Acute Abdomen: Rational Use of us, MDCT, and MRI

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Contents

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Abstract

The term "acute abdomen" defines a clinical syndrome characterized by the sudden onset of severe abdominal pain, requiring early medical or surgical treatment. The acute abdominal pain may be due to trauma or non-trauma diseases and it is a frequent condition in patients presenting to the hospital emergency department. Computed Tomography is universally considered the key imaging modality for the evaluation of severe trauma patients and patients with non-traumatic acute abdominal disease. In case of acute abdomen unenhanced CT scan is not performed routinely. The contrast enhanced CT study is performed with a two-phase protocol, in arterial and portal venous phases; in trauma patients excretory phase is done only in cases of suspected urinary track lesions (renal pelvis, ureter and bladder). Multiplanar reconstruction (MPRs) are useful for interpretation of abdominal diseases as they allow the scanned volume to be viewed in any arbitrary plane interactively determined by the viewer. These reconstructions are especially useful when tubular structures, such as vessels, ureters, and bowel, are followed. Maximum intensity projections (MIPs) are useful for CT angiography and CT urography. The reconstruction of volume rendered (VR) images is particularly helpful for visualization of complex anatomy and pathology of visceral vasculature and best delineates a tortuous course of vessels and small branches.

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1 Trauma

Trauma patients presenting to the hospital emergency department frequently suffer from acute abdominal pain. The "acute abdomen" represents a clinical syndrome characterized by the sudden onset of severe abdominal pain, requiring early medical or surgical treatment (Silen 1996).

Although computed tomography (CT) is universally considered the key imaging modality for the evaluation of severe trauma patients, the major role of sonography (ultrasound, US) for the early demonstration of hemopericardium, hemothorax, or hemoperitoneum in the initial assessment of hemodynamically unstable patients is also widely recognized. US has gained broad acceptance as an effective triage tool to evaluate trauma victims with suspected blunt abdominal injuries, because it is repeatable, non-invasive, non-irradiating and inexpensive (Poletti et al. 2007). In clinical practice, two main trends have recently emerged with regard to the utilization of US in the setting of blunt abdominal trauma in adults: the first consists of using US as a rapid diagnostic test mainly for the depiction of free fluid. This method has been termed FAST "focused assessment sonography for trauma" (Shackford 1993). The second trend consists of using US in association with a second-generation US contrast medium. Despite this and other important improvements in US technology, the presence of life-threatening visceral injuries not detected by contrast-enhanced US, as reported in the literature (Poletti et al. 2007), suggests that this approach cannot be recommended yet to replace CT in the triage of hemodynamically stable trauma patients.

The use of CT in blunt trauma was originally reported in the 1980s (Milia and Brasil 2011), but the long acquisition times and poor resolution limited its use. Since then, newer technologies have expanded the role of CT in the evaluation of injured patients. The first multidetector CT (MDCT) scanner, based on a 4-slice detector array, was developed in 1998. Since then, 16-, 32-, and 64- slice MDCTs, and recently, 128- and 256-slice MDCTs have become available (Rogalla et al. 2009). When combined with helical scanning, MDCT significantly reduces scan times. This reduction allows imaging with a thinner collimation (1–2 mm), yielding rapidly acquired higher-resolution images with a concomitant reduction of motion artifacts due to patient movement and cardiac activity. The use of MDCT has allowed for greater flexibility in image reformatting and in applications such as CT angiography.

In multitrauma patients, radiological investigation is necessary to detect or exclude injuries in all body regions. Given the recent advances in CT technology, a corresponding "whole-body" radiological survey can be obtained within a short time, thereby revealing critical occult injuries and decreasing the number of overlooked lesser injuries. Whole-body CT is the fastest possible radiological investigation permitting "complete" body coverage in the multitrauma patient. A single contiguous scanning pass from the vertex to the pubis symphysis not only results in all of the expected traditional transverse images of the head, neck, chest, abdomen, and pelvis but also provides data that enable the extraction of off-axial or focused images of the entire spine, aorta, facial bones, orbits, and hips without the need for rescanning. These images are readily obtained using a 64-detector row MDCT scanner with a minimum rotation time of 0.35 s, a maximum table speed of 175 mm/s, and maximum volume coverage of 200 cm. The isotropic design of the 40-mm detector delivers 0.35-mm isotropic resolution and thin-slice (64×0.625 and 32×1.25 mm) imaging in all scan modes and at all scan speeds. This allows fast whole-body scanning of a polytraumatized patient from tip-to-toe. All patients receive a single intravenous bolus of 120 mL of intravenous contrast medium injected through an 18- or 20-gauge cannula in an antecubital vein at a rate of 5 mL/s by using a dual-syringe power injector. The administration of saline solution (30 mL) as a bolus chaser, also injected at a rate of 5 mL/s, after the intravenous contrast material injection, is also recommended (Table 1).

