Key CT Findings

Eric Delabrousse

Contents

E. Delabrousse (✉)
Service de Imagerie Digestive et Génito-urinaire,
CHU Besançon, Hôpital Jean Minjoz,
3, Boulevard Fleming, 25030 Besançon, France
e-mail: edelabrousse@chu-besancon.fr

P. Taourel (ed.), *CT of the Acute Abdomen,* Medical Radiology. Diagnostic Imaging,
DOI: 10.1007/174_2010_92, © Springer-Verlag Berlin Heidelberg 2011

Abstract

The CT semiology of acute abdomen is extremely rich and is based on the analysis of the organs of the abdominal cavity. Defined criteria, such as the morphological aspect of organs, spontaneous attenuation of the tissues, enhancement of parenchyma after intravenous contrast material injection, and location of the organs within the abdominal cavity, are the basis of this analysis. It is also very important to look for some key CT findings which correspond to acute modifications of the normal feature and are often specific. Thus, a meticulous analysis of the CT scans and good knowledge of these key CT findings may allow accurate CT diagnosis in acute abdomen.

1 Introduction

The CT semiology of acute abdomen is extremely rich and is based on the analysis of the organs of the abdominal cavity. Defined criteria, such as the morphological aspect of organs, spontaneous attenuation of the tissues, enhancement of parenchyma after intravenous contrast material injection, and location of the organs within the abdominal cavity, are the basis of this analysis. It is also very important to look for some key CT findings which correspond to acute modifications of the normal feature and are often specific. Thus, a meticulous analysis of the CT scans and good knowledge of these key CT findings may allow accurate CT diagnosis in acute abdomen.

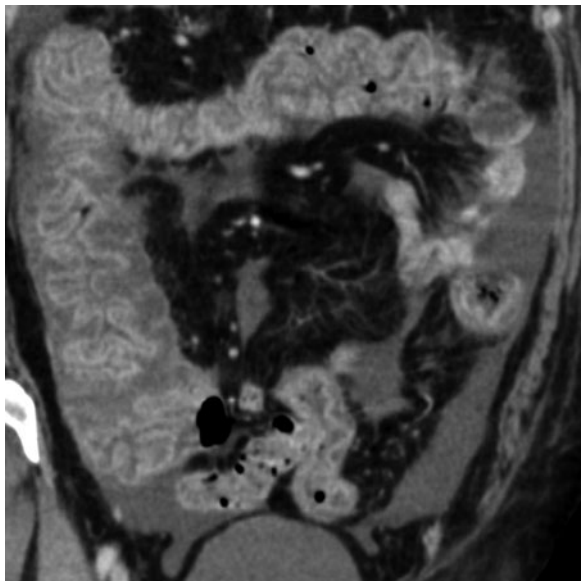

Fig. 1 The accordion sign

2 Accordion Sign

2.1 Features

The accordion sign is a finding that may be seen on CT scans in patients who have received oral contrast material. It was originally defined as alternating edematous haustral folds separated by transverse mucosal ridges filled with oral contrast material simulating the appearance of an accordion (Fishman et al. 1991; O'Sullivan 1998) (Fig. 1).

2.2 Significance

The lower soft-tissue attenuation component of the accordion sign represents marked thickening of the haustral folds due to transmural edema. Small amounts of oral contrast material may become trapped within the crevices between these thickened haustral folds. The bands of alternating lower and higher attenuation have been likened to the appearance of an accordion (Fishman et al. 1991). This appearance may be variable depending on the degree of edema of the haustral folds and the amount of contrast material trapped between the folds (O'Sullivan 1998).

2.3 Causes

2.3.1 Pseudomembranous Colitis

The accordion sign was described first as a finding indicative of pseudomembranous colitis (Fishman et al. 1991). In this case, the high-attenuating oral contrast material is trapped between thickened edematous folds and pseudomembranes in the colonic mucosa. The degree of colonic wall thickening caused by the pseudomembranes and edematous tissues that develop in this condition has been suggested as the reason for the sign's specificity (Ros et al. 1996).

2.3.2 Other Colitides

For some authors, the accordion sign is indicative of severe colonic edema or inflammation, but has no cause-related specificity. It may be related to infectious, inflammatory, or ischemic conditions, and it may even be present in patients with edema secondary to cirrhosis (Macari et al. 1999). Although they were not specifically identified as the accordion sign, massive colonic wall thickening and a similar colonic mucosal pattern have been documented in many CT reports of colitis from other causes (Balthazar et al. 1985; Macari et al. 1999). When the accordion sign is identified in CT studies, it should be viewed as a sign indicative of severe colonic edema of uncertain cause. Correlation with the clinical and laboratory results should be performed to determine the exact cause.

3 Beak Sign

3.1 Features

The beak sign may be seen as a fusiform tapering of the bowel at the site of the obstruction (Fig. 2).

3.2 Significance

At the transition zone of a mechanical small bowel obstruction, a beak sign corresponds to extrinsic compression of the bowel loop.

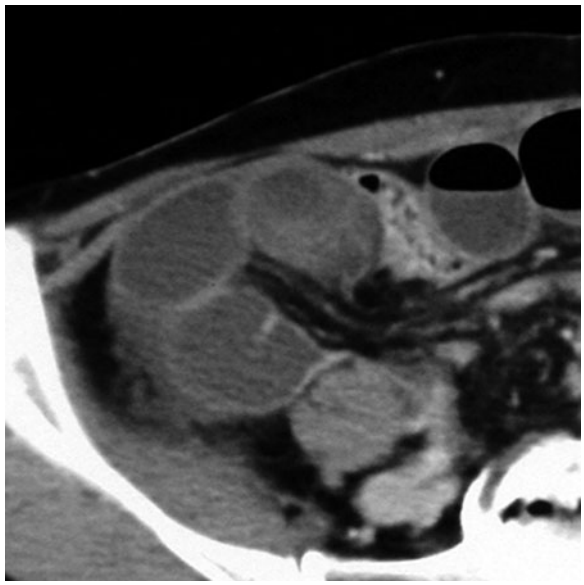

Fig. 2 The beak sign

Fig. 3 The bowel halo sign

3.3 Diagnosis

3.3.1 Adhesive Small Bowel Obstruction

Adhesions themselves cannot be identified by CT. Recognition of a beak sign at the transition zone of small bowel obstruction is highly suggestive of adhesions as the cause for the occlusion (Ha et al. 1993).

3.3.2 Small Bowel Volvulus

In small bowel obstruction, a double beak sign associated with a whirl sign is a CT finding of small bowel volvulus (Balthazar et al. 1992).

3.3.3 Cecal Volvulus

A beak sign and a whirl sign are demonstrated on CT scans in cecal volvulus (Delabrousse et al. 2007).

3.3.4 Sigmoid Volvulus

A beak sign and a double beak sign may be seen in organoaxial sigmoid volvulus and mesentericoaxial sigmoid volvulus, respectively (Bernard et al. 2010).

3.3.5 Closed Loop Obstruction Due to Hernia

The double beak sign is also present in closed loop obstruction secondary to external and internal hernia (Yen et al. 2005).

4 Bowel Halo Sign

4.1 Features

The bowel halo sign is defined by stratification within a thickened bowel wall that consists of either two rings (double halo)—an inner gray attenuation ring surrounded by an outer higher-attenuation ring—or three rings (target sign)—an inner and an outer ring of high attenuation, and a middle ring of lower attenuation (gray attenuation) (Wittenberg et al. 2002). The bowel halo sign is best visualized during the portal venous phase of intravenous contrast material enhancement (Macari and Balthazar 2001) (Fig. 3).

4.2 Significance

A double halo is composed of a higher-attenuation outer annular ring, corresponding to the muscularis propria, surrounding a second ring of gray attenuation (0–10 HU), which is believed to be edema. In the target sign, the inner and outer rings of high attenuation are regarded as the bowel mucosa and the muscularis propria, respectively, whereas the middle ring of gray attenuation represents edema and can be assumed to be located in the submucosa (Macari and

Balthazar 2001). The higher attenuation of the inner and outer rings is assumed to be the consequence of preferential enhancement corresponding to hyperemia.

4.3 Causes

4.3.1 Crohn Disease

The double halo sign was first reported by Frager et al. (1983) in patients with Crohn disease.

4.3.2 Bowel Ischemia

The bowel halo sign (double halo or target sign) may also be present in bowel ischemia (Taourel et al. 1996).

4.3.3 Ulcerative Colitis

The bowel halo sign was initially described with ulcerative colitis (Gore et al. 1996).

4.3.4 Infectious Enterocolitis

The target sign is also a well-known CT feature in infectious enterocolitis, particularly in pseudomembranous colitis (Kawamoto et al. 1999).

4.3.5 Lupus Erythematosus

CT of the abdomen in patients with lupus erythematosus who have abdominal vasculitis shows ascites and thickening of the bowel walls, with a double halo or a target sign (Ko et al. 1997; Horton et al. 2000).

4.3.6 Intestinal Hematoma

Initially, CT should be performed without contrast material, as this may mask the presence of intramural hemorrhage. The findings consist of a thickening of the wall greater than 1 cm, with partial reduction to total obstruction of the passage, and hyperdensity, ranging from 50 to 80 HU depending on the time elapsed between the onset of the event and the examination. The target sign is better demonstrated on contrast-enhanced CT scans (Sorbello et al. 2007).

4.3.7 Portal Hypertension

The bowel halo sign has also been reported as a CT feature of cirrhosis and portal hypertension (Ormsby et al. 2007).

Fig. 4 The coffee bean sign

5 Coffee Bean Sign

5.1 Features

The coffee bean sign is a finding that may be diagnosed on CT scout views. It was originally defined on supine abdominal radiographs as an area of hyperlucency that resembles the shape of a coffee bean (Messmer 1994) (Fig. 4).

5.2 Significance

As the closed loop of the sigmoid colon distends with gas, apposition of the medial walls of the dilated bowel forms the cleft of the coffee bean, whereas the lateral walls of the dilated bowel form the outer walls of the bean (Feldman 2000). Since the volvulus is located at the sigmoid colon, the coffee bean arises from the pelvis and may occupy the entire abdomen. Its apex often extends above the T10 vertebral level and can lie to the left or right of the midline (Young et al. 1978; Burrel et al. 1994). Other terms for this sign include the kidney bean sign and the bent inner tube sign (Kerry et al. 1971; Ballantyne 1982).

Fig. 5 The collar sign

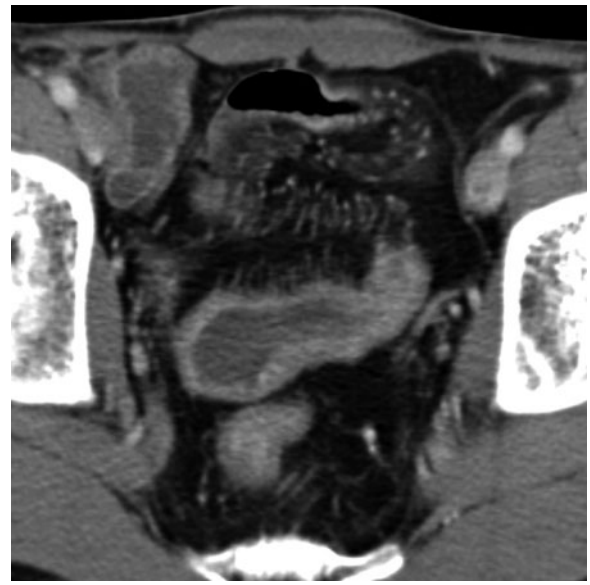

Fig. 6 The comb sign

5.3 Cause

5.3.1 Sigmoid Volvulus

Initially described as an indication of a closed loop in small bowel obstruction (Riger 1944; Mellins and Riger 1954), the coffee bean sign commonly applies to the appearance of a closed loop obstruction of the sigmoid colon (Feldman 2000). Up to 80% of the time, sigmoid volvulus can be diagnosed by viewing the CT scout view alone (id. to the supine abdominal radiograph) (Jones and Fazio 1989). The absence of rectal gas may also contribute to the diagnosis (Messmer 1994).

6 Collar Sign

6.1 Features

The collar sign is defined as a waistlike low-attenuation rim of the diaphragm around the herniated organ (Iochum et al. 2002). On the right side, it can appear as a focal indentation of the liver, a subtle sign easily overlooked on axial images. The collar sign is better seen on sagittal and coronal multiplanar reformatted images (Larici et al. 2002) (Fig. 5).

6.2 Significance

The collar sign corresponds to constriction of the herniated hollow viscus at the site of the diaphragmatic tear.

6.3 Cause

6.3.1 Diaphragmatic Rupture

The collar sign is a valuable CT sign for the diagnosis of blunt diaphragmatic rupture. The collar sign has been reported to have 63% sensitivity and 100% specificity as a sign of diaphragmatic rupture with helical CT (Killen et al. 1999). Other studies have reported a lower incidence of 27–36% for this feature (Demos et al. 1989; Murray et al. 1996).

7 Comb Sign

7.1 Features

The comb sign is defined on contrast-enhanced CT scans as multiple tubular, tortuous opacities on the mesenteric side of the ileum that are aligned as the teeth of a comb (Madureira 2004) (Fig. 6).

7.2 Significance

The arteries that supply the small bowel branch off within the mesentery as a series of intestinal arteries interconnected by arcades. The terminal branches (or vasa recta) are tall and widely spaced in the jejunum and are short and more closely arranged in the ileum (Stallard et al. 1994). When CT depicts hypervascularity of the mesentery with vascular dilatation, tortuosity, and wide spacing of the vasa recta, the comb sign is produced. This is attributed to the increased flow and fibrofatty proliferation in the mesentery of the affected bowel (Meyers and McGuire 1995).

