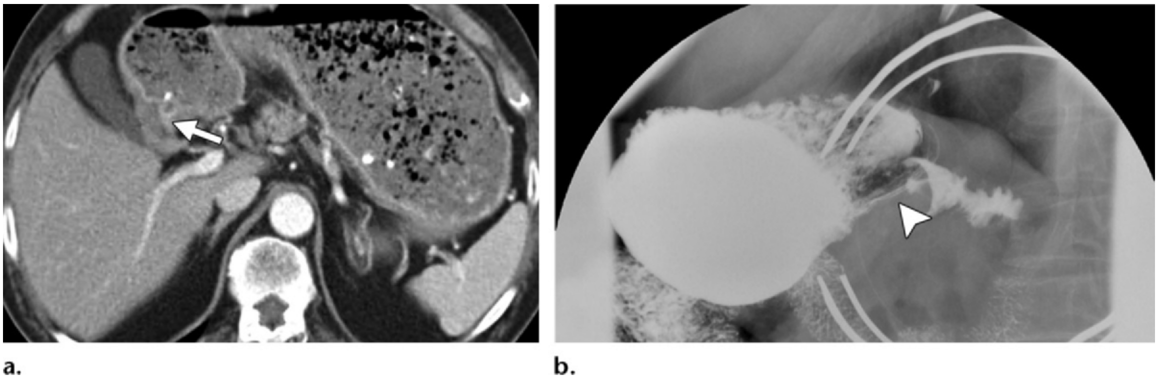


Figure 13. Gastric outlet obstruction in a patient with known PUD who presented acutely with abdominal pain and vomiting. **(a)** Axial CT image shows low-attenuation wall thickening at the pylorus resulting in obliteration of the lumen (arrow). **(b)** Subsequent upper gastrointestinal examination confirms the finding, with only a string of contrast material passing out of the stomach (arrowhead).

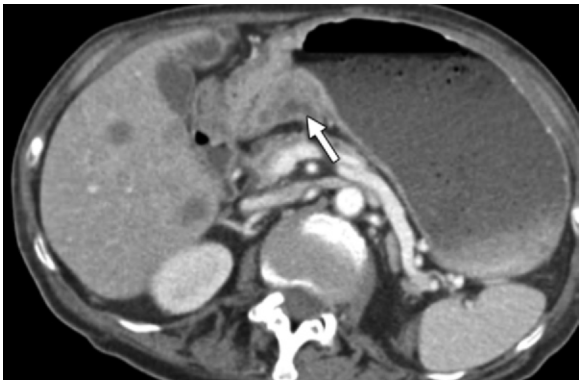


Figure 14. Gastric outlet obstruction in a patient with gastric adenocarcinoma. Axial CT image shows a focal heterogeneously enhancing mass (arrow) in the wall of the gastric antrum, resulting in gastric outlet obstruction. Also note hypoattenuating liver lesions representing metastatic disease.

Figure 15. Gastric outlet obstruction in a patient who presented with abdominal pain and vomiting and was found to have a pancreatic adenocarcinoma. Axial CT image shows gastric outlet obstruction secondary to a mass (arrow) in the pancreatic head.

primary duodenal tumors, primary biliary tumors, and, rarely, lymphoma, can all result in gastric outlet obstruction (Figs 14, 15). Imaging features that suggest malignant gastric outlet obstruction include nodular or enhancing wall thickening, lymphadenopathy, and distant metastatic disease. The imaging appearance of gastritis and gastric tumors may overlap, necessitating endoscopic diagnosis.

Bezoars.—Bezoars are another potential cause of gastric outlet obstruction, and can include trichobezoars, composed of hair, and phytobezoars, composed of fruit or vegetable matter. Trichobezoars are primarily seen in women and patients with psychiatric illness (21). These generally form in the stomach, and may extend into the small bowel. Phytobezoars are more common in patients with decreased gastric motility, particularly in patients who have had prior gastric surgery, and can pass into the small bowel, causing small bowel obstruction (22). Bezoars typically have a similar appearance to particulate matter, producing a "mottled" appearance at CT (Fig 16).

