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MDCT findings in small bowel obstruction: implications of the cause and presence of complications on treatment decisions

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Abstract

Small bowel obstruction (SBO) accounts for a considerable proportion of emergency room visits, inpatient admissions, and surgical interventions in the United States. Multi-detector computed tomography (MDCT) plays a key role in imaging patients presenting with acute symptoms suggestive of SBO, which helps in establishing the diagnosis, elucidating the cause of obstruction, and detecting complications, such as ischemia or frank bowel necrosis and perforation. Recently, management of patients with SBO has shifted toward a more conservative approach with supportive care and nasogastric tube decompression, as the obstruction in many cases can resolve spontaneously without the need for operative intervention. However, management decisions in SBO remain notoriously difficult, relying on a combination of clinical, laboratory, and imaging factors to help stratify patients into conservative or surgical treatment. Imaging is often an important factor assisting in the decision-making process since traditional clinical signs of vascular compromise, such as acidosis, fever, leukocytosis, and tachycardia are often unreliable in predicting the need for operative intervention. Thus, it is critically important for radiologists to identify imaging features that suggest or indicated high likelihood of bowel vascular compromise in order to help optimize management prior to the development of bowel ischemia and eventually necrosis. By excluding signs of potentially ischemic or necrotic bowel on MDCT, patients may be spared unnecessary surgery, thus decreasing postsurgical complications and averting potential increase for the risk of future SBO and repeated surgery. Conversely, if imaging features indicate potential vascular compromise of the bowel wall that may lead to bowel ischemia, urgent surgical intervention may prevent progression to bowel necrosis and subsequent perforation.

Key words: Bowel obstruction—Ischemia—Gastrointestinal—Computed tomography

SBO is frequently encountered in clinical practice, accounting for an estimated 300,000–350,000 hospital admissions yearly in the United States, and approximately 15% of all surgical admissions [1–3]. In patients presenting acutely with high clinical suspicion of SBO and/or suggestive findings on initial screening abdominal radiographs, multi-detector computed tomography (MDCT) evaluation is the most commonly utilized imaging test for establishing the diagnosis of SBO with reported sensitivity of 90–96%, specificity of 96%, and accuracy of 95%, [4–7]. MR imaging can be used for assessing patients with subacute obstructive symptoms, such as patients with long-standing Crohn's disease [8]. However, more limited availability and longer acquisition times (and possible delay in diagnosis) limit the routine use of MR for patients presenting acutely and when bowel ischemia is suspected. Cross-sectional imaging can confirm the diagnosis of obstruction, establish the cause, and, in acute presentations, potentially detect early signs of potentially life-threatening complications related to bowel ischemia and/or necrosis. Recognition of these imaging findings is essential in assisting the clinical decision-making process by recognizing

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certain causes of obstruction (e.g., closed loop, volvulus, internal hernia), and detecting early signs of bowel ischemia, necrosis or perforation that may require urgent surgical intervention.

Unfortunately, several historic descriptions commonly utilized by both radiologists and non-radiologists to characterize bowel obstruction can be confusing and do not adequately address the key clinical questions. Specifically, using complete and partial or high and low-grade SBO to define the type of obstruction is not supported by published data, lacks standardized definitions, and does not reliably predict management or outcomes [1, 6, 9]. For these reasons, imaging evaluation of SBO should instead emphasize findings and causes of SBO which are known to be associated with increased risk of bowel vascular compromise which can lead to ischemia, necrosis, or perforation. After confirming the diagnosis of SBO, radiologists must devote specific attention to these imaging findings, which may influence clinical management, helping to identify the subset of patients that are more likely to need operative intervention vs. conservative management.

Imaging evaluation

Although abdominal radiographs are often utilized as the first screening modality for initial evaluation of patients presenting with suspected SBO, they have limited sensitivity, high inter-reader variability, and, in most cases, cannot identify the site and cause of obstruction or reliably detect early signs of bowel compromise (Fig. 1) [10–15]. By contrast, cross-sectional imaging (most frequently MDCT) can identify dilated bowel loops and diagnose SBO irrespective of the presence of intraluminal gas [16]. CT can also identify the cause of obstruction by localizing the transition zone, including the presence of a closed loop obstruction (if more than one transition zone is present) or abnormal bowel location or configuration (in internal hernias) [4]. In the acute presentation, MDCT can also detect signs of bowel vascular compromise, such as bowel wall thickening (secondary to edema or hemorrhage), mesenteric fat stranding and edema, inter-loop mesenteric fluid, pneumatosis or portomesenteric gas (Fig. 2) [4, 9, 15, 17, 18]. Contrast-enhanced CT can also assess for altered bowel wall enhancement and vascular clots, which are particularly important in the setting of bowel ischemia.

MDCT technique

Optimal CT evaluation of patients with suspected or known SBO should ensure complete coverage of the gastrointestinal tract (including herniated loops that may be in the abdominal wall or groin), starting above the diaphragm and extending to the bottom of the pelvis (to include both the inguinal and femoral regions) in the supine position during a single breath-hold (Fig. 3).

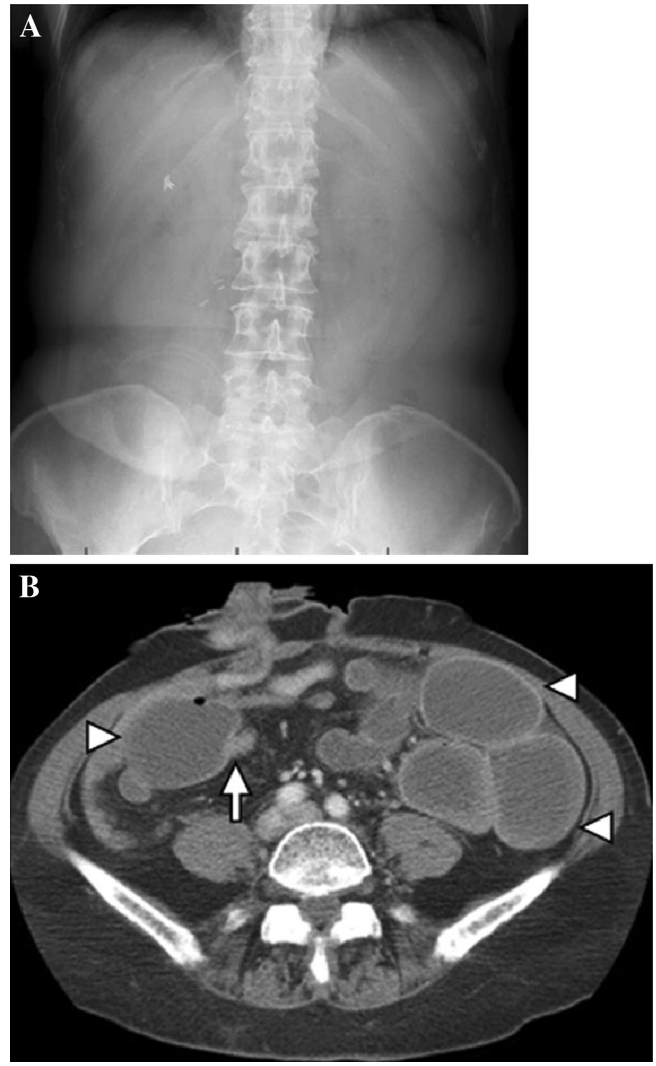

Fig. 1. Limitations of abdominal radiography vs. CT in evaluating a patient with suspected SBO. **A** Supine abdominal radiograph demonstrates a gasless abdomen, thus limiting the detection of dilated fluid-filled small bowel loops. **B** Axial contrast-enhanced MDCT image in the same patient demonstrates dilated fluid-filled bowel loops (*arrowheads*) with an abrupt transition zone (*arrow*) into decompressed distal small bowel loops, confirming the diagnosis of SBO. The obstruction resolved following conservative management.