7.3 Causes

7.3.1 Crohn Disease

Hypervascularity of the mesentery with vascular dilatation, tortuosity, and prominence of the vasa recta, which together produce the comb sign, should suggest Crohn disease first (Madureira 2004). It has been reported that the presence of prominent perienteric vasculature seen on CT in patients with Crohn disease suggests that the disease is clinically active, advanced, and extensive (Lee et al. 2002). Moreover, in patients presenting with clinical symptoms for the first time, the comb sign should raise the possibility of the diagnosis of Crohn disease.

7.3.2 Other Small Bowel Diseases

The comb sign is not absolutely pathognomonic for Crohn disease as it has also been reported in cases of lupus mesenteric vasculitis (Ko et al. 1997; Byun et al. 1999), polyarteritis nodosa, Henoch–Schönlein syndrome, microscopic polyangiitis, Behçet syndrome, mesenteric thromboembolism, and strangulated small bowel obstruction (Rha et al. 2000; Jeong et al. 1997; Ha et al. 1998; Kim et al. 2001; Balthazar et al. 1992). The clinical history, distribution of the disease, and associated findings are useful in the differential diagnosis of these diseases.

8 Contrast Material Extravasation

8.1 Features

Contrast material extravasation is defined by the presence of an area of focal or diffuse high-attenuation

Fig. 7 Contrast material extravasation

isodense structures compared with major adjacent arterial structures that is surrounded by high-attenuation fluid representing hematoma. It may be seen in an organ (Fig. 7) or in the intraperitoneal and retroperitoneal spaces.

8.2 Significance

Contrast material extravasation corresponds to active arterial bleeding (more than 1 mL/min).

8.3 Causes

8.3.1 Blunt Trauma

Contrast-enhanced helical CT has been reported to be the gold standard imaging modality to visualize arterial extravasation after blunt abdominal trauma (Yao et al. 2002).

8.3.2 Gastrointestinal Bleeding

Contrast material extravasation is an accurate CT finding for detection and localization of bleeding sites in patients with acute massive gastrointestinal bleeding (Yoon et al. 2006) (Fig. 7).

8.3.3 Spontaneous Spleen Rupture

Extravasation of contrast material from the spleen has also been reported in the case of spontaneous splenic rupture (Aoyagi et al. 2009).

8.3.4 Intra-abdominal Hemorrhagic Tumors

In intra-abdominal tumors, the presence of contrast material extravasation on CT scans allows the accurate diagnosis and has a direct impact on clinical decision making (Furlan et al. 2009).

9 Dependent Viscera Sign

9.1 Features

The dependent viscera sign is diagnosed on CT scans in the thoracoabdominal area. The viscera (i.e., bowel or solid organ) are positioned against the posterior ribs, with obliteration of the posterior costophrenic recess (Cantwell 2006) (Fig. 8).

Fig. 8 The dependent viscera sign

9.2 Significance

When blunt diaphragmatic rupture occurs, the absence of posterior support by the diaphragm allows viscera to fall against the posterior ribs to a dependent position. On the right side, the upper third of the liver typically does not abut the posterior chest wall when the diaphragm is intact. On the left side, the stomach and bowel lie anterior to the spleen and generally do not abut the posterior left ribs when the diaphragm is intact. Therefore, the dependent viscera sign is said to be present on the right side if the upper third of the liver abuts the posterior ribs and to be present on the left side if the stomach or bowel abuts the posterior ribs or lies posterior to the spleen (Bergin et al. 2001).

9.3 Cause

9.3.1 Diaphragmatic Rupture

The dependent viscera sign is a valuable CT sign that dramatically increases the CT diagnosis of blunt diaphragmatic rupture. In a study published in 2001, Bergin et al. (2001) reported this CT sign to be present in 90% of patients with blunt diaphragmatic rupture. In their series, the dependent viscera sign was up to 100% sensitive as a sign of diaphragmatic rupture and 83% sensitive for right-sided injury (Bergin et al. 2001). The dependent viscera sign is not, however, a reliable indicator of diaphragmatic injury in penetrating trauma, owing to the small size and variable position of the defect (Larici et al. 2002).

10 Disproportionate Fat Stranding Sign

10.1 Features

The disproportionate fat stranding sign is defined on CT scans by stranding that is more severe than expected for the degree of bowel wall thickening present (Pereira et al. 2004) (Fig. 9).

10.2 Significance

Most acute inflammatory diseases of the gastrointestinal tract, including infectious, inflammatory, traumatic, and ischemic disorders, are centered in the bowel wall. For these diseases, the degree of bowel wall thickening typically exceeds the degree of

associated fat stranding. However, in a few acute diseases of the gastrointestinal tract, the pathologic process is characteristically centered in the mesentery adjacent to the bowel wall rather than in the bowel wall itself. In these diseases, a positive disproportionate fat stranding sign is diagnosed (Pereira et al. 2004).

10.3 Causes

10.3.1 Acute Diverticulitis

Diverticulitis occurs when the neck of a diverticulum becomes occluded, resulting in inflammation, erosion, and microperforation. Microperforation results in pericolonic inflammation that is typically more severe than the inflammation of the colon itself. On CT, the most common finding in acute diverticitis is paracolic fat stranding. This fat stranding is characteristically disproportionate to the relatively mild, focal colonic wall thickening.

10.3.2 Acute Appendicitis

Direct visualization of a dilated fluid-filled appendix is the most specific CT finding of appendicitis (Rao et al. 1997; Benjaminov et al. 2002). However, other indirect CT signs are often useful. In acute appendicitis, periappendicular fat stranding remains typically mild to moderate, but it may be severe. The finding of severe fat stranding in the right lower quadrant, even in the absence of substantial appendicular, cecal, or ileal thickening, has been reported to be useful in the diagnosis of appendicitis (Checkoff et al. 2002).

10.3.3 Epiploic Appendagitis

Epiploic appendages are normally invisible on CT scans. CT findings of epiploic appendagitis are usually diagnostic (Torres et al. 1994; Rao et al. 1997). A paracolonic oval fatty mass representing the inflamed or infarcted appendage, surrounded by a well-circumscribed hyperattenuated rim and a very important paracolonic fat stranding, is a pathognomonic feature. These paracolonic inflammatory changes are typically disproportionately more severe than the mild local reactive thickening of the adjacent colonic wall.

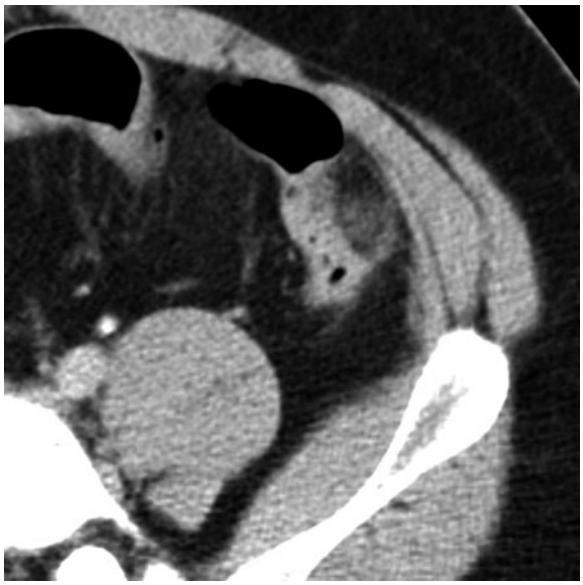

Fig. 9 Disproportionate fat stranding

10.3.4 Segmental Omental Infarction

On CT scans, segmental omental infarction, which is secondary to thrombosis of omental veins, appears as a large high-attenuation fatty mass centered in the omentum (Puylaert 1992; Van Bresla Vriesman et al. 1999). Reactive bowel wall thickening may occur, but the inflammatory process in the omentum is disproportionately more severe.

11 Draped Aorta Sign

11.1 Features

The draped aorta sign is a CT finding that corresponds to close application to the spine and lateral draping of the aneurysm around the vertebral body (Halliday and Al-Kutoubi 1996) (Fig. 10).

11.2 Significance

It is believed that the path of least resistance for extravasated blood from a leaking abdominal aneurysm is into the psoas muscle and, after a subsequent breach of the psoas fascia, into the posterior pararenal space (Hopper et al. 1985). Most cases of leak,

Fig. 10 The draped aorta sign

therefore, show some posterior periaortic hemorrhage (Gale et al. 1986) and, in cases of massive hemorrhage, the posterior pararenal, and perirenal compartments are the most frequently involved sites (Morehouse et al. 1992; White et al. 1992; Siegel and Cohan 1994). The draped aorta sign on CT scans represents an early stage in this sequence where hemorrhage is contained anteriorly by the confluence of the anterior renal fascia and the root of the dorsal mesentery and is starting to pass posteriorly toward the psoas muscle (Halliday and Al-Kutoubi 1996).

11.3 Cause

11.3.1 Contained Leak of Aortic Aneurysm

Although a large leak may be easily identified by CT, a smaller, contained leak may be difficult to diagnose with confidence (Gale et al. 1986). It is important that such cases are identified since clinical features may be misleading, and although the condition of a patient with a contained leak may remain stable for months or even years (Rosenthal et al. 1986; Nakagawa et al. 1990), massive hemorrhage may occur at any time. On CT images, the draped aorta sign is highly indicative of deficiency of the aortic wall and a contained leak (Halliday and Al-Kutoubi 1996).

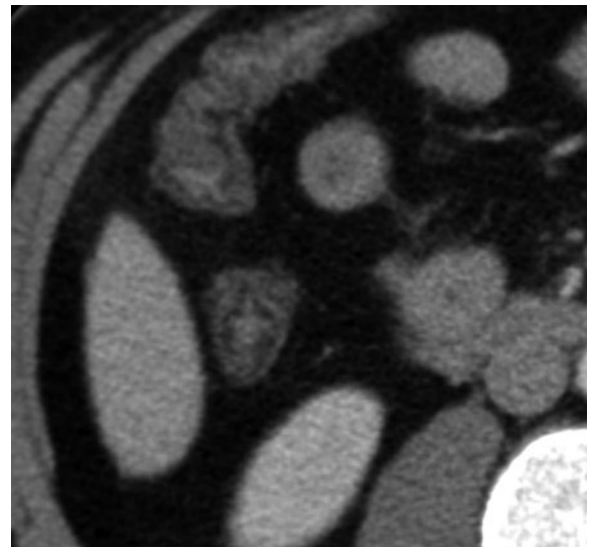

Fig. 11 The fat halo sign

12 Fat Halo Sign

12.1 Features

The fat halo sign is a CT finding that is defined by the presence of a thickened bowel wall demonstrating three layers: an inner and an outer layer of soft-tissue attenuation, between which lies a third layer of fatty attenuation (−10 to −50 HU) (Wittenberg et al. 2002; Ahualli 2007) (Fig. 11).

12.2 Significance

The inner layer of soft-tissue attenuation represents the bowel mucosa, whereas the layer of negative attenuation results from widening and fatty infiltration of the submucosa. The outer soft-tissue attenuation layer represents the muscularis propria and serosa (Philpotts et al. 1994; Gore et al. 1996). The fat halo sign may be depicted on CT scans obtained without intravenous contrast material because of the marked differences in tissue attenuation. However, the different layers of attenuation can also be appreciated during the portal venous phase of contrast enhancement (Macari and Balthazar 2001).

12.3 Causes

12.3.1 Ulcerative Colitis

The fat halo sign has been described as typically appearing in patients with inflammatory bowel disease (Jones et al. 1986; Gore et al. 1996). In ulcerative colitis, this sign occurs only in the large bowel. The fat halo sign is present in 60% of patients with ulcerative colitis (Philpotts et al. 1994).

12.3.2 Crohn Disease

When the fat halo sign is seen in both the small and the large bowel, it is considered evidence of Crohn disease. However, the fat halo sign is seen in less than 10% of patients with Crohn disease (Philpotts et al. 1994).

12.3.3 Graft-Versus-Host Disease

Graft-versus-host disease has been reported as an acute condition that may cause the fat halo sign (Muldowney et al. 1995).

12.3.4 Chronic Radiation Enteritis

The presence of fat within the submucosal layer of the small bowel is a finding which may be demonstrated in patients who have had radiation therapy (Chen et al. 2003).

12.3.5 Chronic Enteritis After Cytoreductive Therapy

The fat halo sign has also been reported as a consequence of cytoreductive therapy (Muldowney et al. 1995).

12.3.6 Normal Variant

Intramural fat may exist in both the distal ileum and the colon as a normal variant in patients without symptoms of gastrointestinal disease or a history of gastrointestinal disease. The normal intramural fat layer is generally thinner than the fat layer seen with inflammatory intestinal disease. Harisingjhani et al. (2003) noted such a normal appearance in 21% of 100 patients with no history of inflammatory bowel disease.