Gallstones.—In cases of gallstone ileus, the impacted gallstone is most often located in the ileum and least commonly located in the stomach (23). Bouveret syndrome is a rare form of proximal gallstone ileus, in which a gallstone obstructs the pylorus or duodenal bulb by way of a cholecystoenteric fistula. Bouveret syndrome is most commonly seen in elderly women and manifests as nonspecific complaints including nausea, vomiting, and epigastric pain (24). The Rigler triad of pneumobilia, an ectopic gallstone, and obstruction is seen in only a small subset of patients. The CT features of Bouveret syndrome include visualization of the obstructing ectopic gallstone in the distal stomach or the duodenum, and air in the gallbladder or biliary tree (Fig 17). Although the cholecystenteric fistula is often difficult to visualize, its presence can be inferred from the other imaging features. Prompt identification of Bouveret syndrome is critical given its high mortality rate, historically as high as 33% and closer to 12% in recent years (25).

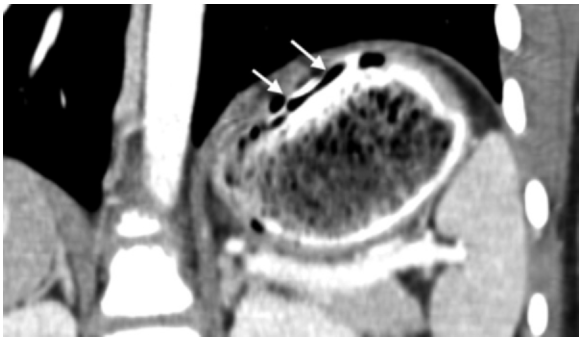
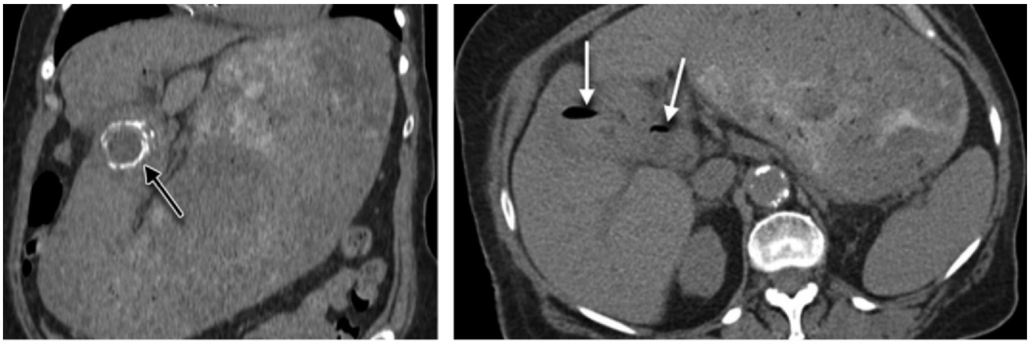


Figure 16. Gastric bezoar resulting in gastric outlet obstruction. Coronal CT image shows a gastric bezoar around which the nasogastric tube courses (arrows). Note the typical mottled appearance. Surgical pathology found a mix of hair and vegetable material.



a. b.

Figure 17. Bouveret syndrome with gastric outlet obstruction. **(a)** Coronal CT image shows a gastric outlet obstruction by a large, lamellated, calcified structure (arrow). **(b)** Axial CT image shows pneumobilia (arrows). These findings are consistent with gastric outlet obstruction due to ectopic gallstone.

a. b.

Figure 18. Normal and slipped gastric bands. **(a)** Topogram from chest CT demonstrates normal positioning of a gastric band with φ angle measurement of 48° (normal, 4°–58°) and overlapping of the anterior and posterior band. **(b)** Topogram from chest CT demonstrates abnormal horizontal positioning of the gastric band with increased φ angle measurement of 88° (normal, 4°–58°). Mottled material is visible in the gastric fundus, which is distended secondary to obstruction from the slipped lap band. The patient presented with intractable vomiting and aspiration pneumonia.

Obstruction and Bariatric Surgery.—Gastric banding is a relatively common bariatric procedure in which an adjustable band is placed approximately 2 cm below the gastroesophageal junction, forming a small gastric pouch (26). The band can slip distally to a larger segment of the stomach, creating the potential for obstruction or volvulus. Patients may present with a range symptoms, including decreased weight loss, severe reflux, vomiting, and gastric outlet obstruction. The angle of the band relative to the spine, referred to as the φ angle, should normally be 4°–58° and the anterior and posterior aspects of the band should be superimposed (Fig 18). A more obtuse angle or horizontal lie of the band, best appreciated on the localizer image or coronal reformatted image, indicates slippage of the gastric band (26) (Fig 18). If severe obstruction occurs, the band may be decompressed immediately to relieve symptoms, followed by laparoscopic fixation.