Administration of intravenous (IV) contrast is essential to assess the patency of the mesenteric vessels, and to evaluate the bowel wall enhancement pattern (to identify potentially ischemic or necrotic bowel). Defining the mesenteric branches on a contrast-enhanced examination is also helpful to detect the presence of vascular engorgement or swirling that can be present in certain types of obstructions (e.g., volvulus). In patients presenting with acute symptoms, CT is most commonly performed as a single acquisition in the portal venous phase at 65–70 s after the start of an IV contrast injection

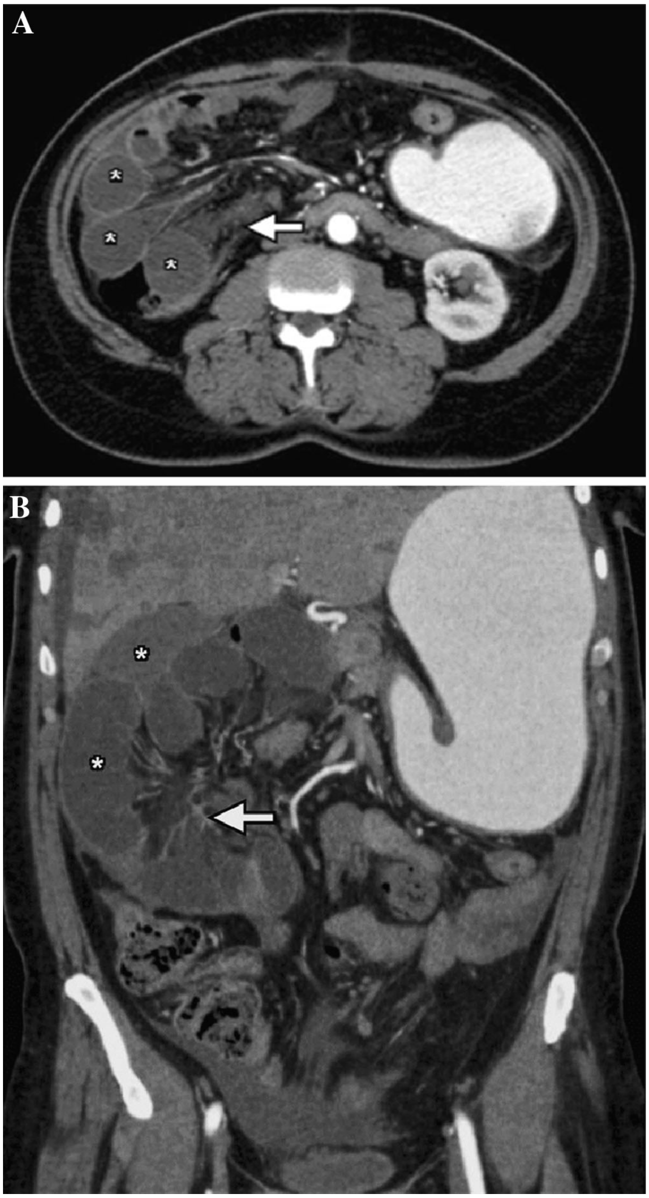

Fig. 2. Closed loop obstruction secondary to trans-mesenteric hernia. Axial and coronal contrast-enhanced MDCT images demonstrate dilated small bowel loops in the right side of the abdomen showing radial arrangement (*asterisks*). Decreased bowel wall enhancement and adjacent inter-loop mesenteric fluid (*arrow*) also noted, suggesting ischemia. Necrotic bowel was found intra-operatively due to a closed loop obstruction secondary to trans-mesenteric hernia.

(100–150 cc of 300–370 mg iodine/mL concentration) delivered at the rate of 2–4 mL/s. In patients with known Crohn's disease, CT enterography (performed in the enteric—at 45–50 s after IV contrast administration—and/or portal venous phase) is advocated to better assess the bowel wall enhancement pattern and to elucidate the contribution of active inflammation to a suspected SBO. In patients for whom there is high clinical concern for SBO and with a contraindication to IV contrast or requiring a prolonged steroid preparation, an unenhanced CT examination can be obtained to prevent delay in diagnosis and help expedite surgical intervention when indicated, noting that the lack of contrast will preclude adequate assessment of the mesenteric vasculature and the presence or pattern of bowel wall enhancement [19].

The use and type of oral contrast material is not standardized for several reasons and often depends on the patient's presentation. Patients who present acutely with obstructive symptoms and vomiting often cannot tolerate oral contrast and are at risk for aspirating ingested oral contrast, thus oral contrast can be omitted in this setting. Additionally, patients with significant small bowel dilatation usually demonstrate adequate distension secondary to fluid retention proximal to the site of the obstruction, obviating the need for oral contrast. If oral contrast can be tolerated safely and is needed to assess passage of contrast beyond the transition zone in proven SBO, the type of oral contrast administered should be considered carefully. Positive contrast material may obscure bowel wall enhancement, which limits assessment for ischemia, acute inflammation, or an underlying enhancing lesion. In these instances a CT enterography performed with neutral oral contrast may be indicated. Moreover, if there is concern for bowel perforation, water soluble oral contrast is preferred over barium-containing contrast in order to avoid spilling barium into the peritoneal space (and the risk of developing peritonitis). If administered, oral contrast is usually given between 1 and 4 h prior to scanning to allow sufficient opacification of small bowel and passage of contrast into the colon. However, in high risk patients with concern for bowel ischemia, oral contrast administration should be avoided as it will result in a prolonged wait time and delay in diagnosis.

Minimum available slice thickness (1–3 mm) should be used to improve the scan resolution and visualization of the bowel wall and mesenteric vessels. Isotropic image acquisition with MDCT also permits the display of high-quality reformatted images in any plane, including display in the coronal and sagittal plane, which facilitates identification of the transition zone(s) and assessment of the location and configuration of the obstructed bowel loops [20].

Diagnostic imaging signs in SBO

The diagnosis of mechanical SBO relies on the identification of dilated proximal (>3 cm in caliber) and decompressed distal small bowel segments with a characteristic intervening abrupt transition zone(s) [21, 22]. By contrast, diffuse small bowel dilatation without abrupt transition zone excludes mechanical SBO and suggests alternative diagnoses or systemic disorders affecting bowel motility, such as metabolic (e.g., ileus) or

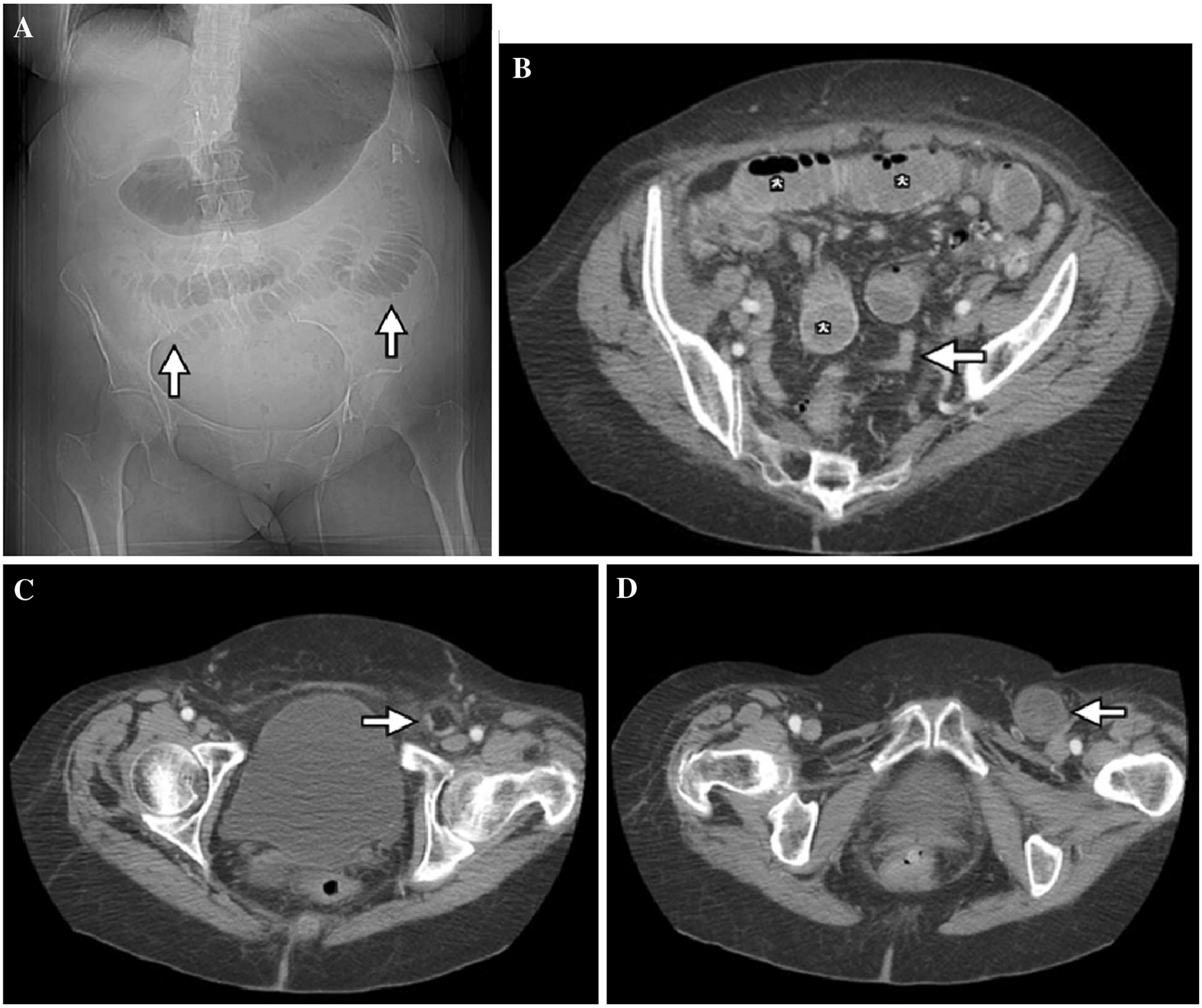

Fig. 3. Importance of CT coverage when evaluating suspected SBO. **A** Abdominal radiograph in a patient with suspected SBO shows small bowel dilatation (*arrows*) with paucity of gas distally suggestive of SBO. **B** Axial contrast-enhanced MDCT image demonstrates dilated proximal small bowel (*asterisks*) and distal decompressed bowel loops (*arrow*), confirming the presence of SBO. **C** The transition zone is identified in the left groin medial to the femoral vasculature (*arrow*). **D** Coverage extends inferiorly to include both groins, demonstrating the incarcerated small bowel loop in the left femoral sheath, indicating a femoral hernia (*arrow*). The diagnosis was confirmed at surgery.

connective tissue disorders (e.g., scleroderma) (Fig. 4) [22]. Once SBO has been diagnosed by identifying asymmetrically dilated proximal small bowel loops leading to an abrupt transition zone, the radiologist next must try to identify certain findings that suggest the cause of the obstruction (e.g., adhesions, closed loop obstruction, volvulus, internal hernia, or intraluminal impaction) and assess for signs of bowel wall vascular compromise (e.g., bowel wall edema, inter-loop fluid, altered bowel wall enhancement, pneumatosis, portomesenteric gas). Distinguishing between complete and partial/incomplete obstruction on CT is often difficult due to lack of specific signs and has not been shown to reliably affect management [1, 5, 15]. With the focus on the cause and complications of vascular compromise, which are more relevant to the management, attempting to make this distinction is likely not needed and irrelevant.

