Diverticulitis

Jean-Michel Bruel and Patrice Taourel

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Abstract

Colonic diverticulosis, defined as a symptomless acquired disease resulting from the development of multiple diverticula on the colonic wall, is the most common colonic disease in Western industrial countries. The spectrum of acute diverticulitis, resulting from acute inflammation and infection of these diverticula, ranges from localized microperforation with a focal diverticulitis to life-threatening free perforation with generalized purulent or fecal peritonitis. After the initial clinical attack, recurrent episodes are frequently observed. The most common complication of diverticulitis is diverticular abscesses, much more severe when they are not confined to the mesocolon. The severity of a clinical episode of acute colonic diverticulitis is related to the development of pericolic lesions (abscess, fistula, peritonitis). In these conditions, computed tomography is now the diagnostic radiological examination of choice in patients with suspected acute diverticulitis, and should be used without delay in every patient in every clinical episode of acute diverticulitis (1) to confirm the diagnosis of acute diverticulitis, (2) to identify or exclude other causes of abdominal pain, (3) to evaluate the severity and the extent of the acute disease, and (4) to assist the decision management.

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1 Introduction

Diverticulitis is defined as inflammation of diverticula, or small outpouchings, of the digestive tract (Balthazar 1994; Ferzoco et al. 1998; Lawrimore and Rhea 2004; DeStigter and Keating 2009). Even though such an inflammation may occur in diverticula everywhere in the digestive tract (such as in the esophagus, stomach, duodenum, jejunum, or ileum), the term "diverticulitis" usually refers to the inflammation of colonic diverticula, and only this part will be discussed in this chapter.

Colonic diverticula are acquired herniations of the mucosa and of parts of the submucosa through the muscularis propria. Colonic diverticulosis is a clinically silent (symptomless) disease resulting from the development of multiple diverticula on the colonic wall. "Diverticular disease" includes the diverticulitis and its complications, and the diverticular hemorrhage. Diverticular hemorrhage is a complication of diverticulosis, but is not related to a clinical attack of diverticulitis, and therefore is discussed not in this chapter but in the chapter "Gastrointestinal Bleeding". "Colonic diverticulitis" refers to the acute inflammation and/or infection of diverticula. "Complicated diverticulitis" corresponds to the development of severe complications such as abscesses, fistula, peritonitis, and digestive stenoses resulting in bowel obstruction. The scheme devised by Hinchey et al. (1978) is a useful tool to classify the variety of inflammatory conditions encountered in patients with acute colonic diverticulitis according to the severity of the disease. This Hinchey scheme separates acute colonic diverticulitis into four stages: stage I pericolic abscess or phlegmon; stage II pelvic, intra-abdominal, or retroperitoneal abscess; stage III generalized purulent peritonitis; and stage IV generalized fecal peritonitis. It has good correlation with the morbidity and mortality of the disease.

2 Epidemiology

Colonic diverticulosis is the most common colonic disease in Western industrial nations, with an estimated incidence of 30% in individuals over 50 years old and up to 50% in individuals over the age of 70 and 66% in individuals over the age of 85 (Ferzoco et al. 1998). The acquired herniations of the colonic mucosa through weak spots of the muscularis propria (mostly at sites where the vasa recta perforate the muscularis propria and penetrate the submucosa) commonly result in multiple diverticula. The diverticular wall is therefore thin, including the mucosa and portions of the submucosa, but not the muscularis propria. The size of the diverticula ranges from tiny spikes to larger spheres up to 2 cm in diameter. Diverticula are found in all parts of the colon, although by far the most common location is the sigmoid, where the intraluminal pressure is the highest, particularly as a response to a lifelong consumption of a low-residue diet (producing low-volume stools that require a high degree of propulsive effort for expulsion). The colonic wall of patients with diverticulosis is markedly thickened by "myochosis" (Balthazar 1994; Ferzoco et al. 1998; Lawrimore and Rhea 2004).

3 Physiopathology

Diverticulitis occurs in 10–35% of patients with diverticulosis. The pathological basis is an infection and inflammation of the apex of a diverticulum, resulting in a microperforation of the diverticulum wall and spreading rapidly into the surrounding pericolic and mesocolic fat inflammation. Consequently, the pivotal lesions of the disease may be better described as "peridiverticulitis" or pericolitis, and the severity of a clinical attack of the disease is related to the development of the pericolic lesions (abscess, fistula, and peritonitis) (Balthazar 1994; Ferzoco et al. 1998; Lawrimore and Rhea 2004). However, the terms"perforated diverticulitis" and "perforated diverticulum" should be reserved for free (not-walled-off) perforation into the peritoneal cavity, resulting in purulent or fecal peritonitis (Ferzoco et al. 1998). These physiopathological data stress the importance of the use of cross-sectional imaging for direct visualization of both the intramural component (diverticula and colonic wall thickening) and the extramural component (inflammatory changes in the pericolic fat and advanced complications) of diverticular disease.

4 Clinical Findings

The clinical diagnosis of acute colonic diverticulitis may be difficult. The classic pattern of left lower quadrant pain, tenderness, fever, and leukocytosis is

theoretically suggestive of acute colonic diverticulitis (Balthazar 1994; Ferzoco et al. 1998; Lawrimore and Rhea 2004; DeStigter and Keating 2009) but the complete combination of these signs is actually seldom found. In a large prospective study including 542 patients with acute diverticulitis of the descending or sigmoid colon, a temperature of more than 99.5°F was found in only 77% of patients and leukocytosis of more than 11,000/mL was found in 54% of patients (Ambrosetti et al. 2002). Moreover numerous acute abdominal conditions can mimic the classic pattern of a diverticulitis, and a final diagnosis of acute colonic diverticulitis is assessed in less than 50% of patients with clinically suspected diverticulitis. Finally, even though clinical and biological findings can indicate the diagnosis of acute colonic diverticulitis, they may fail to assess the site and the severity of the pericolic extension of the lesions. Severe diverticulitis can occur in certain groups of patients with altered immunity response; these risk factors include debilitated elderly patients, patients with renal disorders, and patients receiving corticosteroids or nonsteroidal anti-inflammatory drugs. It has been reported that the initial attack is frequently more severe and that recurrent episodes of diverticulitis do not lead to more complications and more conservative treatment failure (Pittet et al. 2009). Several observers have emphasized that the frequency of acute colonic diverticulitis is increasing in young people (less than 40 years old), particularly with obesity (Shah et al. 2010), and that young patients often develop more severe forms of diverticulitis (Simonowitz and Paloyan 1977; Chodak et al. 1981; Ouriel and Schwartz 1983; Freischlag et al. 1986; Ambrosetti et al. 1994; Hall et al. 2010), but this last issue remains controversial (Zaidi and Daly 2006).

Thus the systematic use of a technique assessing the diagnosis accurately and evaluating the severity of the disease is of outstanding importance. This technique used today is computed tomography (CT).

5 CT Findings

The use of CT for evaluation of acute colonic diverticulitis was initially reported more than 25 years ago (Hulnick et al. 1984; Cho et al. 1990; Balthazar et al. 1990; Pradel et al. 1997) but the diagnosis and management of patients with diverticulitis was dramatically improved with the development of multidetector CT at the beginning of the twenty-first century and CT is nowadays the method of choice. Multidetector CT scanners allow thinner section slices, and a shorter examination time, resulting in images with better resolution and high-quality coronal and sagittal images (Kircher et al. 2002 ; Werner et al. 2003). Moreover, the prospective study by Ambrosetti et al. (2000), demonstrating the higher accuracy of CT versus contrast enema (CE), is of outstanding importance for the definitive acceptance of CT as the method of choice.

The use of CT in patients with suspected diverticulitis requires careful attention to the CT protocol.

The multidetector CT image data volume should be obtained from the dome of the diaphragm to the inferior aspect of the pubic symphysis (with thin collimation and a short acquisition time); CT data are reconstructed with thin, overlapped slices for multiplanar (coronal and sagittal planes) reformation and 3–5-mm-thick contiguous axial slices; the image series are sent to a dedicated workstation and/or a picture archiving and communication system.

Vascular enhancement by iodinated contrast material is mandatory in most cases, unless it is contraindicated; special attention should be paid to older patients and those with metabolic disorders in assessing the renal impact of contrast material administration. In general, the most helpful scanning phase is the late portal phase (70 s) for a better delineation of the colonic wall and the enhanced wall of small pericolic abscesses, but also for evaluating the mesenteric vessels by systematically looking for inferior mesenteric and portal vein thrombosis, and hepatic abscesses, acute colonic diverticulitis being the main cause of the septic thrombosis of the portal vein. Multiphasic scanning should be used only for specific indications to limit the radiation dose particularly in young patients with colonic diverticular disease that may lead to recurrent acute episodes. This stresses the development of CT protocols with a low radiation dose (Tack et al. 2005).

Changes in the CT protocol should be decided on according to the clinical conditions and/or the preliminary results of the CT examination. In selected cases, colorectal opacification (Figs. 1, 2) and/or acquisition of images with the patient in the prone position may be helpful to clarify equivocal findings, particularly for assessing the extradigestive

