Radiology

Review of Small-Bowel Obstruction: The Diagnosis and When to Worry[1]

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This is a review of small-bowel obstruction written primarily for residents. The review focuses on radiography and computed tomography (CT) for diagnosing small-bowel obstruction and CT for determining complications.

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Learning Objectives:

After reading the article and taking the test, the reader will be able to:

- Discuss the role and accuracy of abdominal radiography in the evaluation of small-bowel obstruction (SBO)
- Discuss the specific findings of SBO on supine and upright abdominal radiographs
- Discuss CT technique in patients suspected to have SBO
- Discuss the CT findings of SBO
- Discuss the complications of SBO detected by using CT

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Small-bowel obstruction (SBO) continues to be a substantial cause of morbidity and mortality, accounting for 12%–16% of hospital admissions for the evaluation of acute abdominal pain in the United States (1). Most patients with SBO are treated successfully with nasogastric tube decompression. However, the mortality of SBO ranges from 2% to 8% and may increase to as high as 25% if bowel ischemia is present and there is a delay in surgical management (2–5).

A challenge in the clinical management is that clinical presentation, physical examination findings, and laboratory tests are neither sufficiently sensitive nor specific to determine which patients with SBO have coexistent strangulation or ischemia (3–21). This uncertainty has led to the widespread use of imaging to not only diagnose SBO but to detect complications that require prompt surgery (4–55). More recent articles have analyzed the various computed tomographic (CT) signs in SBO in an attempt to determine their ability to predict which patients with SBO require surgery and which patients can be treated conservatively (22–55).

The purpose of this review is to familiarize radiology residents and other practitioners with basic knowledge of the imaging findings diagnostic of SBO and to emphasize complications that prompt surgical evaluation. The review will focus on the most widely used imaging methods for suspected SBO, which are radiography and CT. A discussion of alternative imaging methods for the diagnosis of SBO, such as luminal contrast material studies, ultrasonography, or magnetic resonance imaging, is beyond the scope of the review.

Essentials

- Small-bowel obstruction (SBO) is a substantial cause of morbidity and mortality, accounting for up to 16% of hospital admissions for acute abdominal pain in the United States.
- The clinical findings are neither sensitive nor specific enough to determine which patients with SBO have complications such as strangulation or ischemia.
- Abdominal radiography is usually the initial imaging modality in patients suspected of having SBO because it is widely available, is inexpensive, and has an accuracy of 50–86%.
- Multidetector CT has been proven to be the single best imaging tool for evaluating patients suspected of having SBO, with sensitivity and specificity of 95%; it is also highly accurate in detecting the complications of SBO.

Definitions of SBO

1. Complete or high-grade obstruction indicates no fluid or gas passes beyond the site of obstruction (4,5).
2. Incomplete or partial obstruction indicates that some fluid or gas pass beyond the obstruction (4,5).
3. Strangulated obstruction indicates that blood flow is compromised, which may lead to intestinal ischemia, necrosis, and perforation (4,5).
4. Closed-loop obstruction occurs when a segment of bowel is obstructed at two points along its course, resulting in progressive accumulation of fluid in gas within the isolated loop, placing it at risk for volvulus and subsequent ischemia (4,5).

Clinical Issues

Clinical findings of SBO include crampy abdominal pain, distention, vomiting, and high-pitched or absent bowel sounds. In patients with SBO, leukocytosis or an elevated serum amylase and lactic acid levels suggest a complication and should prompt a contrast material–enhanced abdominal and pelvic CT to determine the presence and cause of the suspected complication (5–55).

The management of SBO has evolved from prompt surgical repair to an initial trial of nasogastric tube decompression with follow-up abdominal radiography. Surgery is reserved for those patients who have a significant lesion causing complete obstruction and for those patients who fail to respond to nasogastric tube decompression or those with complications such as coexistent strangulation, vascular compromise, or perforation. The job of the radiologist is to diagnose the suspected SBO, determine its site and cause, and determine the presence or absence of complications such as ischemia or perforation (Fig 1). A number of authors have reported using a water-soluble contrast-material challenge to patients who have presumed adhesions producing SBO and who do not improve after 48 hours of conservative management (54). The patients receive 100 mL of water-soluble contrast material diluted with 50 mL of water through their nasogastric tube and abdominal radiographs are obtained 8 and 24 hours later. Those patients in whom the contrast material passes to the colon by 24 hours rarely require surgery. Patients in whom the contrast material does not reach the colon within 24 hours usually require surgery (54).

Etiology

In the Western world, the major cause of SBO is adhesions (3–6,56). The next two most frequent causes are hernias and malignancies (4–6,56). These three etiologies account for more than 80% of all causes of SBO. Other etiologies include Crohn disease, intussusception, volvulus, gallstones, foreign bodies, bezoars, trauma, and iatrogenic problems (3–6,56).

