Bowel Obstruction

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Contents

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Abstract

Bowel obstruction is a common clinical problem, and clinical signs and symptoms do not provide sufficient information for diagnosis or to guide management. CT is becoming a mainstay in diagnosing bowel obstruction and differentiating it from ileus, in locating the site of the obstruction, in identifying the transition point, in determining the cause of the obstruction, which may be intraluminal, intrinsic, or extrinsic, and finally in looking for a complication such as closed loop obstruction or ischemia. Multidetector row CT scanners permit high-quality reformatted series and particularly coronal reformatting useful in the identification of the transition point and in the analysis of the cause and of the mechanism of the obstruction. Because the management of obstruction has dramatically changed with a decrease in the proportion of patients who need surgery, of the time of surgery, which may be delayed, and of the type of surgery, with sometimes a coeliosocopic procedure, a precise CT evaluation is now both the gold standard and the common approach in patients with suspected bowel obstruction.

1 Introduction

Acute intestinal obstruction is defined by the hindrance to the progression of the intestinal content due to a mechanical obstacle. It is responsible for approximately 25% of surgical admissions for acute abdominal conditions, with small bowel obstruction (SBO) accounting for about 65–75% of obstructions

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and large bowel obstruction (LBO) accounting for 25–35%, gastroduodenal obstruction being rarer and accounting for 1–2% of bowel obstructions. Bowel obstructions account for about 5–7% of all emergency department visits for abdominal pain, and reach 12% in patients older than 50 years (de Dombal 1994). The goals of imaging in a patient with suspected intestinal obstruction have been defined by Mondor et al. (1943) and summarized by Herlinger and Maglinte (1989) and are as follows:

- To confirm that it is a true obstruction and to differentiate it from an ileus
- To determine the level of obstruction
- To differentiate high-grade obstruction from incomplete obstruction
- To determine the cause of the obstruction
- To look for findings of strangulation
- To allow good management either medically or surgically by laparotomy or laparoscopy

This chapter deals with the findings, pitfalls, and accuracy of CT when answering these questions, discusses the impact of CT in the diagnosis and management of patients with suspected bowel obstruction, and recommends an approach for the diagnostic triage of such patients. The CT patterns, the causes, the potential severity, and the management of obstruction depend on the localization of the obstruction, and we will discuss separately gastroduodenal obstruction, SBO and LBO.

2 Gastroduodenal Obstruction

Gastroduodenal obstruction, also called gastric outlet obstruction, is clinically characterized by nausea and vomiting, which constitute the cardinal symptoms, whereas epigastric abdominal pain may lack and is usually related to the underlying cause.

Abdominal plain film often demonstrates the outline of the dilated gas-filled stomach with absence of gas distal to the duodenum. However, this pattern is not specific to gastroduodenal obstruction since it may be present in gastroparesis, also called delayed gastric emptying, a disorder in which the stomach takes too long to empty its contents. Gastroparesis occurs in numerous conditions, such as diabetes, postviral syndromes, surgery on the stomach or vagus nerve, use of medications, particularly anticholinergics and narcotics, smooth muscle disorders such as amyloidosis and scleroderma, nervous system diseases, and metabolic disorders. By showing a lesion at the junction between dilated bowel and collapsed bowel, CT differentiates gastroduodenal obstruction from gastroparesia.

The two main causes of gastroduodenal obstruction are malignant lesion and peptic ulcer disease. In the past, peptic ulcer disease accounted for most of the cases of obstruction. With the evolution of effective therapy for peptic ulcer disease, malignancy has emerged to be the most important cause of gastroduodenal obstruction.

Malignant obstruction of the gastric outlet is located mainly in the antropyloric region and is mostly due to advanced gastric neoplasia and is less commonly related to metastatic cancer or invasion of adjacent malignancies (bile duct cancer, gallbladder cancer) (Park et al. 2001). By contrast, malignant obstruction of the duodenum is mainly located at the level of the first part and the second part of the duodenum and is mostly due to invasion of the duodenum by a pancreatic cancer. Gastric neoplasia responsible for obstruction are adenocarcinoma and more rarely carcinoid tumors, whereas tumoral obstruction due to lymphomas (Buyn et al. 2003) or gastrointestinal stromal tumors seems to be exceptional (Sandrasegaran et al. 2005). Gastric adenocarcinomas which lead to obstruction are advanced cancer and may manifest themselves on CT as large, segmental, or diffuse wall thickening with irregular lobulation and often ulceration or as large, polypoid, fungating lesions (Ba-Salamah et al. 2003). Duodenal obstruction is encountered in an advanced stage of pancreatic cancer and is rarely present at the time of the diagnosis, for instance, in only three of 76 consecutive patients with pancreatic cancer (Valls et al. 2002), or in advanced peritoneal carcinomatosis (Fig. 1). Even if duodenal invasion is not itself a criterion for unresectability, it is often associated with criteria for unresectability, such as vascular invasion or liver metastasis well shown by CT. In metastatic disease, gastric and duodenal invasion may be associated. In a study describing imaging features of gastroduodenal obstruction in 438 consecutive women with ovarian cancer, the frequency of gastroduodenal obstruction was 2.5%, with five cases of predominant involvement of the gastric body and six of the gastric outlet and duodenum (Spencer et al. 2000).

Fig. 1 Duodenal obstruction due to duodenal metastasis from an ovarian cancer. Axial slices (**a**, **b**) and coronal reformatting (**c**) show a dilatation of the stomach and of the first two parts of the duodenum. The tumoral mass is seen within the third part of the duodenum (*arrow*). Note also peritoneal carcinomatosis with involvement of the greater omentum

Gastroduodenal obstruction secondary to peptic ulcer disease remains prevalent and represents approximately 5–8% of ulcer-related complications (Behrman 2005). In 80% of cases, the obstruction is due to a duodenal ulcer, outlet obstruction due to gastric ulcer occurring less frequently. The stenosis is often short and may be difficult to identify by CT, making the differential diagnosis between obstruction related to peptic ulcer disease and gastroparesis difficult (Fig. 2).

Other causes of gastroduodenal obstruction mainly include gastritis and gastroenteritis, postsurgical strictures, adult congenital pyloric stenosis and volvulus for the stomach and pancreatitis, annular pancreas, superior mesenteric artery syndrome, Bouveret syndrome, bezoar, and intussusception for the duodenum.

Gastritis is a very common disease but is rarely responsible for gastric outlet obstruction. CT shows thickened gastric folds and wall thickening with soft-tissue attenuation. Eosinophilic gastroenteritis is a relatively classic cause of gastroduodenal obstruction with gastric and often duodenal esophageal involvement (Sheikh et al. 2009). Ingestion of corrosive substances may be responsible for severe gastritis, with fibrous scarring causing antral narrowing responsible for gastric outlet obstruction.

Adult idiopathic hypertrophic pyloric stenosis is a misleading anatomic and radioclinical entity of unknown cause. Only about 200 cases have been reported in the literature. It is a benign disease resulting from hypertrophy of the circular fibers of the pyloric canal. CT shows massive dilatation of the stomach, often without the identification of the wall pyloric thickening and upper gastrointestinal endoscopy which does not show any evidence of peptic ulcer disease or cancer allows both diagnosis and treatment by balloon dilatation of the pyloric sphincter (Franco and Dryden 2007).

Postoperative stenosis has become an increasing cause of gastric obstruction since the development of surgery for morbid obesity. Obstruction, with a reported incidence of up to 5%, may occur in several

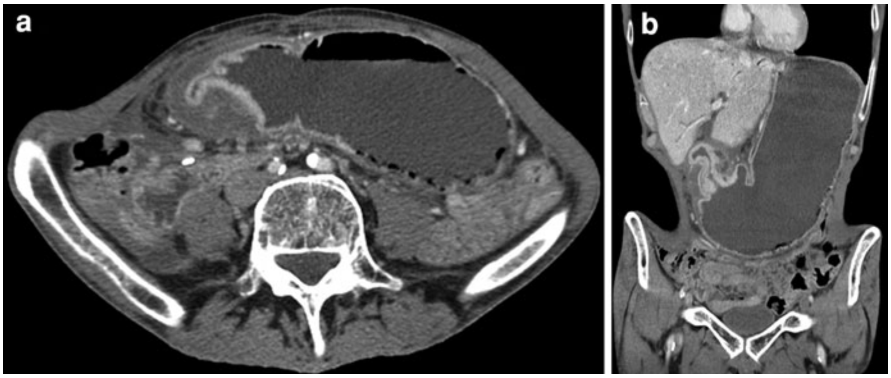


Fig. 2 Inflammatory stenosis of the antrum and of the first part of the duodenum shown on an axial slice (**a**) as well as on coronal reformatting (**b**). There is a thickening of the gastrointestinal wall responsible for a stenosis, with a dilatation of the gastric lumen. The stenosis was consecutive to an ulcer

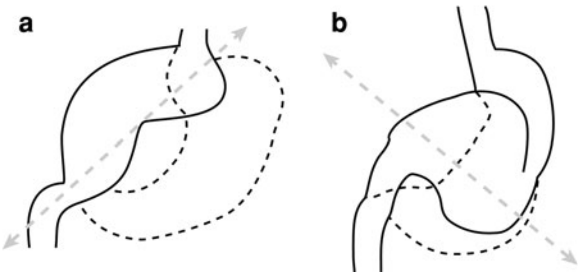


Fig. 3 Subtypes of gastric volvulus. Organoaxial volvulus (**a**) and mesenteroaxial volvulus (**b**)

locations and may result from several mechanisms. Potential sites include the gastrojejunostomy site, the jejunojejunostomy site, the mesocolic window, and behind the Roux limb (Peterson space). In the early postoperative setting, obstruction is often due to severe edema which will resolve spontaneously or can result from iatrogenic stenosis secondary to overzealous suturing. In the late postoperative setting, obstruction may result from fibrotic stenosis, internal hernias, or adhesions. Gastric outlet obstruction is generally the consequence of stricture located at the gastrojejunal anastomosis. The stenosis is better diagnosed by barium esophagography than by CT (Chandler et al. 2008).

The stomach is a relatively uncommon site of volvulus. Patients with acute gastric volvulus typically present with an acute clinical setting with sudden and intense epigastric pain, vomiting, and inability to pass a nasogastric tube in the stomach. CT allows one to differentiate the two forms of volvulus, i.e., organoaxial and mesenteroaxial forms (Fig. 3). The organoaxial form, which is the most common, occurs when the stomach rotates along its long axis and is generally associated with a paraesophageal hernia that follows the stomach along its long axis. This results in inversion of the greater curvature above the lesser curvature; the antrum is in the normal position. The mesenteroaxial form is much less common. It occurs when the stomach rotates along its short axis with consequent displacement of the antrum at the level of or above the gastroesophageal junction (Peterson et al. 2009) (Fig. 4).

Pancreatitis may lead to a gastroduodenal obstruction by two mechanisms: an inflammatory reaction of the gastroduodenal wall or a compression by pseudocysts. These two entities are well differentiated by CT.

Annular pancreas is an uncommon congenital abnormality responsible in adults for pancreatitis and duodenal obstruction and may be asymptomatic. Gastric outlet obstruction may be associated with incomplete or complete obstruction. The presence of pancreatic tissue posterolateral to the second part of the duodenum has both high sensitivity and high specificity for the diagnosis of annular pancreas; in the same way, a crocodile jaw appearance of pancreatic tissue anterior and posterior to the duodenum is highly suggestive of incomplete annular pancreas (Sandrasegaran et al. 2009).

Bouveret syndrome is a form of gallstone ileus with a stone impacted in the duodenum. Even if the stone is easily visible on CT, there are in some cases discrepancies between the diameter of the duodenum and the apparent size of the stone. Some findings such as the identification of air in dependent areas of the duodenal lumen, soft tissue surrounding the calcified part of the stone, or fat within the stone must be identified to better assess the size of the stone and to understand its involvement in the duodenal obstruction (Gan et al. 2008; Brennan et al. 2004).

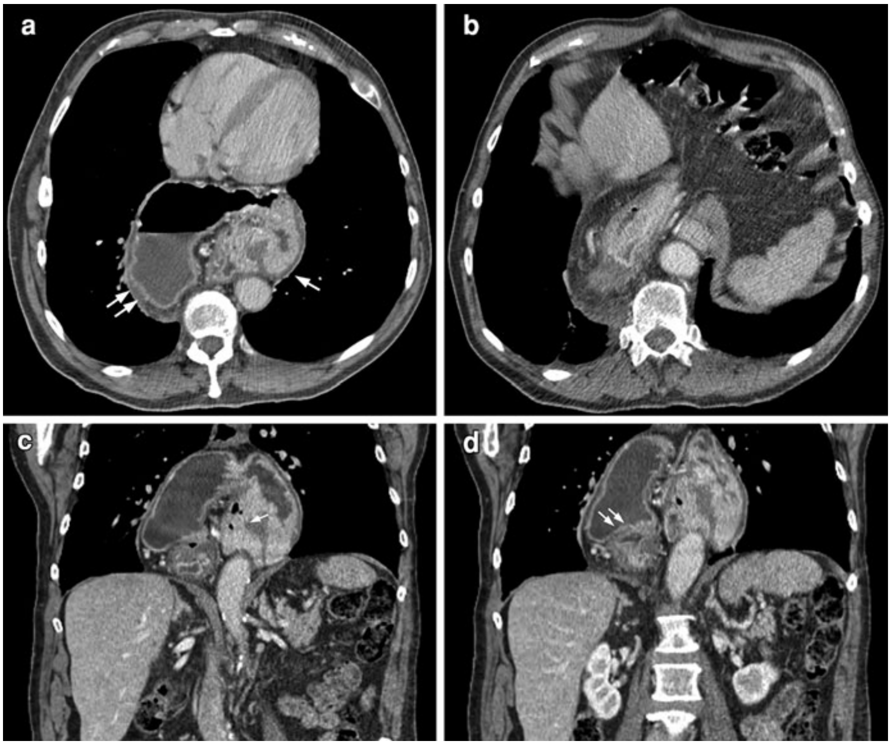


Fig. 4 Mesenteroaxial gastric volvulus. Axial slices (**a**, **b**) show the stomach within the thorax with the proximal part of the stomach (*arrow*) at the same craniocaudal level as the distal part (*double arrows*). On the coronal reconstructions (**c**, **d**), the gastroesophageal junction (*arrow*) and the gastroduodenal junction (*double arrows*) are almost at the same level

Superior mesenteric artery syndrome is characterized by the compression of the third part of the duodenum by the superior mesenteric artery. It is responsible for subacute or chronic forms of obstruction. CT shows a dilatation of the stomach and of the first and second parts of the duodenum, with a decrease of the superior mesenteric artery–aorta distance and angle (Unal et al. 2005).

Duodenoduodenal intussusception is rare, likely because mass in the duodenum is rare, and usually due to a tumoral lead point which is more often a benign tumor. CT easily demonstrates the collapsed intussusceptum lying within the opacified lumen of the distal intussuscipiens and one looks for a tumor at the leading point of the intussusceptum.

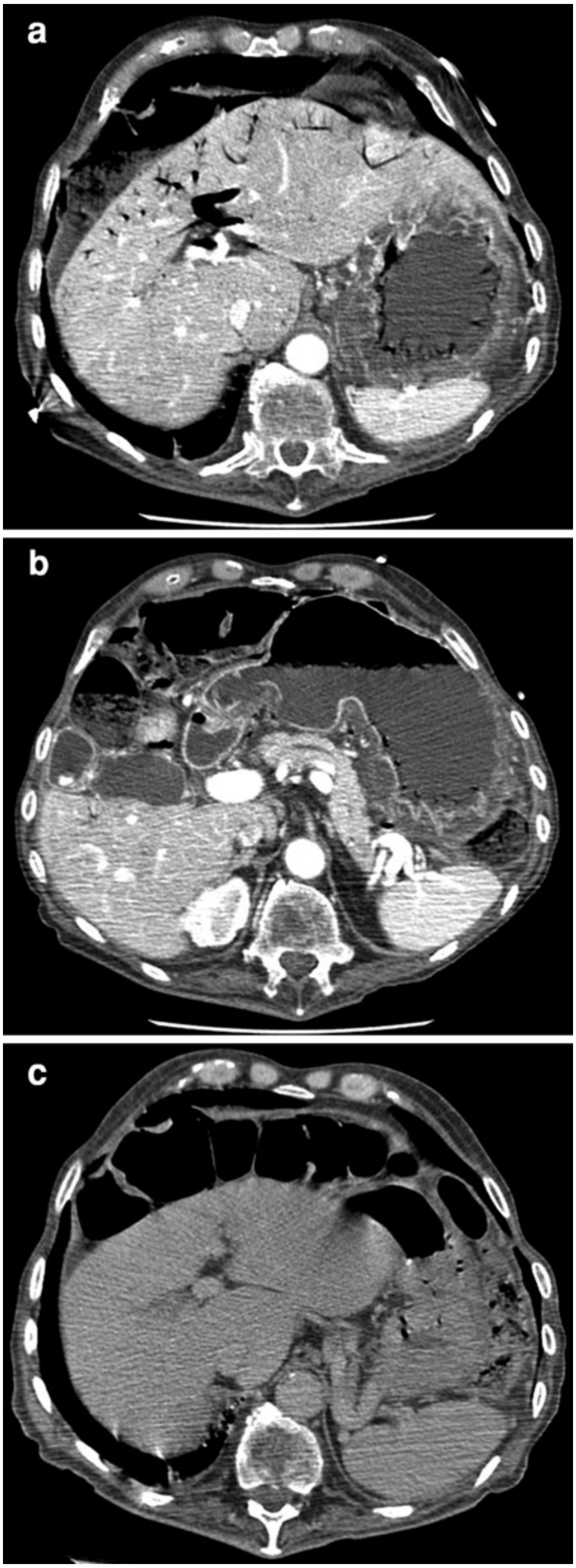
Duodenal bezoar is rarer in the duodenum than in the stomach or in the small bowel. However, bezoars located in the duodenum may be responsible for a gastric outlet obstruction. In a retrospective study of 34 cases of bezoar, only two involved the duodenum (Erzurumlu et al. 2005). Half of the patients had undergone gastric surgery. CT shows a nonenhanced intraluminal mass with gas bubbles and hypodense areas.