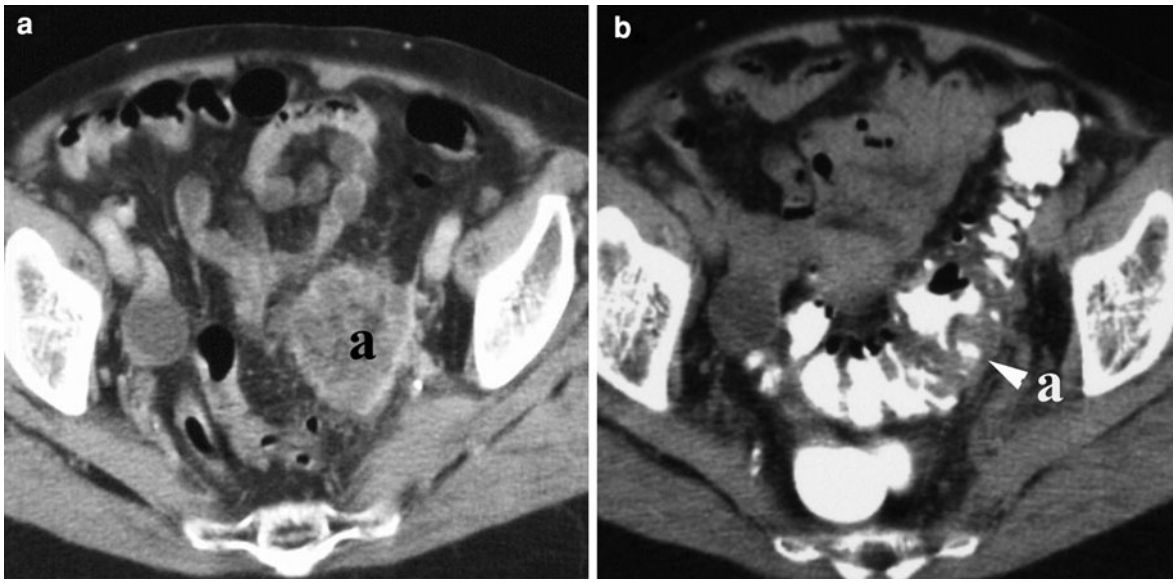

Fig. 1 Acute diverticulitis of the sigmoid colon (complicated by a large abscess). Technical protocol of computed tomography (CT) examination: axial CT slices before (**a**) and after (**b**) colonic contrast material administration through a rectal tube. **a** The heterogeneous content of the abscess (*a*). **b** After colonic contrast material administration, spread of the colonic contrast material into the abscess's cavity is clearly visible (*arrowhead a*)

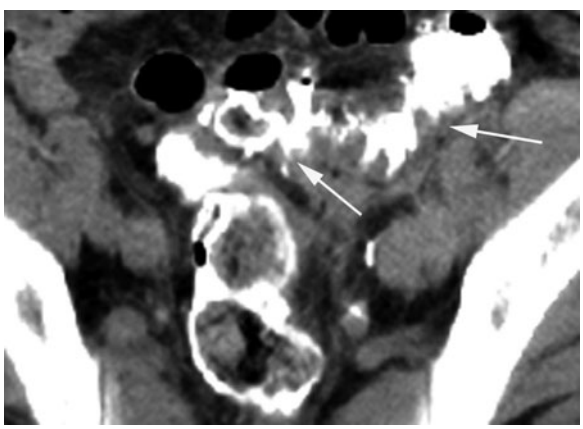

Fig. 2 Acute diverticulitis of the sigmoid colon. Technical protocol of CT examination: multidetector CT (MDCT) examination after rectal administration of colonic contrast material. The coronal reformat shows several "arrowhead sign" patterns (*arrows*), defined by an arrowhead-shaped configuration of contrast material found at the narrowed neck of a diverticulum

location of a small amount of gas and/or the route of a sinus tract or a complex fistula, and to demonstrate the "arrowhead sign," defined as an arrowhead-shaped configuration of contrast material found at the narrowed neck of a diverticulum (Rao and Rhea 1998; Kircher et al. 2002). As many authors, we do not use oral contrast material.

The method of image evaluation is critical to optimize interpretation; additional window level and width settings are mandatory to identify tiny bubbles of extraluminal gas (CT lung windows); the systematic use of multiplanar reformation, particularly in the coronal plane, is recommended (Paulson et al. 2004; Ghekiere et al. 2007).

The main CT findings for the diagnosis of acute colonic diverticulitis are nowadays well established (Pradel et al. 1997; Lefèvre et al. 1999; Horton et al. 2000; Kircher et al. 2002; Werner et al. 2003) and associate both the intramural patterns (diverticula and bowel wall thickening) and the extramural patterns consisting in inflammatory changes in the pericolic and mesocolic fat (Fig. 3).

Thickening of the bowel wall should be considered as present when the thickness of the colonic wall, evaluated in a colonic segment with a slightly distended lumen, exceeds 4 mm. Diverticula are easily identified as flask-shaped outpouchings from the colonic wall, filled with air or residues of fecal or contrast material. Actually, the hallmark of acute diverticulitis on CT scans is the alteration of the pericolic fat (Balthazar 1994; Kircher et al. 2002;

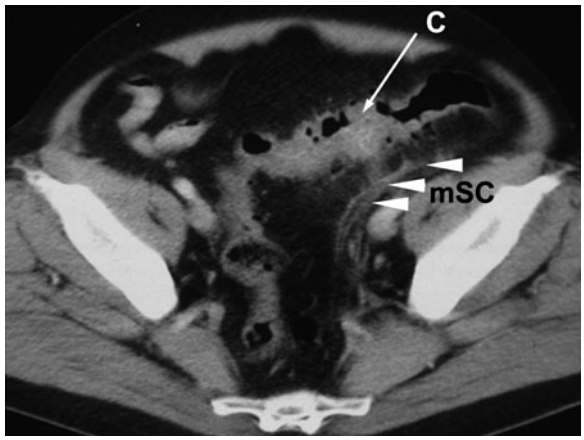

Fig. 3 Nonsevere acute colonic diverticulitis, without any abscess. Characteristic patterns combine intramural patterns—note the thickening of the colonic wall with progressive transition (*arrow C*) and the numerous small air-filled diverticula—and extramural patterns with thickening of the root of the sigmoid mesocolon (*arrowheads mSC*) and the pericolic fat stranding within the mesocolon

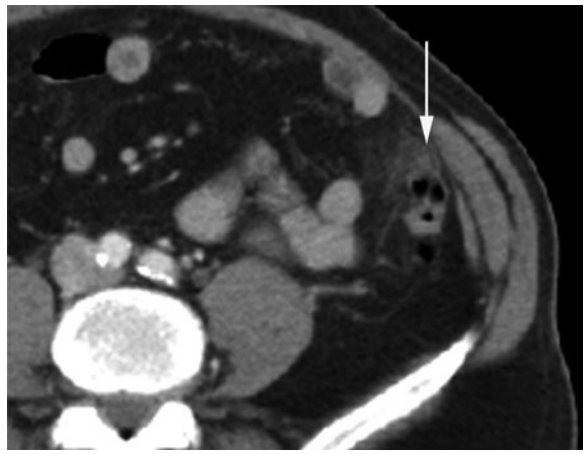

Fig. 5 Focal acute diverticulitis at the descending–sigmoid colon transition. The MDCT axial slice depicts linear or inhomogeneous soft-tissue attenuation interspersed in the pericolic fat, and defined as "fat stranding". Note the diverticulum located in the center of fat stranding, representing the sign of "inflamed diverticulum"

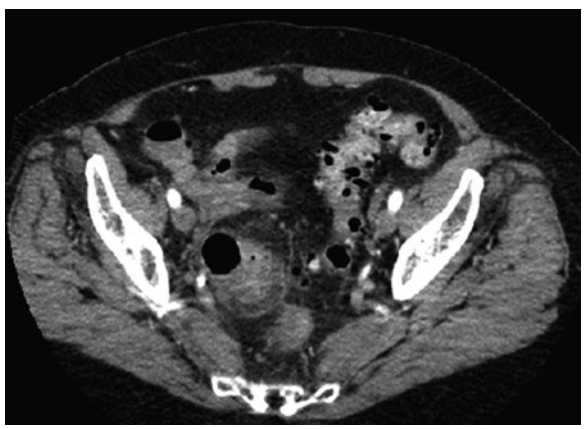

Fig. 4 Diverticulosis without any patterns indicating acute diverticulitis. Note the thickening of the wall of the sigmoid colon and the numerous diverticula of various sizes, filled with air and/or residues of fecal or colonic contrast material

Pereira et al. 2004) because the intramural patterns such as diverticula and bowel wall thickening related to myochosis, even in combination, can be observed in diverticulosis, from any acute disease, as demonstrated in Fig. 4.

The basic alteration of the pericolic fat is the fat stranding, which is defined as a linear or inhomogeneous soft-tissue density interspersed in the fat. The degree of the extracolic inflammatory reaction varies depending on the size of perforation, bacterial contamination, and host response. In focal diverticulitis only a slight increase in the attenuation of fat adjacent to a single diverticulum may be present, and the "inflamed diverticulum" pattern has been defined as a diverticulum located in the center of fat stranding (Kircher et al. 2002) (Figs. 5, 6).

In mild cases with a walled-off perforation into the mesocolon, thickening of the root of the sigmoid mesocolon, fine linear strands, and tiny bubbles of extraluminal gas within the mesocolon can be seen (Fig. 7). In severer cases, heterogeneous soft-tissue densities representing phlegmons and/or partially loculated fluid collections (that may or may not contain tiny bubbles of gas and/or air–fluid level) representing abscesses can develop in the mesocolon (Figs. 8, 9, 10) or more distantly in the peritoneal cavity (Fig. 11) or the retroperitoneum (Fig. 12).

Blind sinus tracts and fistulas are depicted as linear or tubular branching structures within the pericolic tissues. They may contain bubbles of gas and/or colonic contrast material. They can terminate in an abscess (sinus tract) or communicate with adjacent organs (fistulas). The presence of free fluid, depicted as water density fluid within the inferior peritoneal spaces (pelvic peritoneal recesses particularly), may be related to a nonspecific inflammatory reaction of the peritoneum. Instead, free peritoneal air, depicted as a large amount of gas or tiny bubbles of gas free in