Radiography

Most patients suspected of having SBO undergo abdominal radiography largely because it is accurate, widely available, and inexpensive (6–8,57). The reported

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Abbreviation:
SBO = small-bowel obstruction

Conflicts of interest are listed at the end of this article.

accuracy of radiography for the diagnosis of SBO varies from 50% to 86% (6,7,18,23,30,54,57). The differences in accuracy are based in part on study design, patient selection, inconsistent use of nondependent radiographs, use of the term "non-specific bowel gas pattern," and inclusion of patients who have undergone recent surgery in whom the differentiation of ileus from SBO is difficult. In a recent study that included trainees (3rd-year residents) and junior, as well as senior faculty, the mean sensitivity, specificity, and accuracy of supine and upright radiographs were 82%, 83%, and 83% respectively, with a range in accuracy from 69% to 93% (57). Interestingly, the senior faculty was significantly more accurate than junior faculty (93% vs 83%) ($P < .003$). There was no significant difference between the trainees and junior faculty. Older literature reported much lower accuracy rates, in the 50%–60% range (58–61). These articles allowed the use of the terms "non-specific gas pattern," which for some radiologists implied normal and for others implied that the presence of SBO could not be excluded (58–61).

We strive to eliminate the use of the term "non-specific gas pattern" and commit to the presence or absence of SBO in every case where SBO is the clinical concern. The clinical history is critical, especially in cases of the gasless abdomen (62). A general algorithm for evaluation of patients suspected of having SBO is shown in Figure 2. We reserve the diagnosis of ileus when there is distension of both the colon and the small bowel, especially in postoperative patients. While this review does not discuss the roles of enteroclysis and small-bowel follow through in patients suspected of having SBO, the algorithm shows them as final considerations in a number of pathways (6–8).

The diagnosis of SBO is improved substantially if radiographs are obtained in both dependent (spine or prone) and nondependent (upright or decubitus) views (Figs 3, 4) (57).

The radiographic findings of SBO are listed in Table 1. The hallmark of SBO is dilated small bowel proximal to the site of obstruction with decompressed distal bowel. Small bowel dilatation is present, defined as 3 cm or larger (57) (Fig 3), though some prefer the more conservative measurement of 2.5 cm (4,6–8). In SBO, the small bowel will be dilated out of proportion to the colon (Fig 3), and in proximal SBO, the stomach may be distended as well. The "stretch sign" refers to small-bowel gas arranged as low-attenuation stripes perpendicular to the long axis of the bowel (Fig 5) (6). The finding is due to small amounts of gas separated by the valvulae conniventes in primarily fluid-filled bowel (Fig 5) (6). Rectal gas may be absent in SBO but it may also be absent in patients with normal findings, as well as those with colonic obstruction; thus the absence of rectal gas is of little importance when evaluating patients suspected of having SBO.

An additional finding that may occur in SBO is paucity of small-bowel gas or the gasless abdomen (62) (Fig 4). While there are several causes of the gasless abdomen, the most serious cause is SBO with or without ischemia (62). The absence of small-bowel gas in SBO is due

Figure 1

Five Questions to Address in Suspected SBO

1. Is there SBO?
2. Where is the location of the obstruction?
3. What is the cause of the obstruction?
4. Are there any complications such as ischemia, volvulus or internal hernia?
5. How should the patient be treated?

Figure 1: Five questions to address in suspected SBO.

Figure 2

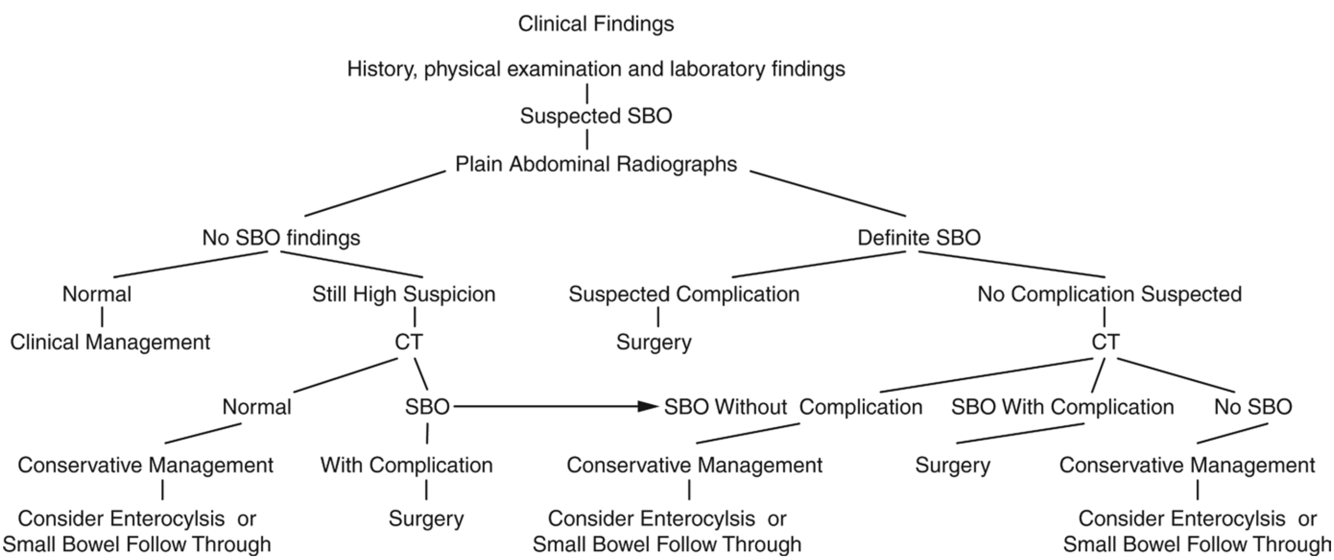
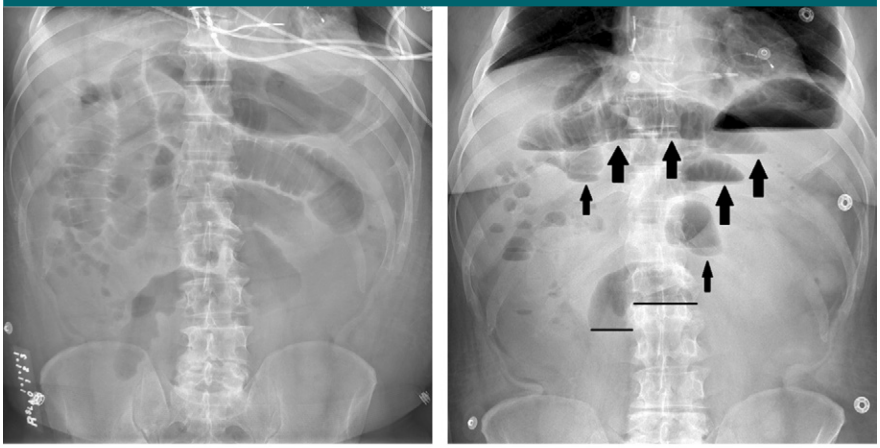