Small bowel feces sign

In some patients with SBO, particularly those with long-standing or subacute obstruction, the "small bowel feces sign" can be seen. This sign refers to the presence of mottled fecal-like material in the dilated small bowel immediately proximal to the transition zone, resembling colonic contents. Without bowel dilatation, the presence of fecal-like material in the small bowel is an incidental

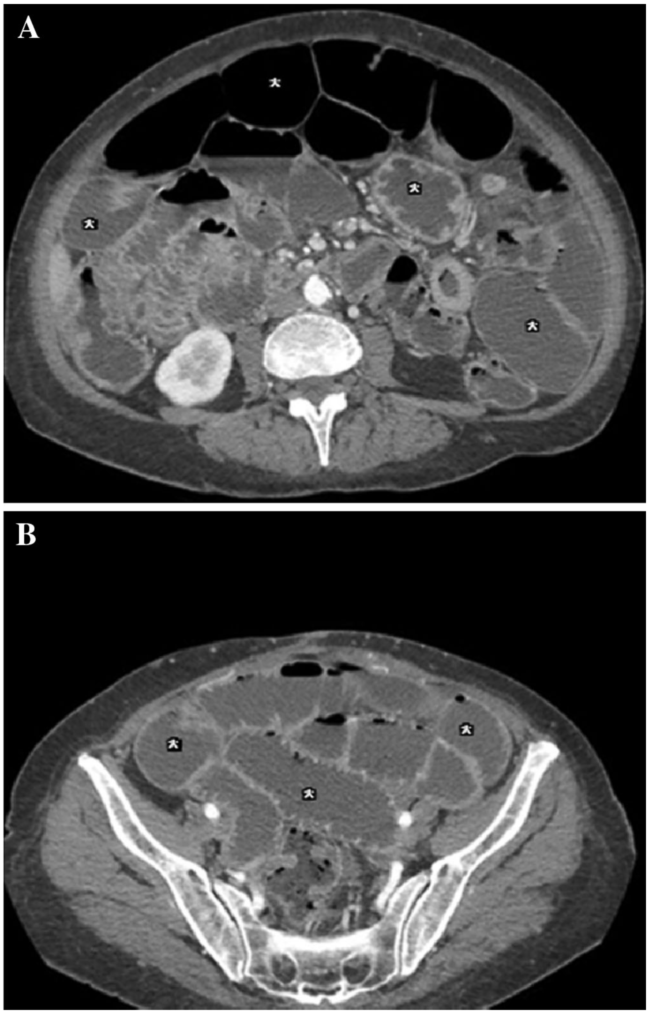

Fig. 4. Diffusely dilated small bowel loops in a patient with scleroderma. **A**, **B** Axial contrast-enhanced CT images demonstrate diffusely dilated small bowel loops in both the upper and lower abdomen (*asterisks*) with no abrupt transition zone, thus excluding mechanical SBO.

finding, which can be seen in asymptomatic patients or may indicate stasis with increased water resorption or bacterial overgrowth. In fact, a series by Jacobs et al. identified the small bowel feces sign more commonly in patients without SBO (68%) [23]. However, when associated with small bowel dilation, the small bowel feces sign may help identify the location of the transition zone. In the same study, Jacobs et al. found that all patients with small bowel feces sign and a dilated segment of small bowel >3 cm had SBO and, of those, the small bowel feces sign was just proximal to the transition zone in 75% of the cases.

Transition zone evaluation

Characterization of the cause and type of obstruction depends on the evaluation of the number (single vs. multiple) and location of the transition zone(s), as well as the shape or location of the dilated proximal bowel loops [6, 24].

Single transition zone

SBO with a single transition zone can be caused by (a) extrinsic, (b) intrinsic bowel wall, and (c) intraluminal pathologies. Extrinsic causes include adhesive bands, external hernias (e.g., inguinal, femoral, Spigelian, umbilical, obturator, or incisional), extension of extra-enteric disease process from the mesentery to the bowel serosal surface (e.g., sclerosing mesenteritis, peritoneal carcinomatosis, endometriosis), and any inflammatory or infectious process adjacent to the small bowel that leads to reactive bowel wall edema [4, 14]. Intrinsic bowel causes include bowel wall inflammation or fibrosis (such as from ischemia, hematoma, infectious enteritides, Crohn's disease, anastomotic stricture, or radiation enteropathy), intussusception, primary bowel neoplasms (e.g., adenocarcinoma, carcinoid, GIST, lymphoma), or metastatic lesions (e.g., melanoma, breast, distant primary GI tumors, etc.) [4, 12, 14, 15]. Intraluminal causes include gallstones (i.e., gallstone ileus), bezoars, thick intestinal secretions (e.g., cystic fibrosis) or ingested foreign body, which are usually visualized at the transition zone and identified by differential attenuation relative to the intraluminal fluid [4].

Extrinsic causes. SBO with a single abrupt transition zone and no visible abnormality at the level of the transition usually indicates an extrinsic obstructing fibrotic band or adhesion, particularly in patients with prior abdominal surgery (Fig. 5) [15]. Adhesions are exceedingly common, reportedly developing in up to 93% of patients who have undergone prior laparotomy and accounting for up to 85% of cases of SBO [25–29]. However, it is also important to note that 10–15% of adhesions develop in patients without prior surgery, usually from prior episodes of inflammation or infection, and should be still considered as the cause of obstruction in this setting [14].

External hernias, particularly in the inguinal region or anterior abdominal wall, are the second most common cause of SBO, though the relative frequency has decreased during the last 30 years [2]. Although traditionally a clinical diagnosis, some hernias may not be obvious on clinical exam due to location or body habitus. In these cases, MDCT can establish the diagnosis by localizing the site of transition at the hernia neck with upstream small bowel dilation (Fig. 6).

Intrinsic bowel causes. Focal small bowel strictures and resultant SBO are a recognized complication of Crohn's disease, which can be due to active inflammation, fibrosis or, most commonly, a combination of the two at the

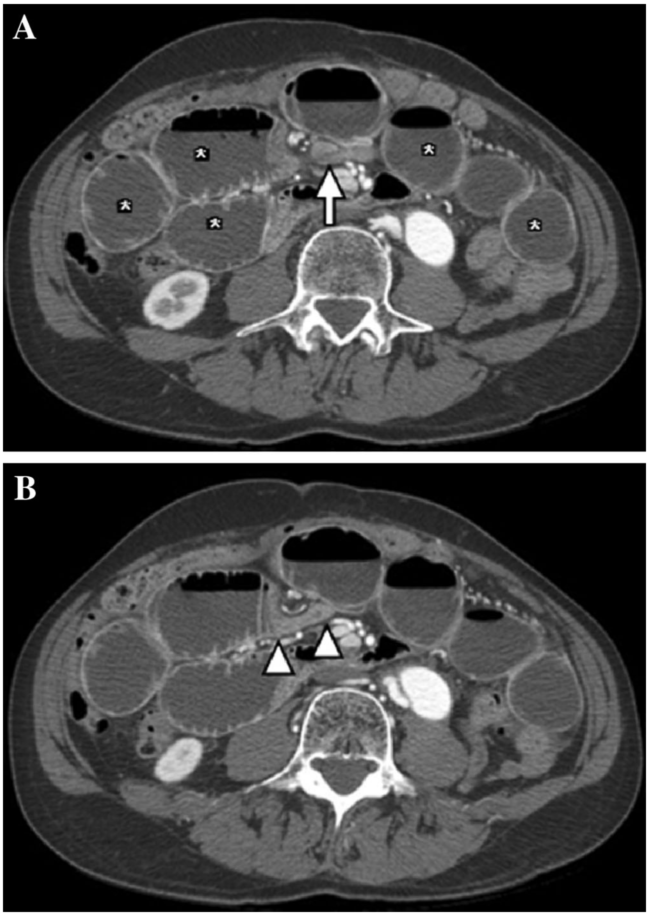

Fig. 5. SBO with single transition zone due to adhesive band. **A** Axial contrast-enhanced MDCT image demonstrates dilated small bowel loops (*asterisks*) and adjacent decompressed bowel segments (*arrow*). **B** Abrupt transition zone is identified between the dilated and decompressed bowel loops (*arrowheads*) without obvious bowel wall thickening or extrinsic masses. Adhesive band was confirmed intra-operatively as the cause of the obstruction.