The outcome of a gastroduodenal obstruction depends more on the cause of the obstruction than on the dilatation of the stomach, with a high risk of gastric ischemia and perforation with peritonitis or mediastinitis in gastric volvulus if there is a delay between patient presentation and intervention. The identification of a gastric pneumatosis and or portal pneumatosis in the setting of a gastric dilatation is not specific to ischemia. Such findings may be present in gastroparesis due to the gastric dilatation and resolve when a nasogastric tube is passed into the stomach (Fig. 5).

3 Small Bowel Obstruction

3.1 Pathophysiology

Mechanical obstruction of the bowel lumen initially leads to an increase in intestinal contractions, which are intended to overcome the blockage. Peristaltis increases both above and below the obstructing lesion, so patients with obstruction may initially



◀ **Fig. 5** Gastric pneumatosis consecutive to gastroparesy which spontaneously resolves. Axial slices (**a**, **b**) show a dilatation of the stomach, with parietal and portal pneumatosis. Intramural air spontaneously disappeared with the regression of the stomach dilatation, as seen on CT performed 1 week later (**c**)

present with the seemingly paradoxical finding of diarrhea. With the onset of muscle fatigue, peristaltic activity diminishes then ceases and the bowel dilates. Increased intraluminal pressures stimulate and increase the normal secretion of water and electrolytes into the bowel lumen and inhibit fluid resorption. Consequently, fluid accumulates in the bowel lumen, leading to further dilatation and increasing intraluminal pressure. Within certain limits, the bowel wall remains able to maintain an adequate blood supply through the process of stretching of its muscular layer with thinning of the wall and dilatation of blood vessels. Then, intraluminal pressures exceed capillary and venous pressures, mucosal perfusion diminishes, and bowel ischemia may result.

According to the process and the mechanism responsible for the obstruction, different pathophysiological responses may occur. In simple obstruction, considered when the bowel is occluded at one or several points along its course, the proximal part of the bowel is variably distended, depending on the severity (high grade vs. low grade) and duration of the process. In closed loop obstruction, considered when a bowel loop of variable length is occluded at both ends at two adjacent points, greater intraluminal pressures are generated and there is a risk of the distended closed bowel loops rotating around the axis of the mesenteric vessels, producing volvulus and arterial ischemia.

3.2 Positive Diagnosis of SBO

3.2.1 Clinical Considerations

The clinical diagnosis of SBO classically depends on four cardinal findings: abdominal pain, vomiting, constipation, and abdominal distension. However, the clinical findings differ with the degree and level of bowel obstruction and with the vascular status of the obstructed segment. In typical mechanical obstruction, abdominal pain is crampy and gradually increases in intensity, only to abate and recur. With time, increasing bowel distention inhibits motility and

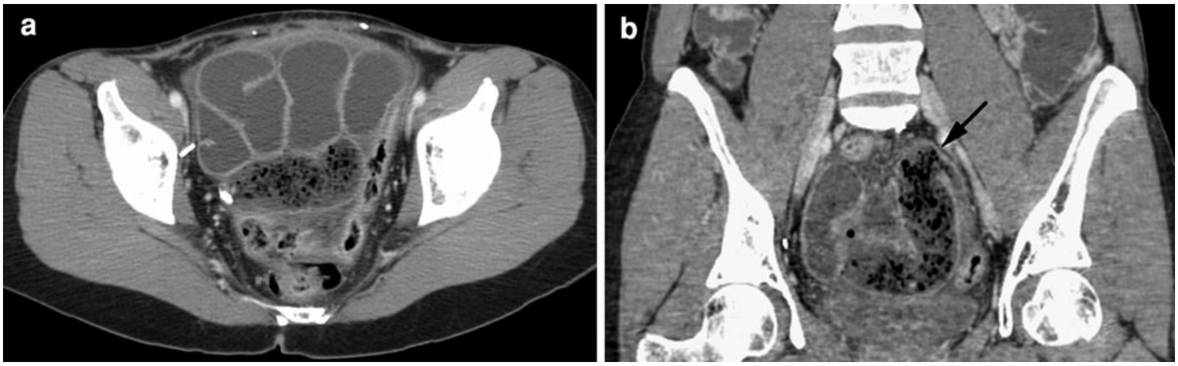


Fig. 6 Feces finding in a small bowel obstruction (SBO). Feces material within a small bowel loop well seen on the axial slice (**a**) as well as on coronal reformatting (**b**). The transition zone (*arrow*) just below the feces finding is better seen on the coronal view

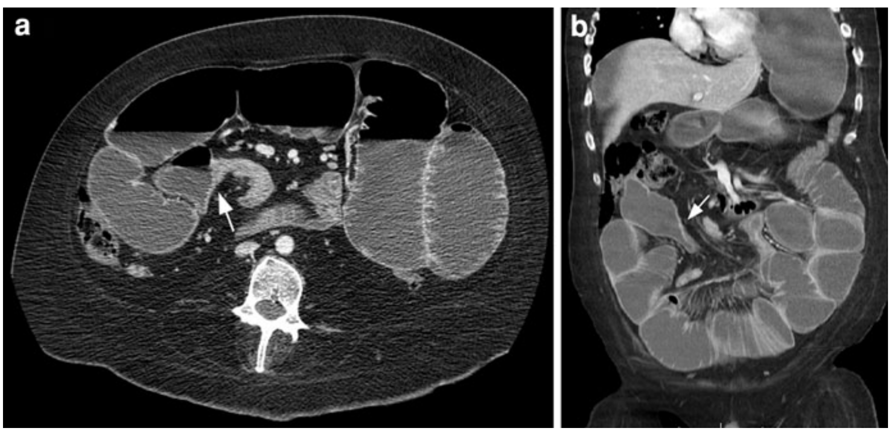


Fig. 7 SBO due to a unique adhesive band. The transition point is perfectly seen on the axial view (**a**) as well as on coronal reformatting (**b**). Note the presence of a beak finding at the transition zone

the pain tends to subside (Herlinger and Rubesin 1994). On the other hand, crampy abdominal pain may be present in other causes of acute abdomen such as renal colic. In the same way, vomiting or constipation is obviously not specific to acute abdomen.

3.2.2 CT Findings

The CT diagnosis of bowel obstruction is based on the presence of dilated bowel proximal to a transition zone and a collapsed distal bowel. The small bowel is considered dilated when its diameter is greater than 2.5 cm. The amount of intraluminal air versus fluid and the degree of dilatation of the small bowel are not reliable criteria to differentiate mechanical obstruction from ileus. Fluid-filled loops as large as 5 cm in diameter can be present in a nonobstructive ileus. In patients with dilated small bowel loops, the presence of a small bowel feces sign is a good ancillary finding of SBO. The small bowel feces sign is defined when intraluminal particulate material is identified in the dilated small bowel responsible for a mottled "feculent" appearance. Although not sensitive and seen in about 20% of cases of SBO, it is relatively specific to an SBO and facilitates the identification of the transition point since it occurs near the transition zone (Fig. 6) (Lazarus et al. 2004).

The identification of the transition point is the most accurate finding of an SBO. The transition point is determined by identifying a caliber change between the dilated proximal and collapsed distal small bowel loops (Fig. 7). The course of the small bowel needs to be tracked, and for that the use of a cine mode on a workstation or a picture archiving and communication system is more efficient than simply relying on static

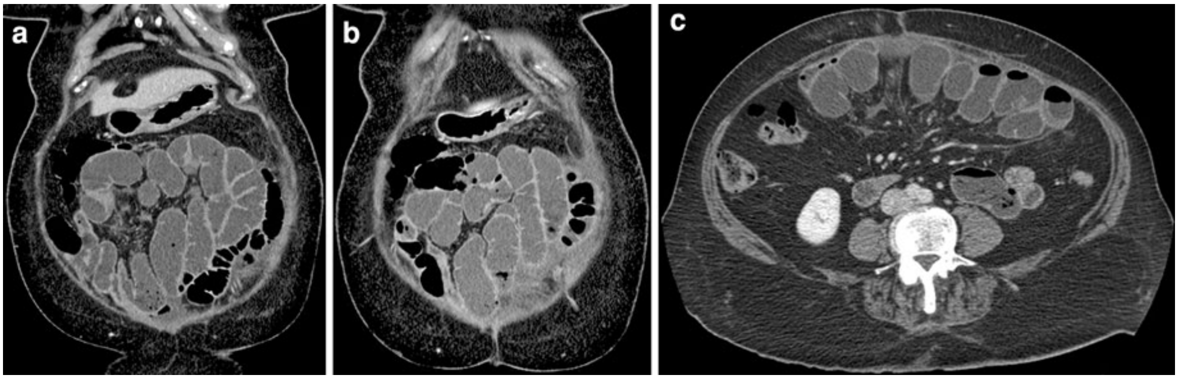


Fig. 8 SBO due to multiple matted adhesions. Coronal reformatting (**a**, **b**) show multiple transition zones. Note the anterior site of the bowel loops against the anterior abdominal wall shown on the axial slice (**c**)

images. Scrolling is generally performed in a retrograde fashion by starting at the rectum and proceeding proximally toward the cecum, ileum, and jejunum. If the transition point is located proximally (jejunum or duodenum), the position should be confirmed by using an anterograde approach, starting at the stomach (Silva et al. 2009; Khurana et al. 2002).

3.2.3 CT Pitfalls

The dilatation of small bowel loops, although not specific, is highly sensitive for the diagnosis of SBO. However, in some cases of SBO with rapidly developing strangulation, dilatation may be limited to one or two small bowel loops.

Although suggestive, the presence of a small bowel feces sign is not specific. By definition, for the small bowel feces sign to be present, particulate material must be within segments measuring greater than 2.5 cm in diameter, since feculent-appearing material may be seen within normal-caliber bowel loops in patients with cystic fibrosis, and in metabolic or infectious enteropathies. Furthermore, particulate material may also be present in the distal ileum owing to reflux through an incompetent ileocecal valve. Finally, small bowel feces must not be confused with bezoar characterized by a well-defined mass mottled with gas bubbles with an encapsulated wall and some fat-density debris floating in bowel lumen proximal to obstructive bezoar.

The transition point may be difficult to identify when SBO is due to matted adhesions defined as dense, multiple, short, and thick adhesive structures (Delabrousse et al. 2009). Furthermore, even if classically there is one transition point in simple bowel obstruction and there are two transition points in closed loop obstruction, more transition points may be present in simple as well as in closed loop obstruction (Fig. 8) (Sandhu et al. 2007).

3.2.4 CT Accuracy

The CT accuracy for the diagnosis of SBO is better than 90% in high-grade SBO and between 70 and 85% for low-grade SBO. Although intravenous injection is the standard in the evaluation of patients with suspected bowel obstruction, a recent study has shown that nonenhanced multidetector CT has comparable accuracy to enhanced multidetector CT in determining the presence or the absence of SBO and determination of the transition point (Atri et al. 2009). Multidetector CT allows one to scan the entire abdomen and pelvis at a nearly isotropic resolution, which gives good reformations. Coronal reformatting allows a better representation of the site of the dilated and nondilated bowel loops (Fig. 9). Several studies have shown that coronal reformations increase both agreement and confidence levels in the diagnosis of SBO. A recent French study has proved that the use of multiplanar evaluation improved the detection of the transition point from 85% with only axial slices to more than 90% (Hodel et al. 2009). This is a crucial finding for the management of patients with SBO.

3.2.5 CT Impact

The distinction between bowel obstruction and ileus is classically based upon clinical examination and abdominal plain film. In complete obstruction, distended loops of small bowel containing gas and fluid

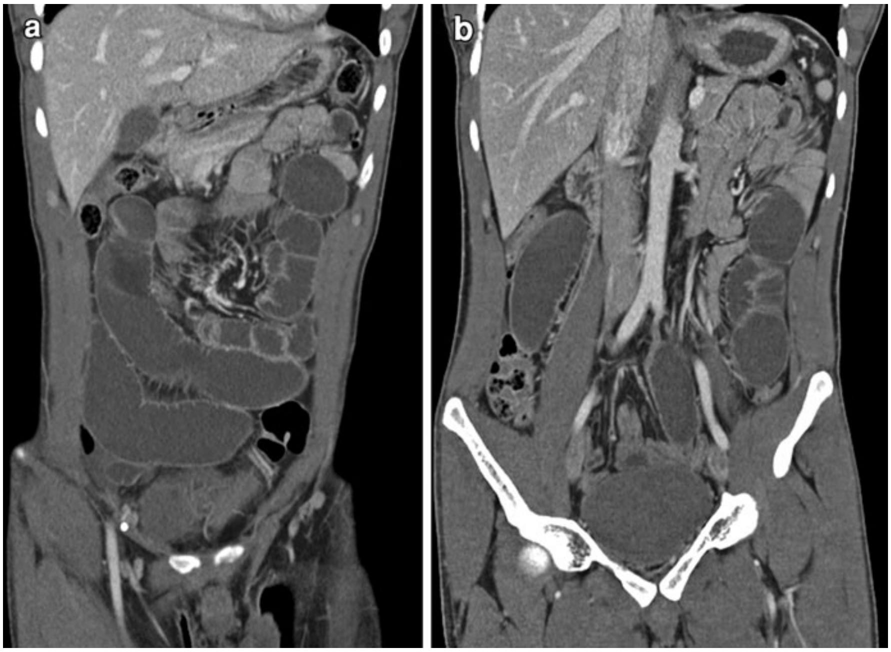


Fig. 9 Repartition of the nondilated bowel loops in an SBO. Coronal reformatting on an anterior (**a**) and posterior (**b**) plane show dilated and nondilated small bowel loops. The nondilated loops correspond to the proximal jejunal loops far from the site of the obstruction and distal pelvic ileal loops below the site of the obstruction

are usually present within 3–5 h of the onset. The interface between gas and fluid forms a straight horizontal margin in the upright or lateral decubitus view. Although gas–fluid levels are occasionally present normally, more than two gas–fluid levels in the small bowel are generally considered to be abnormal; however, gas–fluid levels are also very common in ileus. The presence of gas–fluid levels at different heights in the same loop has traditionally been considered strong evidence for mechanical obstruction; however, this pattern is insensitive and can also be demonstrated in some patients with adynamic ileus (Harlow et al. 1993). Furthermore, in severe complete obstruction, the bowel proximal to an obstruction may contain no gas and may be completely filled with fluid, producing sausage-shaped water-density shadows that can be difficult to diagnose. In one study, obstruction was not supported by abdominal radiographs read by an experienced gastrointestinal radiologist in 34% of surgically proven cases of SBO (Shrake et al. 1991). Consequently, CT plays a central role in the evaluation of patients with suspected SBO. For the diagnosis of SBO, it is particularly helpful in the following cases (Fig. 10):

- Clinical findings of obstruction with abdominal plain film showing no gas, likely meaning that bowel loops are completely filled with fluid
- Gas within one or two dilated loops
- Doubt between ileus and SBO

3.3 Diagnosis of Site

3.3.1 Clinical Considerations

The diagnosis of the site of a mechanical obstruction is not easily performed with only clinical data, even if vomiting is more pronounced in proximal SBO and abdominal distension is more pronounced in distal SBO.

The accurate determination of the site of the obstruction is becoming a major point when considering the management of patients with SBO, by permitting a safe laparoscopic division of adhesions that may be a suitable form of treatment of adhesive bands. Moreover, it may represent a valuable predictive factor in the management of adhesive SBO, since it has been shown that most patients with proximal SBO healed with conservative management, whereas distal SBO more frequently required surgery.