Figure 2: Algorithm for diagnostic work-up of patients suspected of having SBO.

Figure 3



a. b.

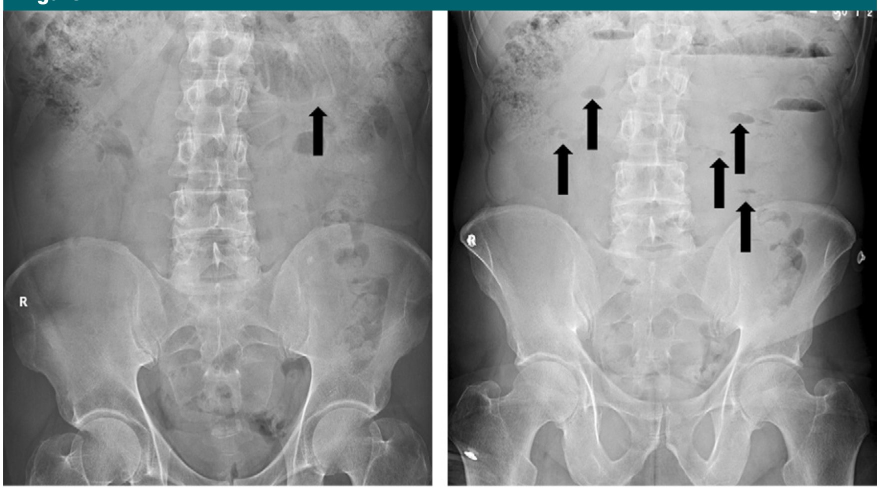
Figure 3: Images in a 50-year-old man with abdominal pain, nausea, and vomiting. **(a)** Supine abdominal radiograph shows dilated small-bowel loops out of proportion to gas in the colon. **(b)** Upright abdominal radiograph shows multiple air fluid levels (large and small arrows), fluid levels greater than 2.5 cm (large arrows), and fluid levels of unequal heights in the same dilated loop of small bowel (horizontal black lines).

Table 1

Radiographic Signs of SBO

Type of Radiograph	Specific Signs
Supine or prone	1. Dilated gas or fluid-filled small bowel (>3 cm)
	2. Dilated stomach
	3. Small bowel dilated out of proportion to colon
	4. Stretch sign
	5. Absence of rectal gas
	6. Gasless abdomen
	7. Pseudotumor sign
Upright or left lateral decubitus	1. Multiple air fluid levels
	2. Air fluid levels longer than 2.5 cm
	3. Air fluid levels in same loop of small bowel of unequal heights
	4. String of beads sign

Figure 4



a. b.

Figure 4: Images in a 70-year-old man with abdominal pain, nausea, and vomiting. **(a)** Supine abdominal radiograph demonstrates a paucity of small-bowel gas. Note the dilated small-bowel loop in the left upper abdomen (arrow). **(b)** Upright abdominal radiograph demonstrates multiple small fluid levels (arrows).Large fluid level seen in dilated small bowel left upper abdomen correlates with same dilated small bowel loop seen on supine radiograph.

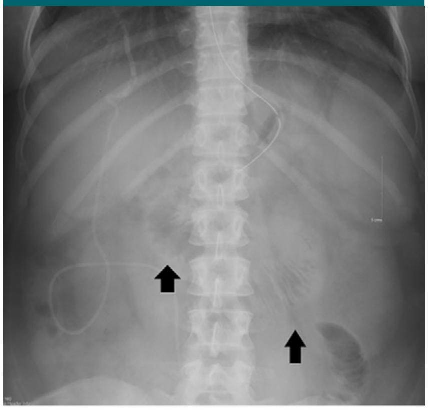
to fluid rather than gas filling the dilated small bowel. The absence of small-bowel gas in the setting of SBO usually indicates high-grade SBO or a SBO complicated by a closed-loop obstruction. In these cases, the supine radiograph demonstrates a paucity of small-bowel gas while the upright radiograph may show the string of beads sign (Fig 4) (62). The string of beads sign is due to fluid-filled loops of bowel, with a small amount of remaining gas trapped in folds between valvulae conniventes, which resembles a string of beads (Fig 4) (6,62). Finally, fluid-filled small bowel can mimic an intra-abdominal mass (Fig 6). This sign, more common in pediatric patients, is the "pseudotumor sign" of Frimann-Dahl, which represents obstructed, dilated, and fluid-filled loops of small bowel (Fig 6) (63). This finding has also been described in primary volvulus of the small intestine and in small-bowel strangulation (64).