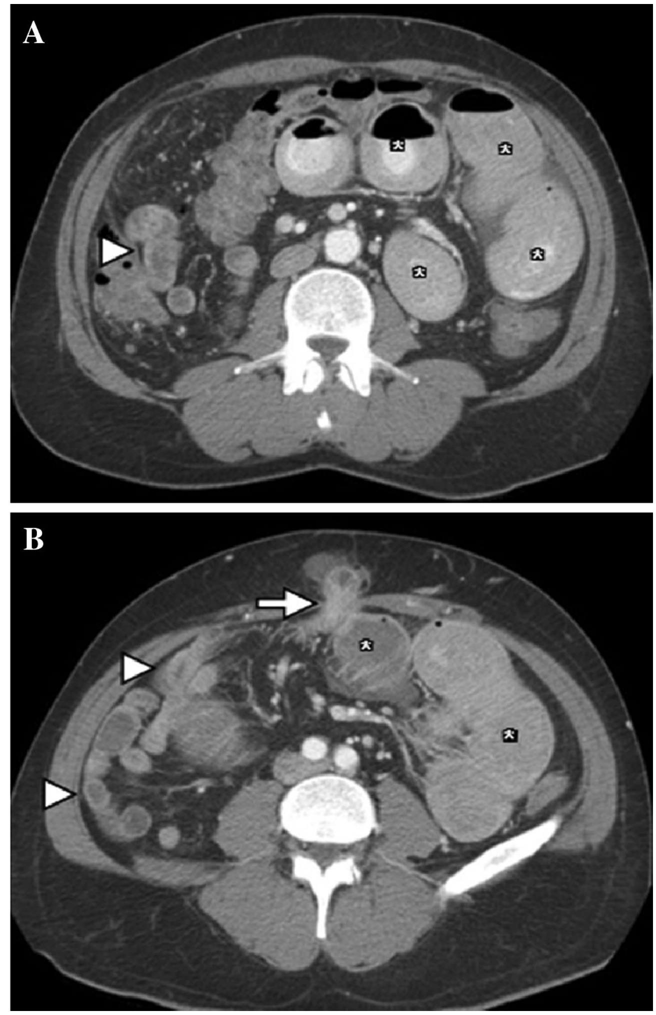

Fig. 6. SBO with single transition zone due to incarcerated umbilical hernia. **A**, **B** Axial contrast-enhanced MDCT images demonstrate dilated proximal small bowel loops (*asterisks*) and decompressed distal small bowel loops (*arrowhead*) with intervening abrupt transition at the incarcerated umbilical hernia (*arrow*). The diagnosis was confirmed at surgery.

stricture site (Fig. 7) [25, 30]. Signs of active inflammation in Crohn's disease include bowel wall thickening, stratified mural hyperenhancement, adjacent mesenteric fat stranding, and engorgement of the supplying mesenteric vessels. These signs of active inflammation are clinically relevant because they usually indicate the potential for response to medical therapy, which can relieve the obstruction by reducing the inflammation [30]. Diagnosing a fibrotic stricture is more challenging as the absence of imaging signs of active inflammation is not diagnostic of fibrosis [31].

Within the gastrointestinal tract, the small bowel is most susceptible to the effect of radiation due to its rapid cellular turnover [32]. Acute radiation enteropathy occurs in the first few days or weeks after exposure and is characterized by mucosal hyperenhancement and bowel wall thickening, which can result in acute SBO (Fig. 8). By contrast, chronic radiation enteropathy may develop months to years after radiation exposure and manifests as luminal narrowing and stricture formation secondary to fibrosis, which can also lead to SBO [32].

Surgical anastomoses are prone to fibrosis, which can lead to progressive narrowing of the lumen and result in SBO. One particular form of SBO caused by anastomotic stricture is afferent loop syndrome in gastric bypass patients where obstruction at the distal entero-enteric anastomosis results in progressive accumulation of biliary, pancreatic, and intestinal secretions in the afferent biliary limb. This is often difficult to detect clinically since the efferent or enteric limb is usually not obstructed and thus patients usually do not display the classic signs of SBO [33]. Diagnosis is best made with MDCT, which will demonstrate a dilated fluid-filled tubular structure in

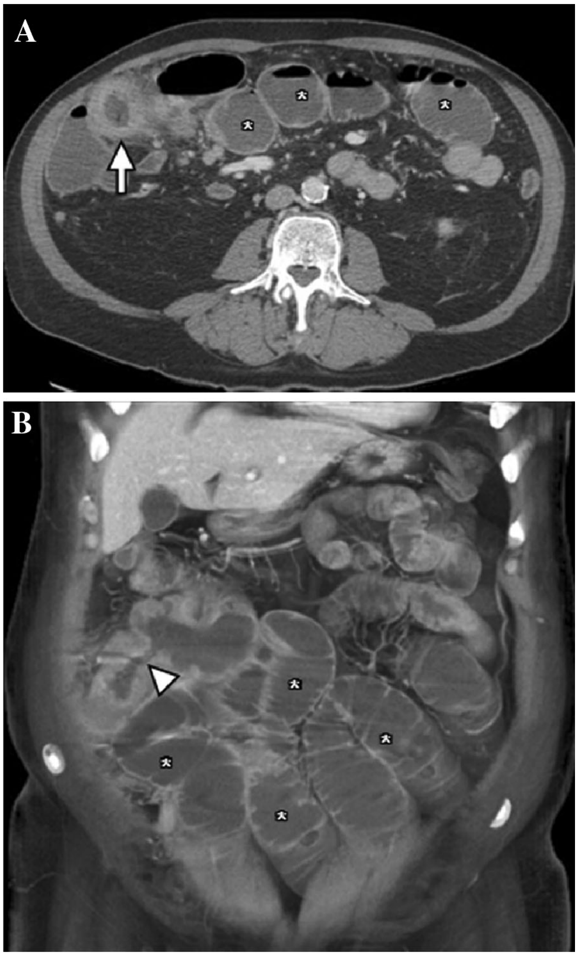

Fig. 7. Crohn's disease stricture with SBO. **A**, **B** Axial and coronal contrast-enhanced MDCT images demonstrate small bowel dilatation (*asterisks*) upstream from a mixed inflammatory and fibrotic stricture in the distal ileum (*arrow*) with luminal narrowing of the involved downstream segment of distal small bowel (*arrowhead*). The obstruction resolved following medical management.

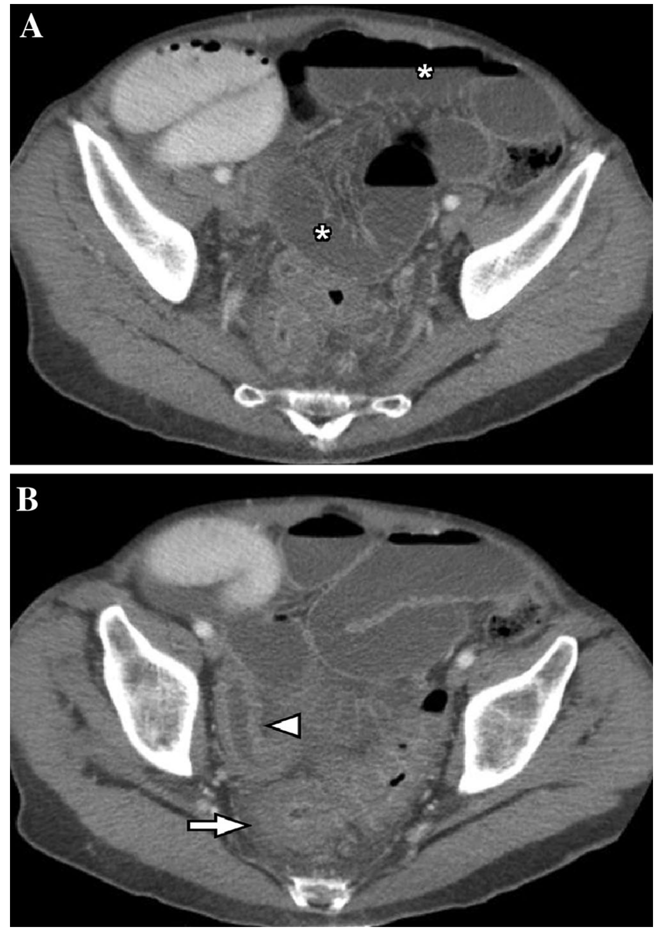

Fig. 8. Acute radiation enteropathy causing SBO. **A**, **B** Axial contrast-enhanced MDCT images demonstrate dilated small bowel loops (*asterisks*) proximal to a transition zone with circumferential bowel wall thickening and mural enhancement (*arrowhead*). Similar inflammatory changes also noted in the rectum (*arrow*). The patient previously received radiation to the pelvis for treatment of rectal cancer. The obstruction resolved following conservative management.

the right upper quadrant or crossing the midline (corresponding to the afferent limb) extending to a transition point at the distal entero-enteric anastomosis (Fig. 9). CT may also demonstrate biliary dilation, which can result from increased pressure within the obstructed afferent loop.