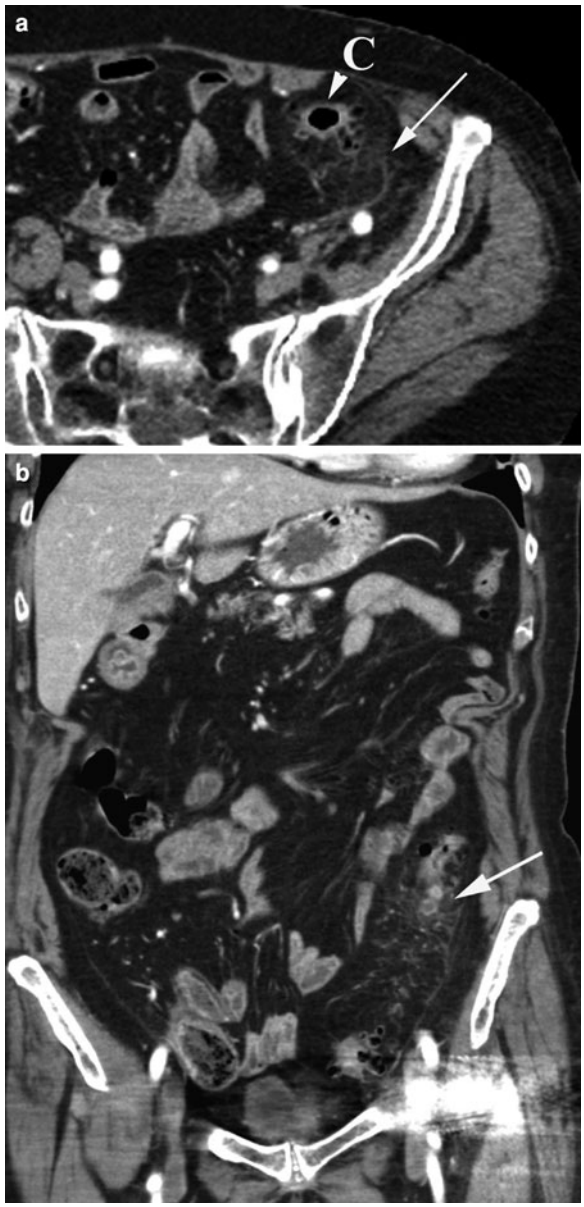

Fig. 6 Focal acute diverticulitis of the descending colon. MDCT examination with axial slice (**a**) and coronal reformat (**b**). **a** The CT axial slice depicts the thickening of the colonic wall (*arrowhead C*), numerous air-filled diverticula, and typical pericolic fat stranding with a slight thickening of the root of the mesocolon (*arrow*). **b** The coronal reformat shows the extent of the fat stranding and mesocolon thickening. Inflamed diverticula slightly thickened and enhanced are clearly visible (*arrow*). Note the punctiform and linear patterns of the pericolic fat alteration and the absence of extradigestive gas

the peritoneal cavity, indicates a free perforation rapidly resulting in generalized purulent peritonitis (Fig. 11). In fecal peritonitis, consisting in the most

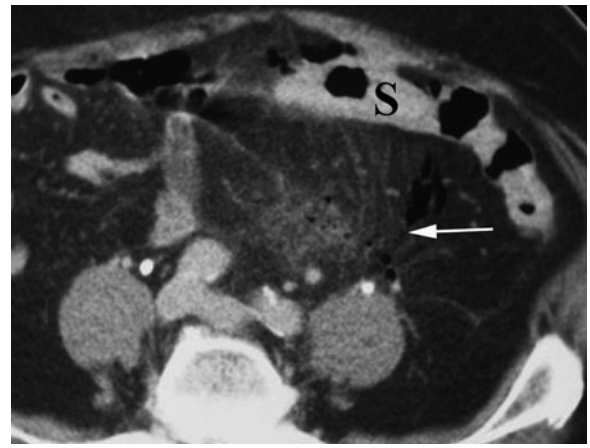

Fig. 7 Acute colonic diverticulitis. Mild form of the disease with a walled-off perforation resulting in an inflammatory lesion confined within the sigmoid mesocolon. The CT axial slice demonstrates the fat stranding of the sigmoid mesocolon. Within this lesion, tiny bubbles, and a slightly larger pocket, of extradigestive gas (*arrow*) are clearly visible

severe complication of acute colonic diverticulitis, fecal material spreads out of the colonic lumen, through a wide perforation of the colonic wall, into the peritoneal cavity.

6 CT Pitfalls and Limits

In 50–70% of patients with clinically suspected diverticulitis this disease is not confirmed as the final diagnosis (Cho et al. 1990; Pradel et al. 1997; Rao et al. 1998; Ambrosetti et al. 2000; Kircher et al. 2002).

Currently CT is the imaging test of choice to identify or exclude other causes of left lower quadrant pain mimicking sigmoid diverticulitis. In patients with left lower quadrant pain, alternative diagnoses that should be considered (Table 1) include colitis (infectious/inflammatory or ischemic), colonic carcinoma, epiploic appendagitis, neutropenic colitis, functional colonic disorders, and extragastrointestinal disorders (pyelonephritis or gynecologic diseases), but differentiating sigmoid diverticulitis from carcinoma remains the major differential diagnostic consideration.

Special attention should be paid to epiploic appendagitis, differentiation of diverticulitis from carcinoma, right-sided colonic diverticulitis, and the limits resulting from delayed CT diagnosis of acute diverticulitis.

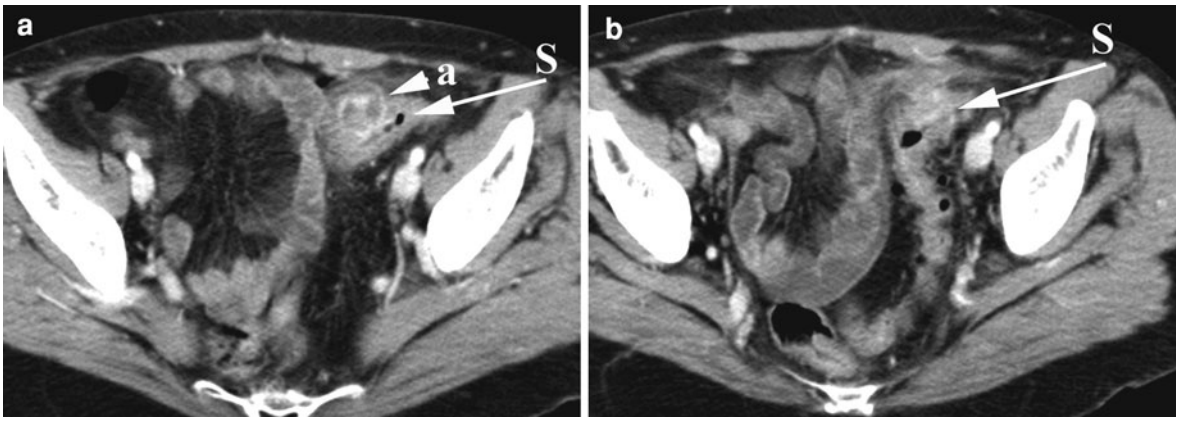

Fig. 8 Acute colonic diverticulitis. Severer form (Hinchey stage I) of the disease. CT axial slices demonstrate a small (less than 3 cm in diameter) fluid-filled abscess, partially loculated (**a**), with an enhanced thickened wall (*arrowhead a*). This lesion is abutting the sigmoid colon (*arrow S*) altered by numerous diverticula spreading distally (**b**), remains confined to the sigmoid mesocolon, and should be described as stage I in the Hinchey scheme

Table 1 Alternative causes of left lower quadrant pain mimicking acute colonic diverticulitis

Colitides
Ischemic colitis
Infectious colitis
Granulomatous colitis
Ulcerative colitis
Neutropenic colitis
Colonic carcinoma
Epiploic appendagitis[a] (Jalaguier et al. 2010)
Bowel obstruction[a] (Kim et al. 1998)
Functional colonic disorders
Extragastrointestinal disorders
Renal colic
Pyelonephritis
Gynecologic diseases[a] (Panghaal et al. 2009)

[a] May also occur as a complication of acute colonic diverticulitis, as reported in the literature and shown on the chapter dealing with acute gynecological disease

6.1 Epiploic Appendagitis

Epiploic appendagitis can be primary or secondary. Primary epiploic appendagitis develops secondary to acute inflammation resulting from the torsion of epiploic appendices (Rioux and Langis 1994; Singh et al. 2005; de Brito et al. 2008) and ischemia by obstruction and/or thrombosis of appendiceal drainage veins. The most common sites of acute epiploic appendagitis are areas adjacent to the sigmoid colon and the descending colon. Primary epiploic appendagitis results in a clinical condition mimicking acute colonic diverticulitis with focal exquisite lower abdominal pain, diagnosed with CT (or ultrasonography) by the demonstration of an ovoid lesion within the pericolic fat, surrounded by inflammatory changes and abutting the colonic wall (Fig. 13). Epiploic appendagitis is usually a self-limiting condition that can be managed conservatively with oral anti-inflammatory medications and resolves spontaneously within a few days. It is important to correctly diagnose acute epiploic appendagitis on CT images to avoid unnecessary hospital admission, antibiotic therapy, laboratory testing, dietary restrictions (Singh et al. 2005), and/or, moreover, unnecessary surgery. Secondary epiploic appendagitis can occur in patients with pericolic inflammatory changes, as in acute diverticulitis or other colitides, from spreading inflammatory process to the local epiploic appendages, and a resultant difficulty of diagnosis on the basis of CT images (Jalaguier et al. 2010).

6.2 Differentiation of Diverticulitis from Carcinoma

Colonic carcinoma is the main consideration in the differential diagnosis for the findings on CT. The presence of diverticula in an involved colonic