The four signs on upright or left lateral decubitus radiographs listed in Table 1 have a high sensitivity and specificity for establishing the diagnosis of SBO (Figs 3, 4) (57). A number of authors indicate that when all four signs are present, the sensitivity and specificity for SBO are very high (6,57). Multiple air-fluid levels, air-fluid levels longer than 2.5 cm, and air-fluid levels in the same loop of small bowel of unequal heights (> 5 mm) are much more common than the string of beads sign (57).

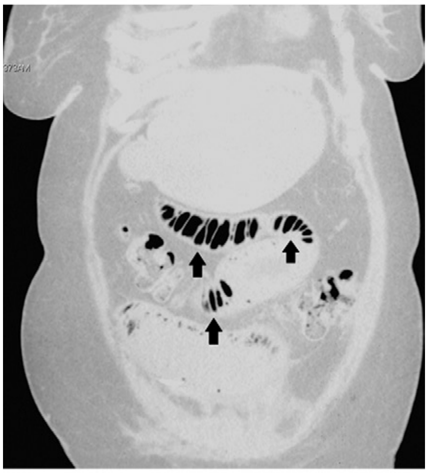
CT Technique

Traditionally, high-attenuation oral contrast material was routinely administered in patients suspected of having SBO. The oral contrast material may be either barium based or iodine based. An advantage of the administration of oral contrast material is that if it passes distally into the decompressed bowel,

Figure 5



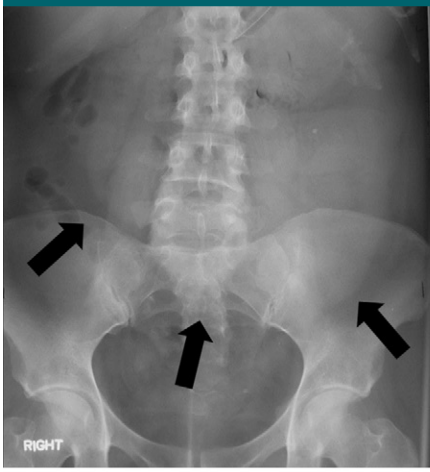
a.



b.

Figure 5: Images in a 55-year-old man with abdominal pain and vomiting. **(a)** Supine abdominal radiograph demonstrates dilated loop of small bowel, which is partially filled with gas outlining the valvulae conniventes (arrows), the so-called stretch sign. **(b)** Coronal CT scan demonstrates the stretch sign.

Figure 6



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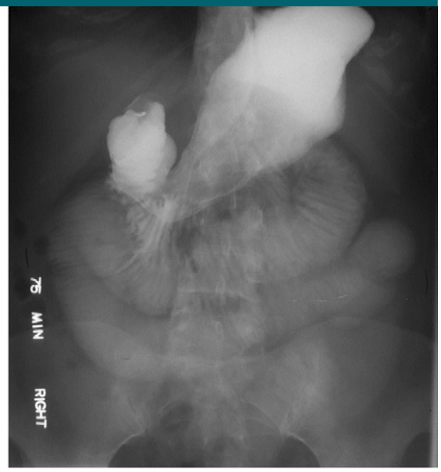

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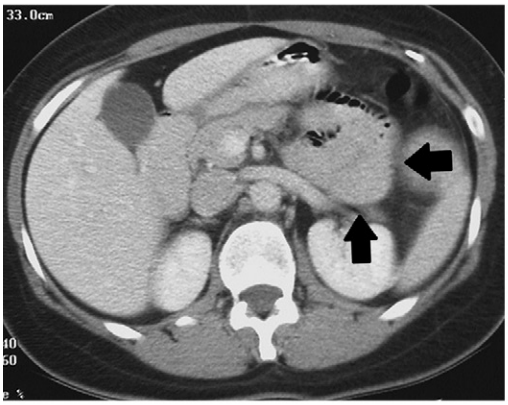


c.

Figure 6: Images in a 60-year-old man with abdominal pain. **(a)** Supine abdominal radiograph demonstrates soft-tissue mass midabdomen (arrows). **(b)** Supine radiograph from upper gastrointestinal series demonstrates the soft-tissue mass is actually due to fluid-filled dilated small bowel secondary to SBO. **(c)** Intravenous contrast-enhanced axial CT scan through midabdomen demonstrates fluid-filled loops of small bowel (arrows) responsible for the pseudotumor sign.

then a high-grade obstruction is ruled out. Recently, many groups have omitted the routine administration of high-attenuation oral contrast material because *(a)* patients with SBO are nauseated and may vomit, potentially leading to aspiration; *(b)* contrast material rarely opacifies the bowel just proximal to the transition point in a high-grade obstruction; and *(c)* the low-attenuation fluid and gas within the obstructed lumen provide excellent contrast relative to the normally enhancing bowel wall, which is obscured by high-attenuation oral contrast material. Omission of oral contrast material also eliminates the 2–3-hour delay in the performance of the CT examination. Our group is increasingly comfortable interpreting CT scans for suspected SBO without the use of oral contrast material.