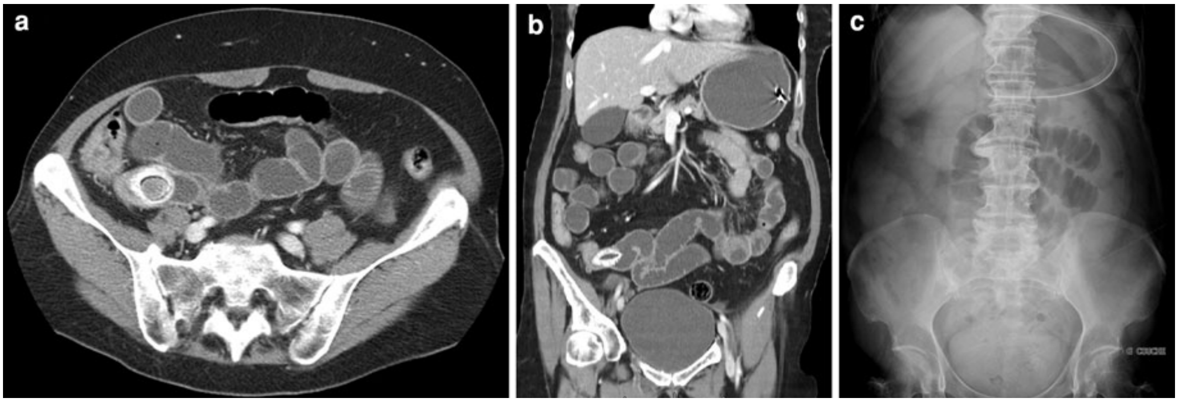


Fig. 10 SBO due to gallstone ileus. The axial slice (**a**) and coronal reformatting (**b**) clearly show the stone responsible for the SBO. Note that the stone is not seen on the abdominal plain film (**c**) and that most of the bowel loops do not contain air

3.3.2 CT Findings

CT determines the site of SBO by detecting the site of the transition zone and by surveying all the abdominal axial images and comparing the relative lengths of the prestenotic versus collapsed intestine. Attempting to determine the level of SBO solely on the basis of the site of transition in terms of the quadrant can result in misleading interpretations. Jejunal loops can be located in the pelvis, and ileal loops can be obstructed in the upper abdomen. When present, the small bowel feces finding is helpful to locate the transition zone in patients with SBO.

3.4 Diagnosis of Obstruction Grade

3.4.1 Clinical Considerations

Differentiating complete from partial grade obstruction is controversial. A low-grade obstruction is more likely than a high-grade obstruction to resolve spontaneously, and this could have an impact on the management of patients with bowel obstruction. In a study including patients with SBO due to adhesions (Hwang et al. 2009), all the 42 patients with incomplete low-grade obstruction were successfully managed without surgery, most of the patients with incomplete high-grade obstruction (43 of 58) were not operated on, whereas most of the patients with complete high-grade obstruction (22 of 28) were operated on. However, low-grade obstruction may theoretically be complicated by strangulation.

3.4.2 CT Findings

The diagnosis of the severity of the obstruction theoretically needs use of oral contrast material, with passage through the transition zone to the collapsed distal bowel loops indicating incomplete obstruction, which may be separated into high grade and low grade according to the amount and delay in the passage of contrast material. However, in clinical practice, oral contrast material is generally not given. Therefore, the severity of the obstruction is determined by the degree of collapse and the amount of residual contents in the portion of the bowel distal to the obstructed site.

3.5 Diagnosis of Causes

3.5.1 Clinical Considerations

The pattern of major causes of SBO has changed over the past five decades. The most common cause was originally external hernia. Now, adhesions compose 60–80% of the total number of SBOs in industrialized countries. The great majority (85%) of adhesions occur after surgery, the second cause is peritonitis, whereas the remaining causes are either congenital or uncertain causes. In patients who have undergone surgery, appendicectomy and gynecologic procedures are more prevalent as a cause of adhesive bands, whereas in patients who have not undergone surgery, inflammatory entities such as adnexitis and appendicitis are common precursors of adhesions. Among adhesive structures, adhesive bands, which are unique, long (more than 1 cm), and thin (less than

1 cm diameter), must be differentiated from matted adhesions, which are multiple, dense, short (less than 1 cm in diameter), and thick (more than 1 cm in diameter).

The second most common causes of SBO are neoplasm, hernias, and Crohn disease, each accounting for about 10%. A fourth miscellaneous group of causes includes inflammatory processes, intussusception, volvulus, endometriosis, ischemia, hematoma, congenital lesions, gallstones, foreign bodies, and bezoar (Fig. 10).

The prevalence of the different causes of SBO varies according to the clinical context.

In patients without a history of surgery, the diagnosis of a congenital adhesive band is still possible, since 5% of adhesive bands are encountered in such patients. Even if it is very rare, small bowel volvulus may occur in patients without adhesions or a predisposing abnormality such as malrotation or hernia, and the differential diagnosis between primary small bowel volvulus and volvulus complicating congenital band is impossible before surgery.

In patients with a previously treated cancer, obstruction is very common (Ha et al. 1998). It occurs in up to 30% of patients with a history of colorectal cancer and in as many as 40% of patients with ovarian cancer (Tang et al. 1995). Determining the cause of obstruction becomes a vexing problem since it may be benign postoperative adhesions, a focal malignant deposit, peritoneal carcinomatosis, ischemic stenosis due to radiation enteritis, or incisional entrapment. Malignant lesions represent the most common cause of obstructions; however, the percentage of benign causes of obstruction ranges from 18 to 38% on the basis of the distribution of the primary cancer. Benign obstruction is more likely if pelvic irradiation was used in the management of the primary tumor, whereas the risk of malignant obstruction is increased if the patient has a known metastatic cancer or if the primary cancer was in an advanced stage or of gynecologic origin. In patients with SBO due to advanced intra-abdominal malignancy, occult synchronous colonic obstruction is present in nearly half of patients. This must be kept in mind before bypass surgery.

In patients with occlusion and fever, the three most classic causes are mesocoeliac appendicitis, sigmoid diverticulitis, and biliary ileus. However, other causes may be responsible for this clinical setting (Table 1).

Table 1 Causes of small bowel obstruction (*SBO*) with fever

Mesocoeliac appendicitis
Sigmoid diverticulitis
Biliary ileus
Pelvic peritonitis from salpingitis origin
Meckel diverticulitis
Inflammatory stenosis (Crohn disease)
Complicated SBO with strangulation

Furthermore, fever may be a sign of complicated obstruction with strangulation and ischemia.

In patients with Crohn disease, SBO may result from three different causes: it may be due to the acute presentation of the disease with a transmural acute inflammatory process; it can result from a long-standing process with cicatricial stenosis; or it may be due to inflammatory or postoperative adhesions or to incisional hernias.

Hernias are classified according to the anatomic location of the orifice through which the bowel protrudes. They are differentiated as external and internal hernias. External hernias result from a defect in the abdominal and pelvic wall at sites of congenital weakness or previous surgery. Internal hernias, which are less common, occur when there is protrusion of the viscera through the peritoneum or mesentery and into a compartment within the abdominal cavity (Armstrong et al. 2007). Both external and internal hernias may be congenital or acquired. The diagnostic hypothesis for the cause of an SBO must take into account these probability data and the clinical context (Table 2). Furthermore, systematic evaluation of imaging data must also be performed by looking for one of the three major categories of SBO, as stated by Herlinger and Rubesin (1994): intraluminal, intrinsic, and extrinsic (Table 3). Most extrinsic causes produce obstruction by flattening, twisting, or kinking the small bowel. Intrinsic lesions constrict the lumen by thickening of the bowel wall, and intraluminal causes obturate the bowel lumen.

3.5.2 CT Findings

Intraluminal causes of obstruction include gallstones (mostly in elderly women) which may be visible on CT but not on plain radiography (Fig. 10), fecal impaction in patients with cystic fibrosis, related to inadequately controlled intestinal absorption

Table 2 Causes of SBO according to the clinical context

History of abdominal surgery	Malignancy context	Crohn disease	AIDS context	Septic context
Adhesions	Adhesions (if history of surgery)	Inflammatory transmural stenosis	Frequency of intussusceptions due to infectious enteritis, lymphoid hyperplasia, mesenteric adenopathy, Kaposi sarcoma, and non-Hodgkin lymphoma	Appendicitis
External hernias	Peritoneal carcinomatosis	Chronic stricture		Sigmoid diverticulitis
Incisional hernias	Focal malignant deposit	Postsurgical or inflammatory adhesions		Meckel diverticulitis
Laparoscopic port site hernias	Intussusception due to metastasis (melanoma)			Salpingitis
Parastomial hernias	External hernias			
Internal hernias	Incisional hernias			
Transmesenteric hernias	Laparoscopic port site hernias			
	Paratonial hernias			

secondary to pancreatic insufficiency, ingested foreign bodies occurring in mentally disturbed or retarded or elderly patients, and bezoars, which are most frequent in patients who have undergone gastric outlet resection or who have small bowel diverticula. The detection of a small bowel foreign body or bezoars requires one to look for an underlying obstructive lesion.

CT findings of gallstone ileus are pathognomonic of pneumobilia, ectopic gallstone, and SBO. Fecal impactions are generally distal in the small bowel with feculent filling defect. Among foreign bodies usually occurring in children or disturbed patients, a particular epidemiological context must be known: the retention of endoscopic capsules used to evaluate inaccessible portions of the bowel when there is an associated bowel lumen narrowing. CT shows the SBO with evidence of a foreign body at the transition zone. The diagnosis of bezoar is performed by the identification of a well-defined mass mottled with gas bubbles associated with an encapsulating wall and fat-density debris within the bowel lumen (Delabrousse et al. 2008).

Intussusception may be considered as an intraluminal cause of SBO, since it obturates the lumen by pushing a proximal small bowel loop and part of its mesentery into the lumen of the small bowel distal to it, even if various extrinsic or intrinsic processes may result in intussusception. The typical imaging features of enteroenteric intussusception are as follows (Gayer et al. 1998): a distended loop of bowel (the intussuscipiens) with a thickened wall; an eccentrically positioned intraluminal intussuseptum; and a crescentic area of fat-density mass representing invaginated fat from the mesentery of the intussusceptum (Fig. 11). CT can also demonstrate the cause of the intussusception by showing the leading point and can suggest its nature by its density: lipoma, cystic mass from a mucocele, or solid mass (Warshauer and Lee 1999). In some cases, CT may show multiple polypoid tumors, which suggest a diagnosis of metastases, especially from malignant melanoma, or Peutz–Jeghers syndrome. The great majority of intussusceptions responsible for an SBO are related to a tumoral cause, but intussusception is almost never the presenting sign of undiagnosed malignancy (Wang et al. 2009; Marinis et al. 2009). By contrast, numerous intussusceptions are asymptomatic without any finding of obstruction, fortuitously discovered by CT, often transient, and without a leading point (Huang and Warshauer 2003; Horton and Fishman

Table 3 Causes of SBO in adults

Extrinsic lesions	Intrinsic lesions	Intraluminal causes
Adhesions	Tumors infiltrating the wall of the small bowel	Obstruction
Hernia	Adenocarcinoma	Gallstone
External	Carcinoid tumor	Bezoar
Inguinal	Lymphoma (rare)	Foreign body
Femoral	Leiomyosarcoma (rare)	Ascaris
Obturator	Inflammatory conditions	Meconium
Sciatic	Crohn disease	Intussusception
Perineal	Tuberculosis	Adhesions
Supravesical	Potassium chloride stricture	Tumor
Spigelian	Eosinophilic gastroenteritis	Duplication
Lumbar	Vascular	Inverted Meckel diverticulum
Incisional	Radiation enteropathy	
Umbilical	Ischemia	
Internal	Hematoma	
Paraduodenal	Posttraumatic	
Epiploic foramen	Thrombocytopenia	
Diaphragmatic (traumatic)	Anticoagulants	
Transomental	Henoch–Schönlein purpura	
Transmesenteric		
Iliac fossa		
Masses		
Extrinsic tumors in mesentery		
Lymphoma		
Peritoneal metastasis		
Carcinoid		
Desmoid		
Abscesses		
Diverticulitis		
Pelvic inflammatory disease		
Crohn disease		
Appendicitis		
Aneurysm		
Hematoma		
Endometriosis		

2008). Intussuception constitutes a relatively common cause of SBO in AIDS patients, and it may be related to numerous causes: infectious enteritis, lymphoid hyperplasia, mesenteric adenopathy, Kaposi sarcoma, and non-Hodgkin lymphoma (Rabeneck 1995).

Intrinsic causes include tumor, inflammatory disease, ischemia, and hematoma. Tumors that are responsible for SBO by infiltration of the bowel wall are mainly adenocarcinoma, primary carcinoid, and metastases. Adenocarcinomas appear as an annular infiltrating lesion located in the duodenum or in the proximal jejunum, although more distal sites are possible (Fig. 12). Conversely, bowel metastases (e.g., from melanoma) usually involve the distal small

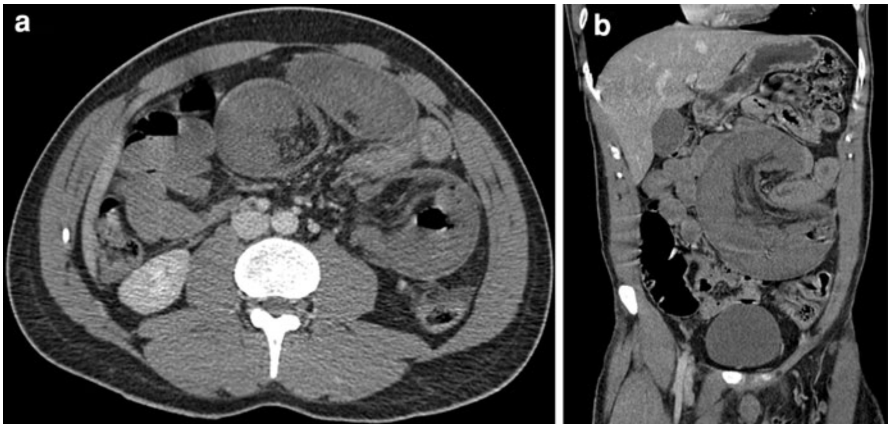


Fig. 11 Small bowel intussusception seen on the axial slice (**a**) and coronal reformatting (**b**)

bowel, making an annular infiltrative lesion in the distal ileum more likely to be a metastasis, especially in the setting of a known primary malignancy. Primary carcinoids obstruct the bowel more by desmoplastic changes (extrinsic process) than the tumor itself, which may be difficult to visualize. The SBO consecutive to inflammatory disease is more often due to Crohn disease and bowel obstruction may be the first manifestation of the disease. Ultrasonography and CT show circumferential inflammatory thickening of the bowel wall, fibrofatty changes (Fig. 13), and abscess in some cases. Other primary inflammatory causes of SBO include tuberculosis and manifestations of Behçet syndrome, both invading the terminal ileum, and ulcerative jejunoileitis complicating celiac disease and occurring in the proximal jejunum. Chronic mesenteric ischemia is responsible for a thickening of the bowel wall, which may be responsible for an SBO. Radiation enteropathy is a form of ischemia since radiation-induced small-vessel occlusions may produce chronic ischemia anywhere in the alimentary tract. CT shows bowel wall thickening with occasional visualization of the target sign. An important clue for diagnosis is that bowel changes are confined to the radiation port (Furukama et al. 2001). Spontaneous intramural hematoma is most commonly caused by excessive anticoagulation. Other causes include coagulopathy, collagen vascular disease, and Henoch–Schönlein purpura. CT shows thickening of the bowel wall occurring mainly in the duodenum and in the proximal jejunum with a characteristic ring pattern of high attenuation on nonenhanced slices (Fig. 14).

Extrinsic causes are the most common causes of SBO. Most extrinsic lesions are adhesions, which are the causes of SBO in approximately 70% of cases. The CT diagnosis of adhesion was classically considered as difficult because it was based on negative findings. The diagnosis is evoked from the presence of an abrupt change in bowel caliber without evidence of another cause of obstruction, the adhesive band itself being unidentifiable by CT. However, thin slices and multiplanar reformation have improved the diagnosis of adhesions. They allow the transition point to be viewed with more confidence and permit one to better individualize two CT signs of adhesive bands (Fig. 15): the beak sign, which is a beaklike narrowing without any mass at the transition zone, described more than 15 years ago (Balthazar et al. 1992; Balthazar and George 1994; Ha et al. 1993), and the fat notch sign, which corresponds to the extraluminal compression made by a band on the bowel at the transition zone (Petrovic et al. 2006). These findings are seen in adhesive bands in more than 60% of cases, whereas they are rarely encountered in matted adhesions (Delabrousse et al. 2009).