Patients with other bariatric surgeries, such as vertical band gastroplasty, may present with acute obstruction of the gastric remnant due to fibrosis or food impaction at the stoma. Clues to

Figure 19. Gastric outlet obstruction in a patient who had vertical ring gastroplasty and who presented with intractable vomiting. Axial CT image demonstrates postoperative changes of vertical ring gastroplasty and distention of the gastric pouch, which contains mottled material (arrowhead). The remainder of the stomach is decompressed, consistent with obstruction of the stoma. At endoscopy, it was discovered that there was a food bolus impacted at the stoma.

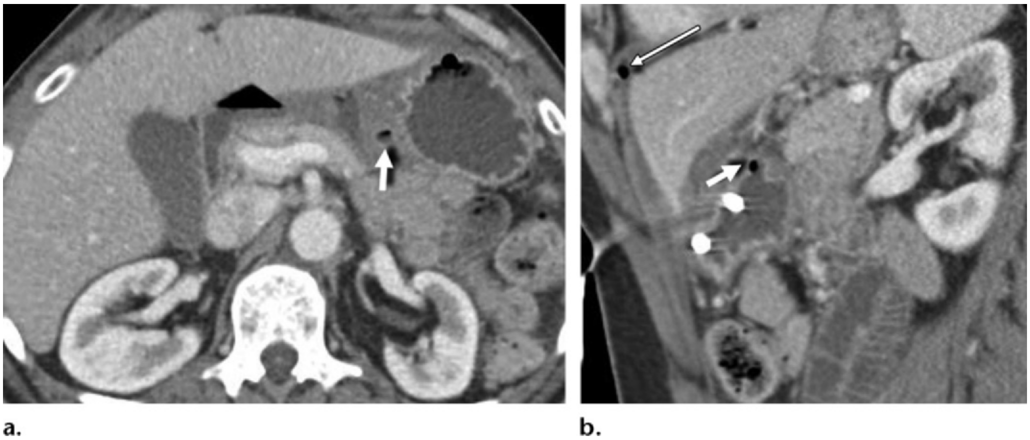


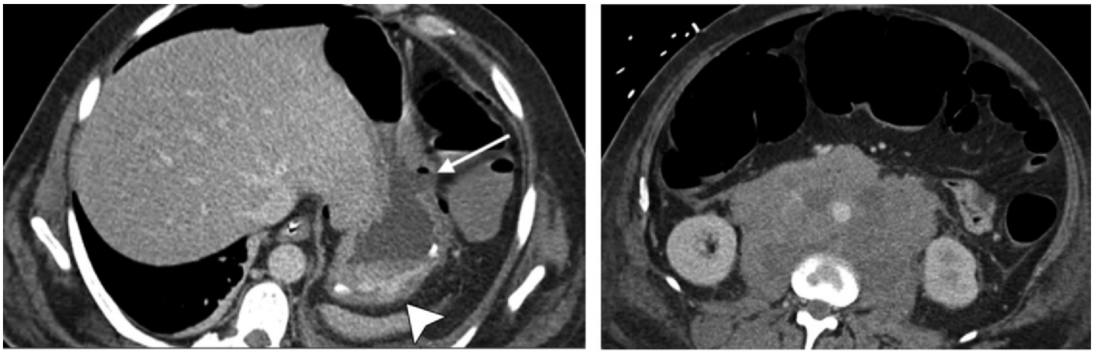
Figure 20. Perforated peptic ulcer in a patient who presented to the emergency department with acute onset of severe left upper quadrant abdominal pain. **(a)** Axial CT image demonstrates a transmural ulcer crater (arrow) with an adjacent mound of edema in the superior gastric antral wall. **(b)** Sagittal CT image shows the ulcer (thick arrow), as well as foci of free intraperitoneal air (thin arrow) adjacent to the liver, consistent with perforation.

this diagnosis include a patient presenting with intractable vomiting, a distended gastric remnant, and mottled material at the stoma (Fig 19). Endoscopic removal and/or dilation of the stenosis are typically the treatments of choice (27).