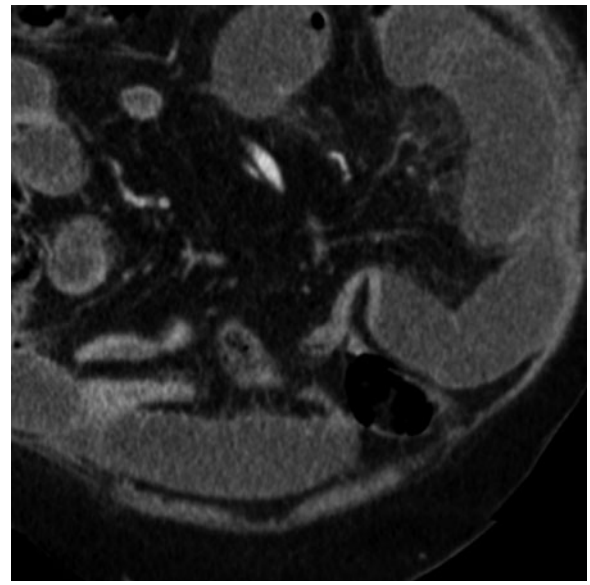

Fig. 12 The fat notch sign

13 Fat Notch Sign

13.1 Features

The fat notch sign is a newly described CT sign which is defined by the presence of a lateral fat notch on the bowel wall at the transition zone in small bowel obstruction (Delabrousse et al. 2009) (Fig. 12).

13.2 Significance

In adhesive small bowel obstruction, the fat notch sign corresponds to lateral extrinsic compression of the bowel made by a band at the transition zone (Delabrousse et al. 2009).

13.3 Diagnosis

13.3.1 Small Bowel Obstruction Due to Adhesive Bands

Although adhesive bands themselves cannot be identified by CT, recognition of CT findings suggestive of an extraluminal band compressing the bowel at the transition zone, which is the natural place to look for clues to the cause of small bowel obstruction

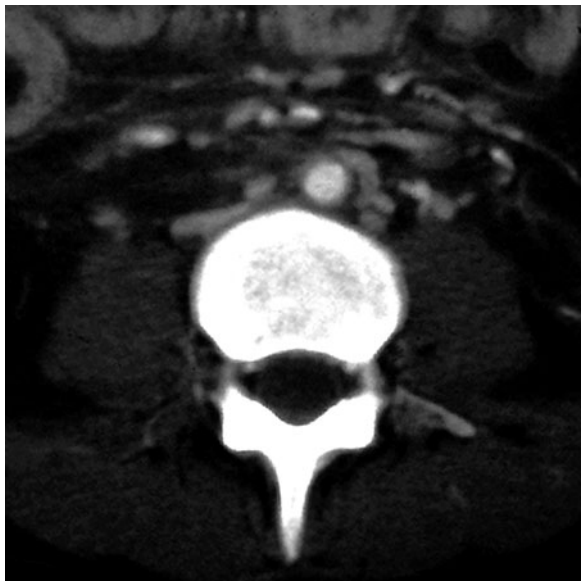

Fig. 13 The flat vena cava sign

(Ha et al. 1993), could enhance the radiologist's ability to diagnose small bowel obstruction from adhesive bands (Petrovic et al. 2006). In simple small bowel obstruction, a dedicated search for a fat notch sign allows good sensitivity (61%) and excellent specificity (100%) for the diagnosis of adhesive bands (Delabrousse et al. 2009).

14 Flat Vena Cava Sign

14.1 Features

The flat vena cava sign on CT was first defined as flattening of the inferior vena cava on at least three contiguous 1-cm images (Jeffrey and Federle 1988). Eisenstat et al. (2002) defined a flattened inferior vena cava by a maximal transverse-to-maximal anterioposterior diameter of 3:1 or more, whereas Mirvis et al. (1994) defined a flattened vena cava as less than 9 mm in the maximal anterioposterior dimension at the level of the renal veins (Fig. 13).

14.2 Significance

In blunt trauma, the collapse of the inferior vena cava in patients with hypovolemia is most likely due to decreased venous return. In some cases, the demonstration of the collapsed inferior vena cava may precede the clinical detection of shock (Jeffrey and Federle 1988). A flat vena cava sign in association with decreased caliber of the aorta, marked diffuse fluid-filled bowel distention, moderate to large fluid peritoneal collections, and abnormally intense enhancement of the bowel wall, kidneys, and pancreas has also been reported to define the hypoperfusion complex in children (Taylor et al. 1987). In clinical practice, the presence of a collapsed inferior vena cava in blunt trauma may be considered evidence of significant hypovolemia from major blood loss and should prompt careful hemodynamic and central venous pressure monitoring.

In contrast to patients with blunt trauma, a flattened vena cava may be seen in normovolemic and normotensive adult patients. Several explanations may be proposed: a normal variation, especially in elderly women, or a change in the vessel tone or connective tissues within the caval wall that occurs with aging; a redistribution of blood volume that does not manifest itself as clinical hypovolemia; and variation in caval shape and volume with ventilation, intra-abdominal pressure, and position of the patient (Eisenstat et al. 2002).

14.3 Causes

14.3.1 Hypovolemia from Blood Loss

The presence of a flat vena cava sign is an important CT sign of hypovolemia from major blood loss (Jeffrey and Federle 1988).

14.3.2 Inferior Vena Cava Variation

The presence of a flat vena cava sign is commonly seen in women and in older patients (Eisenstat et al. 2002).

15 Hemoperitoneum

15.1 Features

Hemoperitoneum is defined by the presence of a high-attenuating fluid (35–60 HU) within the peritoneal cavity. However, its attenuation may vary, and its appearance often depends on the age, extent, and location of the hemorrhage (Lubner et al. 2007) (Fig. 14).

15.2 Significance

The presence of hemoperitoneum corresponds to intraperitoneal bleeding.

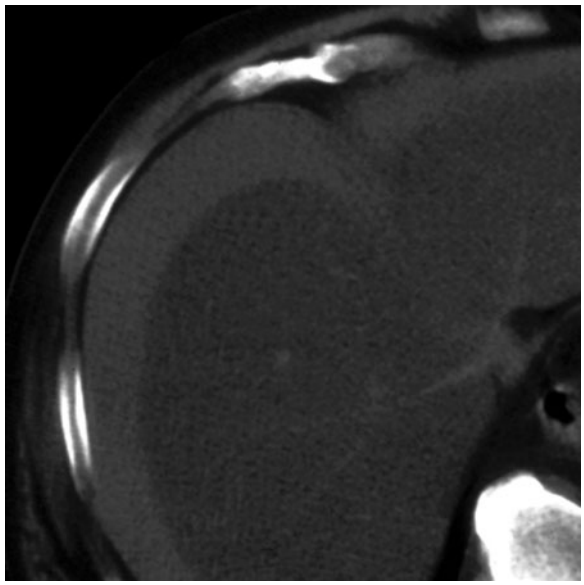

Fig. 14 Hemoperitoneum

Fig. 15 Hemoretroperitoneum

15.3 Causes

15.3.1 Blunt Abdominal Trauma

Liver (Shanmuganathan and Mirvis 1998), spleen (Becker et al. 1994), bowel, and mesentery (Breen et al. 1997) are the more affected sites in blunt abdominal trauma.

15.3.2 Ectopic Pregnancy

Ruptured tubal pregnancy should be the first diagnosis to be searched for in a young female patient with pelvic pain and massive hemoperitoneum on CT scans (Coulier et al. 2008).

15.3.3 Intraabdominal Hemorrhagic Tumors

Ruptured hepatocellular carcinoma (Choi 2001) and adenoma are tumors responsible for intra-abdominal bleeding.

15.3.4 Spontaneous Spleen Rupture

Spontaneous splenic rupture is rare and in most cases occurs in a spleen affected by hematologic, neoplastic, or infectious disease or as a complication of pancreatic pseudocyst (Torricelli et al. 2001).

15.3.5 Ruptured Splenic Artery Aneurysm

This acute condition is often secondary to pancreatitis (Brunet and Greenberg 1991).

16 Hemoretroperitoneum

16.1 Features

Hemoretroperitoneum is defined by the presence of a high-attenuating fluid (35–60 HU) within the retroperitoneal space (Fig. 15).

16.2 Significance

The presence of hemoretroperitoneum corresponds to retroperitoneal bleeding.

16.3 Causes

16.3.1 Rupture of an Abdominal Aortic Aneurysm

Abdominal aortic aneurysm rupture is the most common cause of retroperitoneal hemorrhage (Schwartz et al. 2007).

16.3.2 Blunt Retroperitoneal Trauma

In blunt retroperitoneal trauma, injuries to the pancreas (Venkatesh and Wan 2008), kidneys (Harris et al. 2001), and vertebrae may lead to important retroperitoneal hemorrhage or hematoma.

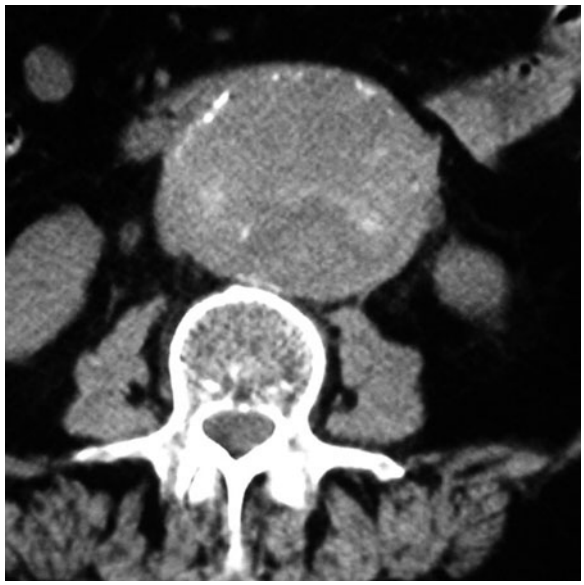

Fig. 16 The high-attenuating crescent sign

16.3.3 Spontaneous Retroperitoneal Hemorrhage

The main condition corresponding to spontaneous retroperitoneal hemorrhage is iliopsoas muscle hematoma in patients undergoing anticoagulant therapy (Lenchick et al. 1994).

16.3.4 Necrotizing Pancreatitis

Retroperitoneal hemorrhage is a rare but life-threatening complication of severe acute pancreatitis (Stroud et al. 1981).

17 High-Attenuating Crescent Sign

17.1 Features

On unenhanced CT scans, the criterion for a positive high-attenuating crescent sign is the presence of a crescent-shaped peripheral area with higher attenuation than that of the true abdominal aortic lumen but with lower attenuation than that of mural calcification. On contrast-enhanced CT scans, the criterion is the presence of a crescent-shaped area with higher attenuation than that of adjacent psoas muscle (Mehard et al. 1994; Arita et al. 1997; Fig. 16).

17.2 Significance

The peripheral high-attenuating crescent sign is due to acute hematoma within the abdominal aneurysm wall or within adjacent mural thrombus (Mehard et al. 1994; Arita et al. 1997).

17.3 Cause

17.3.1 Impending Abdominal Aortic Rupture Aneurysm

In patients without CT evidence of frank aneurysm leak, the high-attenuating crescent sign has a statistically significant correlation with the presence of pain, large aneurysm size, and complicated aneurysms (Mehard et al. 1994). Thus, the high-attenuating crescent sign should be regarded as a sign of impending abdominal aortic rupture, particularly in patients with pain.

18 Misty Mesentery

18.1 Features

The misty mesentery is defined by the CT appearance of mesenteric fat infiltrated with soft-tissue density (Mindelzun et al. 1996) (Fig. 17).

18.2 Significance

Normal mesenteric fat is similar in density (−100 to −160 HU) to the fat in subcutaneous and retroperitoneal spaces. The misty mesentery is defined by a mean density of the mesenteric fat that increases to −40 to −60 HU secondary to infiltration of the mesentery by fluid or cells. Depending on the nature and extent of the infiltration, mesenteric vessels may be either completely or partially effaced. A clue to mesenteric disease is often revealed along the visceral peritoneum as the edge of the mesentery becomes accentuated against the surrounding fat (Mindelzun et al. 1996).

18.3 Causes

18.3.1 Mesenteric Edema

Mesenteric edema may be secondary to many causes (Seo et al. 2003), including hypoalbuminemia,

Fig. 17 The misty mesentery

cirrhosis, nephrosis, heart failure, tricuspid disease, constrictive pericarditis, portal hypertension, portal vein thrombosis, mesenteric artery and vein thrombosis, vasculitis, Budd–Chiari syndrome, inferior vena cava obstruction, and trauma (Silverman et al. 1987; Nghiem et al. 1993).

18.3.2 Lymphedema

Lymphedema of the mesentery may result from causes such as congenital anomalies, inflammation, neoplasm, surgery, and radiation therapy. In all of these, fluid permeates from the lymphatic channels into the interstitium of the mesentery (Browse et al. 1992).

18.3.3 Inflammation

Acute pancreatitis is the typical inflammatory process associated with infiltration of the small bowel mesentery. Other focal inflammatory diseases such as acute appendicitis and diverticulitis may also cause infiltration of the adjacent mesenteries.

18.3.4 Hemorrhage

Blood dissecting into the mesentery may originate from mesenteric vessels. Acute hemorrhage is characterized by its classically high (40–60 HU) CT numbers (Nghiem et al. 1993).

18.3.5 Neoplasms

Non-Hodgkin lymphoma is the most common cause of an isolated misty mesentery (Karaosmanoglu et al. 2009).

18.3.6 Idiopathic Causes

Mesenteric panniculitis (liposclerotic or retractile) is a frequent cause of misty mesentery (Horton et al. 2003). Diagnosis should be suggested on CT scans by radiating bands of soft-tissue density that surround the central vessels without displacing them. Typically, a halo of normal fat surrounds the vessels in the mesentery. Non-Hodgkin lymphoma remains the most difficult differential diagnosis.