Unenhanced CT scans. These are appropriate for the head and face. The neck, chest, abdomen, and pelvis are not routinely explored by this route to avoid unnecessary radioexposure.

Contrast-enhanced CT. Used in examinations of the neck, chest, abdomen, and pelvis. A multiphasic study is performed consisting of arterial, portal-venous and, if necessary, excretory phases. An arterial phase study of the whole body begins at the circle of Willis and extends to the pubis symphysis, using the bolus tracking technique with the region of interest (ROI)

Table 1 Whole body MDCT protocol in trauma patient

	CM concentration	CM volume	Injection rate	Delay	Rotation time	Pitch	Detector width
16-slice MDCT	350 mg I/ml	150 ml	4 ml/sec	Arterial phase: bolus track (ascending aorta)	0.7 s	1,375	1.25 mm
				Portal phase (abdomen): 40″ after a.p.			
	Saline	30 ml	4 ml/sec	Excretory phase (abdomen): 180″ after p.p.			
64-slice MDCT	370–400 mg I/ml	120 ml	5 ml/sec	Arterial phase: bolus track (ascending aorta)	0.5 s	0.938	0.625 mm
				Portal phase (abdomen): 35″ after a.p.			
	Saline	30 ml	5 ml/sec	Excretory phase (abdomen): 180″ after p.p.			

Unhenanced CT: Head, Face
CT + IV cm: Neck, Chest, Abdomen, Pelvis

positioned in the ascending aorta. This phase can detect serious vascular injuries, such as active bleeding of arterial origin, post-traumatic pseudoaneurysms, and acute arterial thrombosis (e.g., in the carotid). In the portal-venous phase, only the abdomen, from the dome of the diaphragm to the iliac bones, is routinely studied. This phase provides evidence of traumatic lesions involving the parenchymal organs as well as effusion into the peritoneal cavity. The excretory phase is done only in patients of injuries to the urinary tract (renal pelvis, ureter, and bladder) are suspected based on evidence of parenchymal renal damage or in case of hematuria. It is performed 180 s after the end of the portal venous phase and well demonstrates the leakage of urine from the urinary tract, with collection in the retroperitoneal space or, less commonly, in the intraperitoneal space.

Multiplanar reconstructions (MPRs) in coronal and sagittal planes are routinely obtained to evaluate the cervical, thoracic, and lumbar spine as well as thoracic and abdominal structures. Maximum-intensity projections (MIPs) and volume-rendering (VR) reconstructions are performed in cases of vascular lesions or fractures of the spine or pelvis.

The practice of whole-body CT in multitrauma patients is increasing rapidly, especially in the emergency setting. One consideration in assessments of the value of this technique is the risk of radiation exposure associated with a full-body CT examination. Radiation risk from diagnostic imaging is a subject of substantial controversy, and estimates of cancer induction and death should be evaluated with caution (Ptak et al. 2003). The risk of cancer development and of the deterministic effects of radiation was recently pointed out in a series of publications and has resulted in attempts to reduce the radiation dose through modulation of the CT technique itself (Fanucci et al. 2007). Moreover, in emergency radiology, CT scanning is being increasingly used for the evaluation of trauma, which typically involves younger population in most instances. As children and young patients are at greater risk than older patients in developing cancer following radiation exposure, the radiation dose associated with CT scanning in these patients has become a cause of concern. Although it is prudent to maintain image quality to reach a satisfactory diagnosis, an immediate benefit with greater priority than the delayed risk of cancer associated with radiation exposure, radiologists, including those in emergency radiology departments, must also ensure that the ALARA (as low as reasonably achievable) radiation dose is used. Recent studies have documented that satisfactory image quality can be achieved with CT scanning performed at radiation dose lower than commonly used (Kalra et al. 2002, 2003). Indeed, low-dose CT scanning has been validated in different regions of the body, including the paranasal sinuses, face, chest, abdomen, and pelvis (Kalra et al. 2003; Frush 2002; Prasad et al. 2002). Amongst emergency CT indications, low-dose CT scanning has been recommended for imaging in children and for the evaluation of facial trauma, chest trauma, appendicitis, renal colic, and flank pain and diverticulosis (Hagtvedt et al. 2003). A weight- and cross-sectional dimensions-based adaptation of scanning parameters (tube current and tube potential) has also been recommended to reduce the radiation dose associated with CT scanning (Kalra et al. 2002, 2003; Frush 2002).