Perforation

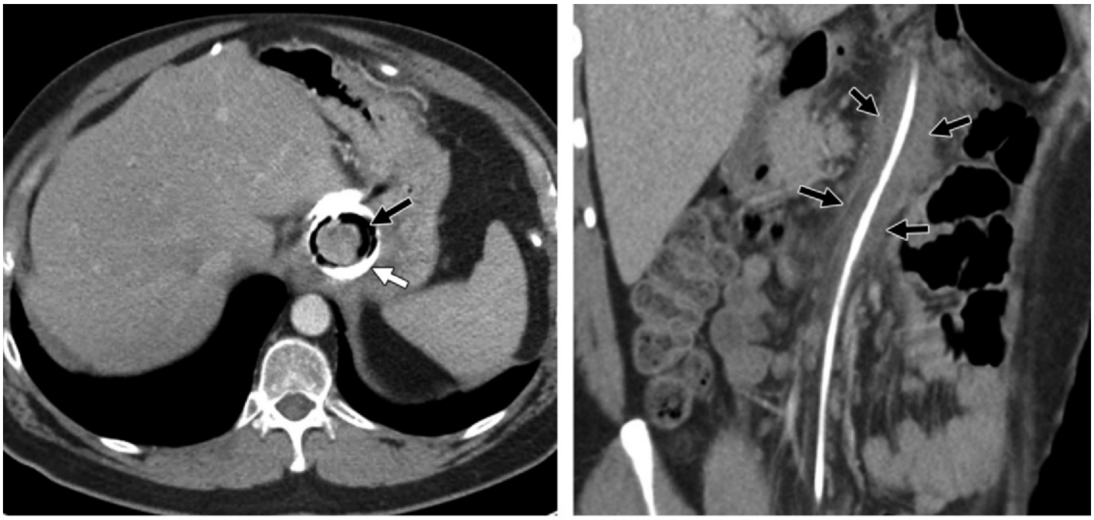
PUD and Perforation.—Perforation is the most common complication of PUD. Ulcers on the anterior wall and curvatures perforate freely into the peritoneal space; posterior ulcers may perforate into the lesser sac and can be relatively contained. Findings at CT may include the features of gastric ulcers discussed previously in combination with free intraperitoneal fluid or gas, extraluminal oral contrast material, and wall discontinuity (Fig 20). Ulcers are more likely to be detected at CT when they perforate, because the defect is transmural and because extraluminal gas and fluid may accumulate at the site of perforation. In cases of free intraperitoneal air, the stomach and proximal duodenum should be closely scrutinized because perforated ulcers are still among the most common causes of a perforated viscus.

Malignancy.—Gastric perforation can also occur with a gastric malignancy, particularly in ulcerated masses such as those seen with adenocarcinoma, lymphoma, and large gastrointestinal stromal tumors (GISTs). Perforation from gastric adenocarcinoma typically occurs in patients more than 65 years of age with advanced stage disease. In patients with lower stage disease, a focal ulcerated mass can perforate if the ulceration is deep (28). Ulcerated gastric lymphoma can also result in gastric perforation (Fig 21), although small bowel perforation is more common (29). Imaging features of malignant causes of gastric perforation include focal mass-like wall thickening and replacement of the submucosa with soft tissue. Extragastric signs of malignancy, such as lymphadenopathy or metastases, may also be present.



a. b.

Figure 21. Gastric perforation from lymphoma. **(a)** Axial CT image shows transmural ulceration of the gastric body with adjacent free intraperitoneal gas (arrow) and wall thickening in the gastric fundus (arrowhead). **(b)** Axial CT image shows a large retroperitoneal mass encasing the aorta and inferior vena cava.



a. b.