19 Mosaic Pattern

19.1 Features

The mosaic pattern corresponds to an inhomogeneous, mottled reticulated-mosaic pattern of parenchymal contrast enhancement of the liver (Gore et al. 1994) (Fig. 18).

19.2 Significance

The mosaic pattern is an accurate CT sign for passive hepatic congestion. It is presumably due to impaired venous outflow leading to altered hepatic hemodynamics and hepatic parenchymal distortion (Gore et al. 1994). Linear and curvilinear regions of poor enhancement may be due to delayed enhancement in the regions of small and medium-sized hepatic veins. Larger patchy regions of poor or delayed enhancement in the periphery of the liver are probably due to a tendency of blood flow to be more stagnant in these regions in patients with hepatic venous hypertension. This stagnant blood most highly affects inflow from the hepatic arterial and portal venous circulations (Holley et al. 1989).

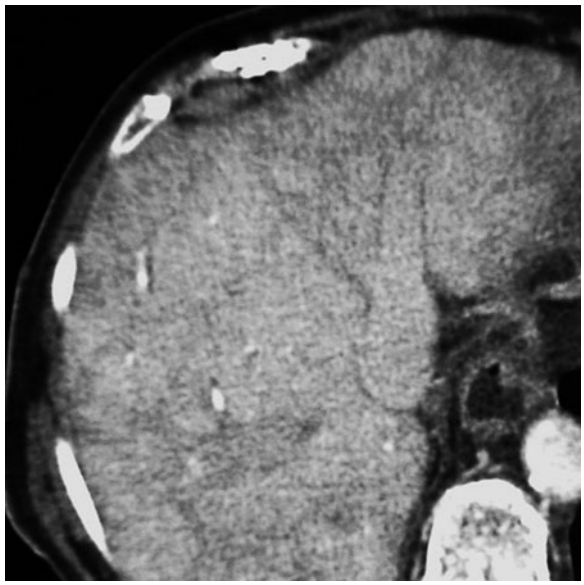

Fig. 18 The mosaic pattern

19.3 Causes

19.3.1 Congestive Heart Failure

In congestive heart failure, the mosaic pattern is due to the elevated central venous pressures which are directly transmitted from the right atrium to the inferior vena cava and the hepatic veins (De Las Heras and Pages 2001). The liver becomes tensely swollen as the hepatic sinusoids dilate and engorge to accommodate the backflow of blood.

19.3.2 Constrictive Pericarditis

Owing to rapid elevation of central venous pressure, constrictive pericarditis leads to a dilated inferior vena cava, dilated hepatic veins, ascites, mesenteric soft-tissue stranding, and mottled-mosaic enhancement of hepatic parenchyma (Johnson et al. 2008).

20 Northern Exposure Sign

20.1 Features

The northern exposure sign is a finding that may be demonstrated on CT scout views and on CT scans (Levsky et al. 2010). It was originally defined on supine abdominal radiographs as a dilated sigmoid colon that ascends cephalad to the transverse colon (Javors et al. 1999) (Fig. 19).

Fig. 19 The northern exposure sign

20.2 Significance

Intraluminal gas always seeks the least dependent colonic location. When the patient is supine, intraluminal gas tends to accumulate in the transverse colon, the most ventral segment of the large bowel. The transverse colon crosses the midline, with its suspending mesentery separating the greater peritoneal cavity into supramesocolic and inframesocolic hemispheres (Meyers 1994). Thus, the transverse colon may be considered the equator of the abdomen. In this schema, the sigmoid colon is normally confined to the southern hemisphere, caudad to the transverse colon. When the apex of the sigmoid colon migrates cephalad (or north) to the transverse colon, as in cases of sigmoid volvulus, this sign is termed the northern exposure sign (Javors et al. 1999).

20.3 Cause

20.3.1 Sigmoid Volvulus

The northern exposure sign is based on the anatomic and physiologic relationships of the sigmoid colon to the other portions of the bowels rather than on vertebral landmarks or the location of other

Fig. 20 The periportal collar sign

viscera. According to Javors et al. (1999), the elevation of the distended sigmoid colon above the transverse colon is a valuable discriminator of sigmoid volvulus from the other causes of large bowel dilatation. Using conventional radiography, they demonstrated the northern exposure sign as a sensitive (88%) and very specific (100%) sign for sigmoid volvulus.

21 Periportal Collar Sign

21.1 Features

The periportal collar sign (or periportal halo sign) corresponds to regions with a relatively low attenuation value approaching that of water paralleling central or peripheral branches of the portal vein on CT scans (Koslin et al. 1988; Shanmuganathan et al. 1993) (Fig. 20).

21.2 Significance

Periportal edema, which is usually attributed to dilatation of lymphatic channels and accumulation of lymph due to obstruction of normal hepatic drainage, may cause this sign in patients with congestive heart failure and secondary liver congestion, hepatitis, or enlarged lymph nodes or tumors in the porta hepatis (Marineck et al. 1986). A periportal halo, attributed either to tracking of hemorrhaged blood along the course of the portal veins (Macrander et al. 1989) or to elevated venous pressure (Shanmuganathan et al. 1993), has been described in patients with hepatic injury. This sign can also be seen in recipients of liver transplants or bone marrow transplants.

21.3 Causes

21.3.1 Blunt Hepatic Trauma

The periportal low attenuation is frequently seen on CT scans of trauma patients, particularly when diffuse and peripheral, and most likely represents distension of periportal lymphatic vessels and lymphedema associated with elevated central venous pressure produced by vigorous intravenous fluid administration (Shanmuganathan et al. 1993). Dissection of hemorrhage along the portal tracts associated with hepatic injury may contribute to focal regions of periportal low density at the site of injury.

21.3.2 Cardiac Failure

In cardiac failure, elevated central venous pressure is assumed to be the cause of the periportal collar sign (Lawson et al. 1993).

21.3.3 Acute Hepatitis

The periportal collar sign may be seen in the preicteric phase of hepatitis, due to liver congestion (Lawson et al. 1993).

21.3.4 Non-Hodgkin Lymphoma

In non-Hodgkin lymphoma, enlarged lymph nodes present in the porta hepatis may obstruct lymphatic drainage and cause a periportal collar sign (Karcaaltincaba et al. 2007).

21.3.5 Liver Transplants

The periportal collar sign is seen more commonly in patients with recently transplanted allografts. The presence of a central or peripheral collar on CT is not reliable CT evidence of acute allograft rejection (Wechsler et al. 1987; Stevens et al. 1991).

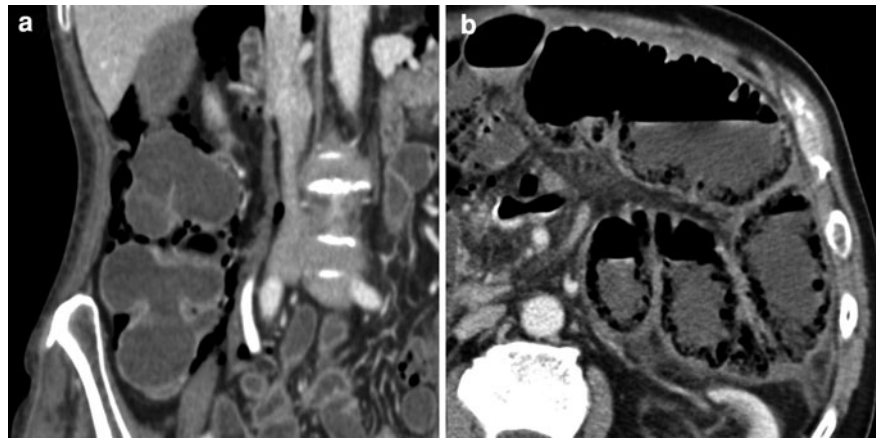

Fig. 21 **a** "Bubblelike" pneumatosis intestinalis; **b** "bandlike" pneumatosis intestinalis

22 Pneumatosis Intestinalis

22.1 Features

Pneumatosis intestinalis is defined as the presence of gas in the bowel wall (Knechtle et al. 1990). It is classified as "bubblelike" if it consists only or mainly of isolated bubbles of air in the bowel wall, whereas it is classified as "bandlike" if it consists of continuous bands of air in the affected bowel wall (Wiesner et al. 2001; Soyer et al. 2008) (Fig. 21).

22.2 Significance

Two basic mechanical features characterize most cases of pneumatosis intestinalis: mucosal injury, the most important and prevalent feature, and increased intraluminal pressure. Moreover, gas-forming organisms invading the bowel wall may also produce pneumatosis intestinalis.

22.3 Causes

22.3.1 Pneumatosis Cystoides Coli

"Bubblelike" pneumatosis intestinalis consists of cystic collections of air, usually located in the colon. It is generally a benign condition that may remain stable for years but may be complicated by obstruction or bleeding. Its cause is unknown, but its frequent association with emphysema suggests that air may dissect through the mediastinum tissues to enter the bowel mesentery and subserosal spaces (Marshak et al. 1977).

22.3.2 Gastrointestinal Disorders

"Bandlike" pneumatosis intestinalis, on the other hand, is characterized by linear or circumferential air in any part of the gastrointestinal tract and is associated with many clinical conditions, such as bowel obstruction (Merlin et al. 2008), ischemic bowel (Keyting et al. 1961), blunt bowel trauma (Furuya et al. 2002), gastrointestinal endoscopy (Meyers et al. 1977), bacterial or fungal enteritis (Kleinman et al. 1980), and cancer cytoreductive therapy (Rha et al. 2000).

Patients manifesting symptoms or signs of acute abdomen merit an aggressive surgical approach. Associated acidosis suggests necrotic bowel and portends a grave prognosis.

23 Pneumobilia

23.1 Features

Pneumobilia is defined in the liver by the presence of multiple tubular branching air images (−1,000 HU) on CT scans. Air is usually central in the liver (as opposed to portal venous gas, which is peripheral) (Fig. 22).

23.2 Significance

Air in the biliary tree may come either from the intestinal tract or from gas-forming infections of the bile ducts. Nonsurgical causes of pneumobilia are

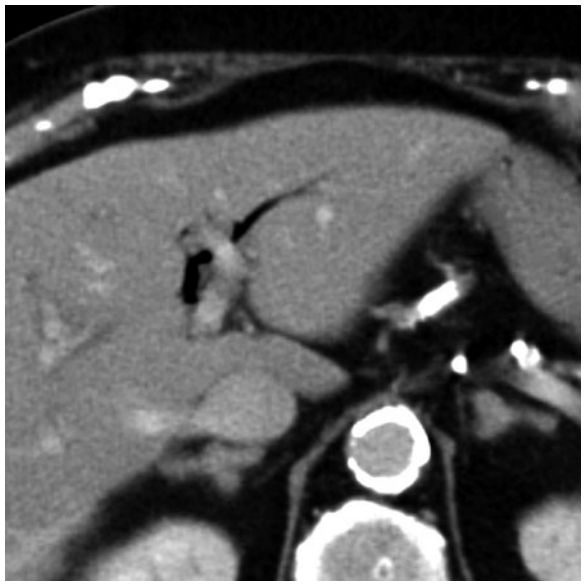

Fig. 22 Pneumobilia

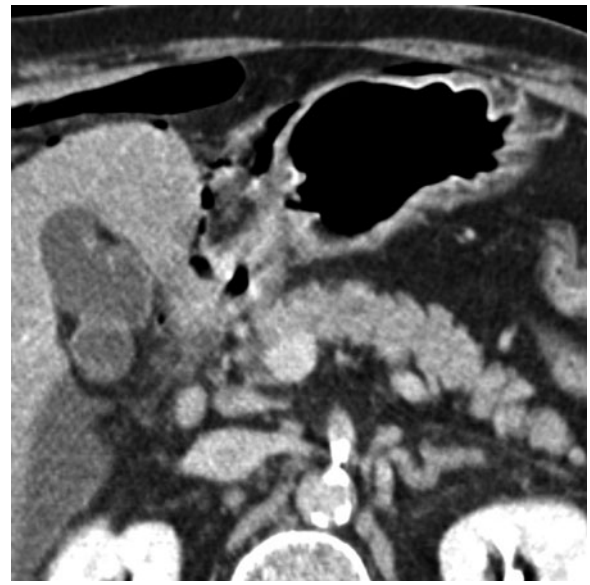

Fig. 23 Pneumoperitoneum

uncommon and are usually indicative of serious disease.

23.3 Causes

23.3.1 Iatrogenic

Pneumobilia is most commonly seen in patients following surgery in which a biliary-enteric anastomosis has been created or a sphincterotomy has been performed (Sherman and Tran 2006).

23.3.2 Gallstone Ileus

Gallstone ileus is a rare complication of recurrent gallstone cholecystitis and is defined by small bowel obstruction due to an ectopic gallstone. In gallstone ileus, the gallstone reaches the intestinal tract by creation of a cholecystoduodenal fistula (Shimono et al. 1998). This fistula between the duodenum and the gallbladder usually leads to the presence of air within the biliary tract (Delabrousse et al. 2000). Bouveret syndrome is defined by a duodenal impaction of the ectopic gallstone (Brennan et al. 2004).

23.3.3 Recurrent Pyogenic Cholangitis

Pneumobilia may be seen in recurrent pyogenic cholangitis due to gas-forming organisms (Afagh and Pancu 2004).

23.3.4 Emphysematous Cholecystitis

Emphysematous cholecystitis is an acute infection of the gallbladder wall caused by gas-forming organisms. Gas may occur in the wall and the lumen of the gallbladder. Pneumobilia is a rare but possible CT sign of emphysematous cholecystitis (Van Dyck et al. 2001).