Although most small bowel volvulus are complications of bowel obstruction due to adhesions, midgut volvulus constitutes a primary cause of small bowel volvulus. The major predisposing factor for midgut volvulus is malrotation of the small bowel. In a malrotation, there is abnormal fixation of the small bowel mesentery, which results in an abnormally short mesentery root. This favors the twisting of the small bowel around its mesentery. With CT, one will look for a swirling of vessels in the mesentery root (Fig. 16), an abnormal relationship between the superior mesenteric artery and

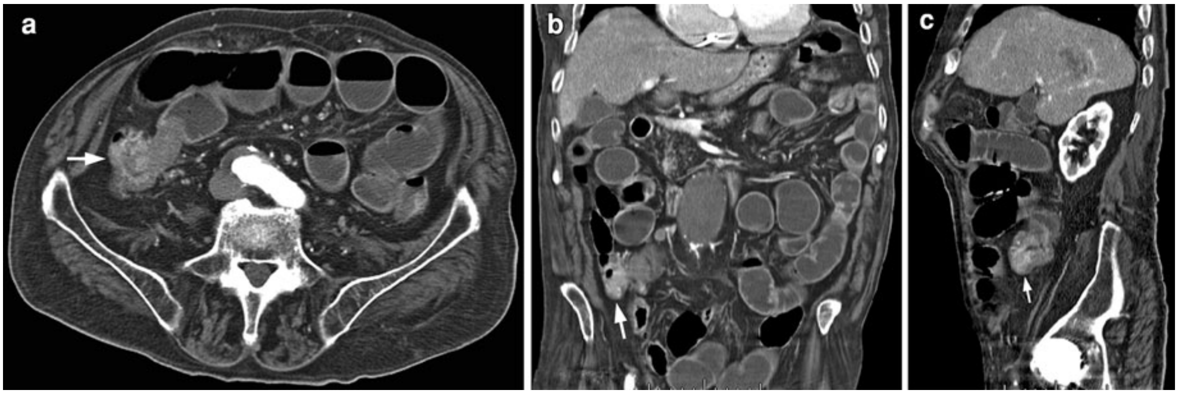


Fig. 12 SBO due to an adenocarcinoma of the terminal ileum. The axial slice (**a**) as well as coronal (**b**) and sagittal (**c**) reformatting show a dilatation of the entire small bowel. Note an enhanced, important and short thickening of the terminal ileum wall suggesting a malignant tumor of the terminal ileum (*arrow*). Surgery confirmed an adenocarcinoma

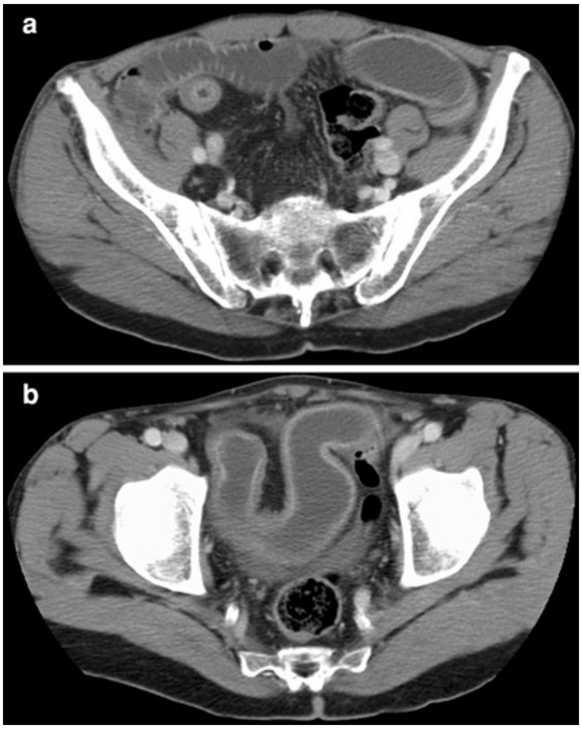


Fig. 13 SBO due to Crohn disease. Axial slices (**a**, **b**) show a thickening of the distal ileum which involved a long segment of intestine. The involved ileum has an enhanced wall with a target finding. Note also a sclerolipomatosis suggestive of Crohn disease

vein, and abnormal position of the angle of Treitz positioned below and to the right of the left L1 pedicle (Silva et al. 2009).

Hernias are the second most common cause of SBO. Approximately 95% of obstructions caused by hernias are external. External hernias, which include inguinal, femoral, umbilical, spigelian, and incisional hernias, consist of a peritoneal sac that protrudes through a weakness or defect in the muscular layers of the abdomen. Diagnosis of external hernias is based on clinical examination, and generally external hernias are treated before occlusive complications. However, in obese patients, the clinical diagnosis may be difficult and patient imaging is required. Indirect inguinal hernias are by far the most common cause of hernias This type of hernia is localized laterally to the inferior epigastric vessels and anteromedially to the spermatic cords and may reach the scrotum. Femoral hernias are far less frequent than inguinal hernias, are encountered in women, and generally reach the superior part of the thigh, at the level of the Scarpa triangle, and when they are small, they may be difficult to distinguish from inguinal hernias. CT is very helpful in differentiating direct inguinal hernia, indirect inguinal hernia, and femoral hernia by using the pubic tubercle as a reference point (Delabrousse et al. 2005) (Figs. 17, 18). Umbilical and subumbilical hernias are the second most common cause of external hernias and are easily diagnosed by CT. Postoperative external hernias are common and include incisional hernia, most frequently occurring in midline or paramidline incision, laparoscopic port site hernias, and parastomial hernias. Obturator hernias and spigelian hernias constitute rarer forms of external hernia, for which CT has a great contribution to the diagnosis (Stabile Ianora et al. 2000). Richter hernia is a special type of external hernia in which a portion of the bowel wall circumference, rather than a

Fig. 14 SBO due to spontaneous hematoma of the small bowel. The axial slice before contrast material administration (**a**) shows a huge, symmetric, and spontaneously hyperdense thickening of bowel wall. Coronal reformatting (**b**, **c**) shows that the thickening is extensive and leads to a small bowel dilatation

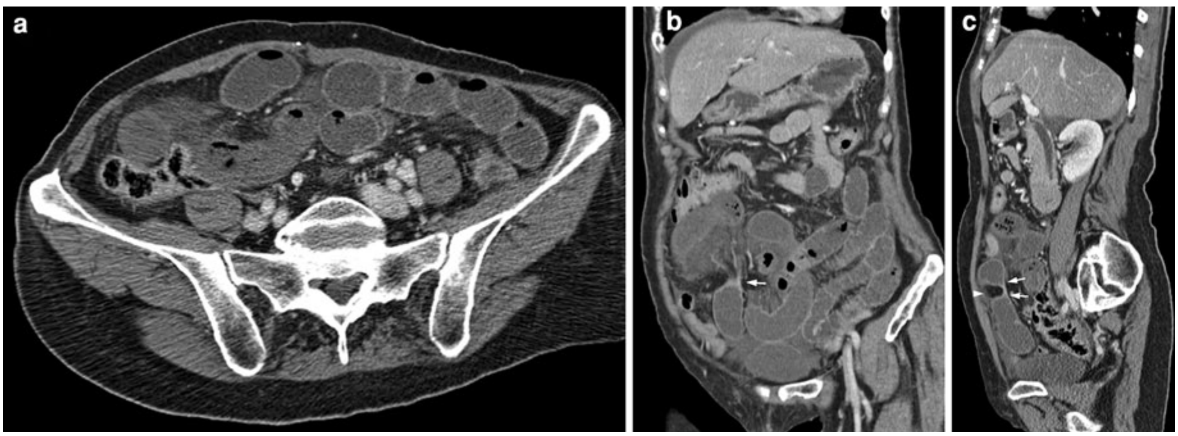


Fig. 15 SBO due to a unique adhesive band with a beak finding and a fat notch finding. The axial slice (**a**) shows a dilatation of the small bowel with a collapsed colon. The transition zone is not well seen, whereas it clearly seen on coronal (**b**) and sagittal (**c**) reformatting with two beak findings (*arrows*) and a fat notch finding (*arrowhead*). Surgery confirmed the unique anterior adhesive band

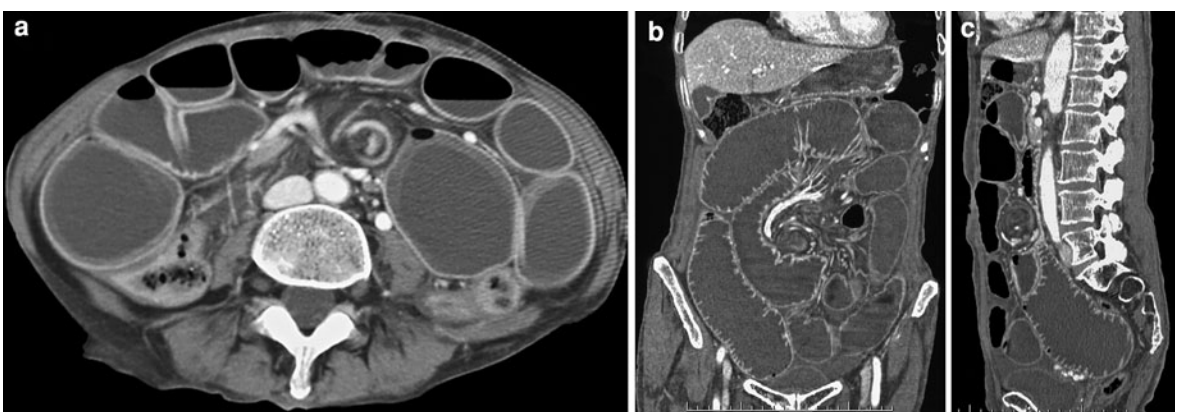


Fig. 16 Whirl sign in primary volvulus of the small bowel. The axial slice (**a**) and coronal (**b**) and sagittal (**c**) reformatting clearly show a whirl finding with swirling of the mesenteric vessels around the mesentery

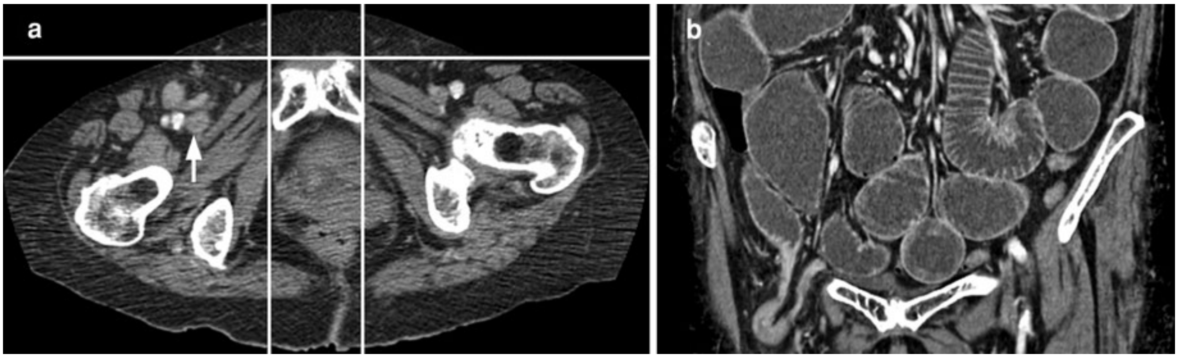


Fig. 17 Right femoral hernia. Construction of orthogonal lines on the axial slice (**a**) focused on the pubic tubercles allows one to differentiate femoral hernia (*arrow*) located dorsal to the axial axis from inguinal hernias located ventral to the axial axis. The coronal view (**b**) clearly shows the herniated small bowel

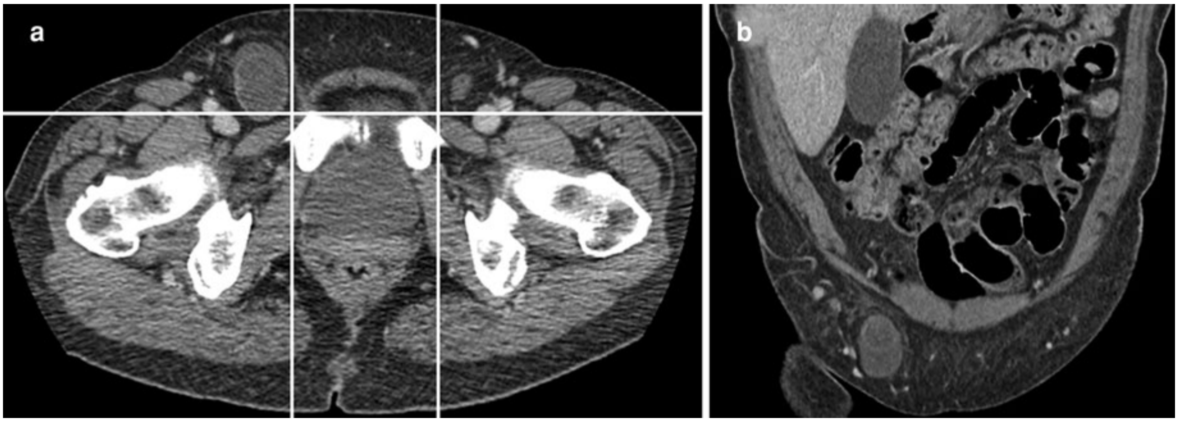


Fig. 18 Right-sided direct inguinal hernia. Construction of orthogonal lines on the axial slice (**a**) focused on the pubic tubercles allows one to differentiate inguinal hernia located ventral to the axial axis from femoral hernias located dorsal to the axial axis, and to differentiate direct inguinal hernia lateral to the sagittal axis from indirect hernia crossing medially the sagittal axis. The coronal view (**b**) clearly shows the herniated small bowel

whole loop, becomes entrapped in a tightly constricting hernia orifice. Richter hernias more rapidly progress to bowel wall necrosis than other strangulated hernias and present with symptoms of ischemia rather than obstruction because the lumen remains open.

In comparison with external hernias, internal hernias are uncommon and remain a vexing problem for CT (Blachar et al. 2001; Takeyama et al. 2005). The two most common internal hernias are paraduodenal hernias and transmesenteric or transmesocolic hernias. Paraduodenal hernias account for approximately 50% of all internal hernias. The small bowel is entrapped between the posterior and the mesocolon in a hernia sac. CT shows that the anterior wall of the sac contains the inferior mesenteric vein and left colic artery in left-sided paraduodenal hernia and the superior mesenteric vein and the right colic artery in right-sided paraduodenal hernia, and these vessels constitute a landmark above the encapsulated bowel loops (Warshauer and Mauro 1992). Transmesenteric and transmesocolic hernias are becoming more common because of transplants and bariatic surgery in which surgical defects in the mesocolon are created to accommodate a Roux loop. CT shows small bowel located laterally to the colon (Fig. 19) and overall directly adjacent to the abdominal wall, and mesenteric vessels stretched and following the course of the herniated bowel (Martin et al. 2006). Other internal hernias include herniation through the foramen of Winslow (Fig. 20), pericecal, intersigmoid, supravesical, and pelvic hernias, including hernias through

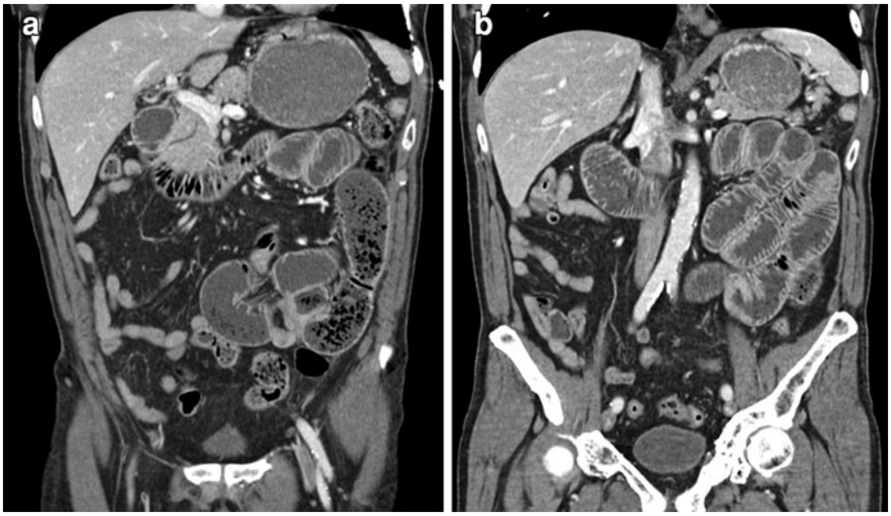


Fig. 19 Transmesenteric hernia shown on coronal views (**a**, **b**). Note the lateral position of the small bowel loops which are dilated with a feces content. The bowel loops are encapsulated. The diagnosis of internal hernia was not performed preoperatively

the broad ligament. Table 4 summarizes CT findings in these different hernias.

Extrinsic causes of SBO other than adhesions and hernias include a wide variety of neoplastic, inflammatory, and vascular processes. Extrinsic masses cause obstruction by two main mechanisms: compression of the lumen by the mass and distortion of the lumen by a desmoplastic process. The most common cause of extrinsic masses is carcinomatosis, most often from ovarian carcinoma. However, any peritoneal process, such as carcinoid desmoplastic reaction which often results in retraction of surrounding loops of small bowel, tuberculous peritonitis, desmoid tumors, severe radiation changes, or peritoneal endometriosis from the small bowel serosa, may mimic peritoneal metastases. In the same way, an inflammatory process may agglutinate the bowel loops responsible for an SBO (Fig. 21)

Abdominal cocoon, also referred to as sclerosing encapsulating peritonitis, is a rare extrinsic cause of SBO. It is characterized by forming a fibrous membranelike sac, which encases the loops of small bowel and causes subacute and recurrent episodes of bowel obstruction. CT shows totally or partially obstructed loops of small bowel concentrated to the center of the abdomen and a thickening of the peritoneal membrane (Tombak et al. 2010).