Because patients suspected of having SBO obstruction have dilated fluid-filled bowel, CT enterography, which requires the ingestion of at least a liter of low-attenuation fluid, is neither required nor appropriate (65). Administration of intravenous contrast material is recommended as a routine unless there is a contraindication. The administration of intravenous contrast material is particularly beneficial to assess for the presence of signs of inflammation and ischemia, which are far more difficult to detect otherwise (2,4,16,55).

Coronal and/or sagittal multiplanar reformations have been shown helpful to identify the transition point and to assess for evidence of a volvulus or closed-loop obstruction (22,65,66,67). The following is a 64-section multidetector CT protocol for suspected SBO: 150 mL nonionic iodinated contrast material injected at 3 mL/sec, 60-second scan delay (or automated scan delay based on hepatic attenuation), 64 × 0.625 detector configuration, and 3–5-mm reconstruction in axial and coronal planes.

CT Findings

Multidetector CT is the single best imaging tool for suspected SBO. Multidetector CT has a sensitivity and specificity of 95% for the diagnosis of high-grade SBO and is less accurate in partial obstruction (4,6–8). As with radiography, the hallmark is dilated (> 2.5 cm) proximal small bowel with decompressed distal small bowel and colon (Table 2, Fig 7) (15). Air-fluid levels will be present and a string of beads sign may be identified. In high-grade obstruction or in chronic obstruction, stasis and mixing of small-bowel contents with gas creates an appearance analogous to feces in colon, the "small-bowel feces" sign (Fig 8) (21,25,30). This sign was first described by Mayo-Smith in 1995 and has been shown to be present in 5%–7% of patients suspected of having SBO (21,25,30). Some reports have shown this sign to be present in high-grade SBO (21,30), while others have shown a negative correlation in patients requiring surgical treatment for SBO (25). The main importance is the small-bowel feces sign is usually seen just proximal to the transition point (23,25,30).

Table 2

CT Criteria for Diagnosis of SBO

Criteria	Specific Criteria
Major	Small bowel dilated to 2.5 cm or greater and colon not dilated (<6 cm)
	Transition point from dilated to nondilated small bowel
Minor	Air fluid levels
	Colon decompressed

One advantage of CT over radiography is the increased confidence of identification of the transition zone, which is the site where dilated bowel transitions to decompressed bowel (Fig 8). It is at this site where a specific cause for the obstruction may be determined. The accuracy of detection of the transition zone location reported in the literature ranges from 63% to 93% (36,40). Further, CT provides an excellent evaluation of the bowel wall, its vessels, and adjacent mesentery, which permits the identification of coexistent ischemia and/or infarction. CT also provides an excellent evaluation for the presence of bowel perforation and the presence of free extraluminal gas.

Sixty to 70% of SBOs are caused by adhesions (3,4,56), which are usually the result of prior abdominal surgery, whether open or laparoscopic. Adhesions represent bands of fibrous tissue that obstruct the lumen and are a consequence of the postoperative inflammatory process. They may lead to bowel obstruction in the early postoperative period or may obstruct years later. On CT scans, the adhesion itself is generally not identified. Rather, its presence is inferred when there is an abrupt transition from dilated to collapsed bowel without an identifiable cause at the transition zone. As adhesions compress the bowel extrinsically, they often cause an abrupt tapering or "beak" at the site of obstruction.

Figure 7

Figure 7: Images in an 81-year-old woman with nausea and vomiting. **(a)** Axial unenhanced CT scan shows dilated loops of ileum filled with contrast material (arrow). Note the contrast material does not pass into decompressed distal loops of small bowel (arrowhead). **(b)** Unenhanced axial CT scan at the level of the pubic symphysis shows protrusion of ileum (arrow) into the obturator canal. **(c)** Unenhanced axial CT scan shows ileum trapped in the obturator canal between the obturator externus and pectineus muscles (arrow). **(d)** Coronal reformation shows the herniated and obstructed ileum protruding into the obturator canal (arrow).

Figure 8

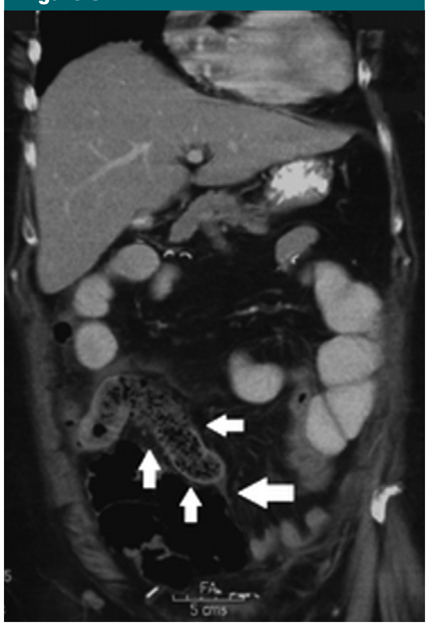


Figure 8: Contrast-enhanced coronal CT scan in a 50-year-old man with abdominal distension, which demonstrates the small bowel feces sign (small arrows) just proximal to the transition point (large arrow) of a small- bowel obstruction due to an adhesion.