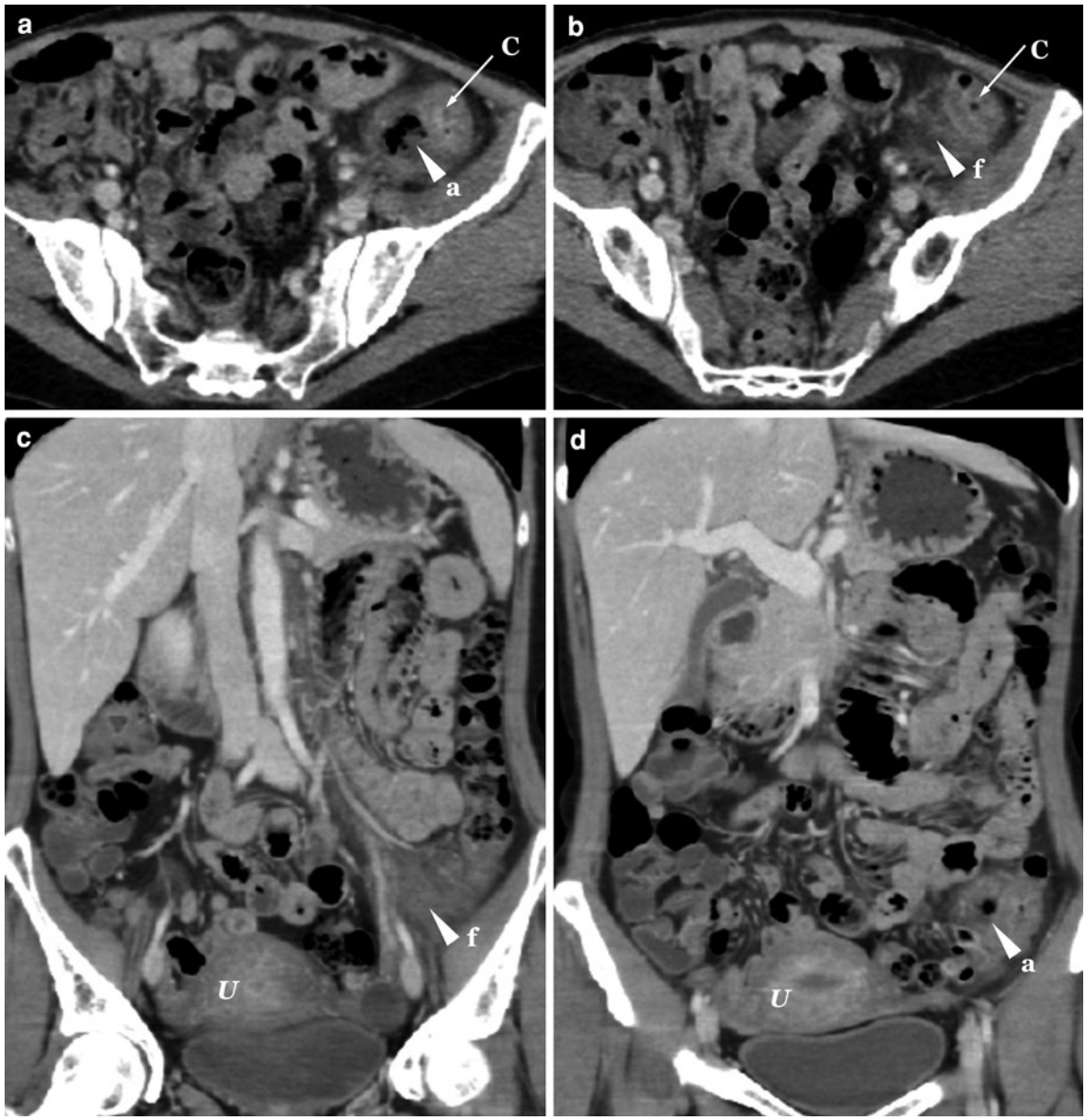

Fig. 9 Left lower quadrant pain with fever occurring in a young female patient in the postpartum period. Acute colonic diverticulitis of the junction of the descending colon with the sigmoid colon is easily confirmed by MDCT with axial slices (**a**, **b**) and coronal reformats (**c**, **d**) demonstrating a collection (*arrowhead a*), with a thickened wall and air content, developed close to the colon (*arrow C*) and confined within the altered fat (*arrowhead f*) of the mesocolon. Coronal reformats evaluate the extent of the lesion clearly within the mesocolon; note the postpartum enlarged uterus (*U*)

segment cannot be used to exclude neoplasm because of the high prevalence of diverticulosis in the general population. In general, pericolic fat stranding with fluid at the root of the mesocolon and engorgement of blood vessels is more suggestive of diverticulitis than of neoplasm. Instead, colonic wall thickening is usually greater (more than 2 cm), more focal, more eccentric, and with a more abrupt zone of transition with overhanging edges (Fig. 14) in neoplasm than in diverticulitis. But a colonic carcinoma, particularly

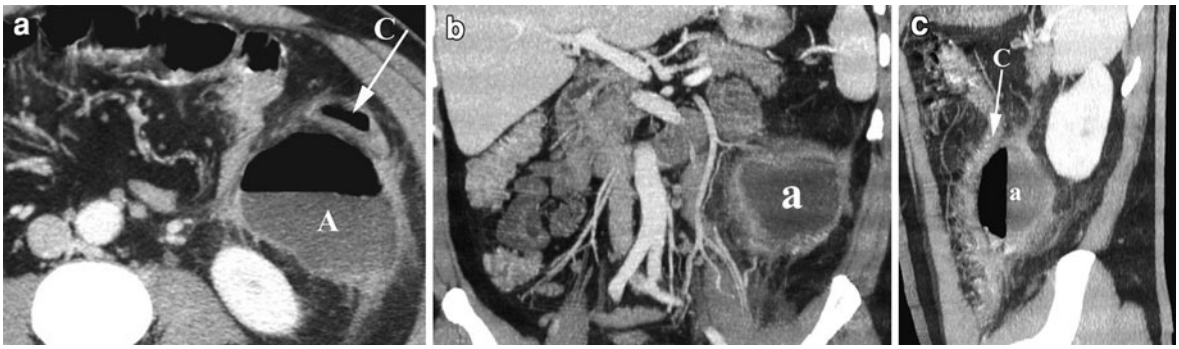

Fig. 10 Acute diverticulitis of the descending colon complicated by a large, but confined abscess, without any spread into the peritoneal cavity. The CT axial slice (**a**) shows a large abscess (*A*) containing an air–fluid level. The coronal reformat (**b**) according to a posterior plane (through the purulent content *a* of the abscess) demonstrates the anatomical relationships between the abscess and the inferior mesenteric vessels. The sagittal reformat (**c**) evaluates the displacement of the descending colon anteriorly (*arrow C*). (Courtesy of D. Regent, Nancy, France)

when the tumor is perforated and or altered by inflammatory reaction, may mimic diverticulitis. Several studies have stressed both the difficulties and limits of this differential diagnosis and have tried to assess specific signs of diverticulitis versus carcinoma (Balthazar et al. 1990; Padidar et al. 1994; Chintapalli et al. 1999). The most helpful issues are the following: (1) the presence of numerous pericolic lymph nodes (measuring 1 cm or more in the short axis) is more frequent in carcinoma, (2) the combination of a mild circumferential thickening of the colonic wall longer than 10 cm with a progressive transition with the nonnarrowed proximal and distal colon, and inflammatory changes of the mesocolon are suggestive of diverticulitis, and (3) none of these CT signs, isolated or in combination, have sufficient specificity for a definitively correct diagnosis.

Goh et al. (2007) reported that CT perfusion measurements enable differentiation and better discrimination, in comparison with morphologic criteria, between cancer and diverticulitis. However, in every patient medically managed for acute diverticulitis, it is crucial to perform colonoscopy 4–6 weeks after the onset of acute diverticulitis to rule out a colonic carcinoma (Haute Autorité de Santé 2006; Zins et al. 2007). If videocolonoscopy is contraindicated or not accepted, a CT examination dedicated to the precise analysis of the colon such as virtual colonoscopy (Hjern et al. 2007; Laurent 2007) or colo-CT examination after water enema (Pilleul et al. 2006) may be used.

6.3 Right-Sided Colonic Diverticulitis

Cecal diverticulitis is a relatively rare pathologic entity in Western countries. Cecal diverticula are classified as true (congenital) or false (acquired). The congenital variety is usually larger and solitary and occurs more frequently in Asian individuals, and is characterized by a fully developed digestive wall, including the different layers of the digestive wall, and particularly the muscularis propria. Most diverticula of the cecum and the ascending colon are acquired and are similar to diverticula currently found in the remainder of the colon (sigmoid, descending, and transverse colon).

Right-sided acute diverticulitis is often clinically misdiagnosed regarding the numerous alternative diagnoses possible in a patient with right lower quadrant pain (Jang et al. 2000; Lee et al. 2008).

The main consideration in the differential diagnosis is acute appendicitis but other diseases that can present with acute right lower quadrant pain, including acute terminal ileitis (Crohn's disease), typhlitis, and, in women, pelvic inflammatory disease, complications of ovarian cyst (hemorrhage, torsion, and leak), endometriosis, and ectopic pregnancy. Less common causes of right lower quadrant pain include segmental infarction of the greater omentum, mesenteric adenitis, epiploic appendagitis, perforated cancer, and ileal or Meckel's diverticulitis.

CT findings in right-sided acute diverticulitis are similar to those depicted in the sigmoid colon:

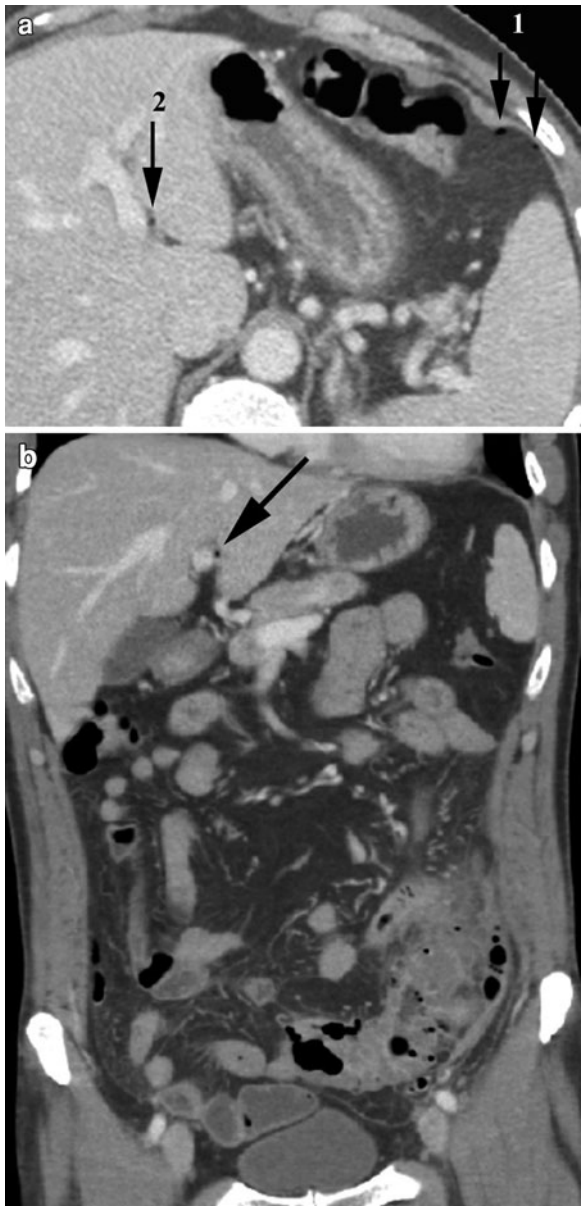

Fig. 11 Severe acute colonic diverticulitis of the junction of the descending colon with the sigmoid colon. Free perforation into the peritoneal cavity is confirmed by MDCT axial slices (**a**) and coronal reformat (**b**). The CT demonstration of tiny bubbles of extraluminal gas within the left side of the subphrenic space (*arrows* 1) and hepatic pedicle (arrow 2), indicating a pneumoperitoneum from the perforated sigmoid diverticulitis (**b**), requires dedicated window settings. Note the regional pericolic spread of the disease with badly limited inflammatory mass and multiple pockets of extradigestive gas. This acute colonic diverticulitis should be described as stage III in the Hinchey scheme (generalized purulent peritonitis), and requires emergency surgery

diverticulum (with or without a high-attenuation value stercolith), bowel wall thickening, and changes of the pericolic fat (with fat stranding, and abscess in severer forms). CT may be helpful by demonstrating a normal entire appendix and ruling out appendicitis. Other CT findings may be the inflamed diverticulum sign (Fig. 15) and the depiction of a stercolith within the diverticulum. Currently it is difficult to differentiate advanced cecal diverticulitis from cecal neoplasm; the precise preoperative diagnosis is difficult and the most helpful patterns for the diagnosis of diverticulitis may be the inflamed diverticulum sign and the depiction of a multilayered diverticulum wall on a high-resolution enhanced CT scan (Jang et al. 2000).