Intussusception can result from intrinsic or extrinsic causes that act as a lead point. Although the majority of small bowel intussusceptions encountered on routine imaging are incidental and inconsequential, some are symptomatic and may be associated with a lead point, which may necessitate surgical intervention (Fig. 10). Most cases of intussusception with resultant SBO and/or bowel ischemia are associated with a visible lead point and require surgical management [34].

Both primary enteric and metastatic neoplasms can also result in a single transition zone due to either luminal narrowing (if intrinsic to the bowel wall) or by causing extrinsic mass effect (Fig. 11).

Intraluminal causes. Intraluminal impaction of a foreign body can lead to luminal obstruction. One such intraluminal cause is gallstone ileus, where a large gallstone passes through the ampulla of Vater into the small bowel lumen, which then becomes impacted, commonly in the distal or terminal ileum, causing SBO (Fig. 12) [35]. In these cases, the combination of pneumobilia, SBO and ectopic gallstone in the small bowel lumen in the right lower quadrant (i.e., Rigler's triad) is pathognomonic for gallstone ileus.

Another common intraluminal cause of SBO is distal intestinal obstruction syndrome (DIOS), seen in adolescent and adult patients with cystic fibrosis (Fig. 13) [36].

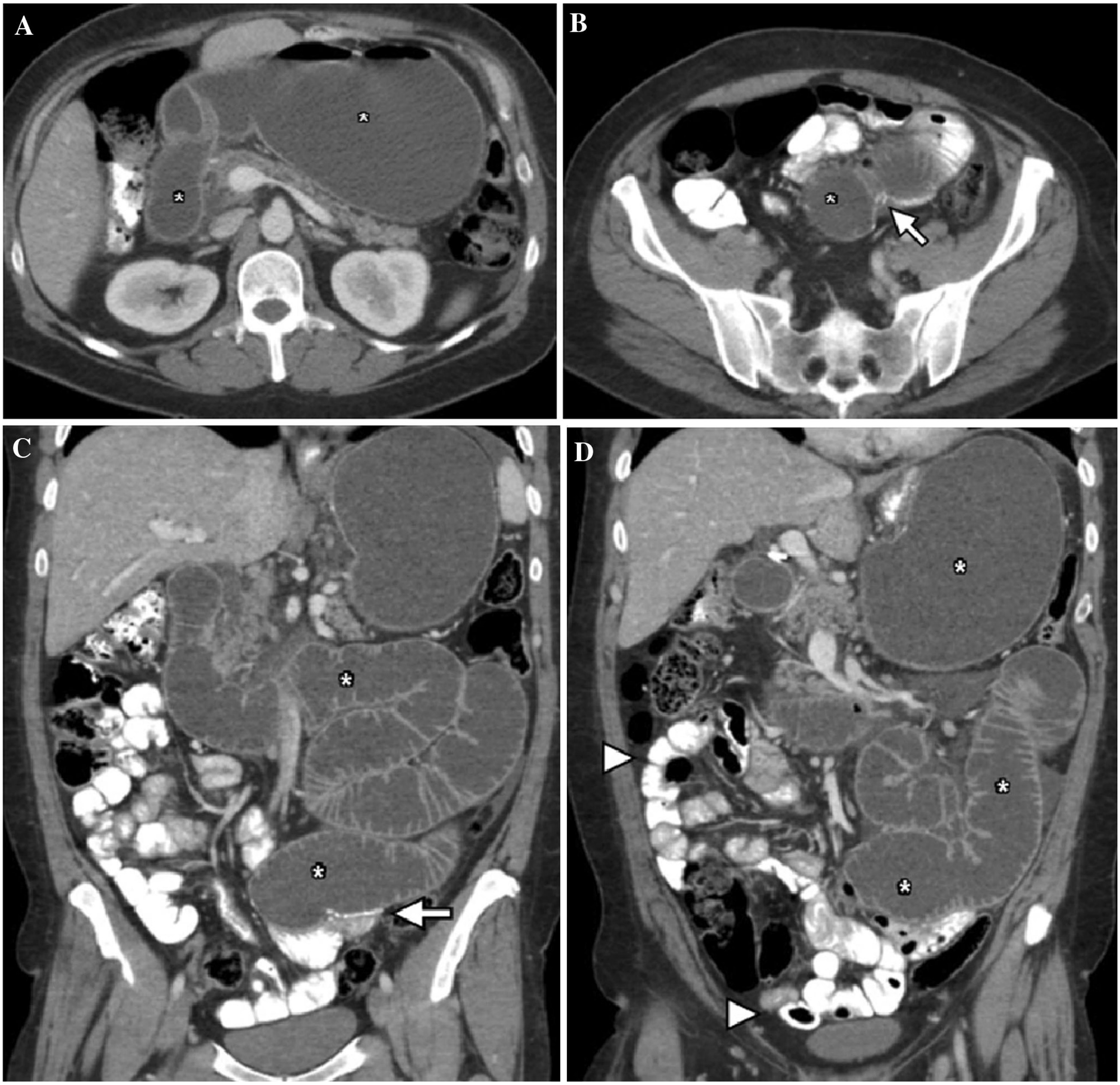

Fig. 9. Anastomotic fibrotic stricture leading to SBO (afferent loop syndrome). **A**–**D** Axial and coronal reformatted contrast-enhanced MDCT images demonstrate dilated afferent biliary limb (*asterisks*), which is not opacified with oral contrast material. Dilation extends to a single abrupt transition zone at the enteroenterostomy (*arrows* in **B** and **C**). A non-dilated efferent Roux limb (*arrowheads* in **D**) is noted with normal filling of contrast. The patient went to surgery for revision of the anastomosis.

In these patients, malabsorption and impaired intestinal secretion leads to inspissated intraluminal contents, frequently accumulating in the terminal ileum and cecum and resulting in SBO. DIOS is an important imaging diagnosis as it typically resolves with conservative management [37].

More than one transition zone

The presence of more than one adjacent transition zone usually reflects a closed loop obstruction, which can be due to adhesions, hernia (internal or external), or volvulus (acquired or in malrotation). In closed loop obstruction, a single site obstructs the bowel at two (or more) adjacent points, preventing the passage of gas and bowel contents from the segment of bowel proximal to the obstruction and from within the obstructed closed bowel loop (Fig. 14) [14]. The configuration of the obstructed bowel loops can be a clue to the diagnosis and site of the obstruction, often demonstrating a radial arrangement with a U- or C-shaped configuration,

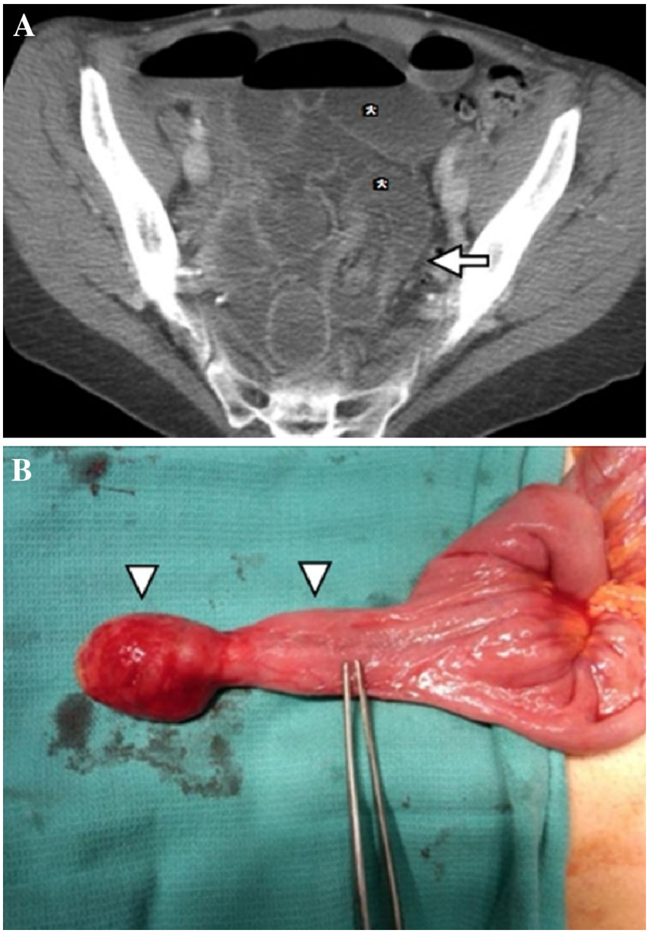

Fig. 10. Intussusception and SBO secondary to a Meckel's diverticulum serving as lead point. **A** Axial contrast-enhanced CT image demonstrates dilated proximal small bowel (*asterisks*) with single abrupt transition zone at the level of the intussusception (*arrow*). **B** Intra-operative image reveals the Meckel's diverticulum (*arrowheads*) as the cause of the intussusception.