During CT scanning, a user can manually set the scanning parameters to reduce or adjust the radiation dose according to patient size, clinical indications and body region being scanned. These scanning parameters may include tube voltage, tube current, gantry rotation time, pitch, and beam collimation or detector configuration. The manual selection of a lower tube current (milliampere) is the most commonly used method to reduce the radiation dose associated with CT scanning (Kalra et al. 2005). Several studies have demonstrated that low-dose CT with reduced tube current is a useful alternative to standard tube current scanning and can provide satisfactory image quality (Kalra et al. 2002, 2003; Frush 2002; Prasad et al. 2002; Hagtvedt et al. 2003).

Few studies have investigated the role of magnetic resonance imaging (MRI) in the work-up of hemodynamically stable trauma patients for non-neurological indications (Poletti et al. 2007). Indeed, beside its limited availability in most emergency centers, MRI is difficult to use in uncooperative patients and in the presence of metallic components such as skin ECG electrodes and life-support equipment. Some authors reported that MRI can be used as a complement to non-enhanced CT in patients with major contraindications for the injection of iodinated contrast agent (Hedrick et al. 2005), or to evaluate the integrity of the pancreatic ducts (Fulcher and Turner 1999). Unfortunately, such reports remain anecdotal and the MRI is not yet integrated into the current diagnostic management of trauma patients, except for neurological indications (Poletti et al. 2007).

Although caution must be exerted regarding the radiation dose, the value of CT in deceleration traumatic injuries is well-established, not only in the diagnosis of these patients but also in decisions regarding their management. Contrast-enhanced MDCT allows a fast and accurate evaluation of all body regions in polytraumatized patients, thus safely directing the patient toward non-operative management (NOM), selective embolization, or surgery. Furthermore, one of the most important achievements of the latest MDCT scanners is the rapid diagnosis of vascular injuries, which are the primary cause of early death in polytraumatized patients.

2 Non-Traumatic Diseases

Acute abdominal pain unrelated to trauma is one of the most common conditions in patients presenting to the hospital emergency department. A wide variety of disorders, ranging from benign, self-limited diseases to conditions that require immediate surgery, can cause acute abdominal pain. Eight conditions account for over 90% of patients who are referred to the hospital and seen on surgical wards: acute appendicitis, acute cholecystitis, small-bowel obstruction, urinary colic, perforated peptic ulcer, acute pancreatitis, acute diverticular disease, and non-specific, non-surgical abdominal pain (dyspepsia, constipation) (Marincek 2002). A confident and accurate diagnosis can be made solely on the basis of medical history, physical examination, and laboratory test findings in only a small proportion of patients. The clinical manifestations of the various causes of acute abdominal pain usually are not straightforward. For proper treatment, a diagnostic work-up that enables the clinician to differentiate between the various causes of acute abdominal pain is important, and imaging plays an important role in this process (Stoker et al. 2009). Due to the impact of cross-sectional imaging, the need for plain abdominal radiographs has declined (Kellow et al. 2008). Although ultrasonography (US) has gained widespread acceptance for evaluating the gallbladder in affected patients and the pelvis in children and women of reproductive age, CT is considered to be one of the most valued tools for triaging patients with acute abdominal pain (Mindelzun and Jeffrey 1997; Novelline et al. 1999; Gore et al. 2000; Rosen et al. 2000; Urban and Fishman 2000). In recent years, most emergency centers have been equipped with newer helical CT scanners that permit imaging procedures to be performed in less time, with greater accuracy, and with less patient discomfort. The introduction of MDCT technology, with substantial improvements in scan speed and z-axis resolution, has further enhanced the utility of CT in abdominal imaging.