External hernias are the second most frequent cause of SBO (3,4,56). They can occur throughout the abdomen and pelvis, but most frequently involve the inguinal canal or anterior abdominal wall. The hallmark of SBO due to hernia is the presence of dilated bowel up to the hernia sac followed by decompressed bowel exiting from the sac.

In patients with known primary tumors and SBO, the most likely cause is metastatic disease either involving bowel or peritoneum. Surgeons hesitate to operate on these patients because while one metastasis may be the cause of the obstruction, multiple abdominal metastases are usually present, and it is not generally feasible or appropriate to address all of these metastases surgically (Fig 9).

Other causes of SBO include internal hernia, acute inflammation such as diverticulitis, acute appendicitis, abscess, chronic inflammation such as Crohn disease, or other causes, including obstruction from objects such as capsular endoscopes or gallstones (Fig 10).

Closed-Loop Obstruction

A closed-loop obstruction implies a segment of bowel that is obstructed at two points along its course essentially isolating the obstructed segment from the remainder of the gastrointestinal tract (9,12,16,32). The sites of obstruction are adjacent to each other, often the result of a single constricting lesion that occludes the bowel and affects adjacent mesentery (Fig 11). The isolated segment continues to secrete fluid and it therefore becomes progressively dilated and fluid filled, which can impair venous return resulting in ischemia. As the bowel proximal and distal to the dilated segment continues to peristalse around its narrow point of obstruction, it is no surprise that a twist or volvulus

Figure 9

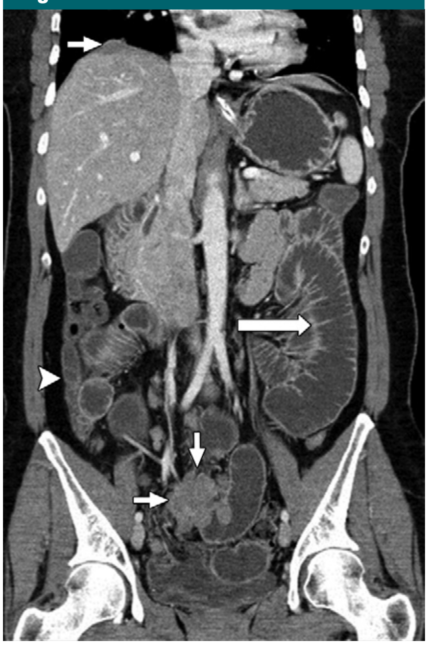
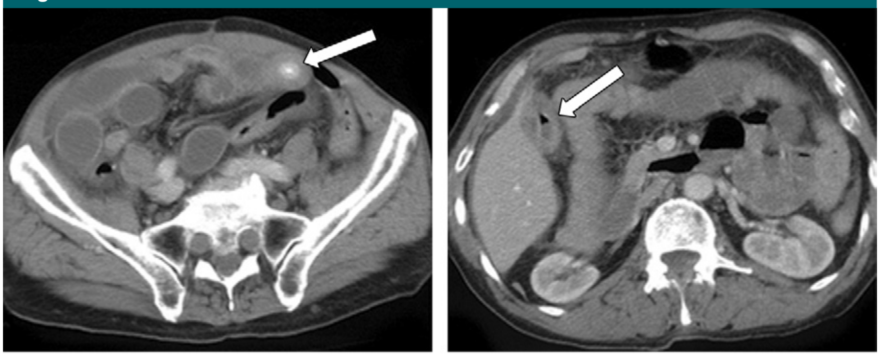


Figure 9: Contrast-enhanced coronal CT reformation in a 51-year-old woman with stage III ovarian cancer shows dilated fluid-filled small bowel (large arrow) with decompressed distal small bowel (arrowhead) and colon consistent with obstruction. A peritoneal-based mass (lower small arrows) is identified at the point of transition. Additional sites of peritoneal involvement are seen in the subphrenic space (upper small arrow). The patient responded to nasogastric tube decompression.

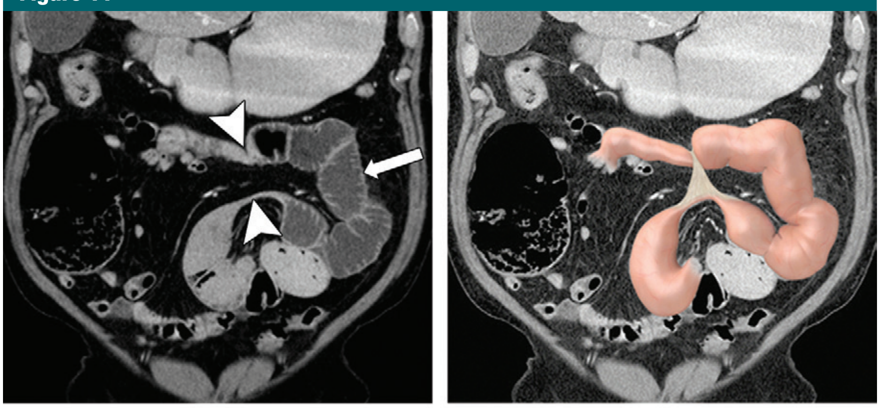
Figure 10



a. b.

Figure 10: Images in a 65-year-old man with abdominal pain. **(a)** Dilated fluid-filled small bowel and decompressed distal small bowel consistent with obstruction. The point of transition corresponds to a high-attenuation intraluminal filling defect (arrow), which proved to represent a gallstone that eroded from the gallbladder to obstruct the small bowel. **(b)** Contrast-enhanced axial image shows gas in the gallbladder (arrow), a result of the fistulous communication to the small bowel.