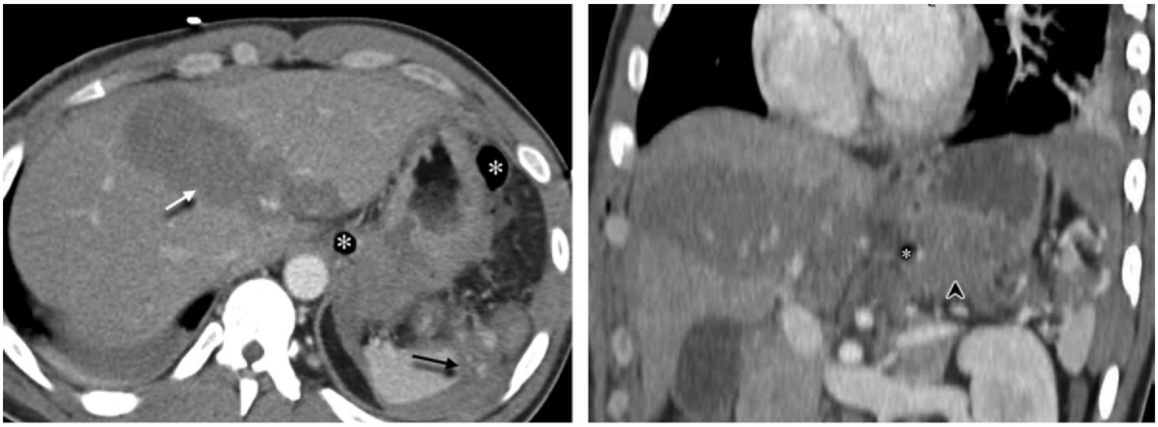
Figure 22. Transmural erosion of a gastric band in a patient with abdominal pain. **(a)** Axial CT image demonstrates transmural erosion of the gastric band (white arrow), which is delineated by gas (black arrow), indicating perforation. **(b)** Coronal CT image shows inflammatory fat stranding (arrows) along the entire course of the tubing tract.

Postoperative.—Gastric banding can result in gastric perforation either acutely as a postoperative complication or in the chronic setting secondary to transmural band erosion (30). Acute perforation is a rare complication, but chronic erosion is slightly more common. Gastric band erosion may be due to surgical trauma, inflammatory reaction to foreign body, or NSAID use. The clinical presentation varies, ranging from asymptomatic to acute abdominal emergency. In gastric banding patients with gastric perforation, CT may show free or loculated extraluminal gas or subphrenic abscess. Oral contrast material or air can be seen outlining the band (Fig 22) (31). Patients with band erosion may alternatively present with infection of the port site or tubing tract, which can be seen either clinically or at CT, as inflammatory fat stranding.

Trauma.—Penetrating trauma is another potential cause of gastric perforation. In all cases of penetrating trauma, it is crucial to identify the injury tract. The stomach often collapses around the site of injury, so that a defect is not visible at imaging, making the injury tract the only sign of gastric trauma. Free intraperitoneal air can be seen with gastric perforation, and an intraluminal hematoma may also be present. When injuries of the spleen, diaphragm, or left hemiliver are present, gastric injury should also be considered (Fig 23).

Hemorrhage

Gastric hemorrhage can be seen in a variety of gastric diseases, including PUD, tumor, varices, gastritis, and arteriovenous malformations. Patient presentation is variable, ranging from asymptomatic to hypovolemic shock. Direct signs of bleeding include hematemesis, coffee-ground emesis, melena, or, in the setting of rapid bleeding, hematochezia. Although endoscopy is the preferred method of



a. b.

Figure 23. Gunshot wound resulting in gastric perforation. Axial **(a)** and coronal **(b)** CT images demonstrate both splenic (black arrow) and liver (white arrow) lacerations. In addition, the trajectory of injury extends through the stomach, resulting in gastric intramural hematoma (arrowhead) and free intraperitoneal gas (*). Perforation was confirmed intraoperatively.

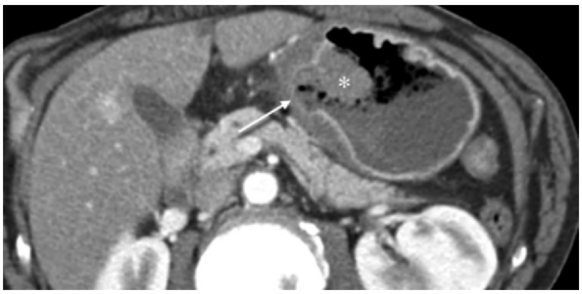


Figure 24. Hemorrhagic gastric ulcer. Axial CT image demonstrates a large gastric ulcer (arrow) with high-attenuation blood clot in the gastric body (*) and at the site of ulceration. Inflammatory changes are seen in the adjacent fat.