In patients with an acute abdomen, unenhanced CT scan is not performed routinely. Instead, the contrast-enhanced CT study, with a two-phase protocol

Table 2 MDCT protocol in acute abdomen

	CM concentration	CM volume	Injection rate	Delay	Rotation time	Pitch	Detector width
16-slice MDCT	350 mg I/ml	140 ml	4 ml/sec	Arterial phase: bolus track (abdominal aorta)	0.7 s	1,375	1.25 mm
	Saline	30 ml	4 ml/sec	Portal phase: 40″ after a.p.			
64-slice MDCT	370-400 mg I/ml	120 ml	5 ml/sec	Arterial phase: bolus track (abdominal aorta)	0.5 s	0.938	0.625 mm
	Saline	30 ml	5 ml/sec	Portal phase: 35″ after a.p.			

consisting of arterial and portal-venous phases, is the preferred approach (Table 2).

The interpretation of abdominal diseases is well accomplished with MPRs, as they allow the scanned volume to be viewed in any arbitrary plane interactively determined by the viewer. These reconstructions are especially useful when tubular structures, such as vessels, ureters, and bowel, are followed. MIPs are obtained by the projection onto an image plane of the highest-attenuation voxels encountered through a volume, which allows structures not lying in a single plane to be evaluated. Thus, MIP has found many applications in CT angiography and CT urography (Leschka et al. 2005). The reconstruction of VR images is particularly helpful for visualizing the complex anatomy and pathologies of the visceral vasculature and better delineates a tortuous course of vessels and small branches than MPR or axial images alone (Leschka et al. 2005).

According to the American College of Radiology (ACR) appropriateness criteria (2006), contrast-enhanced CT of the abdomen and pelvis is the most appropriate examination for patients with fever, non-localized abdominal pain, and no recent surgery. Non-enhanced CT, US, and conventional radiography are considered less appropriate initial imaging examinations for these patients. In the right upper quadrant, acute cholecystitis is by far the most common disease. In such cases, US is the preferred imaging method for evaluating patients with acute right upper abdominal pain. The ACR criteria also recommend the use of US in patients suspected of having acute calculous cholecystitis (Bree et al. 2000). The primary criterion is the detection of gallstones. Secondary signs include the sonographic Murphy sign, gallbladder-wall thickening ≥3 mm, and peri-cholecystic fluid (Fig. 1). In acute calculous cholecystitis a calculus typically obstructs the cystic duct. Gallbladder perforation and complicating peri-cholecystic abscess usually occur adjacent to the gallbladder fundus because of the sparse blood supply. MDCT may be useful for confirmation of the sonographic diagnosis (Marincek 2002). Emphysematous cholecystitis is a rare complication of acute cholecystitis and is associated with diabetes mellitus. US or MDCT demonstrate gas in the wall and/or lumen of the gallbladder, which implies underlying gangrenous changes (Marincek 2002) (Fig. 2).

Fig. 1 Acute calculous cholecystitis. Sonography shows a gallstone and sludge in the gallbladder lumen. Gallbladder wall thickening is also evident

Acute abdomen with left upper quadrant pain is an infrequent complaint. Splenic infarction, splenic abscess, gastritis, and gastric ulcer are the most important causes. US is mostly reserved for screening, with CT enabling accurate further evaluation. The diagnosis of gastric pathology is established by endoscopy, with imaging playing a minor role.

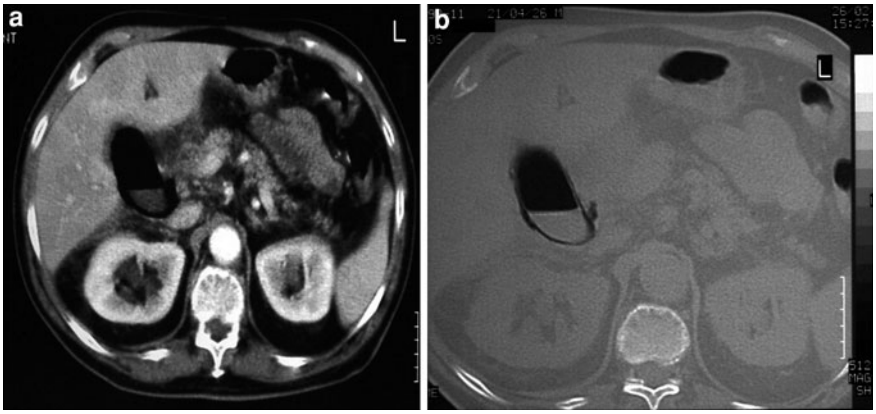

Fig. 2 Acute emphysematous cholecystitis. CT scan (**a**) demonstrates gas in the lumen of the gallbladder, with air-fluid level, and in the gallbladder wall, more evident using a lung window (**b**)