6.4 Delayed Diagnosis of Diverticulitis

One of the main difficulties of CT in diverticulitis is a too long interval between the clinical onset of the acute episode and the time when the CT examination is performed. Too many patients with likely nonsevere clinical forms of acute diverticulitis are medically managed, particularly as outpatients, without any morphological evidence, and the CT examination is finally performed several days (or weeks) after the medical treatment starts; in such a condition, the CT examination may show few signs, limited to the depiction of diverticula and bowel wall thickening, which may indicate only a diverticulosis, and the significant patterns, indicating the acute episode and its severity, may have disappeared. Moreover, this lack of evidence is critical: the choice of the correct management of a patient who has likely had several recurrent episodes and for whom there is indication for elective surgical resection of the sigmoid colon should be discussed as a function of the evidence and the severity of the acute episodes of diverticulitis (Haute Autorité de Santé 2006).

7 CT Impact on the Management

The recommendation to perform a nondelayed CT scan in every patient when acute diverticulitis is clinically suspected serves the following functions: (1) to confirm the diagnosis of diverticulitis, (2) to evaluate the severity and extent of disease, (3) to

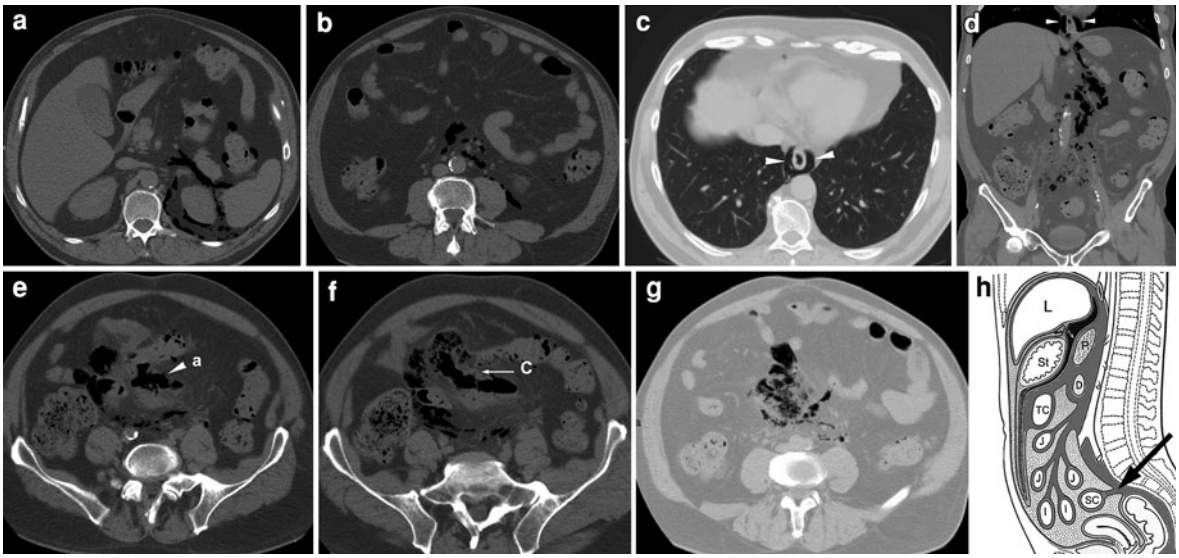

Fig. 12 Severe acute sigmoid diverticulitis. Free perforation into the retroperitoneum. Perforation of the diverticulitis into the subperitoneal space is not confined to the sigmoid mesocolon. Extradigestive air spreads to the retroperitoneal space, resulting in retroperitoneal emphysema ("pneumoretroperitoneum") dissecting the fatty retroperitoneal content, and depicted as linear tracts and/or small rounded pockets of air-attenuation values (**a**, **b**). This retroperitoneal emphysema spreads to the inferior mediastinum (*arrowheads* in **c**, **d**). On the inferior MDCT slices (**e**, **f**), note that retroperitoneal gas is abutting a juxtacolic abscess (*arrowhead a*) and inflamed sigmoid colon (*arrow C*) with thickened wall and air-filled diverticula. **g** The axial CT slice with dedicated settings of the window level and width (CT lung windows) demonstrates clearly the patterns of extradigestive gas spreading into the retroperitoneal spaces. **h** The sagittal view drawing demonstrates the continuity of the subperitoneal space of the sigmoid mesocolon with retroperitoneum (in *gray*); the *black arrow* points to the continuity of the sigmoid mesocolon with retroperitoneum. *D* duodenum, *I* ileum, *J* jejunum, *L* liver, *P* pancreas, *SC* sigmoid colon, *St* stomach, *TC* transverse colon. (**h** From Ragu 2010)

assist the treatment planning of complications such as abscess, and (4) to demonstrate other causes of abdominal pain that may mimic diverticulitis.

7.1 CT Confirms the Diagnosis of Diverticulitis

The initially reported sensitivities of CT for the diagnosis of acute diverticulitis ranged from 69 to 95%. With the advancement of CT scan technology, the improving technique of CT examination, the more precise CT criteria, and the greater experience in the interpretation of these CT findings, the reported sensitivities for the diagnosis of diverticulitis have progressively increased up to 98–99% (Table 2).

In a study including 312 patients and with the use of thin-section helical CT with colonic contrast material, the overall CT interpretation had sensitivity, specificity, positive and negative predictive values, and overall accuracy of 99% (Kircher et al. 2002).

7.2 CT Evaluates the Severity and Extent of Diverticulitis

The severity of a clinical attack of the disease (initial or recurrent episode) is related to the development of the extracolic lesions (abscess, peritonitis, fistula, and portal septic thrombosis). CT can evaluate the locoregional and distant spread of the infection accurately, and CT findings correlate with the surgical staging scheme reported by Hinchey et al. (1978) and its adaptation by Wasvary et al. (1999). Moreover the Hinchey scheme correlates with the mortality of the disease: 0, 4, 20, and 45% in Hinchey stages I, II, II, and IV, respectively (Nespoli et al. 1993) (Table 3).

CT is also known to be a helpful method to investigate patients with bowel obstruction (Taourel

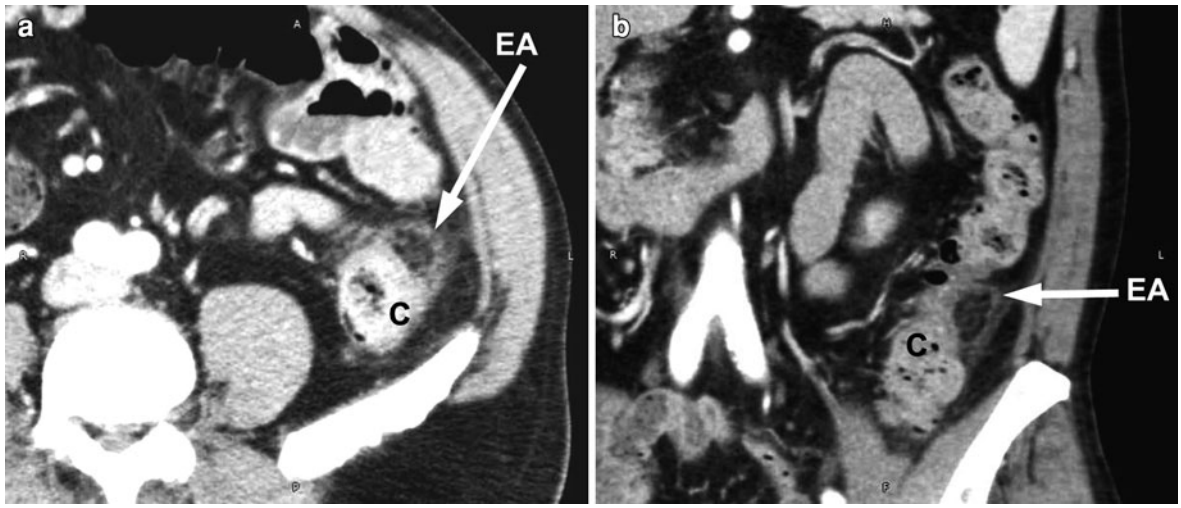

Fig. 13 Epiploic appendagitis depicted on MDCT axial slice (**a**) and coronal reformat (**b**) of the left iliac fossa. CT images demonstrate an ovoid lesion (*arrow EA*) within the pericolic fat, abutting the wall of the descending colon (*C*)

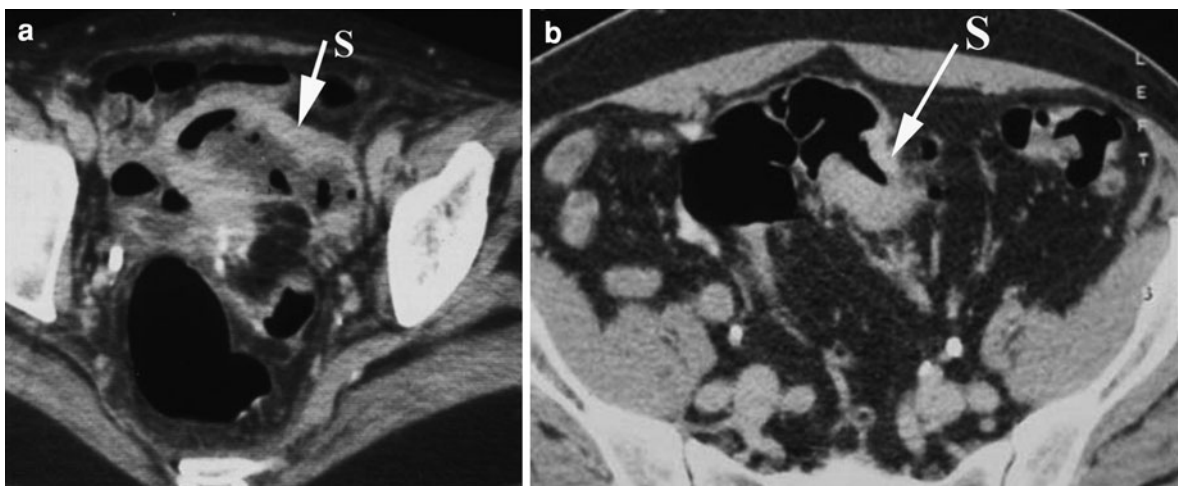

Fig. 14 Perforated carcinoma of the sigmoid colon (*arrow S*). CT axial images demonstrate a 4-cm-long thickening of the colonic wall and inflammatory changes of the pericolic fat (**a**). The abruptly altered caliber of the colonic lumen with overhanging-edge thickening of the bowel wall should suggest a carcinoma rather than a diverticulitis (**b**)

et al. 1995), particularly complicating acute colonic diverticulitis.