Figure 11



a. b.

Figure 11: Images in a 54-year-old man with a remote history of abdominal surgery and intermittent abdominal pain. **(a)** Dilated and fluid-filled jejunum (arrow) with beaklike narrowing (arrowheads) both proximally and distally, consistent with closed-loop obstruction without volvulus or ischemic changes. Note proximal bowel is dilated and filled with contrast material. **(b)** Superimposed schematic shows a closed-loop obstruction caused by an adhesion that isolates a loop of fluid-filled bowel.

may occur, increasing the risk of coexistent ischemia. Most commonly, the closed loop is caused by a single adhesive band, but internal hernias or congenital or iatrogenic defects in the mesentery or omentum may serve to trap a segment of the bowel leading to a closed-loop obstruction. In particular, patients who have undergone Roux-en-Y gastric bypass are at increased risk for closed-loop obstruction, a result of surgically created rents in the mesentery (68,69). While patients with closed-loop obstruction and volvulus are more likely to be acutely ill, it is not known how often closed-loop obstructions are complicated by volvulus.

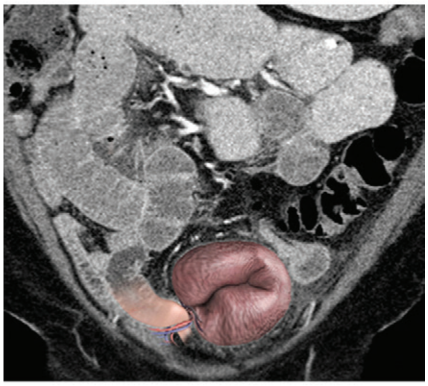
The CT findings of a closed-loop obstruction depend in part on the orientation of the loop relative to the plane of imaging. If the loop is within the plane of imaging, the lesions often appear as a "U," "C," or "coffee bean" configuration pointing to the site of twist (Fig 12) (9,14,52). If orthogonal to the plane of imaging, dilated bowel in a radial configuration may be encountered. Careful review of the images will show two loops in close proximity at the site of transition tethered by a single adhesive band or trapped in a mesenteric rent. At the site of the tethering, loops will taper, creating a beak configuration (9,16). When there is a coexistent volvulus, the adjacent vessels will show a swirled configuration reflecting the twist in the mesentery, the so-called whirl sign (Fig 13) (70,71). It is important to carefully search for evidence of volvulus as patients with volvulus are at higher risk for ischemia and require prompt surgical evaluation and repair. The findings of a closed-loop obstruction may be best seen in the coronal or sagittal plane. The dilated bowel in a closed-loop obstruction may be difficult to detect because the bowel proximal to the point of obstruction is also obstructed, but tends to have less upstream dilation than the closed loop.

Ischemia

Ischemia is the complication that increases the morbidity and mortality associated with SBO (14). Specifically,

Figure 12

a.



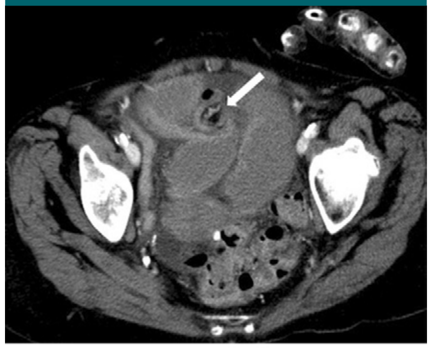
b.

Figure 12: Contrast-enhanced axial CT scan in a 65-year-old woman with history of lymphoma. **(a)** Note the C-shaped fluid-filled jejunum with a heterogeneously enhancing thickened wall (arrow) with associated mesenteric edema (arrowhead). At surgery there was a closed loop obstruction with volvulus and jejunal ischemia. **(b)** Superimposed schematic illustrates closed-loop obstruction with volvulus, twisted mesenteric vessels, and bowel ischemia.

the mortality rate in patients who undergo surgery for SBO with ischemic bowel is as high as 25% compared with those with SBO without strangulation, which may be as low as 2% (2–5). When ischemia is suspected, immediate surgery is required to avoid transmural necrosis and perforation.

However, physical examination and laboratory findings are not sufficiently sensitive to accurately help predict which patients with SBO have coexistent ischemia. Accordingly, contrast-enhanced multidetector CT is widely used to identify patients with SBO and coexistent ischemia. Unfortunately, the sensitivity, even in selected patient groups with ab-

Figure 13



a.

b.

Figure 13: Images in a 65-year-old woman with nausea, abdominal pain, and peritonitis. **(a)** Contrast-enhanced CT scan shows closely opposed mesenteric vessels near the site of a volvulus associated with a closed-loop obstruction, with a whirl sign (arrow). **(b)** Note the C-shaped closed loop (arrow). The thickened wall, heterogeneous enhancement, mesenteric edema, and free intraperitoneal fluid are associated with bowel ischemia.

dominal pain and proven bowel obstruction, varies between 75% and 100%, and specificities range from 61% to 93% (2,4,16,28). One experienced group reported a prospective 15% sensitivity for the detection of ischemia in SBO (30). So a high degree of suspicion needs to be in the mind of the interpreting radiologist.