Acute pain in the right lower quadrant is also a common complaint in clinical practice. The differential diagnosis includes a broad spectrum of clinical entities, from benign self-limited disorders to those with high morbidity. Acute appendicitis is not only the most frequent cause of acute right lower quadrant pain, but also the most commonly encountered cause of an acute abdomen (Marincek 2002). Other diseases manifesting as acute right lower quadrant pain include acute terminal ileitis (Crohn's disease), acute typhilitis, and, in women, pelvic inflammatory disease, complications of ovarian cyst (hemorrhage, torsion, leak), endometriosis, and ectopic pregnancy. Recent advances in US and CT have greatly improved the preoperative diagnostic accuracy in these patients (Birnbaum and Jeffrey 1998). US has become an important imaging option in the evaluation of acute appendicitis, particularly in children. Demonstration of a swollen, non-compressible appendix >7 mm in diameter with a target configuration is the first sonographic criterion (Fig. 3). Generally, the normal appendix cannot be defined with US; thus, clear visualization of the appendix is suggestive of inflammation. Appendicitis may be diagnosed in indeterminate cases based on increased appendiceal perfusion on color Doppler examination. Gangrenous appendicitis is suggested when there is a loss of the echogenic submucosal layer and color Doppler flow to that segment of the appendix is absent (Birnbaum and Jeffrey 1998). The advantages of US include the lack of ionizing radiation, relatively low cost, and widespread availability. On the other hand, US requires considerable skill and is difficult to perform in obese patients, patients with severe pain, and patients likely to have a complicating peri-appendiceal abscess. When the sonographic findings are unclear, MDCT can provide a rapid and definitive diagnosis (Fig. 4).

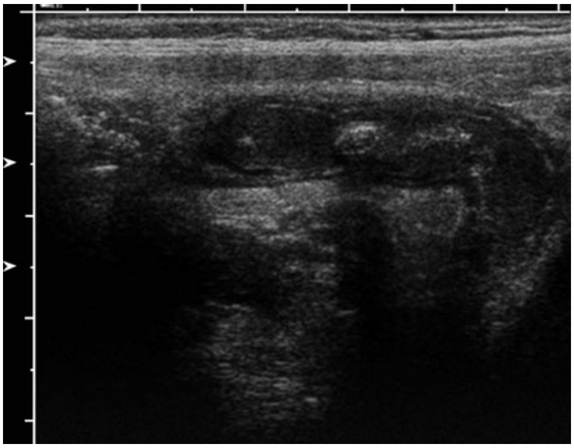

Fig. 3 Phlegmonous appendicitis. Sonography shows a completely visualized thickened appendix with an appendicolith; a peri-appendiceal fat infiltration is also observed

In the left lower quadrant, diverticular disease is the most common cause of acute abdominal pain. Diverticulitis occurs in up to 25% of patients with known diverticulosis and typically involves the sigmoid colon (Marincek 2002). MDCT is very sensitive and approaches 100% specificity and accuracy in the diagnosis or exclusion of diverticulitis; it has thus largely replaced barium enema examinations (Rao et al. 1998). The advent of CT has revolutionized the diagnosis and management of patients with diverticulitis. Fulfillment of the following four criteria is considered diagnostic: presence of diverticula,