7.2.1 Diverticular Abscesses

Abscess formation occurs in 16–35% of patients with acute diverticulitis, and the severity of this complication depends on the size, number, and mainly location of the abscess.

Hinchey stage I denotes a phlegmon or abscess confined to the mesocolon and that is commonly less than 3 cm in diameter. These patients are currently managed with antibiotics and dietary restrictions. A follow-up CT examination is recommended, depending on the clinical condition, to rule out progression to a severer stage of the disease. In the case of unsuccessful medical management, surgical resection by open laparotomy or laparoscopy is indicated, with or without the protection of a proximal diverting colostomy.

In Hinchey stage II, a pericolic abscess spreads to the pelvic and/or abdominal peritoneal recesses, or to the retroperitoneum, but remains contained by an

Table 2 Diagnostic value of computed tomography for suspected acute colonic diverticulitis

Investigation	No. of patients	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)	Alternative diagnosis seen (%)
Cho et al. (1990)	56	93	100	NA	NA	NA	69
Stefánsson et al. (1997)	88	69	100	NA	NA	NA	NA
Pradel et al. (1997)	64	91	77	81	88	84	50
Rao et al. (1998)	150	97	100	100	98	98	58
Ambrosetti et al. (2000)	420	98	NA	97	NA	NA	NA
Kircher et al. (2002)	312	99	99	99	99	99	70

NA not applicable

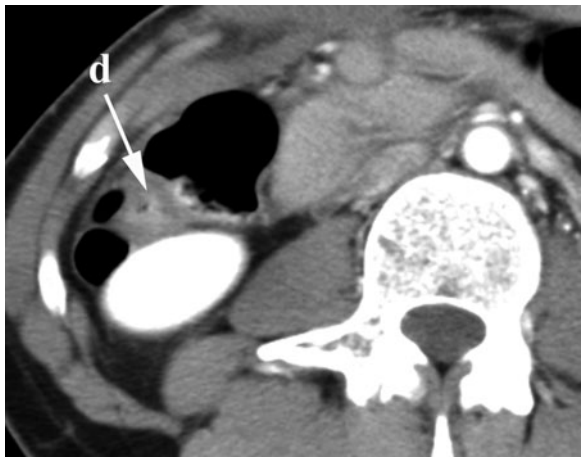

Fig. 15 Right-sided diverticulitis. The CT axial image demonstrates a slightly enhanced diverticulum (*arrow d*) wall within the altered pericolic fat, close to the descending colon

abscess wall and the surrounding peritoneal or retroperitoneal structures. Large abscesses (5 cm in diameter) are treated with antibiotics, but a complementary interventional procedure by percutaneous drainage may be indicated. Large pericolic abscess may be difficult to differentiate from a giant colonic diverticulum (Steenvoorde et al. 2004; Thomas et al. 2006; Chatora and Kumaran 2009).

7.2.2 Peritonitis

Hinchey stage III corresponds to a generalized purulent peritonitis. More than the clinical findings

Table 3 Hinchey's surgical scheme of acute diverticulitis and correlation to mortality

Stage	Surgical criteria	Mortality (%)
I	Phlegmon or abscess confined to the mesocolon	0
II	Abscess within the pelvis, abdomen, or retroperitoneum	4
III	Generalized purulent peritonitis	20
IV	Fecal peritonitis	45

From Hinchey et al. (1978) and Nespoli et al. (1993)

(diffuse abdominal guarding and other clinical signs of peritonitis), sometimes masked by the immunoreactive behavior of the patient, the presence of free peritoneal gas, even as very tiny bubbles trapped in peritoneal recesses or within the subphrenic spaces (Fig. 11), is diagnostic of generalized peritonitis and indicates emergency surgery. The indication for a single-stage colonic resection versus resection with anastomosis protected by a proximal lateral diverting colostomy versus Hartman's procedure depends on the operative findings and general condition of the patient.

Hinchey stage IV is defined by a fecal spread into the peritoneal cavity, through a large perforation of the bowel wall, resulting in fecal peritonitis with life-threatening sepsis. Patients with this most severe complication of colonic diverticulitis should undergo immediate laparotomy.

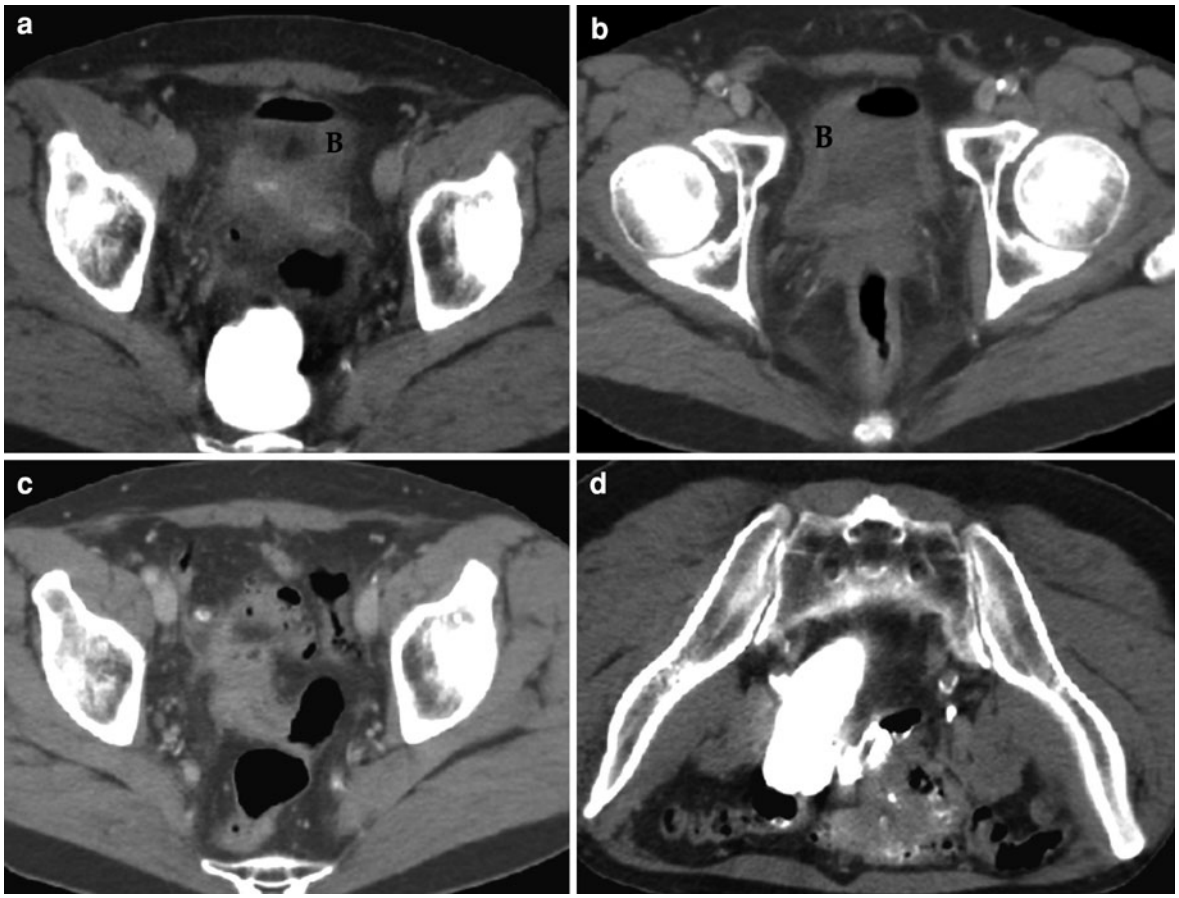

Fig. 16 Severe acute sigmoid diverticulitis with colovesical fistula. CT axial slices easily demonstrate gas within the urinary bladder; note the thickening of the bladder wall (*B*) and the air–fluid level in the anterior part of the bladder (**a**). The sigmoid colon is altered by an inflammatory process, with an inflammatory mass abutting the bladder wall (**b**) but the full assessment of the fistula route remains difficult (**c**), even after administration of colonic iodinated contrast rectally and CT scanning with the patient in the prone position (**d**)

7.2.3 Fistulas

Five percent to 9% of surgical operations for complicated diverticulitis are related to fistula. Colovesical fistulas are the most frequent fistulas complicating acute colonic diverticulitis and should be suspected in patients with urinary infection and pneumaturia. They are less common in women than in men, probably because of the interposition of the uterus between the sigmoid colon and the urinary bladder; and are often easily demonstrated by CT scans, with a perisigmoid inflammatory mass abutting or immediately adjacent to the urinary bladder wall, and a variable amount of air over an air–fluid level within the lumen of the bladder (Fig. 16). These patterns have a high specificity value when there is no history of prior urinary instrumentation. Other types of fistulas can communicate with a small bowel loop, salpinx, uterus, vagina, or abdominal wall, and the route of the fistulas may be highly complex, and not or only partially demonstrated by CT examination (Cho et al. 1990; Werner et al. 2003, Panghaal et al. 2009) even when using iodinated contrast material injected anorectally (Fig. 17) or through the external orifice of a colocutaneous fistula, and dedicated changes of the position of the patient.