3.5.3 CT Pitfalls

As previously said, the lack of identification of a lesion in adhesion was classically a cause of lack of confidence. However, the identification of a beak sign or a fat notch sign at the transition zone dramatically increases the radiologist's ability to affirm an adhesive band. In some cases, at the level of the beak finding, there is some thickening of the bowel wall which may evoke an intrinsic bowel lesion. By contrast with adhesive band, the diagnosis of matted obstruction, for which the beak sign and the fat notch sign are generally missing, remains difficult.

The diagnosis of internal hernias remains very challenging, and even though numerous case reports of CT diagnosis of internal hernia have been published, mostly the pictures are correctly interpreted only after the surgical procedure. The diagnostic criteria making diagnostic possible include abnormal location of bowel, encapsulation, and crowding of bowel loops, but these findings are not pathognomonic and key points such as an abnormal location of a vessel, an abnormal distance between the portal vein and the inferior vena cava, or a surgical context consistent with a mesocolic defect must be looked for. In clinical practice, paraduodenal hernias are more often diagnosed preoperatively because of their relative frequency (Fig. 22)

Endometriosis is a common disease, but is rarely revealed by an SBO, and findings such as a solid nodule penetrating the bowel wall or a transition point which appears as a short circumferential mural thickening and on surgery a stricture due to fibrosis secondary to endometriotic implants looking like an adhesive band are often difficult to identify (Silva et al. 2009).

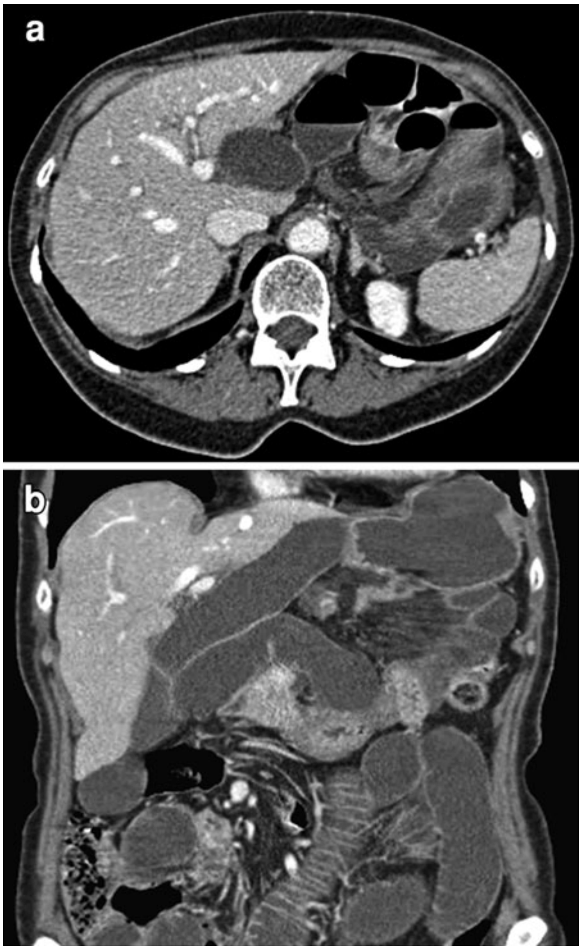


Fig. 20 Foramen of Winslow hernia. The dilated small bowel loops are encapsulated and localized in the lesser sac. The axial slice (**a**) show the loops within the lesser sac, whereas the coronal view (**b**) show bowel loops passing through the foramen of Winslow

The CT diagnosis of intussusception is easy with a pathognomonic finding, but a leading mass as the cause of the intussusception may be difficult to differentiate from the soft-tissue pseudotumor that represents the intussusception itself (Aufort et al. 2005; Tresoldi et al. 2008).

3.5.4 CT Impact

The practical value of knowing the cause of SBO before surgery has dramatically improved treatment in the last decade. The philosophy of never letting the sun set or rise on SBO has been followed by management according to the cause and the severity of the obstruction. Most modern surgeons actually recommend an emergent operative management in hernias, a more delayed surgical management in malignant focal tumor, a medical management in most cases of peritoneal carcinomatosis, radiation enteritis, or jejunal hematoma, a conservative management in Crohn disease when an acute flare is causing bowel obstruction whereas obstruction caused by a chronic fibrotic structure may in some cases necessitate surgical resection, and treatment of adhesions, balancing between medical treatment and surgical exploration according to the patient's status, the location of the adhesions, and above all the suspicion of strangulation. The distinction between adhesive bands and matted obstruction is of importance because the risk of closed loop obstruction and strangulation is dramatically higher in adhesive bands, whereas a higher rate of surgical accidental bowel perforation seems to be associated with matted adhesions. In clinical practice, fewer than 50% of patients with a CT diagnosis of adhesion are operated.

3.6 Diagnosis of Complications

3.6.1 Clinical Considerations

Strangulation occurs in about 10% of SBO cases. It represents the main factor of morbidity and mortality, with a mortality above 10%, increasing with the diagnostic delay. It is characterized by an impaired vascular circulation to the obstructed intestine. Balthazar and George (1994) have very clearly summarized the mechanisms which lead to a strangulation:

1. The first event is a closed loop or incarcerated intestinal obstruction due to adhesions or hernias, in which a loop of bowel is occluded at two or more adjacent points along its course. There is a mechanical obstruction proximal to the involved bowel segment. The length of the closed loop is variable, from a single loop to several loops of bowel. If the length of the closed loop is sufficient, the loop may twist and produce a volvulus. It the length of the closed loop is short (e.g., in some external hernias), the bowel proximal to the obstacle may twist. Volvulus is a common but not invariable complication of an incarcerated loop. It tends to occur in patents with high degrees of obstruction, but once developed, it further

Table 4 CT patterns in internal hernias

	Relative incidence	Mechanism	CT position of the loops	Key points
Left-sided paraduodenal hernia	+++	Congenital	Encapsulated loops between the stomach and pancreas or behind the pancreas or between the transverse colon and the left adrenal gland	Inferior mesenteric vein displaced anteriorly
Right-sided paraduodenal hernia	++	Congenital	Encapsulated loops lateral and inferior to the descending duodenum	Superior mesenteric artery displaced anteriorly (located in the anteromedial border of the sac)
Pericecal hernia	++	Congenital or acquired	Clustered loops posterior and lateral to the ascending colon	
Foramen of Winslow hernia	+	Congenital	Small bowel loops and sometimes ascending colon in the lesser sac	Mesentery between the abnormally distant portal vein and the inferior vena cava
Transmesenteric and transmesocolic hernias	+++	Acquired (in adults)	Small bowel loops lateral to the colon	Displaced omental fat with small bowel directly abutting abdominal wall. Epidemiological data: history of Roux-en-Y surgery (liver transplant, bariatric surgery)
Intersigmoid hernias	+	Congenital or acquired	Clustered small bowel loops posterior and lateral to the sigmoid colon	
Hernias through the broad ligament	+	Congenital or acquired	Clustered bowel loops compressing the rectosigmoid dorsolaterally and the uterus ventrally	Mesenteric fat tissue and vessels penetrating the broad ligament

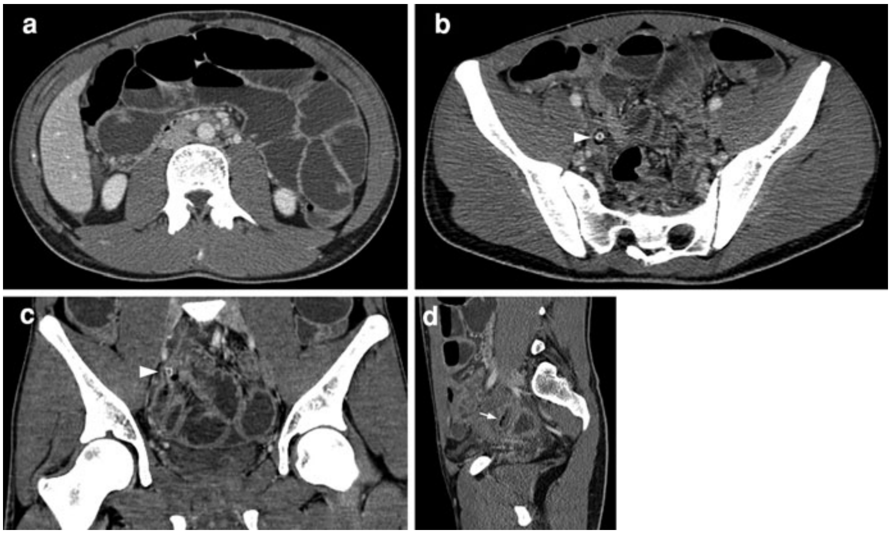


Fig. 21 SBO due to appendicitis. The upper axial slice (**a**) show a dilatation of the small bowel with a collapsed descending colon. The pelvic slice (**b**) and coronal (**c**), and sagittal (**d**) reconstructions show agglutination of the small bowel loops on an appendicitis (*arrow*) with an appendicolith (*arrowhead*)

aggravates the mechanical obstructive process and contributes to the development of mesenteric ischemia.

2. The second event is strangulation, which is defined as a closed loop obstruction associated with intestinal ischemia. The severity and duration of the intestinal and mesenteric obstructive process determines the severity of the ischemia. Initially, the venous return of blood from the involved bowel segment is compromised because intraluminal pressure exceeds venous pressure, with congestive changes affecting the bowel wall and the mesentery, while the influx of arterial blood continues. Ischemia may resolve with an emergent surgical

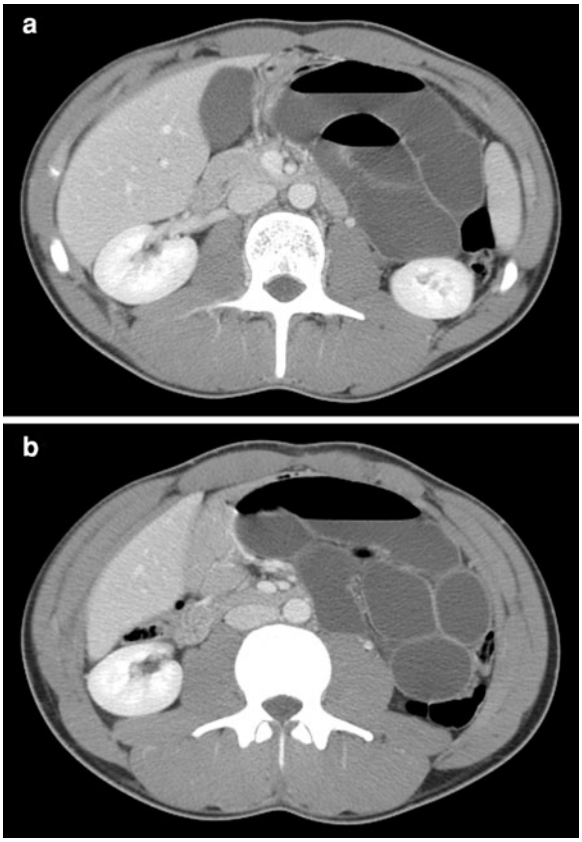


Fig. 22 Left-sided paraduodenal hernia shown on two axial slices (**a**, **b**)

treatment of the cause. Increasing distension also predisposes the closed loop to rotation about its mesentery. Then arterial insufficiency follows, aggravating the anoxia and further contributing to the rapid development of gangrene and perforation.

The clinical diagnosis of strangulation is difficult. Intestinal strangulation is suspected when the intermittent crampy pain becomes continuous and increases in severity, and in patients with tachycardia, fever, peritoneal irritation, and leukocytosis. However, these findings cannot reliably differentiate simple from strangulated obstruction, which means that before the development of CT, strangulation was not diagnosed preoperatively in about 75% of patients with surgically proved strangulation.

3.6.2 CT Findings

In strangulating SBO, the CT findings can be divided into two categories: findings indicative of closed loop obstruction and findings indicative of strangulation.

Closed loop obstruction. In closed loop obstruction, CT shows incarcerated small bowel with a radial distribution and stretched mesenteric vessels converging toward torsion (Fig. 23) and a U- or C-shaped dilated bowel loop and at the site of torsion, the presence of two adjacent collapsed, round, oval, or triangular loops, the beak sign appearing as a fusiform tapering when the bowel is imaged in longitudinal section. The whirl sign is a classic sign of closed loop obstruction. It appears as a twist of bowel wrapping around a single constrictive focus of mesentery with a spiral arrangement of mesenteric vessels (Khurana 2003).

Strangulation. CT shows bowel wall and mesentery abnormalities (Balthazar et al. 1997; Catel et al. 2003) (Table 5). Bowel wall findings are a circumferential thickening wall, increased attenuation, a target or a halo sign, or, on the contrary, a bowel wall thinning that corresponds to late mucosal desquamation, a pneumatosis, or a lack of enhancement of the wall of the incarcerated bowel after intravenous administration of contrast material (Figs. 23, 24). This last finding is the most specific finding of strangulation. The nonenhanced bowel wall is responsible for the disappearing loop sign, which refers to isodense bowel wall indistinguishable from adjacent mesenteric fluid. Before intravenous administration of contrast material, bowel wall hemorrhage with a spontaneously hyperdense wall (Fig. 25) is a good finding of ischemia, and needs a narrow window to be identified. Mesentery abnormalities include congestion, blurring, haziness, and obliteration of the mesenteric vessels and fluid or hemorrhage in the mesentery.

Theoretically, the CT appearance in strangulating obstruction depends on the stage of the strangulation. When the blood inflow is higher than venous outflow, the appearance of the bowel loop is that of a loop with impaired mesenteric venous drainage: bowel wall thickening with mesenteric engorgement and mesenteric edema, abnormal enhancement of the bowel wall is usually present with increased attenuation, a halo sign, or a target sign. At a more advanced stage of the disease, the arterial supply and the bowel wall may be thin and nonenhanced.

3.6.3 CT Pitfalls

The whirl sign, which indicates a rotation of the mesentery, is suggestive of a closed loop obstruction. However, this sign is not specific and may be present in patients with altered mesenteric anatomy due to

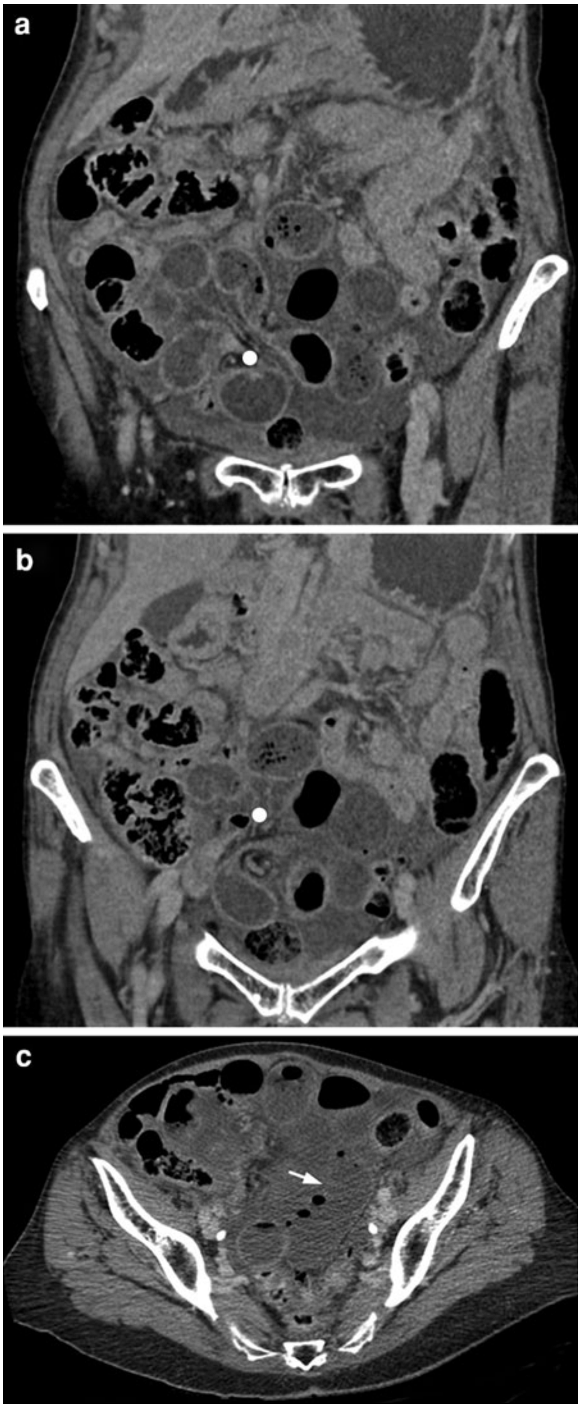


Fig. 23 Closed loop obstruction with several converging beak findings. Coronal views (**a**, **b**) show dilated bowel loops with several beak findings converging toward the same point (*right dot*). This is very suggestive of a closed loop obstruction. Note also the lack of enhancement of the bowel wall on the axial slice (**c**), suggestive of strangulation (*arrows*)

Table 5 CT features of ischemia in SBO

Bowel wall findings
Without injection phase
Increased attenuation
Arterial phase
Decreased or delayed wall enhancement
Pneumatosis
Wall thinning
Venous phase
Circumferential thickening
Target or halo sign
Mesentery
Blurring of mesenteric fat
Interloop fluid
Congestion of mesenteric vessels
Combined
Disappearing loop sign

prior bowel surgery. In a large retrospective study at Memorial Sloan-Kettering, most CT scans in patients with small bowel volvulus had a whirl sign, but most whirl signs were not due to volvulus (Gollub et al. 2006). However, it must be known that in patients with bowel obstruction, the presence of a whirl sign has great value in predicting the need for surgery (Duda et al. 2008).