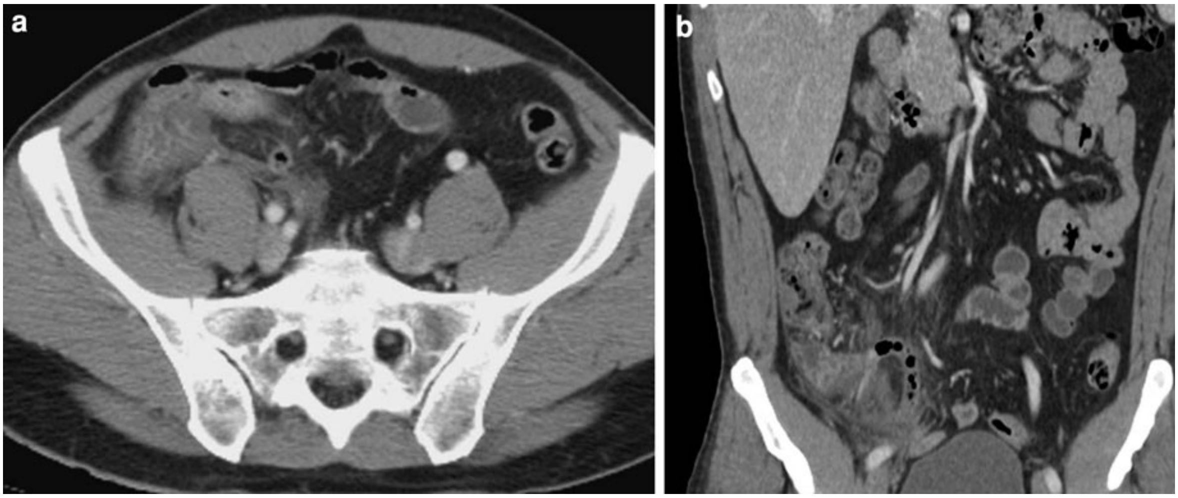

Fig. 4 Gangrenous appendicitis. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show a distended thickened appendix. Peri-appendiceal and peri-cecal fat infiltration is also evident. Note the involvement of the cecum in the inflammatory peri-appendiceal fat changes

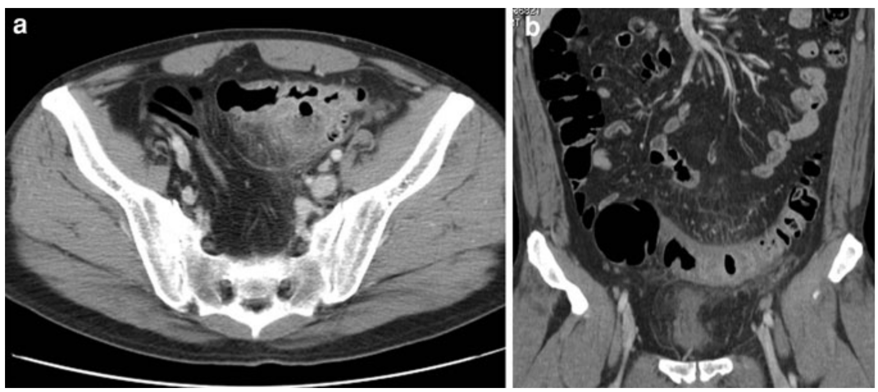

Fig. 5 Acute diverticulitis. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show thickening of the sigmoid wall with inflammatory pericolic fat changes and the presence of a pericolic abscess (**a**)

thickening of the bowel wall >4 mm, inflammatory pericolic fat, and pericolic abscess (Pradel et al. 1997). The CT findings in complicated diverticulitis may include the presence of an abscess (defined as a fluid-containing mass with or without air and an enhancing wall) and contained or free extraluminal air bubbles or pockets (Fig. 5). Other complications, such as bowel obstruction, hepatic abscess, fistula and inferior mesenteric vein thrombosis, can often be demonstrated with CT. Fistulas frequently communicate with an abscess or other hollow viscus, with colovesicular fistulas as the most common type (DeStigter and Keating 2009).

MDCT is also very useful in differentiating sigmoid diverticulitis from carcinoma, the most common condition in the differential diagnosis of colonic thickening.