7.2.4 Portomesenteric Veins Septic Thrombosis and Liver Abscesses

Septic thrombosis of the inferior mesenteric vein is a rare complication of acute colonic diverticulitis (Balthazar and Gollapudi 2000; Sebastià et al. 2000; Bekkhoucha et al. 2008). The spread of septic

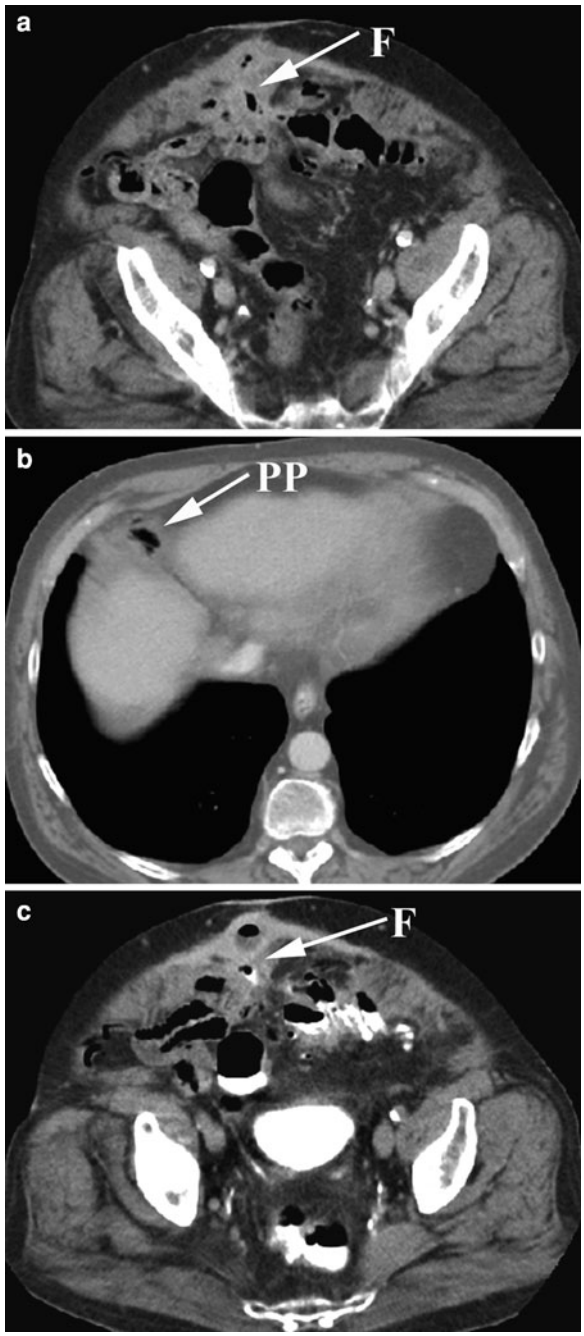

Fig. 17 Severe acute sigmoid diverticulitis with complex colovesical fistula and perforation into the peritoneal cavity. Axial CT slices. CT demonstrates a complex fistula route partially marked by gas bubbles (*arrow F*), spreading into the anterior abdominal wall (**a**). On a CT slice of the upper abdomen (**b**), note the clear CT depiction of a small gas pocket (*arrow PP*), within the right side of the subphrenic space, indicative of pneumoperitoneum and diagnostic of generalized peritonitis. The anterior route of this complex colocutaneous fistula is better analyzed (**c**) after administration of colonic iodinated contrast rectally (*arrow F*)

thrombosis to the portal vein and its intrahepatic branches can lead to pyogenic abscess of the liver (Fig. 18). Systematic attention should be paid to the inferior mesenteric vein, portal vein, and liver when analyzing CT images. The diagnosis of this complication advocates the use of enhanced CT examination and careful display of the windowing settings (see "Sect. 5"). Thrombosis, with or without intravascular gas, of the inferior mesenteric and portal veins can easily be demonstrated with contrast-enhanced CT. Gas in the mesentericoportal veins appears as tubular areas—or linear-branching images within the liver—of air-attenuation values (Fig. 19). On contrast-enhanced CT, these abscesses are generally large hypoattenuating lesions, with well-defined outlines, and may contain gas (Mortelé et al. 2004).

Treatment consists of anticoagulation plus antibiotic therapy. Elective sigmoid colectomy is indicated but an emergency colectomy may be required in the cases of failure of medical therapy (Bekkhoucha et al. 2008).

7.2.5 Colonic Stenoses and Bowel Obstruction

Bowel obstruction can occur in patients with colonic diverticulitis, either as small bowel obstruction related to a diverticular abscess (Kim et al. 1998) or by direct obstruction of the colonic lumen by narrowing inflammatory diverticular disease, resulting in large bowel obstruction, mostly of the sigmoid loop (Taourel et al. 2003).

Acute colonic diverticulitis is an uncommon cause of small bowel obstruction and may be overlooked as a cause. Clinically the diverticulitis may be masked by the clinical symptoms of small bowel obstruction and the diagnosis is doubtful when the patient suffers the first attack of diverticulitis. Anatomic proximity of the distal jejunum and the proximal ileum to the sigmoid colon explains why small bowel loops can be trapped in the pericolic inflammatory process, resulting in fixation, narrowing, and finally obstruction. When diverticulitis is correctly diagnosed as the cause of the small bowel obstruction, the patient can be initially managed medically, immediate surgery may be avoided, and elective sigmoid colectomy may be planned as a safe one-stage surgical procedure (Kim et al. 1998). Obstructing colonic stenoses resulting from diverticulitis may be difficult to differentiate from obstructing colonic carcinoma.

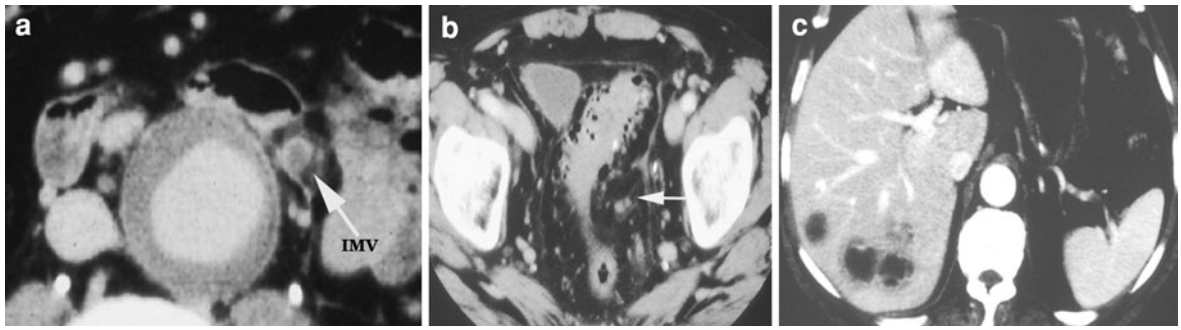

Fig. 18 Severe acute colonic diverticulitis with portomesenteric vein septic thrombosis and hepatic abscesses. CT axial images demonstrate the enlargement of the inferior mesenteric vein with an enhanced vascular wall and unenhanced lumen (**a**, *arrow IMV*). More proximally, the inferior mesenteric pedicle is seen on the inferior CT slice (**b**, *arrow*), close to a slightly changed sigmoid colon, with diverticula and thickening of the root of the sigmoid mesocolon. Septic thrombosis spreads to the portal vein and results in the development of right-sided hepatic abscesses (**c**). (Courtesy of D. Regent, Nancy, France)

7.3 CT Assists the Treatment Planning of Abscesses

A number of studies evaluating percutaneous CT-guided catheter drainage of diverticular abscesses as an adjunct to surgical therapy have been reported (Neff et al. 1987; Mueller et al. 1987; Stabile et al. 1990; Ambrosetti et al. 2005). Patients with abscesses of 4–5 cm or larger can be managed with CT-guided abscess drainage (Fig. 20) followed by secondary colectomy. This type of management obviates surgical abscess drainage and results in rapid resolution of clinical sepsis and stabilization of the patients. Once the abscesses are resolved, a single-stage surgical operation, by sigmoid resection and closure, can be performed safely. The benefit of CT scan-guided percutaneous abscess drainage and the size of the abscesses to be drained (vs. dedicated antibiotherapy alone) remain controversial (Siewert et al. 2006; Brandt et al. 2006), and the criteria for successful management are actually based on the clinical outcome and the laboratory test results. In the case of successful management, the indication for an elective sigmoid resection is still debated (Pessaux et al. 2004; Klarenbeek et al. 2010).

7.4 CT Demonstrates Other Causes of Abdominal Pain

CT is the imaging test of choice to identify or exclude other causes of abdominal pain that may mimic diverticulitis. Numerous alternative diagnoses may be discussed in a patient with left lower quadrant pain as previously shown. Given the epidemiological factors and clinical expression of diverticular disease in the aging population, differentiation of colonic carcinoma from diverticulitis should be stressed again as one of the major concerns; it should be also remembered that this differentiation on the basis of only CT findings is very difficult, not to say hazardous.

8 Diagnostic Strategy

CT is now widely accepted as the diagnostic radiological examination of choice in patients with suspected acute diverticulitis (Haute Autorité de Santé 2006; Zins et al. 2007; American College of Radiology 2008).

8.1 CT: The Imaging Test of Choice for the Diagnosis and Management

It is recommended to perform a CT examination in every patient every time an acute diverticulitis is clinically suspected. This CT examination should be performed within 24 h of the patient being admitted to hospital or within 72 h after acute diverticulitis is suspected and the medical treatment is initialized in an outpatient setting (Zins et al. 2007).

For the diagnosis and the management of colonic diverticular disease, in most cases CT, as the safest and most cost-effective method of diagnosis, should replace the other imaging modalities such as plain

Fig. 19 Severe acute colonic diverticulitis with portomesenteric vein septic thrombosis. CT axial slices depict a thrombosis of the inferior mesenteric vein (**a**, *arrow IMV*) with enhanced vascular wall and unenhanced lumen. On inferior CT slices (**b**) the inferior mesenteric vein is abutting the sigmoid colon (*arrows SC*), with diverticula but without any pericolic abscess. In this patient, peritoneal effusion (*PF*) is related to a rapidly extensive portal vein full thrombosis. On CT coronal reformats (**c**, **d**) tubular images of air-attenuation values are seen within both the inferior mesenteric vein (*arrow IMV*) and the portal vein (*arrowhead PV*)

films of the abdomen (PFA), CE, ultrasonography, magnetic resonance imaging, and colonoscopy.