Among classic findings of bowel strangulation, it is well known that a thickening of the bowel wall, a target finding or a halo finding is not specific and may be present in infectious or inflammatory bowel disease. It has more recently been shown that a pneumatosis might be the consequence of the bowel distension in the lack of ischemia. The only finding specific to ischemia is the lack of enhancement of the bowel wall. It may be difficult to affirm if the bowel wall is thin, and above all if there is no fluid around the bowel wall permitting one to identify the disappearing loop sign. Contrary to common opinion, the arterial phase is not useful to evaluate the bowel wall enhancement, the portal phase is preferable, and in some cases, some residual enhancement of the bowel wall may be shown only on the delayed phase, but delayed enhancement of the bowel wall may be considered as a finding of ischemia, as may be a lack of enhancement.

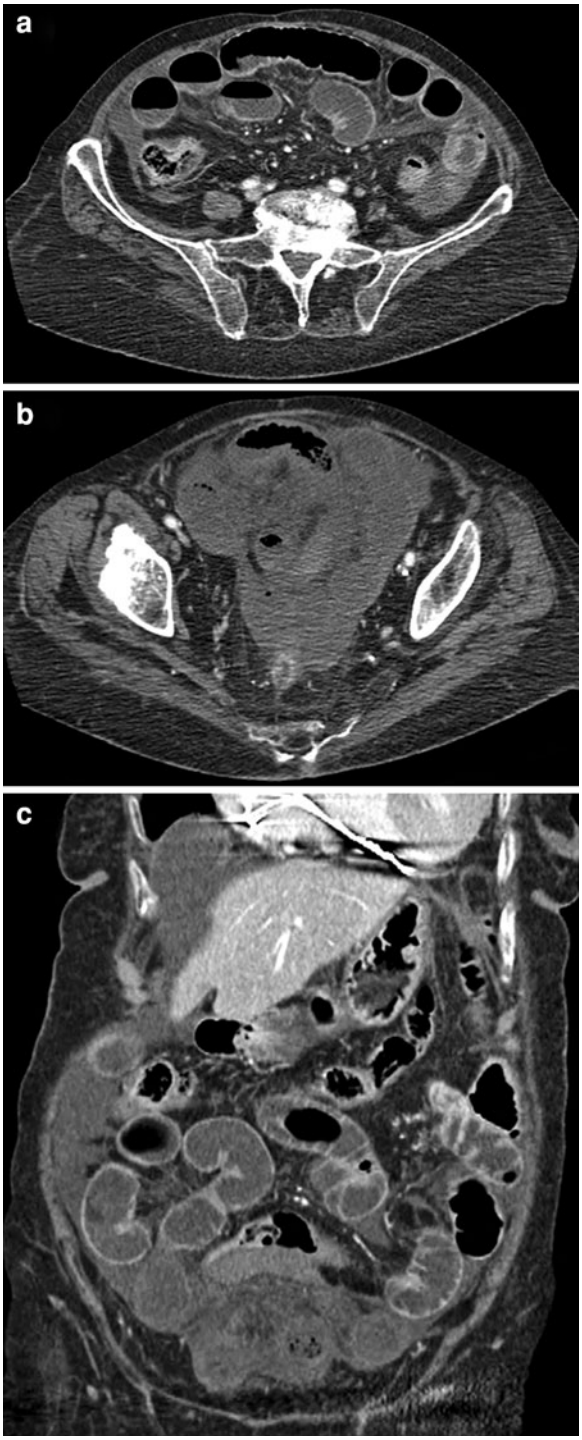


Fig. 24 Strangulating obstruction. The upper axial pelvic slice (**a**) shows dilated small bowel loops with normal wall enhancement. At a lower level (**b**), the wall of the dilated bowel loops is not identified because it is not enhanced and with the same density as the bowel content. Coronal reformatting (**c**) shows the upper enhanced and lower nonenhanced small bowel loops

3.6.4 CT Accuracy

Several studies have investigated the accuracy of CT for the diagnosis of bowel ischemia among patients with SBO. The reported accuracies of CT in these retrospective studies are good, with sensitivities reported from 76 to 100% and specificities ranging between 76 and 100% (Balthazar et al. 1997; Zalcman et al. 2000; Kim et al. 2004; Mallo et al. 2005). By contrast, a review of prospective interpretation in patients with suspected SBO found very poor performance for detecting ischemia, with only 14.8% sensitivity but a specificity of 94% (Sheedy et al. 2006). In our experience, discrepancies between CT and surgical findings are more due to CT false positives, with findings of ischemia not confirmed at surgery. We also found a lack of enhancement or a delayed enhancement of the bowel wall as a highly specific finding of bowel ischemia. However, the sensitivity ranges from 33 to 50% in the published experiences (Sheedy et al. 2006; Catel et al. 2003).

There is a main difficulty in the evaluation of CT in strangulating obstruction: the delay between CT and surgery, which hinders correlation between CT and surgical findings. Ischemia may have worsened between CT and surgery or, on the contrary, ischemic bowel wall may have been reperfused during this time. Furthermore, surgery is not an absolute gold standard since we have encountered patients with CT findings of strangulation, not confirmed by a first surgical investigation and recognized during a second surgical investigation, this latter investigation being performed because no improvement of the clinical status of the patient.

3.6.5 CT Impact

Despite these limitations, CT has a great impact on the diagnosis of strangulation. Clinical findings of strangulation are lacking in about 75% of cases in patients with strangulation, and a conservative attitude in patients with SBO is more and more recommended since in patients with adhesions unnecessary additional abdominal interventions represent a source for future occlusive episodes. Consequently, information regarding ischemic complications in patients with SBO is important for the surgeon in order to plan the correct time for a surgical therapy. Regression analysis of multiple clinical biological and CT preoperative criteria has demonstrated that

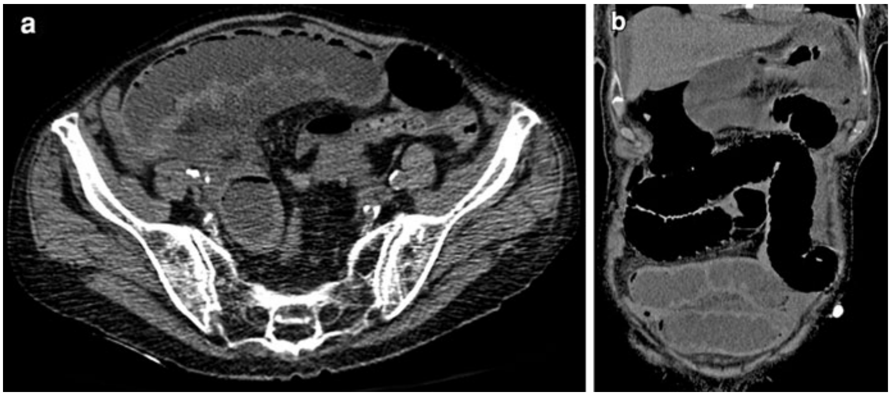


Fig. 25 Strangulating obstruction CT performed without intravenous administration of contrast material. On axial (**a**) as well as on coronal (**b**) reformatting the wall of a low and anterior bowel loop is spontaneously hyperdense. This is suggestive of strangulation

reduced wall enhancement on CT was the most significant factor of strangulation (Jancelewicz et al. 2009)

4 Large Bowel Obstruction

4.1 Diagnosis of Mechanical Obstruction

4.1.1 Clinical Considerations

The clinical diagnosis of LBO classically depends on four cardinal findings: abdominal pain, constipation or obstipation, abdominal distention, and vomiting if the ileocecal valve is incompetent. However, diagnosis can be difficult because clinical findings differ with the degree and level of bowel obstruction and with the vascular status of the obstructed segment. In typical mechanical obstruction, abdominal pain is crampy and gradually increases in intensity, only to abate and recur. With time, increasing bowel distention inhibits motility and the pain tends to subside. Furthermore, because most colonic obstructions are due to cancer, patients are often elderly and have symptoms related to the tumor location, with fewer acute symptoms than with SBO. However, crampy abdominal pain can occur with other causes of acute abdomen, such as renal colic. In the same way, vomiting or constipation is not specific to mechanical obstruction. As its name indicates, colonic pseudoobstruction is the main differential diagnosis of LBO. Colonic pseudoobstruction is a syndrome in which the clinical features resemble those of mechanical obstruction, that is, failure of motility associated with pain and abdominal distention, but there is no mechanical obstruction (De Giorgio and Knowles 2009). Abdominal plain film is the classic imaging modality used to confirm the diagnosis of LBO. However, in about one third of patients supposed to have mechanical obstruction on clinical examination, abdominal plain film shows no obstruction. Conversely, about 20% of patients suspected of having colonic pseudoobstruction have mechanical LBO.

4.1.2 CT Findings

The CT diagnosis of LBO is based on the presence of a dilated colon proximal to a transition zone and a collapsed distal colon. The large bowel is considered dilated when its diameter is more than 8 cm. However, a colon diameter larger than 10 cm may be present in colonic pseudoobstruction. Conversely, proximal colonic dilatation with gas, feces, or fluid, with an abrupt transition zone and a collapsed distal colon, is a reliable and convincing finding of LBO.

4.1.3 Pitfalls and Limitations

CT has limitations in the diagnosis of colonic obstruction, with false-negative and false-positive results.

False-negative CT diagnosis in LBO may be encountered in patients with partly obstructing carcinoma of the colon, with no significant proximal dilatation. CT interpretation in these cases requires proper colon cleaning and the use of air insufflation. An obstructive process at the ileocecal valve or the colonic flexure with residual fecal content in the distal colon may also lead to an erroneous diagnosis of ileus. Furthermore, despite an obstruction leading to LBO, distal colonic segments may be filled with gas.

False-positive diagnosis may be due to some pattern of ileus with dilatation of the small bowel and the ascending colon and a distal totally collapsed colon that should not lead to a diagnosis of colonic obstruction unless a colonic lesion is visualized at the transition zone. In fact, there is often a dilatation limited to the ascending and transverse colon in colonic pseudoobstruction. In a retrospective study including eight cases of colonic pseudoobstruction, the transition zone was located in six patients at the splenic flexure and in the other two patients in the midportion of the transverse and descending colon (Choi et al. 2008).

4.1.4 Accuracy

In contrast to SBO, which has been studied extensively, the value of CT in the diagnosis of LBO has been established in only two studies (Frager et al. 1998; Beattie et al. 2007): one study reported a sensitivity of 96% and a specificity of 93% and the other study reported a sensitivity and a specificity of 91%.

4.1.5 CT Impact

In all situations of suspected LBO, no matter how clear the diagnosis appears on plain radiography, another imaging test must be performed to differentiate mechanical obstruction from pseudoobstruction. Although contrast enema and CT are still the tests recommended, both tests having good sensitivity and specificity, CT has at least five advantages (Taourel et al. 2003): it is easier to perform; it is always diagnostic, in opposition to contrast enema, for which the patient may not retain the contrast material or may not tolerate insertion of the rectal tube; it is better for investigating the cause of the obstacle; it allows more accurate measurement of bowel diameter; and it is better for analyzing the viability of the colonic wall.

4.2 Diagnosis of the Site of the Obstruction

4.2.1 Clinical Considerations

The diagnosis of an LBO site is not done easily with only clinical data. Lesions at the ileocecal valve or ileocolic intussusception cause acute symptoms with vomiting, but lesions in the ascending colon cause more insidious manifestations because the lumen is wide and the contents are semiliquid. Left-sided lesions cause major abdominal distention with progressive constipation and ultimately obstipation. The determination of the LBO site due to cancer is important for the surgical procedure, particularly when laparoscopic surgery is scheduled.

4.2.2 CT Findings

It is generally easier to follow the course of the large bowel than that of the small bowel on CT slices, and CT is accurate in establishing the exact point of transition between the dilated and collapsed colon. Misinterpretations may be encountered between an obstructing terminal ileal lesion and a cecal lesion.

4.3 Diagnosis of the Cause of the Obstruction

4.3.1 Clinical Considerations

The main cause of LBO is constituted by malignant lesions (Fig. 26). In a study including 234 consecutive patients who underwent emergency surgery for colonic obstruction, colorectal cancer accounted for 82% of obstructions (Biondo et al. 2004). The second most common causes were extracolonic cancer and volvulus, each representing in the same study about 5% of causes. Rarer causes included diverticular disease, hernias, ischemic colitis, inflammatory mass, colonic tuberculosis, and colonic invagination.

The sigmoid colon constitutes the most common site of obstructive colon cancer because of its relatively narrow diameter and solid fecal contents. In the same way, nearly 20% of sigmoid cancers are complicated by some degree of obstruction.

Volvulus represents the second most common cause of LBO. Colonic volvulus requires a segment of redundant mobile colon and relatively fixed points around which the volvulus can occur. As a consequence, the sigmoid colon (70%), the cecum (25%), and the transverse colon (5%) are the most common sites of volvulus. Other contributing factors are distention of the colon by feces or gas, increased muscular activity, and changes in the intraperitoneal relationship as seen in pregnancy (sigmoid volvulus is the first cause of obstruction in pregnant woman) or parturition, previous abdominal surgery resulting in adhesions, congenital abnormalities such as malrotation, and acquired obstructive lesions in the distal colon. The diagnosis of colon volvulus is often

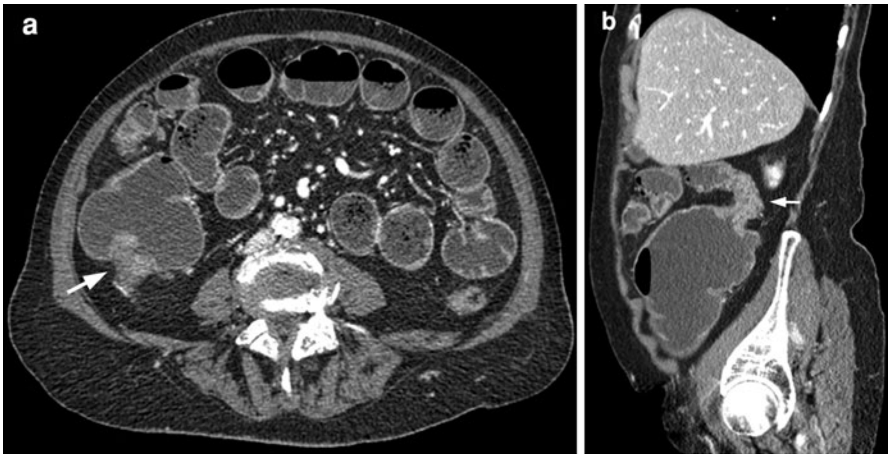


Fig. 26 Large bowel obstruction (LBO) due to ascending colon cancer. The axial slice (**a**) shows dilated small bowel loops and cecum with a short thickening of the wall of the ascending colon (*arrow*). Sagittal reformatting (**b**) shows clearly the relationship between the proximal dilated colon, the tumor (*arrow*), and the distal collapsed colon

evident on abdominal plain film. This shows a greatly distended paralyzed loop with fluid–fluid levels, mainly on the left side, extending toward the diaphragm with a "northern exposure sign", meaning that the sigmoid colon extends cranially beyond the level of the transverse colon, and a "coffee bean sign", referring to the coffee-bean-like shape that the dilated sigmoid colon may assume in a sigmoid volvulus. In the cecum volvulus, a distended cecum is typically positioned in the left upper quadrant; however, in nearly half of cases of cecal volvulus, the cecum twists in the axial plane, rotating around its long axis and appears in the right lower quadrant.

Diverticulitis is a classic but relatively rare cause of LBO. Several mechanisms may lead to an obstruction in patients with diverticulitis: adherence of small bowel loops to an inflammatory focus, a pelvic colon angulated by adhesions, pericolic fibrosis, or compression by intramural or extramural abscesses. In our experience, bowel obstruction consecutive to diverticulitis is more often SBO by agglutination of the bowel loops (Kim et al. 1998), and LBO due to colitis is mainly due to ischemic colitis.

4.3.2 CT Findings

CT may diagnose intraluminal, intrinsic, and extrinsic causes of bowel obstruction.