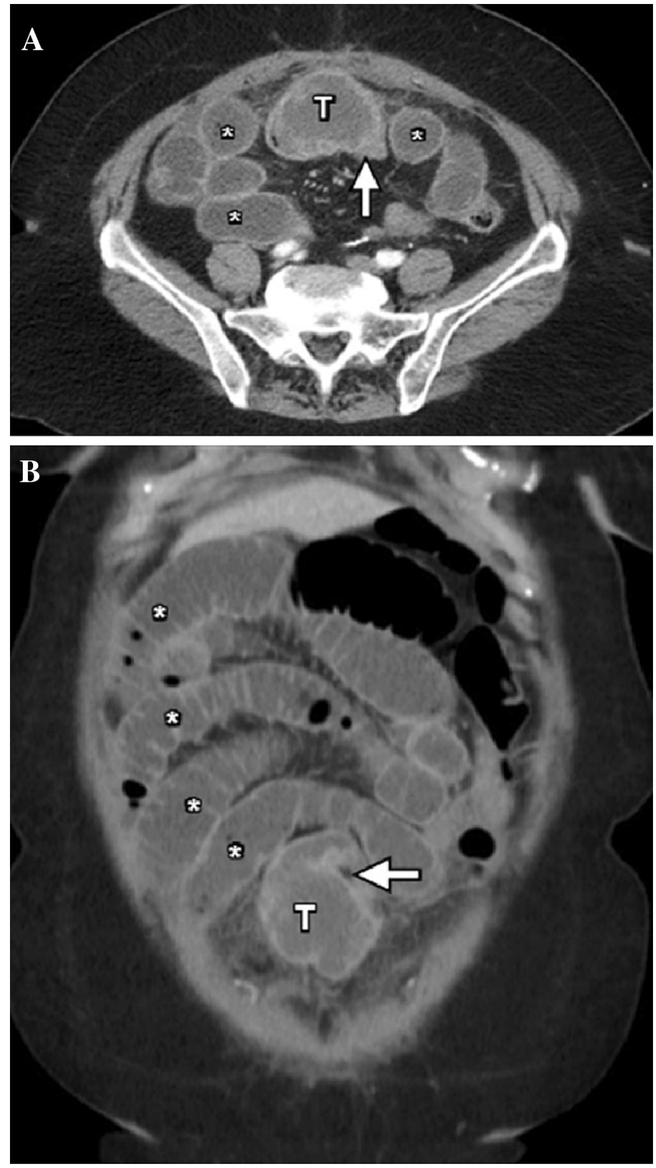

Fig. 11. SBO due to extrinsic mass effect from metastasis. **A**, **B** Axial and coronal contrast-enhanced MDCT images demonstrate dilated small bowel loops (*asterisks*) with single transition zone (*arrow*) due to an extraluminal lesion (*T*). This was confirmed to be a metastatic deposit from a previously resected abdominal leiomyosarcoma.

converging at the site of obstruction (Fig. 15) [4, 15]. If the closed loop rotates around its mesenteric axis and a volvulus develops, swirling of mesenteric vessels may also be identified (Fig. 16) [38]. However, in the absence of dilated bowel, swirling of the mesenteric vessels should not be considered a sign of volvulus as it may be seen in asymptomatic patients or due to normal post-operative changes from prior small bowel surgery.

Closed loop obstructions are critical to identify as they are the most common precursor to bowel strangulation at laparotomy (even if CT signs of ischemia are not present initially) [17, 27]. As the closed loop rapidly dilates and accumulates fluid, vascular perfusion becomes increasingly compromised, which rapidly increases the risk of bowel necrosis if the obstruction is not relieved [2].

Although internal hernias account for less than 1% of all cases of bowel obstruction, the presentation is frequently non-specific, often with symptoms occurring only intermittently, thus making clinical diagnosis difficult. A high level of suspicion and imaging during acute symptoms are crucial to establish the diagnosis and guide management, which is frequently surgical [1]. Internal hernias result in more than one transition zone when bowel prolapses through defects or potential spaces in the peritoneum or mesentery and become obstructed at both the entry and exist sites [12, 39, 40]. The defect or potential space can be congenital (most commonly right and left paraduodenal, foramen of Winslow, and pericecal) or acquired from prior abdominal or pelvic

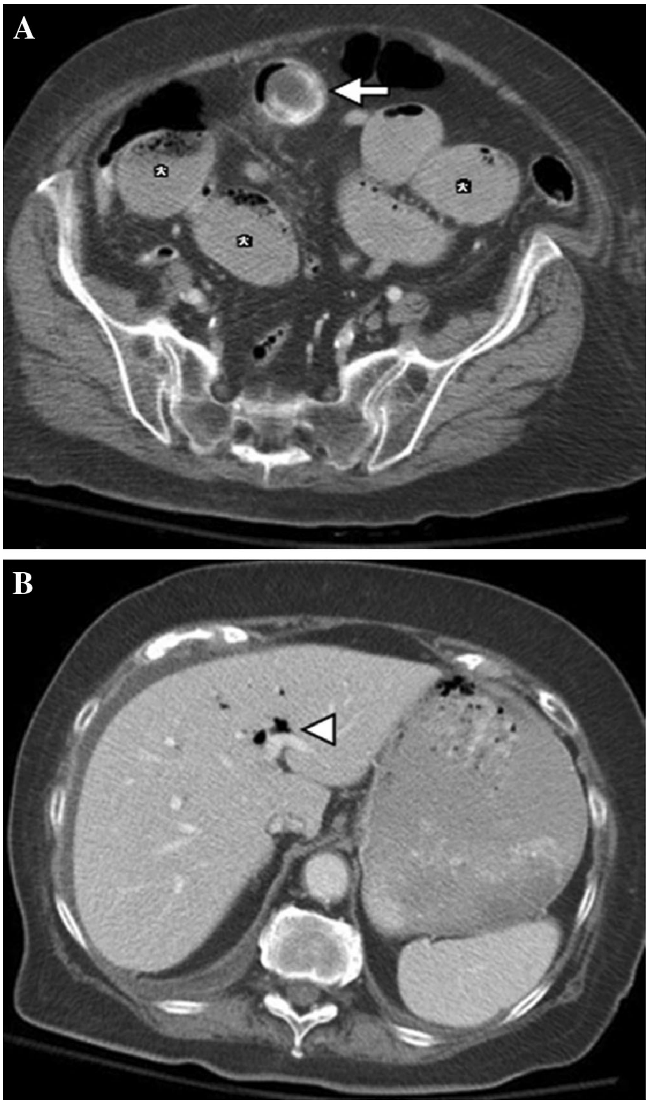

Fig. 12. Gallstone ileus with Rigler's triad. **A** Axial contrast-enhanced MDCT image demonstrates dilated small bowel (*asterisks*) with abrupt transition in the mid abdomen (*arrow*) where there is an oval-shaped high attenuation intraluminal structure, corresponding to an impacted gallstone. **B** Pneumobilia (*arrowhead*) noted secondary to the passage of the gallstone from the CBD through the ampulla of Vater. The diagnosis was confirmed at surgery.

surgery (e.g., trans-mesenteric hernias related to mesenteric defect created (intentionally or inadvertently) or incompletely repaired during surgery) [2]. Imaging findings include abnormal grouping of bowel loops in unusual locations, in addition to adjacent transition zones at the entry site into the hernia sac (Fig. 17) [40, 41].

CT signs of bowel ischemia

Although it is the most feared outcome, bowel ischemia complicates a minority of SBO with wide reported ranges of incidence (4–42%) and average incidence of approximately 10% [14]. Identifying these patients is difficult as