Acute diffuse abdominal pain may be caused by any disorder that irritates a large portion of the GI tract and/or the peritoneum. The most frequently seen disorder is gastroenterocolitis but other important disorders are bowel obstruction, acute mesenteric ischemia, and GI tract perforation. Bowel obstruction is a frequent reason for abdominal pain and accounts for approximately 20% of surgical admissions for acute abdominal conditions (Marincek 2002). The small

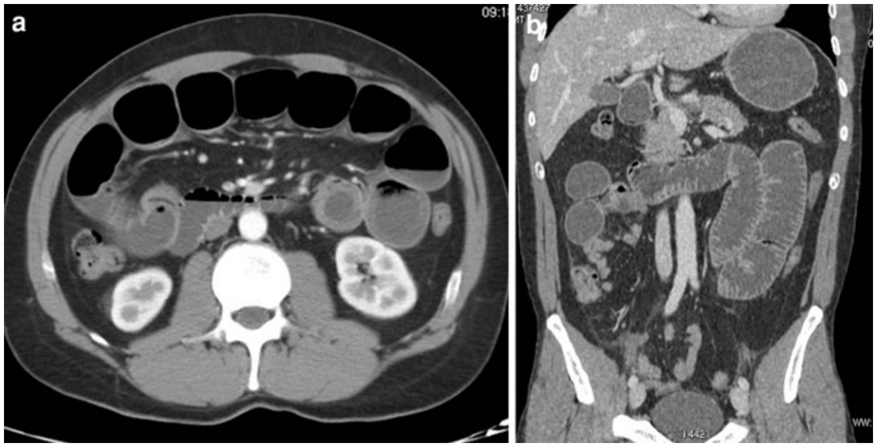

Fig. 6 Small-bowel obstruction. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show dilated jejunal loops and collapsed ileal loops. The transition point with the "beak sign" is also evident (**a**)

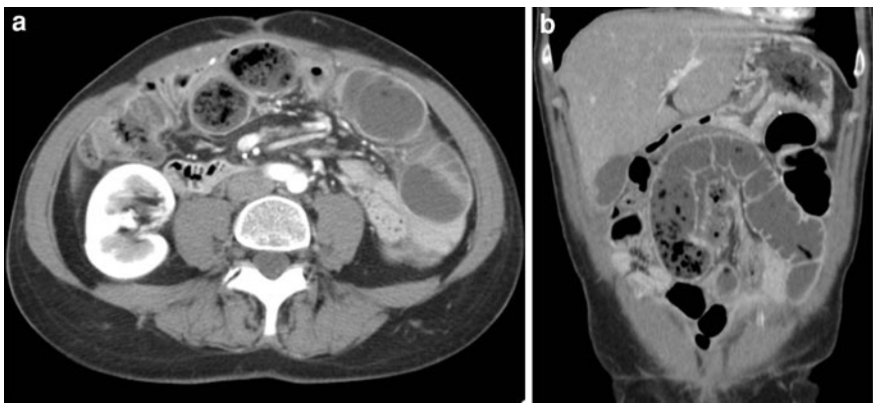

Fig. 7 Small-bowel obstruction. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show dilated jejunal loops at the level of the mesogastrium and collapsed ileal loops. The small-bowel feces sign is observed near the point of obstruction

bowel is involved in 60–80% of cases. Small-bowel obstruction (SBO) are typically the result of adhesions, hernias, and neoplasms. In the large bowel, mechanical obstruction is very often due to carcinoma and diverticular disease; sigmoid volvulus, although relatively infrequent, ranks third among all causes of large-bowel obstruction (Marincek 2002). The diagnosis of bowel obstruction is established on clinical grounds and usually confirmed with plain abdominal radiographs. However, because of the diagnostic limitations of plain films, MDCT is increasingly used to identify the site, severity, and cause of obstruction and to determine the presence or absence of associated complications, particularly bowel ischemia (Ha et al. 1997; Caoili and Paulson 2000; Furukawa et al. 2001; Boudiaf et al. 2001). The essential CT finding of bowel obstruction is the delineation of a transition zone between the prestenotic, dilated bowel and the poststenotic, decompressed bowel (Fig. 6).

A helpful sign for identifying the point of obstruction is the small-bowel feces sign, i.e., feces-like material in the distended small bowel (Lazarus et al. 2004) (Fig. 7). The transition point should be scrutinized for the source of the obstruction. Additional reformatted images using sagittal, coronal, oblique, or curved planes help to trace the intestine and to determine the transition point (Caoili and Paulson 2000). MDCT facilitates this task substantially.