23.3.5 Incompetence of the Sphincter of Oddi

Transient pneumobilia has been attributed to incompetence of the sphincter of Oddi (Shariatzadeh and Bolivar 1973), particularly when duodenal air pressure increases.

24 Pneumoperitoneum

24.1 Features

Pneumoperitoneum is defined by the presence of air out of the gastrointestinal tract (Baker 1996) (Fig. 23).

24.2 Significance

In an acute condition, pneumoperitoneum is often a sign of intestinal perforation. Periportal free air on CT scans has been reported to be specific of upper gastrointestinal tract perforation (Cho et al. 2009).

24.3 Causes

24.3.1 Gastrointestinal Perforation

When pneumoperitoneum is diagnosed in a nontraumatic patient, gastrointestinal perforation due to gastric or duodenal ulcer, sigmoid diverticulitis, bowel ischemia, toxic megacolon, or a foreign body must be looked for (Ghekiere et al. 2007).

24.3.2 Gastrointestinal Anastomosis Leakage

Perianastomotic loculated fluid containing air is the only feature statistically more frequently seen with gastrointestinal anastomosis leakage (Power et al. 2007).

24.3.3 Blunt Abdominal Trauma with Gastrointestinal Injury

The initial and follow-up CT scans are reported to detect extraluminal air in 58 and 92% of cases, respectively. The chance of detecting extraluminal air increases as time elapses (Saku et al. 2006).

24.3.4 Penetrating Peritoneal Trauma

Unlike pneumoperitoneum seen on plain films, pneumoperitoneum detected on CT scans is not pathognomonic of bowel perforation (Kane et al. 1991), and an associated pneumothorax may be considered as a possible cause.

24.3.5 Iatrogenic Perforation

Gastrointestinal perforation may occur during bowel endoscopy (Eisenbach et al. 2008), bowel surgery, or colonic enema (Chong et al. 1987).

24.3.6 Spontaneous Pneumoperitoneum

The more common sites of origin of spontaneous peritoneum are intrathoracic sites, and the genital organs in women (Madura et al. 1982).

25 Pneumoretroperitoneum

25.1 Features

Pneumoretroperitoneum is defined by the presence of free air (−1,000 HU) within the retroperitoneal space. Most often, air is seen surrounding the kidneys, and overlying the contour of the iliopsoas muscles (Fig. 24).

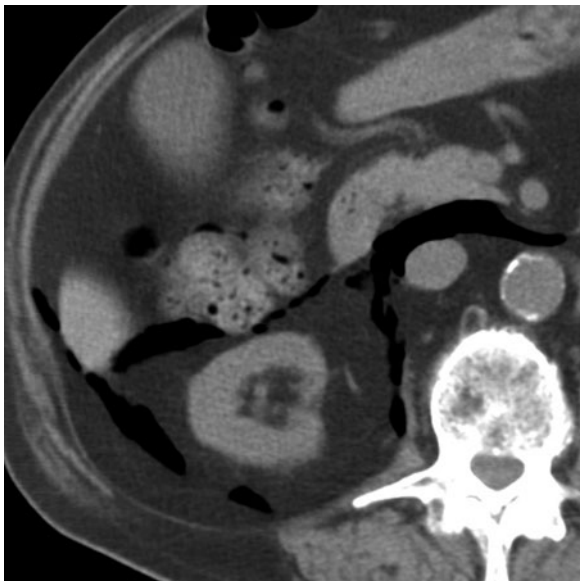

Fig. 24 Pneumoretroperitoneum

25.2 Significance

Free air can accumulate in the retroperitoneal space after perforation of a retroperitoneal bowel segment, or air can spread below the diaphragm from a pneumomediastinum (Daly et al. 2008).

25.3 Causes

25.3.1 Duodenal Perforation

Duodenal perforation may be secondary to peptic ulcer (Pun and Firkin 2004), leukemia (Chao et al. 1999), a penetrating foreign body (Maniatis et al. 2000), and duodenal trauma (Yagan et al. 2009).

25.3.2 Rectal Perforation

Perforation is mainly due to iatrogenic causes (endoscopy, surgery, biopsy) (Miyatani and Yashida 2007) and rectal trauma (foreign body) (Waraich et al. 2007).

25.3.3 Spread of Pneumomediastinum

Air tracks along the great vessels (aorta and inferior vena cava) through the diaphragm into the pararenal spaces (Perrone et al. 2005).

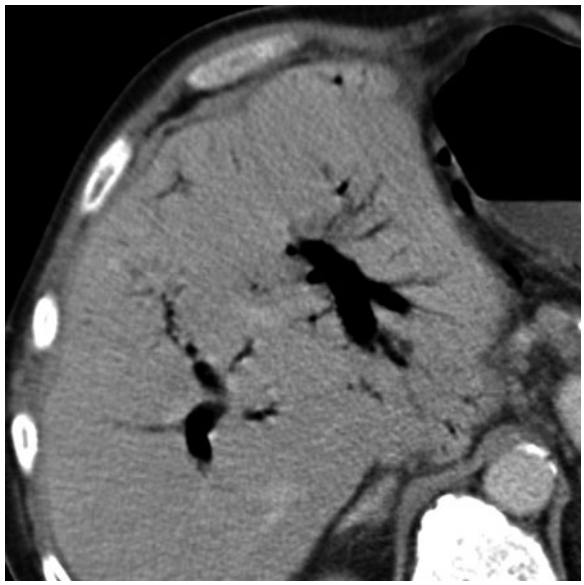

Fig. 25 Portomesenteric venous gas

26 Portomesenteric Venous Gas

26.1 Features

Portomesenteric venous gas is defined as the presence of gas (−1,000 HU) in the portomesenteric venous circulation (Wiesner et al. 2001). In the liver, the more peripheral position of the tubular air images (extending to within 2 cm of the liver capsule) will help to differentiate them from pneumobilia, which is situated more centrally (Fig. 25).

26.2 Significance

Portomesenteric venous gas may occur after damage to the wall of gastrointestinal tract caused by infection and inflammation, but also secondary to ulceration or overdistention (Sebastia et al. 2000). Besides, portomesenteric venous gas may occur without pneumatosis intestinalis in many other conditions.

26.3 Causes

26.3.1 Bowel Ischemia

Portomesenteric venous gas is an impressive, but uncommon, CT finding that most commonly develops because of bowel ischemia (Schulze et al. 1995). In bowel ischemia, the presence of portomesenteric venous gas on CT is associated with a mortality rate of 56% (Wiesner et al. 2001).

26.3.2 Ulcerative Colitis

Portal venous gas may be a benign finding in cases of stable ulcerative colitis.

26.3.3 Gastric Ulcer

Few cases of portal venous gas from peptic gastric ulcer have been reported (Liebman et al. 1978).

26.3.4 Bowel Obstruction

Hepatic portal venous gas and small bowel obstruction with no signs of intestinal gangrene after appendicectomy have been reported by Tsai et al. (2000).

26.3.5 Necrotizing Pancreatitis

Acute necrotizing pancreatitis is a rare cause of hepatic portal venous gas (Wu and Wang 2009).

26.3.6 Complicated Acute Diverticulitis

Sigmoid diverticulitis complicated by a colovenous fistula, pylephlebitis, or a perisigmoid abscess is a rare cause of hepatic portal venous gas (Haak et al. 1990; Heye et al. 2002).

26.3.7 Blunt Abdominal Trauma

Blunt abdominal trauma may lead to portal venous gas. The gas is caused by a sudden increase in the intra-abdominal pressure with concomitant mucosal disruption, which thus forces intraluminal gas into the portal circulation in blunt trauma patients (Furuya et al. 2002).

26.3.8 Iatrogenic

Barium enema (Stein et al. 1983), colonoscopy, a nasogastric intubation, and liver transplantation are classic causes of portomesenteric venous gas in adults.

27 Round Belly Sign

27.1 Features

The positive round belly sign is defined by an increased ratio of anteroposterior-to-transverse abdominal diameter > 0.80. This ratio is measured at

Fig. 26 The round belly sign

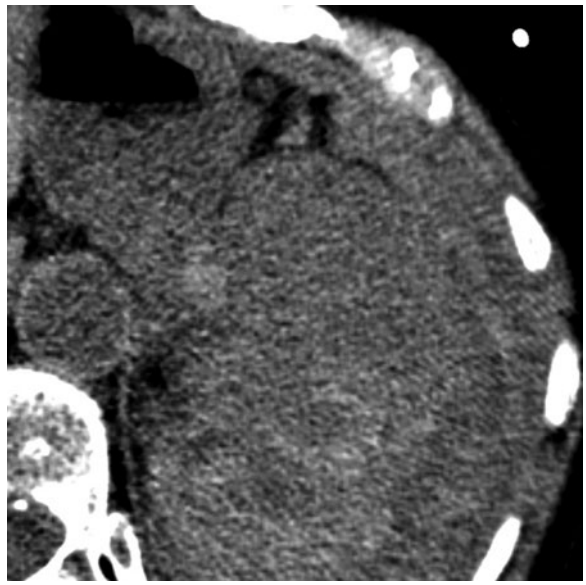

Fig. 27 The sentinel clot sign

the level where the left renal vein crosses the aorta, not including the subcutaneous fat (Pickhardt et al. 1999) (Fig. 26).

27.2 Significance

The round belly sign corresponds to massive abdominal distention secondary to increased intra-abdominal pressure.

27.3 Cause

27.3.1 Abdominal Compartment Syndrome

The round appearance of the abdomen on axial CT scans in patients with abdominal compartment syndrome correlates well with the massive abdominal distention on physical examination. Pickhardt et al. (1999) reported a cutoff value of 0.80 (the round belly sign) with 100% sensitivity and 94% specificity for the diagnosis of abdominal compartment syndrome. For other authors, more than an absolute value for this ratio, the occurrence of an acute increase, without any explanation for it, such as the development of ascites or a bowel obstruction, may give additional support for the diagnosis of abdominal compartment syndrome (Zissin 2000; Laffargue et al. 2002; Patel et al. 2007).

28 Sentinel Clot Sign

28.1 Features

On unenhanced CT scans, the sentinel clot sign is defined by the presence of a focal high-density collection having a mean CT number greater than 60 HU when measured by computed region of interest cursor readout. If region of interest measurements are unavailable, the presence of a focal heterogeneous collection that is visibly more dense than hemoperitoneum is accepted as evidence of a sentinel clot sign (Orwig and Federle 1989) (Fig. 27).

28.2 Significance

The sentinel clot sign corresponds to a localized intra-abdominal blood clot. The sentinel clot sign is assigned a relationship to an adjacent solid or

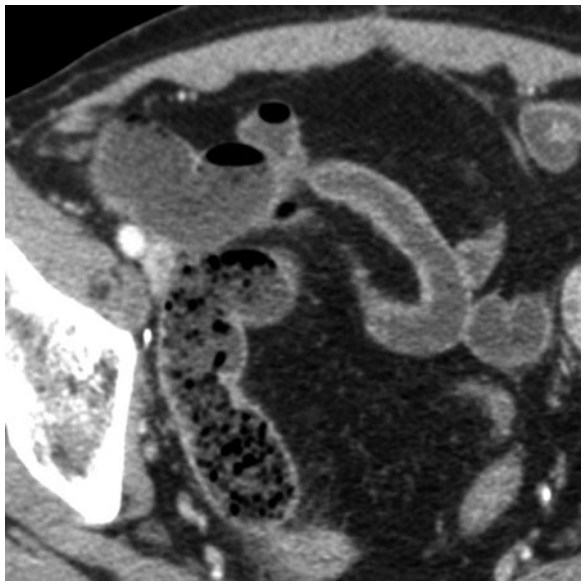

Fig. 28 The small bowel feces sign

hollow viscus as the most likely site of injury and source of hemorrhage (Orwig and Federle 1989).

28.3 Cause

28.3.1 Blunt Abdominal Trauma

The sentinel clot sign is an important clue that the bleeding source is an injured adjacent organ (Hamilton et al. 2008). It is a frequent and accurate sign that may help to focus attention on the traumatic lesion (Shinn et al. 2007). By facilitating diagnosis of trauma to a specific organ, it influences the management decision of surgical versus conservative therapy (Orwig and Federle 1989).

28.3.2 Gastrointestinal Bleeding

Nonbleeding protuberances in ulcer bases can be separated into vessels, which have a high risk of rebleeding, and sentinel clots, which have a low risk of rebleeding (Freeman et al. 1993).

28.3.3 Spontaneous Spleen Rupture

The formation of a clot close to the bleeding source may be a valuable sign in spontaneous spleen rupture (Gayer et al. 2003). During the subsequent course, clot lysis will progressively occur and the attenuation values of the fluid will decrease.

29 Small Bowel Feces Sign

29.1 Features

The small bowel feces sign was first described in 1995 by Mayo-Smith et al. (1995). It is defined by the presence of particulate (colonlike) feculent matter mingled with gas bubbles in the lumen of dilated loops of the small bowel (Fuchsjäger 2002) (Fig. 28).

29.2 Significance

The heterogeneous mottled particulate matter mixed with small gas bubbles observed in the small bowel feces sign resembles the appearance of stool in the large bowel on CT. It is the result of an abnormally low intestinal transit time, either mechanical or functional in origin, and is believed to be caused by incompletely digested food, bacterial overgrowth, or increased water absorption of the distal small bowel contents due to obstruction (Mayo-Smith et al. 1995; Catalano 1997).