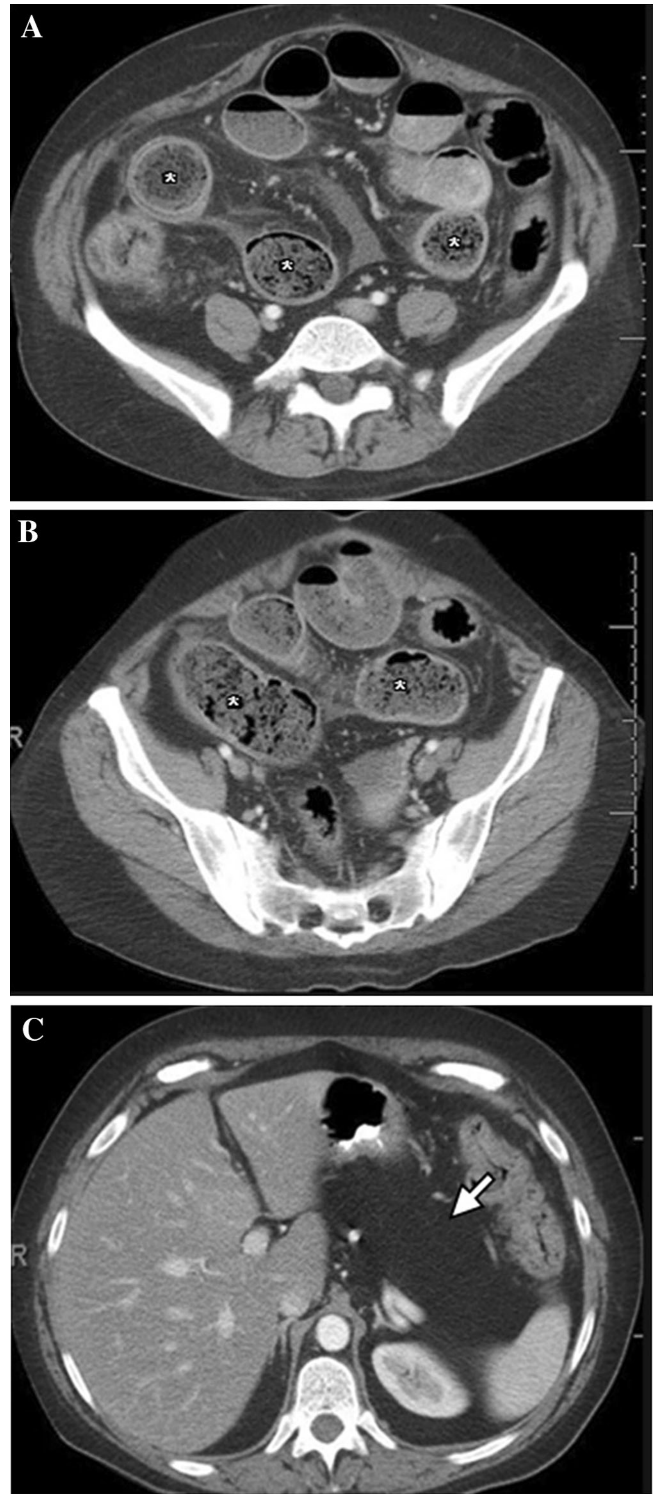

Fig. 13. Distal intestinal obstruction syndrome (DIOS) in a patient with cystic fibrosis. **A**, **B** Axial contrast-enhanced CT images demonstrate multiple dilated small bowel loops (*asterisks*) with impacted stool-like intraluminal contents representing inspissated intestinal secretions and undigested food residue. **C** Image of the upper abdomen in the same patient demonstrates complete fatty replacement of the pancreas as seen in adult patients with cystic fibrosis (*arrow*). The obstruction resolved following conservative management.

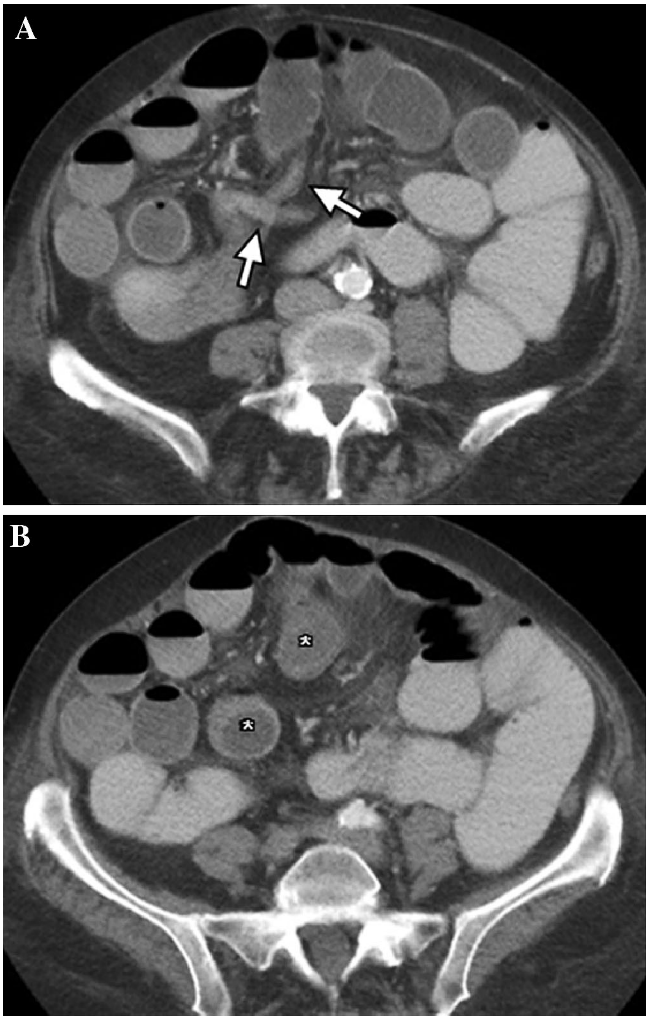

Fig. 14. Closed loop obstruction due to adhesive band. **A** Axial contrast-enhanced MDCT image demonstrates two abrupt adjacent transition zones in the right lower quadrant (*arrows*). **B** There is dilation and wall thickening of the small bowel loops both proximal to and within the closed loop (*asterisks*). The patient underwent surgery to release the adhesion and relief the obstruction.

clinical and laboratory data have not been shown to reliably indicate the presence or absence of bowel ischemia. Yet, in a meta-analysis, CT was shown to be highly accurate for detecting ischemic bowel with an overall sensitivity of 83% and specificity of 92% (although standardized criteria for diagnosing ischemia are notably lacking) [42]. Imaging findings in SBO that suggest bowel vascular compromise and thus favor surgical intervention include bowel wall edema or hemorrhage, inter-loop fluid or fat stranding, altered bowel wall enhancement, and vascular engorgement, although the relative presence of each of these findings is quite variable [4, 14, 15, 17]. Of these findings, altered bowel wall enhancement is the only finding that has been shown to reliably identify ischemic bowel [9, 17, 42]. Early ischemic bowel wall will

Fig. 15. Closed loop obstruction with a U-shaped configuration of obstructed bowel loops and associated ischemia. Coronal reformatted contrast-enhanced MDCT image demonstrates a dilated bowel segment with a U-shaped configuration (*arrowheads*). The involved loop demonstrates decreased bowel wall enhancement and central inter-loop mesenteric fluid, suggestive of ischemia. Closed loop obstruction due to adhesive band with necrotic bowel was found surgically.

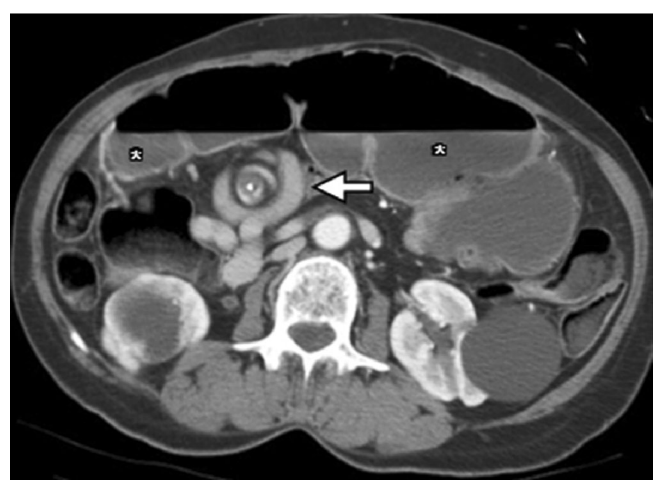

Fig. 16. Midgut volvulus with swirling of mesenteric vessels. Axial contrast-enhanced MDCT image demonstrates dilated proximal small bowel loops (*asterisks*) with swirling of the mesenteric vessels at the site of transition in the right side of the abdomen (*arrow*). Closed loop obstruction and volvulus due to congenital band was found intra-operatively.

often show hyperenhancement, indicating vasodilatation as the bowel preserves perfusion [15]. However, as ischemia is prolonged, the bowel wall will subsequently