The CT findings associated with ischemic bowel include bowel with thickening, mesenteric edema and/or fluid in the adjacent mesentery or peritoneal space, abnormal decreased bowel wall enhancement, and pneumatosis with or without associated gas in mesenteric or portal veins (Fig 14). While the diagnosis of ischemia can be made with CT, it is controversial to what extent CT can be

Figure 14

CT Findings of Ischemia

1. Bowel wall thickening (> 3 mm)
2. Mesenteric edema
3. Fluid in mesentery and/or peritoneal cavity
4. Abnormal bowel wall enhancement, either increased or decreased
5. Occlusion of mesenteric vesssels
6. Engorged mesenteric veins
7. Whirl sign
8. Closed-loop obstruction or volvulus
9. Pneumatosis
10. Mesenteric venous gas
11. Portal venous gas

Figure 14: CT findings of ischemia.

Figure 15

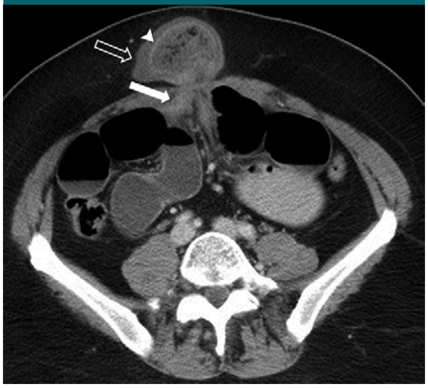


Figure 15: Contrast-enhanced CT scan in a 48 year-old woman with vomiting and peri-umbilical pain shows dilated fluid and gas-filled small bowel consistent with SBO. There is an incarcerated loop of small bowel (arrowhead) within a ventral hernia. Note the rim of fluid (open arrow) abutting the incarcerated bowel. A decompressed loop of small bowel (solid arrow) exits the hernia sac.

Figure 16

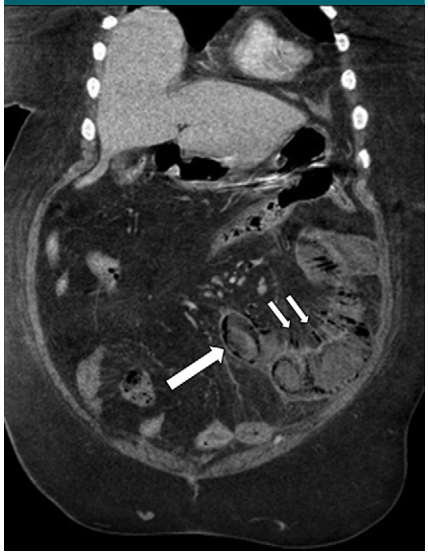


Figure 16: Contrast-enhanced CT scan with coronal reformation shows SBO with pneumatosis (arrow) in a 58-year-old woman with diabetes mellitus and end-stage renal disease with several days of fatigue, vomiting, and abdominal pain. Note the gas in adjacent mesenteric veins (small arrows).

used to exclude ischemia. Some studies suggest caution when using CT to exclude ischemia, citing a low sensitivity, while others note the absence of edema and fluid in the mesenteric fat adjacent to dilated bowel is associated with viable bowel. Most patients with bowel ischemia have circumferential segmental bowel wall thickening, defined as greater than 3 mm, but on average measuring 8 mm (4). The thickening is due to edema, hemorrhage, or both; on noncontrast-enhanced CT scans, hemorrhage may create high attenuation in the bowel wall. On contrast-enhanced CT scans, ischemia is associated with abnormal bowel wall enhancement and may manifest as decreased enhancement relative to the uninvolved bowel, hyperenhancement of the mucosa relative to the remainder of the bowel wall creating a "target" appearance, or as heterogeneous enhancement.

Additionally, the mesenteric fat adjacent to ischemic bowel will show increased attenuation due to edema, engorged vessels, or both. Fluid is often present, either trapped within folds of mesenteric fat or free in the peritoneal recesses or fluid abutting obstructed bowel in a hernia sac in the absence of generalized ascites (Fig 15). A relatively late sign is the presence of pneumatosis and is associated mesenteric venous gas and portal venous gas, which suggest the presence of transmural necrosis (Fig 16) (19). Pneumatosis may be subtle to detect even with CT as gas within the lumen that rims the mucosa may mimic pneumatosis. Gas in mesenteric veins may be identified in conjunction with pneumatosis in the bowel wall. Identification of gas in veins draining a segment of the bowel, or portal venous gas, often confirms the suspicion of pneumatosis.

Additionally, when interpreting imaging findings in patients suspected of having SBO, it is important to not only assess for the presence of ischemia, but to carefully search for causes of obstruction associated with strangulation and ischemia. These conditions include internal or external hernia, closed-loop obstruction with volvulus, and surgical history of Roux-en-Y gastric bypass. Search carefully for a whirl sign, which suggests a volvulus (69,70). The whirl sign has been reported to have 60% sensitivity and 80% positive predictive value in patients requiring surgery for SBO (70).

In conclusion, when evaluating patients suspected of having SBO, address the issues that are relevant to surgical management including the presence of SBO, site, cause, and presence of complications. It is critical to search carefully for evidence of volvulus and closed-loop obstruction as these conditions are associated with strangulation and place patients at risk for ischemia.

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