29.3 Cause

29.3.1 Small Bowel Obstruction

The small bowel feces sign has been reported as a finding indicative of small bowel obstruction by many authors (Mayo-Smith et al. 1995; Catalano 1997; Delabrousse et al. 2005). Since the sign is usually seen immediately proximal to the level of obstruction, it may be helpful in recognition of the exact site and cause (Lazarus et al. 2004). The main source of the small bowel feces sign is small bowel obstruction due to adhesions. On the basis of the fact that this sign was initially described with subacute small bowel obstruction, Lazarus et al. (2004) stated that the small bowel feces sign may relate more to the chronic nature than to the degree of obstruction. Moreover, the small bowel feces sign has been reported to be secondary to incomplete obstruction with progressive

Fig. 29 The spoke wheel sign

slowing of small bowel transit as opposed to complete obstruction. Therefore, the notion that the small bowel feces sign could be a predictor of successful conservative management may be entertained (Delabrousse et al. 2005).

30 Spoke Wheel Sign

30.1 Features

The spoke wheel sign is defined as fluid-filled, dilated bowel loops that are radially arranged around converging thickened and stretched mesenteric vessels (Jaramillo and Raval 1986) (Fig. 29).

30.2 Significance

In small bowel volvulus, torsion at the root of the mesentery results in a shortened, tight mesentery with a funnel shape along the axis of rotation. The shortening and tightening of the mesentery causes the fluid-filled, dilated bowel loops that are attached to the twisted mesentery to lie in a concentric, more peripheral location, with engorged and thickened vascular structures occupying the center. Stretched and engorged mesenteric vessels that reach the concentrically arranged bowel loops and that converge toward the center of mesenteric torsion create folds of soft-tissue attenuation that ressemble spokes connected to the hub of a wheel. The resultant spoke wheel sign is best appreciated on cross sections when imaging is performed to the long axis of the bowel rotation (Rudloff 2005). Most often, a whirl sign may be demonstrated in association with the spoke wheel sign.

30.3 Cause

30.3.1 Small Bowel Volvulus

The spoke wheel sign is highly suggestive of small bowel volvulus. It incorporates diagnostics of both the mesentery and the small bowel, thereby aiding in the detection of closed loop obstruction (Balthazar et al. 1997). The association of this sign with bowel ischemia and infarction should lead to a search for other signs of bowel necrosis and raise suspicion of bowel strangulation.

31 String of Pearls Sign

31.1 Features

The string of pearls sign, which may be demonstrated on CT scans, was originally defined on abdominal radiographs (Maglinte et al. 1996). Also commonly referred to as the string of beads sign, this sign consists of a row of several small air bubbles trapped between the valvulae conniventes along the superior wall of dilated small bowel loops (Nevitt 2000) (Fig. 30).

31.2 Significance

The string of pearls sign corresponds to small amounts of air trapped between the valvulae conniventes. Dilatation of the small bowel stimulates the mucosa to secrete fluid. Thus, the distended bowel contains varying amounts of air and fluid. As the small bowel dilates, the valvulae conniventes widen, and this causes the small bowel air to be trapped (Nevitt 2000). The meniscal effect of the surrounding fluid gives the

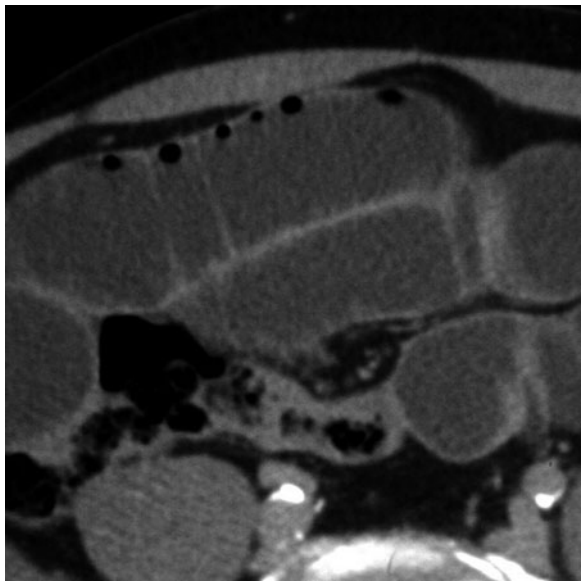

Fig. 30 The string of pearls sign

Fig. 31 The tissue rim sign

trapped air an ovoid or rounded shape, leading to the string of pearls appearance.

31.3 Cause

31.3.1 Mechanical Small Bowel Obstruction

Although the string of pearls sign is rarely seen in adynamic ileus, acute gastroenteritis, and saline catharsis, when present in the right clinical setting, it is considered to be diagnostic of mechanical small bowel obstruction (Levin 1973; Maglinte et al. 1996). The importance of recognizing the string of pearls sign is often related to the clinical and other CT findings of small bowel obstruction.

32 Tissue Rim Sign

32.1 Features

The tissue rim sign is a CT finding defined by the presence of a rim (or halo) of soft-tissue attenuation seen around the circumference of an intraureteral stone on unenhanced axial CT scans (Heneghan et al. 1997; Kawashima et al. 1997) (Fig. 31).

32.2 Significance

The tissue rim sign is believed to represent thickening of the ureteral wall secondary to edema from a stone lodged in the ureteral lumen (Smith et al. 1995). It has been reported to be useful in differentiating ureteral calculi from extraurinary calcifications (Smith et al. 1995; Smith et al. 1996) Stones without a rim sign are commonly larger than stones with a rim sign, likely because of stretching of the ureteral wall by the larger stones (Heneghan et al. 1997). For a time, the duration of obstruction was proposed as another explanation for the presence or absence of the rim sign. However, Heneghan et al. (1997) found no statistically significant difference in the duration of symptoms between patients with stones who exhibited a rim sign and those who did not.

32.3 Cause

32.3.1 Ureterolithiasis

A positive tissue rim sign is specific to the diagnosis of ureterolithiasis. However, a negative sign does not preclude such a diagnosis. The presence of the tissue rim sign should lead to careful inspection for other CT

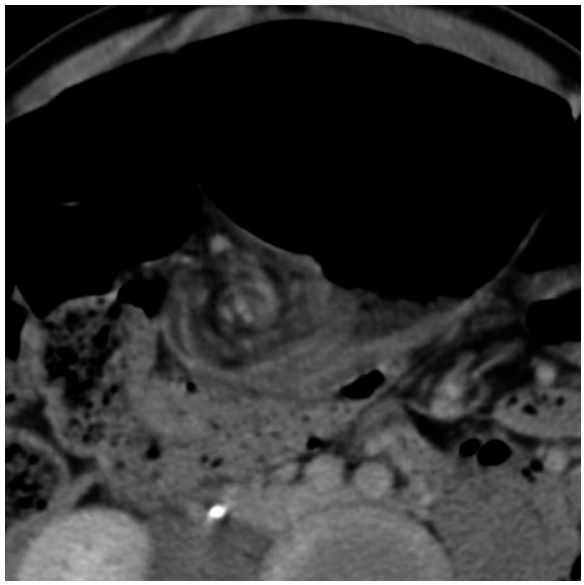

Fig. 32 The whirl sign

findings, such as ipsilateral dilatation, perinephretic edema, dilatation of intrarenal collecting system and renal swelling (Kawashima et al. 1997)

33 Whirl Sign

33.1 Features

The appearance of the whirl sign is that of soft-tissue mass with an internal architecture of swirling strands of soft-tissue and fat attenuation (Khurana 2003) (Fig. 32).

33.2 Significance

The whirl sign is highly suggestive of intestinal volvulus that occurs when afferent and efferent bowel loops rotate around a fixed point of obstruction, which results in tightly twisted mesentery along the axis of rotation. These twisted loops of bowel and mesenteric vessels create swirling strands of soft-tissue attenuation within a background of mesenteric fat attenuation, giving the appearance of a hurricane on a weather map (Moore et al. 2001). The whirl sign is best appreciated when CT scanning is performed perpendicular to the axis of bowel rotation (Khurana 2003).

33.3 Causes

33.3.1 Midgut Volvulus

The whirl sign was first described by Fisher (1981) as a CT finding of midgut volvulus, where the center of the whirl was the superior mesenteric artery, and the whirled appearance was created by the encircling loops of bowel .

33.3.2 Sigmoid Volvulus

Four years later, the definition of the whirl sign was extended to include the CT appearance of sigmoid volvulus where a whirl was formed by the afferent and efferent sigmoid loops with the central portion composed of tightly twisted bowel and mesentery. For some authors, the tightness of the whirl is proportional to the degree of rotation.

33.3.3 Cecal Volvulus

The whirl sign has also been reported in cecal volvulus. In cecal volvulus, the whirl sign comprises the twisted mesentery and the collapsed cecal loop (Frank et al. 1993). Pathophysiologically, three types of cecal volvulus are differentiated. In the loop type, the distal ileal loops may also participate in the creation of the whirl sign.

33.3.4 Small Bowel Volvulus

The main causes of small bowel volvulus are postoperative adhesions in which the bowel is fixed to a point that acts as a pivot, leading to closed loop obstruction, and hernia (Balthazar et al. 1997). In small bowel obstruction, the presence of a whirl sign is the very key feature that indicates a bowel volvulus.

References

Afagh A, Pancu D (2004) Radiologic findings in recurrent pyogenic cholangitis. J Emerg Med 26:343–346

Ahualli J (2007) The fat halo sign. Radiology 242:945–946

Aoyagi S, Kosuga T, Ogata T, Yasunaga M (2009) Spontaneous rupture of the spleen caused by bacillus infection: report of a case. Surg Today 39:733–737

Arita T, Matsunaga N, Takano K et al (1997) Abdominal aortic aneurysm: rupture associated with the high-attenuated crescent sign. Radiology 204:765–768

Baker SR (1996) Invited commentary: imaging of pneumoperitoneum. Abdom Imaging 21:413–414

Ballantyne GH (1982) Review of sigmoid volvulus: history and results of treatment. Dis Colon Rectum 25:494–501

Balthazar EJ, Megibow AJ, Fazzini E, Opulencia JF, Engel I (1985) Cytomegalovirus colitis in AIDS: radiographic findings in 11 patients. Radiology 155:585–589

Balthazar EJ, Birnbaum BA, Megibow AJ, Gordon RB, Whelan CA, Hulnick DH (1992) Closed-loop and strangulating intestinal obstruction: CT signs. Radiology 185:769–775

Balthazar EJ, Birnhaum BA, Megibow AJ, Gordon RB, Whelan CA, Hulnick DH (1997) Closed-loop and strangulating obstruction: CT signs. Radiology 185:769–775

Becker CD, Spring P, Glättli A, Schweizer W (1994) Blunt splenic trauma in adults: can CT findings be used to determine the need for surgery? AJR Am J Roentgenol 162:342–347

Benjaminov O, Atri M, Hamilton P, Rappaport D (2002) Frequency of visualization and thickness of normal appendix on nonenhanced helical CT. Radiology 225:400–406

Bergin D, Ennis ER, Keogh C, Fenlon HM, Murray JG (2001) The "dependant viscera" sign in CT diagnosis of blunt traumatic diaphragmatic rupture. AJR Am J Roentgenol 177:1137–1140

Bernard C, Lubrano J, Moulin V, Mantion E, Kastler B, Delabrousse E (2010) Value of Multidetector-row CT in the management of signoid Volvulus. J Radiol 91(2): 213–220

Breen DJ, Janzen DL, Zwirewich CV, Nagy AG (1997) Blunt bowel and mesenteric injury: diagnostic performance of CT signs. J Comput Assist Tomogr 21:706–712

Brennan GB, Rosenberg RD, Arora S (2004) Bouveret syndrome. RadioGraphics 24:1171–1175

Browse NL, Wilson NM, Russo F, al-Hassan H, Allen DR (1992) An etiology and treatment of chylous ascites. Br J Surg 9:1145–1150

Brunet WG, Greenberg HM (1991) CT demonstration of a ruptured splenic artery aneurysm. J Comput Assist Tomogr 15:177–178

Burrel HC, Baker DM, Wardrop P et al (1994) Signifiant plain film findings in sigmoid volvulus. Clin Radiol 49:317–319

Byun JY, Ha HK, Yu SY et al (1999) CT features of systemic lupus erythematosus in patients with acute abdominal pain: emphasis on ischemic bowel disease. Radiology 211:203–209

Cantwell CP (2006) The dependant viscera sign. Radiology 238:752–753

Catalano O (1997) The faeces sign: a CT finding in small-bowel obstruction. Radiologe 37:417–419

Chao TC, Wang CS, Wen MF (1999) Gastroduodenal perforation in cancer patients. Hepatogastroenterology 46:2878–2881

Checkoff JL, Weschler RJ, Nazarian LN (2002) Chronic inflammatory appendiceal conditions that mimic acute appendicitis on helical CT. AJR Am J Roentgenol 179:731–734

Chen S, Harisinghani MG, Wittenberg J (2003) Small bowel Ct fat density target sign in chronic radiation enteritis. Australas Radiol 47:450–452

Cho HS, Yoon SE, Park SH, Kim H, Lee YH, Yoon KH (2009) Distinction between upper and lower gastrointestinal perforation: usefulness of the periportal free air sign on computed tomography. Eur J Radiol 69:108–113

Choi BG (2001) The findings of ruptured hepatocellular carcinoma on helical CT. Br J Radiol 74:142–146