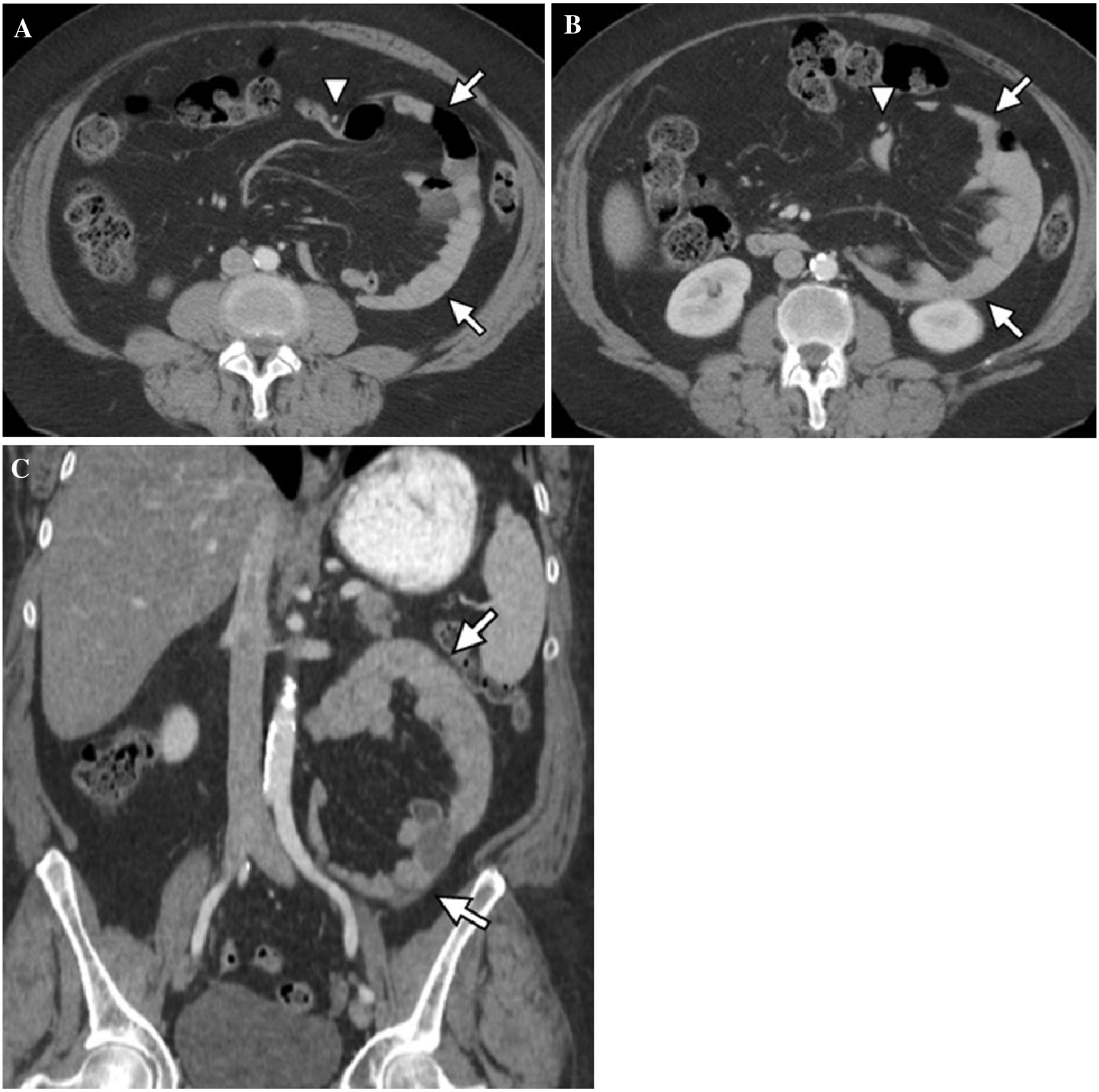

Fig. 17. Internal hernia (left paraduodenal type). **A**–**C** Axial and coronal reformatted contrast-enhanced MDCT images demonstrate focal cluster of small bowel loops in the left side of the abdomen (*arrows*) with anterior displacement of the inferior mesenteric vein (*arrowhead*). No bowel dilatation was present at the time of the scan however the patient complained of recurrent symptoms of obstruction. Left paraduodenal internal hernia was found intra-operatively.

demonstrate decreased or absent enhancement. This is of particular importance since, even in the absence of classic clinical signs of bowel ischemia, such as leukocytosis or peritonitis, CT evidence of decreased wall enhancement has been shown to independently predict bowel ischemia with a specificity of 94% [17].

Nonetheless, it is important to note that none of these imaging features described above are present with 100% consistency in all patients with ischemic bowel. Each finding, when present, should be taken in the overall clinical context, noting that the presence of multiple findings may be additive when predicting the likelihood of bowel vascular compromise [9, 43]. Pneumatosis, portal venous gas, and free intraperitoneal air are also important in the setting of SBO, but are late findings and usually indicate irreversible bowel ischemia that has already led to necrosis and subsequent perforation.

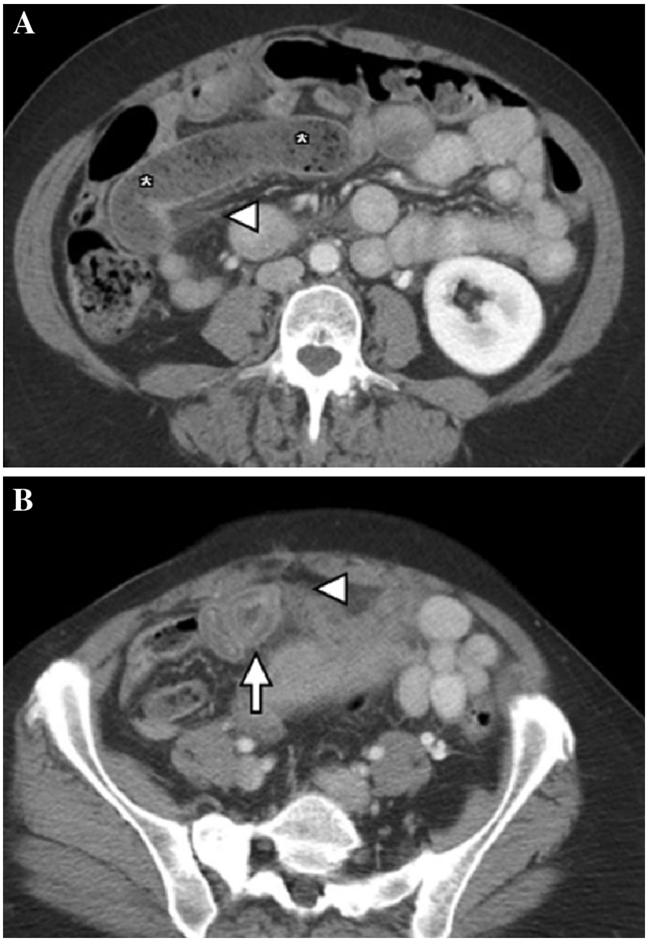

Fig. 18. Suspected intestinal ischemia in SBO. **A**, **B** Axial contrast-enhanced MDCT images demonstrate dilated small bowel loops in the right side of the abdomen (*asterisks*) showing the small bowel feces sign with abrupt transition in the right lower quadrant (*arrow*). Bowel wall edema and inter-loop fluid (*arrowhead*) are also noted, suggesting ischemia. Despite signs of bowel ischemia, the patient was managed conservatively with resolution of symptoms on follow-up.

Certain causes of obstruction have a higher likelihood of bowel vascular compromise and may require surgical attention, even when CT findings of ischemia are not present. These include an obstructing mass, intussusception with fixed lead point, internal hernia, closed loop obstruction, or volvulus [14, 44].

Conservative vs. surgical management of SBO

Clinical management of SBO relies on a combination of clinical, laboratory, and imaging factors, which help stratify patients to conservative or surgical treatment [2]. Most cases of SBO, particularly without clinical (such as peritoneal signs, elevated white count, or lactate level) or imaging features associated with increased risk of bowel vascular compromise (such as closed loop obstruction, internal hernia, ischemic, or necrotic appearing bowel) resolve with conservative non-operative management. By contrast, a small percentage of patients with SBO present with obvious signs of sepsis and peritoneal signs and are often taken immediately to surgery without preoperative imaging. However, the diagnosis is more difficult for patients presenting with non-specific symptoms or who are difficult to examine (e.g., confused, obtunded or comatosed patients). It is important to note that neither the preoperative judgment of experienced surgeons nor the traditional clinical signs of vascular compromise, such as acidosis, fever, leukocytosis, and tachycardia, have been shown to be sensitive or specific for the diagnosis of strangulation or the need for operative intervention, highlighting the difficulty faced when managing SBO [1, 45].

Moreover, the decision to operate or not operate in patients with SBO carries important ramifications. Delaying surgical intervention in patients with strangulated SBO has higher associated mortality (up to 40%) with increased risk of resection and consequently longer and more complicated hospital stays [17, 46]. By contrast, patients with uncomplicated SBO who needlessly undergo surgery are inappropriately exposed to inherent surgical risks, lengthened hospitalizations, and subsequent adhesion-related complications, including recurrent SBO [25, 26, 46, 47]. Determining operative vs. non-operative management can be very challenging as no single factor has been shown to consistently predict which patients will require immediate surgical management (Fig. 18) [6, 17, 48]. Radiologists must be aware of these challenges faced when managing SBO and the role for CT to help management decisions. CT can help the clinical decision-making by identifying signs of ischemia or specific types of obstruction which are more frequently associated with bowel vascular compromise (e.g., closed loop obstruction).

Conclusion

Using MDCT to diagnose SBO and identify early imaging signs of bowel vascular compromise is complementary to clinical and laboratory findings in deciding clinical management. Although most cases of SBO resolve with conservative management, it is important to appreciate the difficulty when managing SBO, and specifically that the classic clinical signs of vascular compromise are often unreliable in predicting the need for operative intervention. As such, it is crucial to identify the subset of patients with imaging findings suggesting bowel vascular compromise or those with causes or types of obstruction unlikely to resolve spontaneously in order to avoid life-threatening complications. The cause and type of obstruction, in addition to the presence or absence of findings suggesting ischemia, can improve confidence and help guide clinical decision-making of either conservative management or urgent surgical intervention.

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