Intraluminal causes of colonic obstruction are often in the sigmoid colon, which is the narrowest portion of the colon. The most frequent cause is fecal impaction, which is a rather common cause of LBO in elderly and inactive patients. Other intraluminal objects that may cause LBO include gallstones (mostly in elderly women), foreign bodies in mentally ill or disturbed patients, medications such as antacid containing nonabsorbable aluminum hydroxide antacid gel given to prevent hyperphosphatemia, and bezoars, which usually do not affect the colon unless there is a stricture. Intussusception may be considered as an intraluminal cause of LBO because it occludes the lumen of the colon by pushing an ileal loop or the proximal colon and part of its mentery into the lumen of the colon distal to it, even if various extrinsic or intrinsic processes may result in intussusception. The typical CT features of ileocolic or colocolic intussusception include a distended bowel loop (the intussuscipiens) with a thickened wall, an eccentrically positioned intraluminal intussusceptum, and a crescentic area of fat density representing invaginated fat from the mesentery of the intussusceptum. CT can also demonstrate the cause of intussusception by showing the leading mass and suggesting its nature by its density: fat-containing lipoma, cystic mass from a mucocele, or solid tumor. In contrast to ileoileal intussusception, colocolic intussusceptions are more usually due to large bowel tumor (Wang et al. 2009) (Fig. 27).

Intrinsic causes include tumor, diverticulitis, inflammatory disease, and ischemic colitis. In colon cancer, CT shows an asymmetric and short thickening of the colon wall (Fig. 28) or an enhanced soft tissue mass. The dilatation of the colon proximal to the tumor makes the identification and the analysis of the

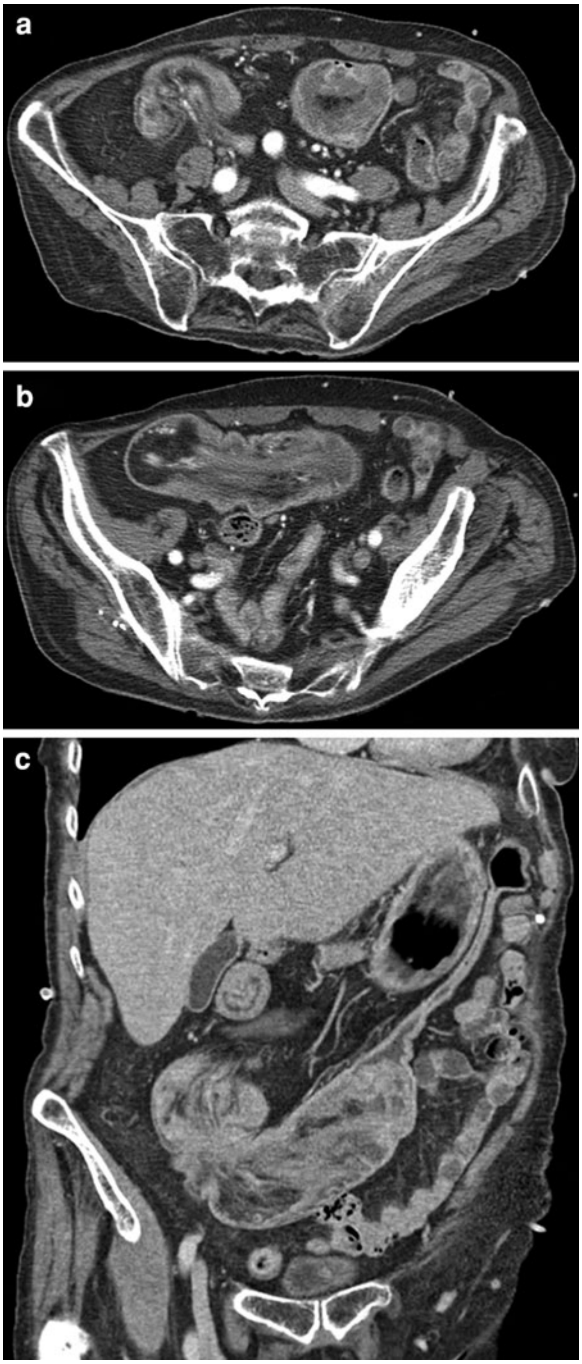


Fig. 27 Colocolic intussusception due to colon cancer. Axial slices (**a**, **b**) and coronal reformatting (**c**) show the intussuscipiens and the intracolic intusussception. Note the presence of several enhanced vessels in the mesentery which are adjacent to the intussuscepted colon. The tumoral lead point is difficult to distinguish from the intussuscepted bowel

tumor easier. Three-dimensional reconstruction images can demonstrate the transition point between the dilated and collapsed colon in problem cases (Filippone et al. 2007). In diverticulitis, thickening of the bowel wall is symmetric, more moderate, and extended on a longer segment. Moreover, pericolic changes are more important with fat stranding and, in some cases, phlegmon or intramural or extramural abscesses. In typhilitis, which occurs in neutropenic patients undergoing chemotherapy for acute leukemia, CT demonstrates cecal distention and circumferential thickening of the cecal wall. Crohn disease and ulcerative colitis are rarely the cause of LBO. The location of the involved segment and the extent and appearance of wall thickening may help distinguish these entities. In ischemic colitis, CT typically demonstrates circumferential, symmetric wall thickening (Fig. 29), often with a double-halo sign or a target sign. Pericolic fat stranding is present in 60% of patients with ischemic colitis (Balthazar et al. 1999). CT is helpful in distinguishing tumoral from ischemic segments in patients with ischemic colitis proximal to colonic carcinoma. The tumoral segment has an irregular thickening and heterogeneous enhancement by contrast material, with the ischemic segment generally smoothly thickened and homogeneously enhanced. Radiation colitis is a form of ischemic colitis, and the stricture is generally responsible for the obstruction. The sigmoid colon and the rectum are affected most frequently because radiation therapy is used for pelvic disease.

Extrinsic causes include volvulus, hernias, adhesions, and compression by diseases from adjacent organs.

Cecal volvulus results from an abnormal mobility of the cecum because of congenital improper fusion of the cecal mesentery with the posterior parietal peritoneum. The CT appearance depends on the pathophysiological mechanism of the volvulus (Delabrousse et al. 2007). Three types of cecal volvulus are defined: the axial torsion type, the loop type, and the bascule type (Fig. 30).

1. In the axial torsion type (Fig. 31), the cecum rotates along its long axis and twists in the axial plane. The distended cecum is located in the right side of the lower abdomen. The whirl sign composed of

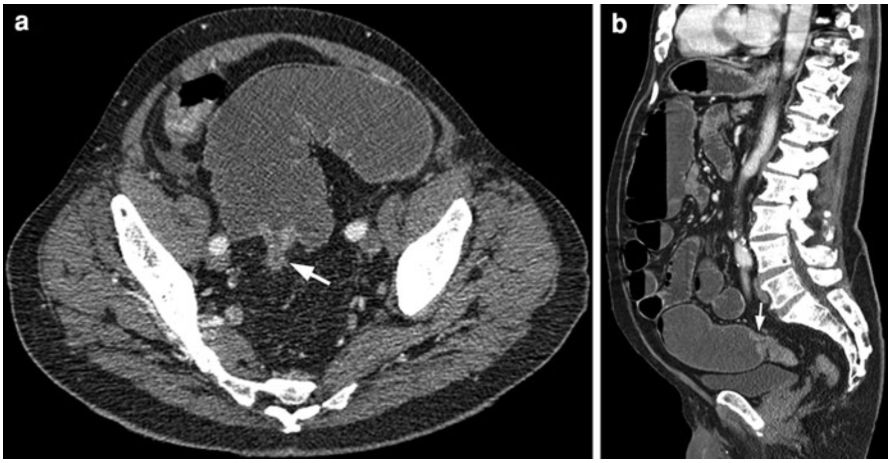


Fig. 28 LBO due to sigmoid colon cancer. The axial slice (**a**) and sagittal reformatting (**b**) show the sigmoid carcinoma (*arrow*) responsible for LBO

spiraled vessels and loops of collapsed cecum is well seen and distal ileum is present in a clockwise appearance.

2. In the loop type, the distended cecum both twists and inverts. The distended cecum is located in the left upper quadrant. The whirl sign is well seen. A counterclockwise appearance is present.
3. In the bascule type, the distended cecum folds anteriorly without any torsion. The distended cecum is located in the central abdomen and the whirl sign is absent.

Three-dimensional imaging may allow selection of the optimal plane for viewing the volvulus and localizing the precise source of torsion (Moore et al. 2001).

The transverse colon is the rarest site of colonic volvulus, but it is associated with the highest mortality. Transverse colon volvulus occurs in the setting of abnormal fixation of a long transverse colon. CT shows a beaklike narrowing of the transverse colon at the volvulus site and an adjacent whirl sign.

The sigmoid colon is the most common site of colonic volvulus. CT shows a whirl pattern of the collapsed colon, twisted mesentery, and enhanced engorged vessels, with a bird beak aspect of the afferent and efferent segments (Catalano 1996), constituting a closed loop obstruction. This represents the classic form of sigmoid volvulus (Figs. 32, 33). A new form of sigmoid volvulus has been described recently (Levsky et al. 2010): the organoaxial volvulus, for which the sigmoid colon rotates along its long axis with only one point of beak finding, the proximal colon running at a distance from the site of volvulus.

LBO secondary to hernias or adhesions is much less common than SBO because of the relatively fixed nature of the colon and its larger caliber. Extrinsic compression may be caused by endometriosis, which involves the rectum and the distal sigmoid colon, with thickening that may simulate a colon cancer on CT; actinomycosis, which must be considered in a woman with prolonged use of an intrauterine device (Yeguez et al. 2000); pancreatitis, or more often, involvement due to extracolonic neoplasm either directly or by serosal metastasis. The rectum or the sigmoid may be obstructed by direct invasion from gynecologic and prostatic neoplasms and by drop metastases to the pouch of Douglas. Pelvic lipomatosis, benign pelvic masses, retroperitoneal fibrosis, and pregnancy can compress the colon but rarely lead to LBO.

4.3.3 Pitfalls and Limitations

False-positive pictures of narrowing in the colon may be encountered when the colon is collapsed. In these cases, supplementary scanning in the left-side-up position if the descending colon is suspicious, or in the right-side-up position if the ascending colon is suspicious, shifts colonic air and opens up the suspicious segment, ruling out true obstruction (Beattie et al. 2007).

False-positive diagnosis of rectal lesion may be encountered in patients with circumferential thickening of the rectal wall. In these cases, air insufflation

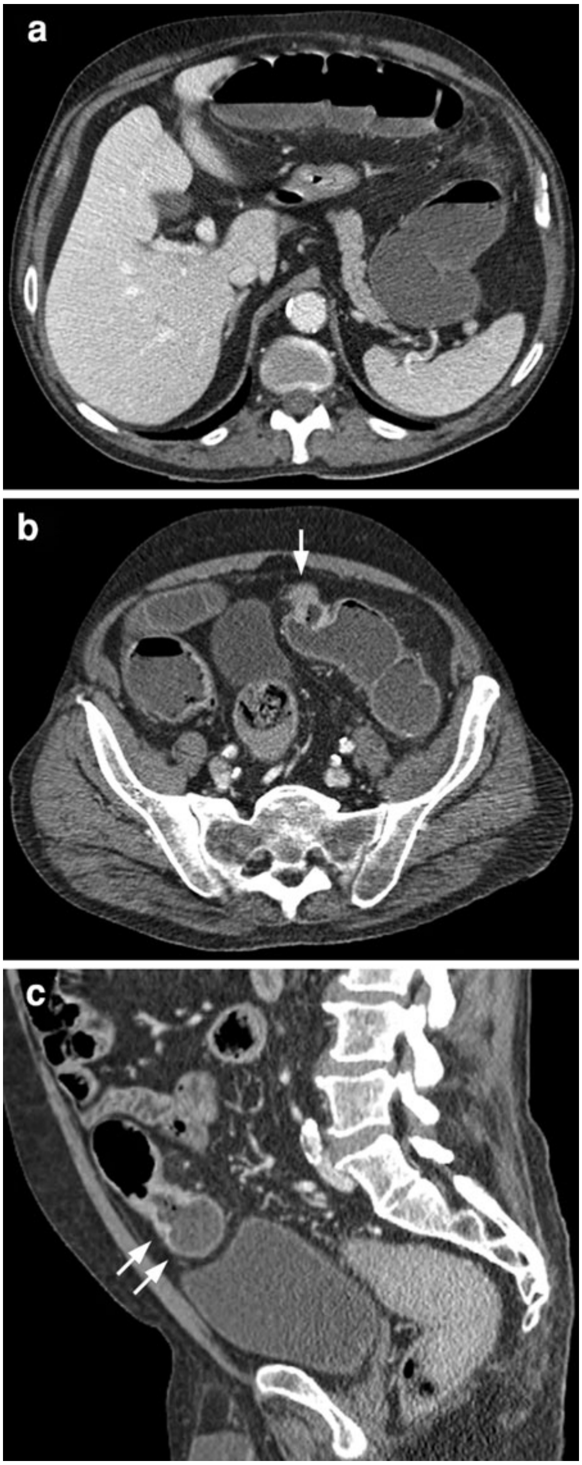


Fig. 29 LBO due to ischemic colitis. Axial slices (**a**, **b**) show a colonic dilatation due to a short stenosis with a symmetric thickening of the sigmoid wall (*arrow*). Sagittal reformatting (**c**) shows distal colon which is not entirely collapsed (*double arrows*). The CT diagnosis was LBO due to cancer with the diagnosis of ischemic colitis revealed by surgery and pathologic analysis

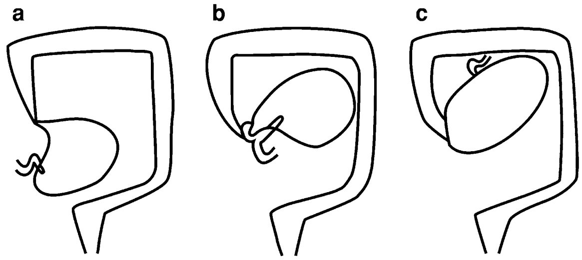


Fig. 30 Subtypes of cecal volvulus: organoaxial volvulus (**a**), loop type volvulus (**b**), and cecal bascule type (**c**)

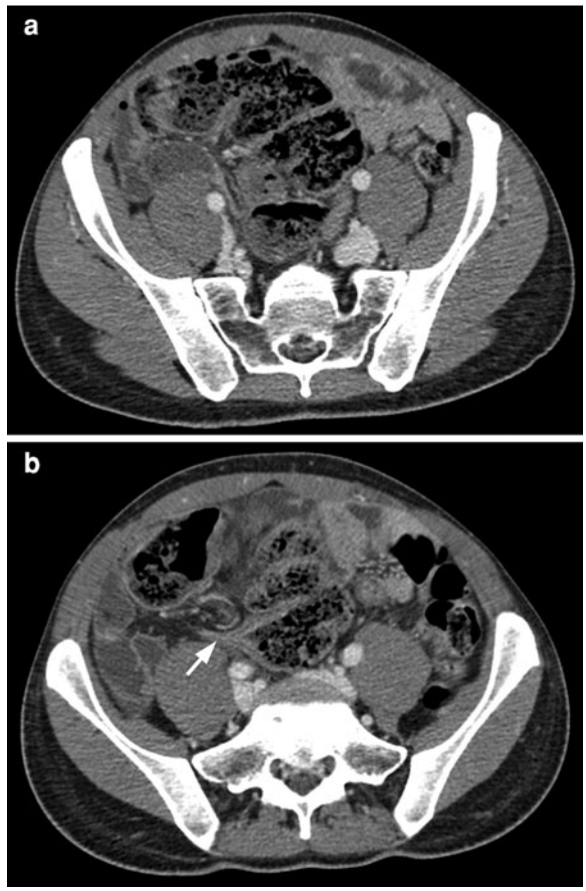


Fig. 31 Cecal volvulus of the axial torsion type. Axial slices (**a**, **b**) show a distended cecum medially located with a beak finding well seen in **b** (*arrow*). Note also the whirl sign shown in **b**. The cecum has not moved in the left upper quadrant but is medially located because of the lack of posterior mesocecum, which favors motility

with rectal distention can make the thickening disappear.

False-negative diagnoses may be encountered in partial colonic obstruction, where there is no proximal dilatation to delineate the obstructing lesion and

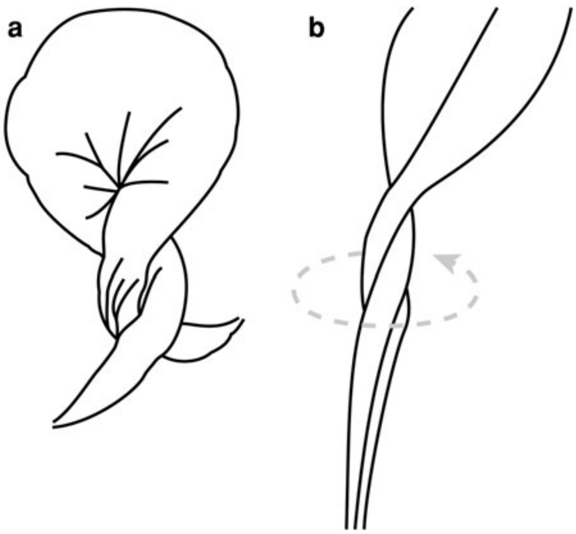


Fig. 32 Subtypes of sigmoid volvulus. Classic form of volvulus with two loops obstruction (**a**) and organoaxial volvulus (**b**)

particularly when the lesion is located at the splenic flexure; in these cases, CT images are much more difficult to interpret without proper colon cleaning and air insufflation.