Chong WK, Tanner A, Wilkins RA (1987) Pneumoperitoneum, omental emphysema and intramural barium perforation following double contrast barium enema. Clin Radiol 38:319–320

Coulier B, Malbecq S, Brinon PE, Ramboux A (2008) MDCT diagnosis of ruptured tubal pregnancy with massive hemoperitoneum. Emerg Radiol 15:179–182

Daly KP, Ho CP, Persson DL, Gay SB (2008) Traumatic retroperitoneal injuries: review of multidetector CT findings. RadioGraphics 28:1571–1590

De Las Heras D, Pages M (2001) Abnormal hepatic enhancement on CT in congestive heart failure. J Hepatol 35:431

Delabrousse E, Bartholomot B, Sohm O, Wallerand H, Kastler B (2000) Gallstone ileus: CT findings. Eur Radiol 10:938–940

Delabrousse E, Baulard R, Sarlième P, Michalakis D, Rodière E, Kastler BA (2005) Value of the small bowel feces sign at CT in adhesive small bowel obstruction. J Radiol 86:393–397

Delabrousse E, Sarlième P, Sailley N, Aubry S, Kastler BA (2007) Cecal volvulus: CT findings and correlation with pathophysiology. Emerg Radiol 14:411–415

Delabrousse E, Lubrano J, Jehl J et al (2009) Small bowel obstruction from adhesive bands and matted adhesions: CT differentiation. AJR Am J Roentgenol 192:693–697

Demos TC, Solomon C, Posniak HV, Flisak MJ (1989) Computed tomography in traumatic defects of the diaphragm. Clin Imaging 13:62–67

Eisenbach C, Bläker H, Stremmel W, Sauer P, Schaible A (2008) Pneumoperitoneum following endoscopic mucosal resection without perforation of the colon. Endoscopy 40(Suppl 2):E64–E65

Eisenstat RS, Whitford AC, Lane MJ, Katz DS (2002) The flat cava sign revisited: what is it significance in patients without trauma? AJR Am J Roentgenol 178:21–25

Feldman D (2000) The coffee bean sign. Radiology 216:178–179

Fisher JK (1981) Computed tomographic diagnosis of volvulus in intestinal malrotation. Radiology 140:145–146

Fishman EK, Kavuru M, Jones B et al (1991) Pseudomembranous colitis: CT evaluation of 26 cases. Radiology 180:57–60

Frager DH, Goldman M, Beneventano TC (1983) Computed tomography in Crohn disease. J Comput Assist Tomogr 7:819–824

Frank AJ, Goffner LB, Fruauff AA, Losada RA (1993) Cecal volvulus: the CT whirl sign. Abdom Imaging 18:288–289

Freeman ML, Cass OW, Peine CJ, Onstad GR (1993) The nonbleeding visible vessel versus the sentinel clot: natural history and risk of rebleeding. Gastrointest Endosc 39:359–366

Fuchsjäger MH (2002) The small-bowel feces sign. Radiology 225:378–379

Furlan A, Fakhran S, Federle MP (2009) Spontaneous abdominal hemorrhage: causes, CT findings, and clinical complications. AJR Am J Roentgenol 193:1077–1087

Furuya Y, Yasuhara H, Ariki K et al (2002) Hepatic portal venous gas caused by blunt abdominal trauma: is it true ominous sign of bowel necrosis? Report of a case. Surg Today 32:655–658

Gale ME, Johnson WC, Gerzof SG, Robbins AH (1986) Problems in the CT diagnosis of ruptured abdominal aortic aneurysms. J Comput Assist Tomogr 10:637–641

Gayer G, Zandman-Goddard G, Kosych E, Apter S (2003) Spontaneous rupture of the spleen detected on CT as the initial manifestation of infectious mononucleosis. Emerg Radiol 10:51–52

Ghekiere O, Lesmik A, Millet I, Hoa D, Guillon F, Taourel P (2007) Direct visualization of perforation sites in patients with non-traumatic free pneumoperitoneum: added value of thin transverse slices and coronal and sagittal reformations for multidetector CT. Eur Radiol 17:2302–2309

Gore RM, Mathieu DG, White EM, Ghahremani GG, Panella JS, Rochester D (1994) Passive hepatic congestion: cross-sectional imaging features. AJR Am J Roentgenol 162:71–75

Gore RM, Balthazar EJ, Gharemani GG, Miller FH (1996) CT features of ulcerative colitis and Crohn's disease. AJR Am J Roentgenol 167:3–15

Ha HK, Park CH, Kim SK et al (1993) CT analysis of intestinal obstruction due to adhesions: early detection of strangulation. J Comput Assist Tomogr 17:386–389

Ha HK, Lee HJ, Yang SK et al (1998) Intestinal Behçet syndrome: CT features of patients with and patients without complications. Radiology 209:449–454

Haak HR, Kooymans-Coutinhao MF, von Teefelen ME, Adhin S, Falke TH (1990) Portal venous gas in a patient with diverticulitis. Hepatogastroenterology 37:528–529

Halliday KE, Al-Kutoubi A (1996) Draped aorta: CT sign of contained leak of aortic aneurysms. Radiology 199: 41–43

Hamilton JD, Kumaravel M, Censullo ML, Cohen AM, Kievlan DS, West OC (2008) Multidetector CT evaluation of active extravasation in blunt abdominal and pelvic trauma patients. RadioGraphics 28:1603–1616

Harisingjhani MG, Wittenberg J, Lee W, Chen S, Guttierez AL, Mueller PR (2003) Bowel wall fat halo sign in patients without intestinal disease. AJR Am J Roentgenol 181:781–784

Harris AC, Swirewich CV, Lyburn ID, Torreggiani WC, Marchinkow LO (2001) CT findings in blunt renal trauma. RadioGraphics 21:201–214

Heneghan JP, Dalrymple NC, Verga M, Rosenfield AT, Smith RC (1997) Soft tissue rim sign in the diagnosis of ureteral calculi with use of unenhanced helical CT. Radiology 202:709–711

Heye S, Ghijselings L, van Campehoudt M (2002) Hepatic portal gas as a complication of diverticulitis with a colovenous fistula: a case report. Emerg Radiol 9:234–236

Holley HC, Koslin DB, Berland LL, Stanley RJ (1989) Inhomogeneous enhancement of liver parenchyma secondary to passive congestion: contrast-enhanced CT. Radiology 170:795–800

Hopper KD, Sherman JL, Ghaed N (1985) Aortic rupture into retroperitoneum. AJR Am J Roentgenol 145:435–437

Horton KM, Corl FM, Fishman EK (2000) CT evaluation of the colon: inflammatory disease. RadioGraphics 20:399–418

Horton KM, Lawler LP, Fishman EK (2003) CT findings in sclerosing mesenteritis (panniculitis): spectrum of disease. RadioGraphics 23:1561–1567

Iochum S, Ludig T, Walter F, Sebbag H, Grosdidier G, Blum AG (2002) Imaging of diaphragmatic injury: a diagnostic challenge? RadioGraphics 22:S103–S118

Jaramillo D, Raval B (1986) CT diagnosis of primary small bowel volvulus. AJR Am J Roentgenol 147:941–942

Javors BR, Baker SR, Miller JA (1999) The northern exposure sign: a newly described finding in sigmoid volvulus. AJR Am J Roentegenol 173:571–574

Jeffrey RB, Federle MP (1988) The collapsed inferior vena cava: CT evidence of hypovolemia. AJR Am J Roentgenol 150:431–432

Jeong YK, Ha HK, Yoon CH et al (1997) Gastrointestinal involvement in Henoch–Schönlein syndrome: CT findings. AJR Am J Roentgenol 168:965–968

Johnson KT, Julsrud PR, Johnson CD (2008) Constrictive pericarditis at abdominal CT: a commonly overlooked diagnosis. Abdom Imaging 33:349–352

Jones IT, Fazio VW (1989) Colonic volvulus: etiology and management. Dig Dis 7:203–209

Jones B, Fishman EK, Hamilton SR et al (1986) Submucosal accumulation of fat in inflammatory bowel disease: CT pathologic correlation. J Comput Assist Tomogr 10:759–763

Kane NM, Francis IR, Burney RE, Wheatley MJ, Ellis JH, Korobkin M (1991) Traumatic pneumoperitoneum. Implications of computed tomography diagnosis. Invest Radiol 26:574–578

Karaosmanoglu D, Karcaaltincaba M, Oguz B, Akata D, Ozmen M, Akhan O (2009) CT findings of lymphoma with peritoneal, omental and mesenteric involvement: peritoneal lymphomatosis. Eur J Radiol 71:313–317

Karcaaltincaba M, Haliloglu M, Akpinar E et al (2007) Multidetector CT and MRI findings in periportal space pathologies. Eur J Radiol 61:3–10

Kawamoto S, Horton KM, Fishman EK (1999) Pseudomembranous colitis: spectrum of imaging findings with clinical and pathologic correlation. RadioGraphics 19:887–897

Kawashima A, Sandler CM, Boridy IC, Takahashi N, Benson GS, Goldman SM (1997) Unenhanced helical CT of ureterolithiasis: value of the tissue rim sign. AJR Am J Roentgenol 168:997–1000

Kerry RL, Lee F, Ransom HK (1971) Roentgenologic examination in the diagnosis and treatment of colon volvulus. AJR Am J Roentgenol 113:343–348

Keyting WS, McCarver RR, Kovanik JL, Daywitt AL (1961) Pneumatosis intestinalis: a new concept. Radiology 76:733–741

Khurana B (2003) The whirl sign. Radiology 226:69–70

Killen KL, Mirvis SE, Shanmuganathan K (1999) Helical CT of diaphragmatic rupture caused by blunt trauma. AJR Am J Roentgenol 173:1611–1616

Kim JK, Ha HK, Byun JY et al (2001) CT differentiation of mesenteric ischemia due to vasculitis and thromboembolic disease. J Comput Assist Tomogr 25:604–611

Kleinman PK, Brill PW, Winchester P (1980) Pneumatosis intestinalis. Am J Dis Child 134:1149–1151

Knechtle SJ, Davidoff AM, Rice RP (1990) Pneumatosis Intestinalis: surgical management and clinical outcome. Ann Surg 212:160–165

Ko SF, Lee TY, Cheng TT, Ng SH, Lai HM, Cheng YF et al (1997) CT findings at lupus mesenteric vasculitis. Acta Radiol 38:115–120

Koslin BD, Stanley RJ, Campbell WL, Zakjo AB, Demetris AJ (1988) Hepatic perivascular lymphedema. AJR Am J Roentgenol 150:111–113

Laffargue P, Taourel P, Saguintaah L, Lesnik A (2002) CT diagnosis of abdominal compartment syndrome. AJR Am J Roentgenol 178:771–772

Larici AR, Gotway MB, Litt HI et al (2002) Helical CT with sagittal and coronal reconstructions: accuracy for detection of diaphragmatic injury. AJR Am J Roentgenol 179:451–457

Lawson TL, Thorsen MK, Erickson SJ, Perret RS, Quiroz FA, Foley WD (1993) Periportal halo: a CT sign of liver disease. Abdom Imaging 18:42–46

Lazarus DE, Slywotsky C, Bennett GL, Megibow AJ, Macari M (2004) Frequency and relevance of the small-bowel feces sign on CT in patients with small bowel obstruction. AJR Am J Roentgenol 183:1361–1366

Lee SS, Ha HK, Yang SK et al (2002) CT of prominent pericolic or perienteric vasculature in patients with Crohn's disease: correlation with clinical disease activity and findings on barium studies. AJR Am J Roentgenol 179:1029–1036

Lenchick L, Dovgan DJ, Kier R (1994) CT of the iliopsoas compartment: value in differentiating tumor, abscess and hematomas. AJR Am J Roentgenol 162:83–86

Levin B (1973) Mechanical small bowel obstruction. Semin Roentgenol 8:281–297

Levsky JM, Den EI, Dubrow RA, Wolf EL, Rozenblit AM (2010) CT findings of sigmoid volvulus. AJR Am J Roentgenol 194:136–143

Liebman PR, Patten MT, Manny J, Benfield JR, Hechtman HB (1978) Hepatic-portal venous gas in adults: etiology, pathology and clinical significance. Ann Surg 187:281–287

Lubner M, Menias C, Rucker C, Bhalla S, Peterson CM, Wang L, Gratz B (2007) Blood in the belly: CT findings of hemoperitoneum. RadioGraphics 27:109–125

Macari M, Balthazar EJ (2001) CT of bowel wall thickening: significance and pitfalls of interpretation. AJR Am J Roentgenol 176:1105–1116

Macari M, Balthazar EJ, Megibow AJ (1999) The accordion sign at CT: a non-specific finding in patients with colonic edema. Radiology 211:743–746

Macrander SJ, Lawson TL, Foley DW, Dodds WJ, Erickson SJ, Quiroz FA (1989) Periportal tracking in hepatic trauma: CT features. J Comput Assist Tomogr 13:952–957

Madura MJ, Craig RM, Shields TW (1982) Unusual causes of spontaneous pneumoperitoneum. Surg Gynecol Obstet 154:417–420

Madureira AJ (2004) The comb sign. Radiology 230:783–784

Maglinte DDT, Reyes BL, Harmon BH et al (1996) Reliability and role of plain film radiography and CT in the diagnosis of small-bowel obstruction. AJR Am J Roentgenol 167:1451–1455

Maniatis V, Chryssikopoulos H, Roussakis A et al (2000) Perforation of the alimentary tract: evaluation with computed tomography. Abdom Imaging 25:373–379