CT has a clinical impact both on the diagnosis and on the management of patients with acute colonic diverticulitis and has been demonstrated as a valuable tool for determining prognosis factors.

Ambrosetti et al. (2002) reported that abdominal CT findings such as abscess, extradigestive gas, and extradigestive colonic contrast are indicators of severe forms of acute diverticulitis. In this same prospective study including 542 patients, by comparing severe acute colonic diverticulitis and nonsevere forms, these

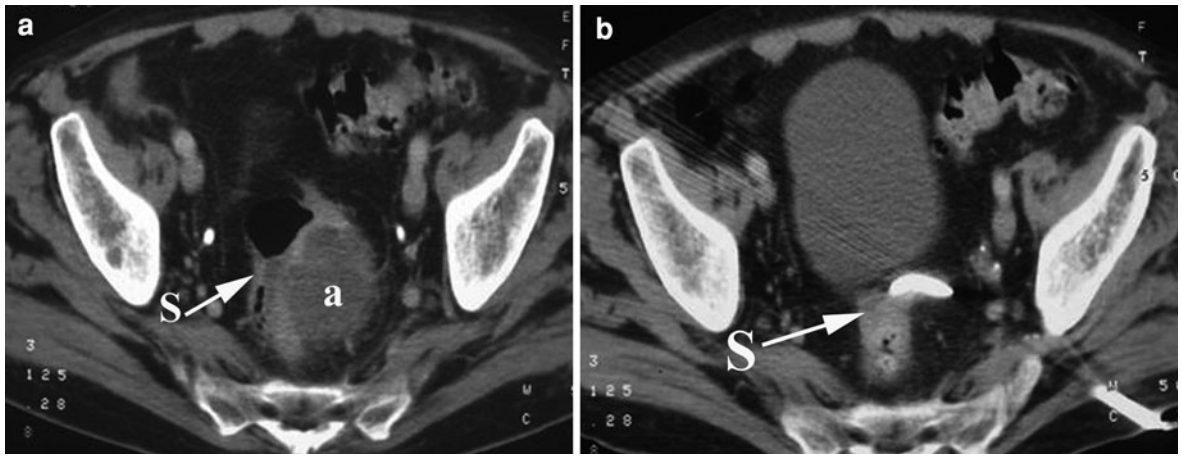

Fig. 20 Severe acute sigmoid diverticulitis with pelvic abscess. Percutaneous abscess drainage under CT guidance. **a** The CT axial slice demonstrates a large abscess (*a*) abutting the wall of the sigmoid colon (*arrow S*) and spreading down in the presacral region on the left side of the rectum. **b** This abscess is drained percutaneously, via a transgluteal approach. Note the location of the tip of the draining catheter, close to the rectosigmoid junction (*arrow S*) and the emptying of the abscess cavity

authors reported a higher risk of unsuccessful medical management of the acute phase and a higher risk of recurrence (26% vs. 4% with $p < 0.0001$ and 36% vs. 17% with $p < 0.0001$, respectively). Moreover, in a more recent prospective study, Poletti et al. (2004) reported that the CT findings significantly correlating with an unsuccessful medical management were abscess and/or tiny bubbles of extradigestive gas more than 5 mm in diameter. These data should be considered when transcutaneous drainage and/or surgical operation are discussed, but this issue and the actual indications for elective sigmoid resection in diverticular disease are still debated (Klarenbeek et al. 2010).

8.2 Plain Films of the Abdomen

The plain films of the abdomen (PFA) cannot assess the diagnosis of acute colonic diverticulitis. In a retrospective study including 1,000 consecutive patients with acute abdominal pain, the sensitivity of PFA for the diagnosis of acute colonic diverticulitis was 0% (Ahn et al. 2002). The role of PFA for diagnosing a free perforation, either in the peritoneal cavity or in the retroperitoneum, is uncertain. The sensitivity of PFA for the diagnosis of a suspected pneumoperitoneum in patients with diverticulitis is much lower than that of CT, because tiny bubbles of distant intraperitoneal gas, which have the same clinical significance of generalized peritonitis in this condition as a large pneumoperitoneum, are easily demonstrated by CT and are overlooked by PFA. Therefore, in patients with suspected acute colonic diverticulitis, CT rather than PFA should be used.

8.3 Contrast Enema

Traditionally, the contrast enema (CE) examination has been the primary method for examining patients suspected of having acute colonic diverticulitis. The classic findings are sigmoid narrowing (typically long, symmetric, and with a gradual zone of transition), muscle hypertrophy with sacculations, and diverticula. But these patterns may be seen in patients with chronic diverticular disease and may not be diagnostic of acute diverticulitis. A specific diagnosis can be made only when there is extravasation of contrast material from a diverticulum. The contrast material may extravasate into the peritoneal cavity, a walled-off abscess, a sinus tract, or a fistula. The main limit of CE examination is not depicting the pericolic lesions directly, and a large pericolic abscess can only be indirectly inferred mainly from compression and displacement of the colonic wall. Instead, CE may be helpful for differentiating diverticulitis from carcinoma. As early as 1984, a study by Hulnick et al. (1984) showed that, compared with CT, CE

underestimated the severity of the diverticulitis in 41% of patients. In 1990 Cho et al. (1990) reported a better diagnostic accuracy with CT (93%) than with CE (80%). Finally, in 2000 Ambrosetti et al. (2000), in the main prospective study comparing CE and CT and including 420 patients, demonstrated the superiority of CT for both the diagnosis of acute colonic diverticulitis and the precise assessment of the severity of the disease. Even though use of CE is still proposed in a few selected patients with colonic diverticulitis (for evaluating the route of a complex fistula or differentiating diverticulitis from colonic carcinoma), CE has less and less of a significant role in acute colonic diverticulitis and should be replaced by CT as the first-step imaging method for the diagnosis of acute colonic diverticulitis.

8.4 Ultrasonography

The ultrasonography findings in acute colonic diverticulitis have been reported for15–20 years and are similar to the CT findings: hypoechoic thickening of the colonic wall, alterations of the pericolic fat depicted as hyperechoic, and diverticula (Pradel et al. 1997; Puylaert 2001; Ripollés et al. 2003). The reported sensitivity and specificity of ultrasonography for the diagnosis of acute colonic diverticulitis are 84–98% and 80–98%, respectively. This high accuracy has been reported mainly for nonsevere acute colonic diverticulitis and requires a rigorous examination technique and great experience of the investigator in ultrasonography examination of the gastrointestinal tract. Ultrasonography examination may be sufficient for the diagnosis of either nonsevere diverticulitis (focal diverticulitis with limited changes of the pericolic fat) or several alternative diagnoses (epiploic appendagitis). However a recent meta-analysis showed no statistically significant difference in the accuracy of ultrasonography and CT in diagnosing acute colonic diverticulitis (Laméris et al. 2008). CT examination is considered more useful for precise determination of alternative diagnoses, but transabdominal ultrasonography complemented by an endovaginal ultrasonography examination should be the initial preferred modality in women of childbearing age. However, ultrasonography examination should likely have a more prominent place in the initial setting of acute abdominal pain: in a fully paired multicenter diagnostic accuracy study with prospective data collection, including 1,021 patients, 665 (25%) having a final diagnosis classified as urgent, Laméris et al. (2009) evaluated the added value of plain radiographs, ultrasonography, and CT after clinical evaluation for making urgent diagnoses in patients presenting with abdominal pain. The main objective of the study was to identify an optimal imaging strategy for the accurate detection of urgent conditions in patients with acute abdominal pain. Although CT was the most sensitive imaging method for detecting urgent conditions in these patients with acute abdominal pain, using ultrasonography first and CT only in those patients with negative or inconclusive ultrasonography findings resulted in the best sensitivity and lowered exposure to radiation.

8.5 Magnetic Resonance Imaging

Even though magnetic resonance imaging may be considered to provide patterns similar to the CT ones (Buckley et al. 2007), it has several limitations for its use in patients with suspected acute colonic diverticulitis: limited accessibility and longer examination time, and moreover lack of sensitivity to depict a pneumoperitoneum, particularly for tiny bubbles of extraluminal gas.

8.6 Colonoscopy

Colonoscopy is strictly contraindicated in the acute phase of an onset of suspected colonic diverticulitis. Virtual colonoscopy, with CT or magnetic resonance imaging, requires a high degree of colonic distension after anorectal insufflation and is, therefore, contraindicated in the acute phase of an onset of suspected colonic diverticulitis. Instead, 4–6 weeks after the acute diverticulitis resolves, it is mandatory to rule out a colonic carcinoma and colonoscopy should be performed particularly in patients with a doubtful narrowing of the colonic lumen, and for many authors as a systematic test in all patients over 50 years old or with risk factors for colonic carcinoma; virtual colonoscopy (Hjern et al. 2007; Laurent 2007) or colo-CT examination after water enema (Pilleul et al. 2006; Ridereau-Zins et al. 2009) has been performed may be used as an

alternative for ruling out a colonic carcinoma, if videocolonoscopy is not accepted or is contraindicated.

9 Conclusion

CT is now widely accepted as the diagnostic radiological examination of choice in patients with suspected acute diverticulitis.

CT examination should be performed in every patient every time an acute diverticulitis is clinically suspected to serve the following functions: (1) to confirm the diagnosis of acute diverticulitis by demonstrating inflammatory pericolic changes associated with colonic diverticula, (2) to identify or exclude other causes of abdominal pain that may mimic diverticulitis, (3) to evaluate the severity and the extent of the acute disease, and (4) to assist the decision management not only in emergency conditions by evaluating the complications accurately and in selective (but still debated) conditions by guiding a percutaneous drainage, but also in discussing the actual need for an elective sigmoid colectomy.

This CT examination should be performed within 24 h of the patient being admitted to hospital or within 72 h after acute diverticulitis is suspected and the medical treatment is initialized in an outpatient setting.

Ultrasonography should be considered as a helpful imaging method for the diagnosis of unexplained acute abdominal pain when performed by an experimented observer familiar with the ultrasonographic evaluation of the gastrointestinal tract, but is of more limited value in severe diverticulitis. However, ultrasonography examination should be the initial preferred imaging modality in the setting of left lower quadrant pain with or without fever in women of childbearing age.

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