Colon volvulus may be difficult to diagnose on CT. Visualization of the beak sign requires thin slices and should be in the axial plane. This underlines the potential usefulness of three-dimensional imaging.

Some causes of colonic obstruction may be difficult to characterize, such as radiation colitis and endometriosis. For this latter cause, the diagnosis must be considered in a woman of childbearing age who has a rectal or sigmoid obstructing tumor and normal endoscopy findings (Thomassin et al. 2004) (Fig. 34).

The appearance of colon cancer may mimic diverticulitis, especially if tumor involvement of the wall has resulted in infiltration of the pericolic fat. As demonstrated by Padidar et al. (1994), fluid in the root of the sigmoid mesentery and engorgement of the adjacent sigmoid mesenteric vasculature favor the diagnosis of diverticulitis. However, pericolic lymph nodes in patients with suspected diverticulitis should raise the suspicion of colon cancer (Chintapalli et al. 1999). In some cases, it may be impossible to distinguish diverticulitis from perforated carcinoma. Otherwise, differential diagnosis between ischemic colitis and colon cancer may be problematic. Classically, ischemic involvement is greater with concentrically and smoothly thickened wall. However, ischemic thickening responsible for obstruction may be short and important.

Different causes of colonic obstruction may be associated, for instance, fecal impaction in the rectum or an obstructing tumor may lead to a colonic ischemia that can worsen the obstruction. Distinguishing tumoral from ischemic segments in patients who have ischemic colitis proximal to colonic carcinoma is important to obtain a true evaluation of the length of the tumoral segment and to adapt the surgical procedure. Before identifying a foreign body as the cause of a LBO, one must carefully look for a tumor responsible for the blockage of the foreign body (Fig. 35).

4.3.4 Accuracy

In the only two studies (Frager et al. 1998; Beattie et al. 2007) focused on CT findings of LBO, a correct preoperative pathologic diagnosis was established by CT in, respectively, 89% of patients (40 of 45) and 70% of patients (14 of 20) in whom obstruction was diagnosed by CT.

4.3.5 CT Impact

One of the advantages of CT in comparison with contrast enema classically considered as the gold standard imaging method in LBO is it can better analyze the characteristic of the thickening bowel wall responsible for a stenosis and differentiate tumor from other intrinsic stenoses. Furthermore right-sided colonic obstructions are difficult to characterize and in cases of cecal volvulus of the axial torsion type because the cecum is normally located, abdominal plain film and contrast enema may fail to identify the cause of the obstruction.

Consequently, CT is becoming the reference examination in the assessment of LBO.

4.4 Diagnosis of Complications of the Obstruction

4.4.1 Clinical Considerations

Traditionally, the diagnosis of bowel obstruction has been performed by clinical examination and abdominal plain film, the key point being to differentiate mechanical obstruction from ileus. Bowel obstruction was treated emergently by surgery, whereas ileus was

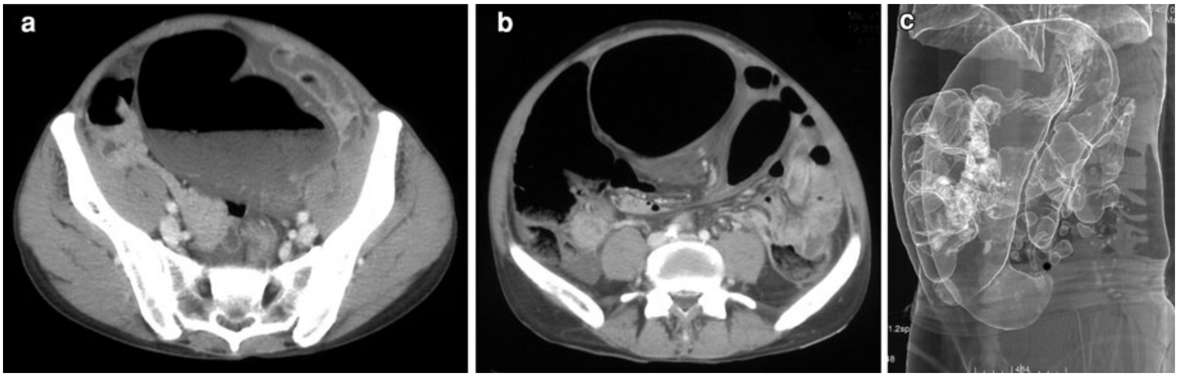


Fig. 33 Sigmoid volvulus with two loops obstruction. Axial slices (**a**, **b**) show the two distended loops with an inverted-U pattern. Three-dimensional volume rendering (**c**) shows clearly the mechanism of the volvulus with the two distended loops converging toward the same point (*star*)

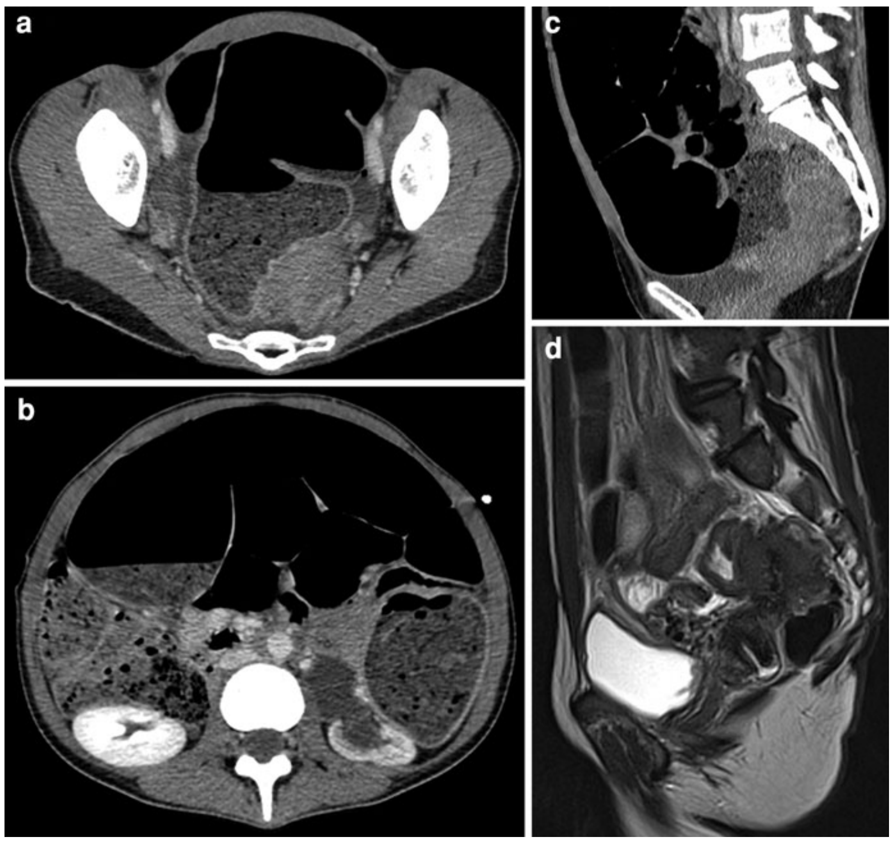


Fig. 34 LBO due to pericolic endometriosis in a woman of childbearing age. Axial slices (**a**, **b**) show an enhanced mass located at the junction between the sigmoid and the rectum responsible for an LBO. On sagittal CT reformatting (**c**) and the sagittal T2-weighted MRI slice (**d**), the relationship between the mass, in hyposignal T2, and the colon is clearly seen. A colostomy was performed in an emergency and revealed that the colon was compressed by the mass, with pathologic analysis of the mass diagnosing endometriosis

managed medically. However, in patients with bowel obstruction, management should depend on the site, cause, and viability of the bowel. The main complication of an LBO is peritonitis due to perforation. Indeed, progression of LBO, particularly in the presence of a competent ileocecal valve, may result in cecal perforation with fecal peritonitis. Some rules are generally followed for the treatment of patients with LBO:

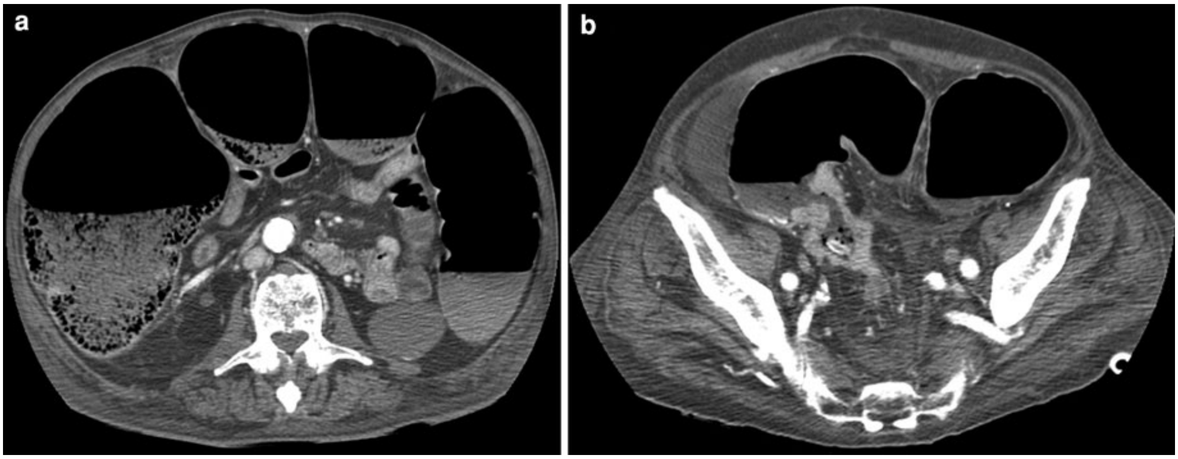


Fig. 35 LBO due to sigmoid cancer with an intraluminal foreign body. The upper axial slice (**a**) shows a distended colon and the lower slice (**b**) shows an irregular thickening of the sigmoid wall suggestive of colon cancer. Note the presence of a foreign body at the site of the obstruction

- Bowel obstruction with perforation or ischemia requires emergent surgery.
- Sigmoid volvulus is treated initially by endoscopic detorsion unless it is complicated by peritonitis, which requires surgery.
- Ideally obstruction due to colon cancer is first medically managed to prepare the colon for surgery, with resection of the tumor and anastomisis in one stage.

These rules underscore the importance of diagnosing the potential complications of LBO.

4.4.2 CT Findings

In LBO due to cancer, pneumatosis affecting the proximal colon wall suggests an infarction. In the same way, dilatation of the cecum, proximal to an obstructing colon cancer, to 12-cm diameter is a risk factor for diastatic perforation. The perforation may arise from the tumor itself or from the distended cecum above the tumor. In the former instance, free pneumoperitoneum is rare; more often, small air bubbles with fluid and mesenteric stranding are detected in the pericolic fat. In the case of perforation from the distended cecum above the tumor, pneumoperitoneum is abundant (Fig. 36).

In colonic volvulus, CT findings of ischemia are sought in the colonic wall and the mesocolon. Bowel wall abnormalities include circumferential thickening, increased attenuation, target or halo sign, and extreme lack of mural enhancement of the incarcerated bowel after intravenous administration of contrast material. Mesocolonic abnormalities include congestion, blurring, haziness, obliteration of the mesocolic vessels, and fluid or hemorrhage in the mesocolon. This may be crucial for the therapeutic choice between sigmoidoscopic decompression with insertion of a rectal tube in patients without findings of infarct or perforation and emergent sigmoid resection for other patients. However, the usefulness of CT in differentiating between sigmoid volvulus with and without infarction has not been evaluated.

4.4.3 CT Pitfalls

Although being a classic sign of ischemia, cecal pneumatosis in dilated cecum proximal to bowel cancer may be the consequence of the dilatation without any finding of ischemia (Taourel et al. 2004). Otherwise, the assessment of the wall enhancement of the sigmoid colon is very difficult because of the spontaneous contrast between colonic wall and air which fills the colonic lumen. Therefore, in clinical practice the therapeutic choice in sigmoid volvulus between endoscopic aspiration and surgery relies on clinical data.

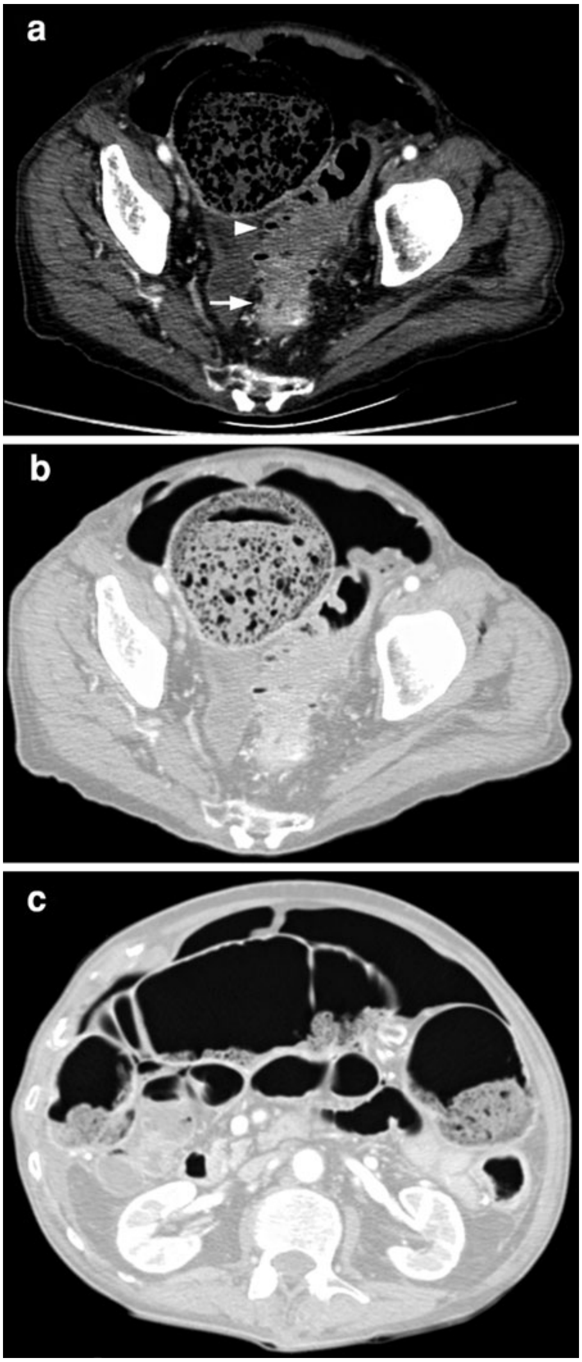


Fig. 36 Diastatic cecal perforation consecutive to LBO due to sigmoid cancer in a patient with diverticulosis. The axial slice (**a**) shows a thickening of the sigmoid wall more pronounced and more enhanced in its lower part; the lower thickened wall corresponded to cancer (*arrow*), whereas the upper wall corresponded to diverticulosis (*arrowhead*). On the slices with lung window (**b**, **c**), a pneumoperitoneum and a huge amount of stool outside the colon (**b**) are clearly seen, consequences of bowel perforation

5 Diagnostic Strategy

In patients with suspected intestinal obstruction, the primary diagnostic triage is based on clinical, laboratory, and abdominal plain film findings, which allow the schematic individualization in the following four situations:

1. There is a strong suspicion of paralytic ileus. The cause must be investigated by clinical and laboratory examinations and in some cases by ultrasonography or CT.
2. There is a strong suspicion of SBO. If there are findings of strangulation or the cause of the SBO is obvious and needs emergent surgical management, surgery must be performed without other investigations. In other patients with acute symptoms, CT helps in the search for the mechanism and cause. In patients with nonacute symptoms (suspicion of low-grade obstruction), CT with enteroclysis is a good alternative to CT.
3. There is a strong suspicion of LBO. If abdominal plain film shows signs of volvulus, which is more common in the sigmoid colon than in the cecum, treatment of the volvulus must be performed (colonoscopic or surgical detorsion in sigmoid volvulus and surgery in cecal volvulus). The benefit of CT for therapeutic choice in sigmoid volvulus remains to be evaluated. If there is no finding of volvulus, stenosis is the presumed cause of LBO. In complicated diverticulitis, CT is considered the method of choice in its diagnosis and for staging complications. Contrast enema traditionally is the recommended radiologic examination for evaluating patients with suspected obstructing colonic carcinoma. However, the findings may be incomplete because the patient cannot retain the contrast material or tolerate the rectal tube and may be inconclusive in right-sided colonic obstruction. In addition, it is associated with an increased risk of barium inspissation and may necessitate a delay before surgery to adequately clean the colon. CT examination is widely accepted as faster and simpler to perform and interpret and gentler on the patient. CT has the advantages of diagnosing the tumor, evaluating its local and metastatic spread, and searching for synchronous cancer of the colon, which is found in nearly 10% of patients

4. There are some difficulties in distinguishing between an obstruction and an ileus or some doubts about the site of an obstruction in the small or large bowel. CT should be performed to investigate the nature, site, cause, and any signs of strangulation.

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