Marineck B, Barbier PA, Becker CD, Mettler D, Ruchti C (1986) CT appearances of impaired lymphatic drainage in liver transplant. AJR Am J Roentgenol 147:519–523

Marshak RH, Linder AE, Maklansky D (1977) Pneumatosis cystoides coli. Gastrointest Radiol 2:85–89

Mayo-Smith WW, Wittenberg J, Bennett GL, Gervais DA, Gazelle GS, Mueller PR (1995) The CT small bowel faeces sign: description and clinical relevance. Clin Radiol 50:765–767

Mehard WB, Heiken JP, Sicard GA (1994) High-attenuating crescent in abdominal aortic aneurysm wall at CT: a sign of acute or impending rupture. Radiology 192:359–362

Mellins HZ, Riger LG (1954) The roentgen finding in strangulating obstructions of the small intestine. AJR Am J Roentgenol 74:409–415

Merlin A, Soyer P, Boudiaf M, Hamzi L, Rymer R (2008) Chronic intestinal pseudo-obstruction in adult patients: multidetector row helical CT features. Eur Radiol 18:1587–1595

Messmer JM (1994) Gas and soft tissue abnormalities. In: Gore RM, Levine MS, Laufer I (eds) Textbook of gastrointestinal radiology. Saunders, Philadelphia, pp 175–176

Meyers MA (1994) Dynamic radiology of the abdomen: normal and pathologic anatomy, 4th edn. Springer-Verlag, Berlin, pp 55–57

Meyers MA, McGuire PV (1995) Spiral CT demonstration of hypervascularity in Crohn disease: "vascular jejunization of the ileum" or "the comb sign". Abdom Imaging 20:327–332

Meyers MA, Ghahremani GG, Clement JL Jr, Goodman K (1977) Pneumatosis intestinalis. Gastrointest Radiol 2:91–105

Mindelzun RE, Jeffrey RB Jr, Lane MJ, Silverman PM (1996) The misty mesentery on CT: differential diagnosis. AJR Am J Roentgenol 167:61–65

Mirvis SE, Shanmuganathan K, Erb R (1994) Diffuse small bowel ischemia in hypotensive adults after blunt trauma (shock bowel): CT findings and clinical significance. AJR Am J Roentgenol 163:1375–1379

Miyatani H, Yashida Y (2007) Retroperitoneal perforation caused by endoscopic biopsy in patients with ulcerative colitis and cytomegalovirus infection. Endoscopy 39(1):E246

Moore CJ, Corl FM, Fishman EK (2001) CT of the cecal volvulus. AJR Am J Roentgenol 177:95–98

Morehouse HT, Hochstein JG, Louie W, States L (1992) Pitfalls in the CT diagnosis of ruptured abdominal aortic aneurysms (abstract). Radiology 185:181

Muldowney SM, Balfe DM, Hammerman A, Wick MR (1995) Acute fat deposition in bowel wall submucosa: CT appearance. J Comput Assist Tomogr 19:390–393

Murray JG, Caoili E, Grunden JF, Evans SJJ, Halvorsen RA Jr, Mackersie RC (1996) Acute rupture of the diaphragm due to blunt trauma: diagnostic sensitivity and specificity. AJR Am J Roentgenol 166:1035–1039

Nakagawa Y, Masuda M, Shiihara H et al (1990) A chronic contained rupture of an abdominal aortic aneurysm complicated with severe back pain. Ann Vasc Surg 4: 189–192

Nevitt PC (2000) The string of pearls sign. Radiology 214:157–158

Nghiem HV, Jeffrey RB Jr, Mindelzun RE (1993) CT of blunt trauma to the bowel and mesentery. AJR Am J Roentgenol 160:53–58

O'Sullivan SG (1998) The accordion sign. Radiology 206:177–178

Ormsby EL, Duffield C, Ostovar-Sirjani F, McGahan JP, Troppmann C (2007) Colonoscopy findings in end-stage liver disease patients with incidental CT colonic wall thickening. AJR Am J Roentgenol 189:1112–1117

Orwig D, Federle MP (1989) Localized clotted blood as evidence of visceral trauma on CT: the sentinel clot sign. AJR Am J Roentgenol 153:747–749

Patel A, Lall CG, Jennings SG, Sandrasegaran K (2007) Abdominal compartment syndrome. AJR Am J Roentgenol 189:1037–1043

Pereira JM, Sirlin CB, Pinto PS, Jeffrey RB, Stella DL, Casola G (2004) Disproportionate fat stranding: a helpful CT sign in patients with acute abdominal pain. RadioGraphics 24:703–715

Perrone L, Piacentini F, Minordi LM, Vecchioloi A (2005) Pneumomediastinum and abdominal pain: which correlation? Rays 30:63–69

Petrovic B, Nikalaidis P, Hammond NA, Grant TH, Miller FH (2006) Identification of adhesions on CT in small bowel obstruction. Emerg Radiol 12:88–93

Philpotts LE, Heiken JP, Westcott MA, Gore RM (1994) Colitis: use of CT findings in differential diagnosis. Radiology 190:445–449

Pickhardt PJ, Shimony JS, Heiken JP, Buchman TG, Fisher AJ (1999) The abdominal compartment syndrome: CT findings. AJR Am J Roentgenol 173:575–579

Power N, Atri M, Ryan S, Haddad R, Smith A (2007) CT assessment of anastomotic bowel leak. Clin Radiol 62:37–42

Pun E, Firkin A (2004) Computed tomography and complicated peptic ulcer disease. Australas Radiol 48:516–519

Puylaert JB (1992) Right-sided segmental infarction of the omentum: clinical, US and CT findings. Radiology 185:169–172

Rao PM, Wittenberg J, Lawrason JN (1997) Primary epiploic appendagitis: evolutionary changes in CT appearance. Radiology 204:713–717

Rha SF, Ha HK, Lee SH et al (2000) CT and MR findings of bowel ischemia from various primary causes. RadioGraphics 20:29–42

Riger LG (1944) Roentgen diagnosis of acute abdominal conditions. Bull Univ Minn Hosp 116:120–137

Ros PR, Bluetow PC, Pantograg-Brown L, Forsmark CE, Sobin LH (1996) Pseudmembranous colitis. Radiology 198:1–9

Rosenthal D, Clark MD, Stanton PE, Lamis PA (1986) Chronic contained ruptured abdominal aortic aneurysm: is it real? J Cardiovasc Surg 27:723–725

Rudloff U (2005) The spoke wheel sign: bowel. Radiology 237:1046–1047

Saku M, Yoshimitsu K, Murakami I et al (2006) Small bowel perforation resulting from blunt abdominal trauma: interval change of radiological characteristics. Radiat Med 24:358–364

Schulze CG, Blum U, Haag K (1995) Hepatic portal venous gas: imaging modalities and clinical significance. Acta Radiol 36:377–380

Schwartz SA, Taljanovic MS, Smyth S, O'Brien MJ, Rogers LF (2007) CT findings of rupture, impending rupture and contained rupture of abdominal aortic aneurysms. AJR Am J Roentgenol 188:57–62

Sebastia C, Quiroga S, Espin E, Boye R, Alvarez-Castells A, Armengol M (2000) Portomesenteric vein gas: pathologic mechanism. RadioGraphics 20:1213–1226

Seo BK, Ha HK, Kim AY et al (2003) Segmental misty mesentery: analysis of CT features and primary causes. Radiology 226:86–94

Shanmuganathan K, Mirvis SE (1998) CT evaluation of blunt hepatic trauma. Radiol Clin North Am 36:399–411

Shanmuganathan K, Mirvis SE, Amoroso M (1993) Periportal low density on CT in patients with blunt trauma: association with elevated venous pressure. AJR Am J Roentgenol 160:279–283

Shariatzadeh AN, Bolivar JC (1973) Transient incompetence of the sphincter of Oddi with pneumobilia: a case report. Am Surg 39:406–409

Sherman SC, Tran H (2006) Pneumobilia: benign or life-threatening. J Emerg Med 30:147–153

Shimono T, Nishimura K, Hayakawa K (1998) CT imaging of biliary enteric fistula. Abdom Imaging 23:172–176

Shinn SS, Jeong YY, Chung TW et al (2007) The sentinel clot sign: a useful CT finding for the evaluation of intraperitoneal bladder rupture following blunt trauma. Korean J Radiol 8:492–497

Siegel CL, Cohan RH (1994) CT of abdominal aortic aneurysms. AJR Am J Roentgenol 163:17–29

Silverman PM, Baker ME, Cooper C, Kelvin FM (1987) Computed tomography of mesenteric disease. RadioGraphics 7:309–320

Smith RC, Rosenfield AT, Choe KA et al (1995) Acute flank pain: comparison of non-contrast-enhanced CT and intravenous urography. Radiology 194:789–794

Smith RC, Verga M, McCarthy S, Rosenfield AT (1996) Diagnosis of acute flank pain: value of unenhanced CT. AJR Am J Roentgenol 166:97–101

Sorbello MP, Utiyama EM, Parreira JG, Birolini D, Rasslan S (2007) Spontaneous intramural small bowel hematoma induced by anticoagulant therapy: review and case report. Clinics 62:785–790

Soyer P, Martin-Grivaud S, Boudiaf M et al (2008) Linear or bubbly: a pictorial review of CT features of intestinal pneumatosis in adults. J Radiol 89:1907–1920

Stallard DJ, Tu RK, Gould MJ, Pozniak MA, Pettersen JC (1994) Minor vascular anatomy of the abdomen and the pelvis: a CT atlas. RadioGraphics 14:493–513

Stein MG, Crues JV 3rd, Hamlin JA (1983) Portal venous air with barium enema. AJR Am J Roentgenol 140: 1171–1172

Stevens SD, Heiken JP, Brunt E, Hanto DW, Flye MW (1991) Low-attenuation periportal collar in transplanted liver is not reliable CT evidence of acute allograft rejection. AJR Am J Roentgenol 157:1195–1198

Stroud WH, Cullom JW, Anderson MC (1981) Hemorrhagic complications of severe pancreatitis. Surgery 90: 657–665

Taourel PG, Deneuvielle M, Pradel JA, Regent D, Bruel JM (1996) Acute mesenteric ischemia: diagnosis with contrast-enhanced CT. Radiology 199:623–626

Taylor GA, Fallat ME, Eichelberger MR (1987) Hypovolemic shock in children: abdominal CT manifestations. Radiology 164:479–481

Torres GM, Abbitt PL, Weeks M (1994) CT manifestations of infarcted epiploic appendages of the colon. Abdom Imaging 19:449–450

Torricelli P, Coriani C, Marchetti M, Rossi A, Manenti A (2001) Spontaneous rupture of the spleen: report of two cases. Abdom Imaging 26:290–293

Tsai JA, Calissendorff B, Hanczewski R, Permert J (2000) Hepatic portal venous gas and small bowel obstruction with no signs of intestinal gangrene after appendicectomy. Eur J Surg 166:826–827

Van Bresla Vriesman AC, Lohle PN, Coerkamp EG, Puylaert JB (1999) Infarction of omentum and epiploic appendage: diagnosis, epidemiology and natural history. Eur Radiol 9:1886–1892

Van Dyck P, Vanhoenacker P, D'Haenens P (2001) Acute emphysematous cholecystitis. JBR-BTR 84:77

Venkatesh SK, Wan JM (2008) CT of blunt pancreatic trauma: a pictorial essay. Eur J Radiol 67:311

Waraich NG, Hudson JS, Iftikhar SY (2007) Vibrator-induced fatal rectal perforation. N Z Med J 120:U2685

Wechsler RJ, Munoz SJ, Needeleman L et al (1987) The periportal collar sign: a CT sign of liver transplant rejection. Radiology 165:57–60

White EM, Ankenbrandt WJ, Gore RM, Gharemani GG, Golan JF (1992) CT manifestations of ruptured abdominal aortic aneurysms (abstract). Radiology 185:359

Wiesner W, Mortele KJ, Glickman JN, Hoon J, Ros P (2001) Pneumatosis intestinalis and portomesenteric venous gas in intestinal ischemia: correlation of CT findings with severity of ischemia and clinical course. AJR Am J Roentgenol 177:1319–1323

Wittenberg J, Harisinghani MG, Jhaveri K, Varghese J, Mueller PR (2002) Algorithmic approach to CT diagnosis of the abnormal bowel wall. RadioGraphics 22:1093–1109

Wu JM, Wang MY (2009) Hepatic portal venous gas in necrotizing pancreatitis. Dig Surg 26:119–120

Yagan N, Auh YH, Fisher A (2009) Extension of air into the right perirenal space after duodenal perforation: CT findings. Radiology 250:740–748

Yao DC, Jeffrey RB, Mirvis SE et al (2002) Using contrast-enhanced helical CT to visualize arterial extravasation after blunt abdominal trauma: incidence and organ distribution. AJR Am J Roentgenol 178:17–20

Yen C, Chen J, Tui C, Chou Y, Lee C, Chang C, Yu C (2005) Internal hernia: computed tomography diagnosis and differentiation from adhesive small bowel obstruction. J Chin Med Assoc 68(1):21–28

Yoon W, Jeong YY, Kim JK (2006) Acute gastrointestinal bleeding: contrast-enhanced MDCT. Abdom Imaging 31:1–8

Young WS, Engelbrecht HE, Stroker A (1978) A plain film analysis in sigmoid volvulus. Clin Radiol 29:553–560

Zissin R (2000) The significance of a positive round belly sign on CT. AJR Am J Roentgenol 175:267–268