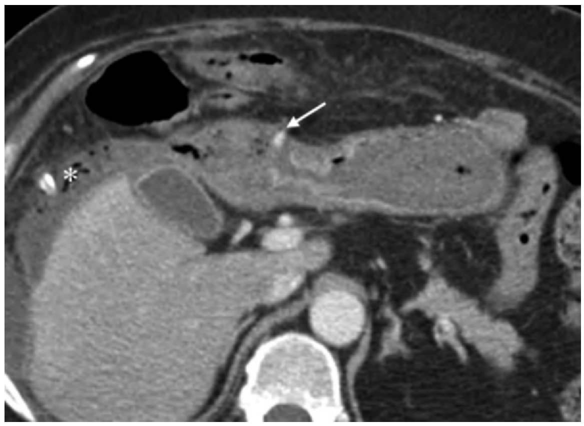


Figure 25. Hemorrhagic gastric ulcer in a patient who presented with abdominal pain and hematemesis. Axial CT image with intravenous contrast material demonstrates active extravasation (arrow) at the site of a perforated gastric antral ulcer, with adjacent fluid and air collections (*).

diagnosing and treating upper gastrointestinal bleeding, CT is useful in cases where endoscopy is not clinically feasible or is nondiagnostic.

CT findings of gastric hemorrhage include intraluminal contrast blush from active bleeding or hyperattenuating clot from recent bleeding (Figs 24, 25). Clots in these cases are often seen in the fundus, which is the most dependent location in the supine patient. The location of the highest-attenuation clot (the *sentinel clot*) can indicate the source of bleeding. Hyperattenuating material in the stomach, including ingested material such as residual contrast medium or medications, surgical material, or foreign bodies, can potentially result in both false-positive and false-negative studies by mimicking or obscuring bleeding. Obtaining a noncontrast scan can avoid this imaging pitfall. Even in the absence of active bleeding, CT may be helpful in identifying the underlying culprit (Fig 24).

Ischemia

Gastric ischemia is an uncommon condition caused by diffuse or focal vascular insufficiency. Although the extensive collateral blood supply to the stomach is protective, systemic hypotension (as is seen in sepsis or shock) may result in gastric ischemia. Other described causes of gastric ischemia include celiac and mesenteric stenosis, vasculitis, and disseminated thromboembolism (32,33). Imaging findings in gastric ischemia range from focal ulceration to gastric wall thickening to intramural gas (Fig 26). Ischemic ulcerations most commonly occur along the anterior and posterior gastric walls near the anastomoses between the two arterial arches over the lesser and greater curvatures (32). Gastric dilatation may also be seen and is thought to be due to ischemic gastroparesis (32).

Conclusion

A variety of pathologic conditions of the stomach can result in abdominal pain and acute patient presentation. Although barium fluoroscopy and endoscopy still have important roles in evaluation of acute gastric disease, CT is now the first-line

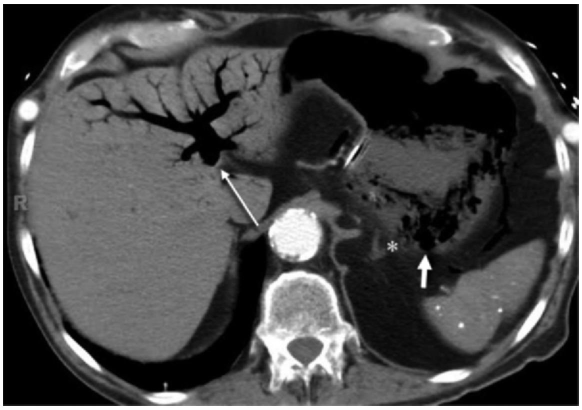


Figure 26. Gastric ischemia. Axial CT image with intravenous contrast material shows gastric dilatation and intramural gas (short arrow) with ulceration of the gastric wall and adjacent fat stranding (*). Gas extends into the portal venous system (long arrow).

imaging modality used for evaluating abdominal pain in the acute setting, and can often provide a rapid and accurate diagnosis. Familiarity with CT features of various gastric disorders is crucial for appropriate diagnosis and management.

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