Patients with bowel ischemia often have a short clinical history of prominent abdominal pain, while other possible symptoms, such as nausea, vomiting, diarrhea, and distended abdomen, are substantially less prominent. Nonetheless, all of these symptoms are non-specific. A diagnosis of bowel ischemia is often made after the usual diagnoses, i.e., those with similar associated symptoms, are excluded. Bowel ischemia should be considered especially in elderly patients with known cardiovascular disease

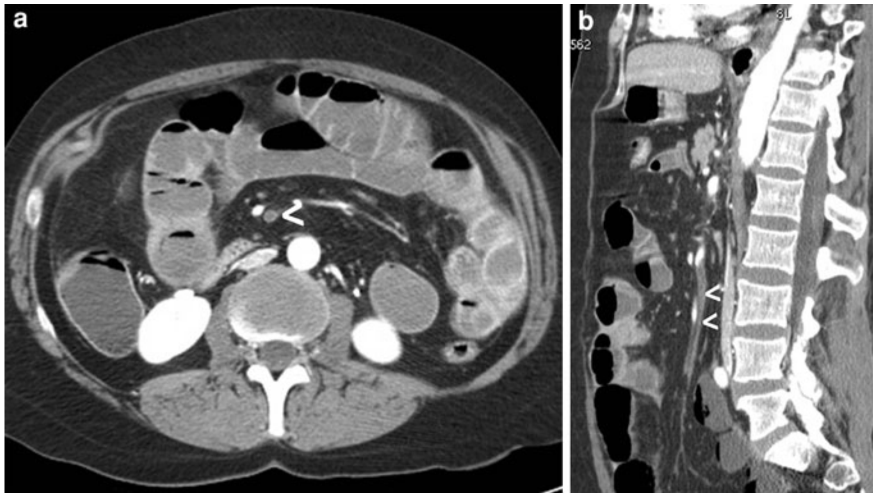

Fig. 8 Small-bowel ischemia due to arterial occlusion. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) demonstrate the presence of dilated small-bowel loops with thin walls. Embolic occlusion of the superior mesenteric artery is evident (*arrowheads*)

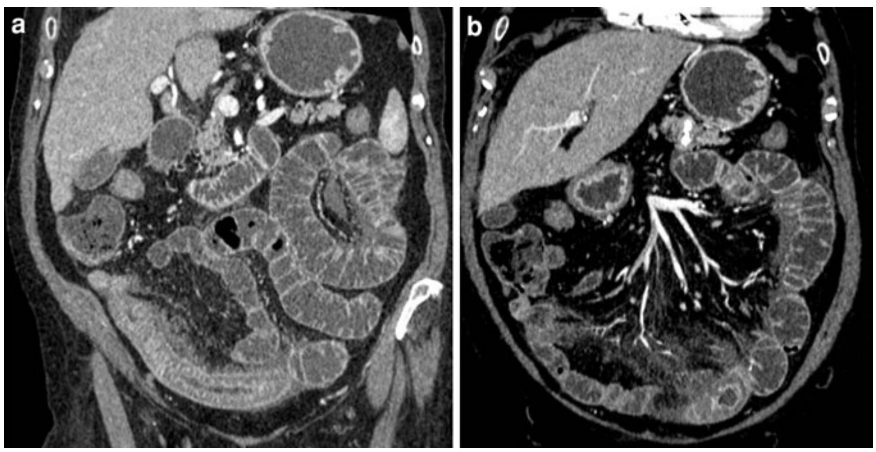

Fig. 9 Small-bowel ischemia due to venous thrombosis. Multiplanar coronal CT reconstructions (**a, b**) show the presence of dilated small-bowel loops in the left upper quadrant. In the pelvis, an ileal loop demonstrates an abnormal bowel-wall thickening associated with bowel-wall hypoattenuation. Free fluid is visible in the peritoneal cavity. Mesenteric venous thrombosis is observed (**b**)

(e.g., atrial fibrillation) and in younger patients known to have diseases that may give rise to inadequate mesenteric blood flow, such as vasculitis, hereditary or familial coagulation disorders (e.g., antiphospholipid syndrome), and protein C or S deficiency. Causes of acute mesenteric ischemia are arterial occlusion (thromboembolism; external compression by adhesion, volvulus, hernia, intussusception; vasculitis), hypotension (congestive heart failure; hypovolemia; sepsis), vasoconstrictive medications, or impaired venous drainage; often, a combination of these conditions is observed. Colonic ischemia generally results from hypoperfusion or hypotension; a mesenteric thrombus is rare. The predominance of one condition determines the outcome and the findings on MDCT. Although several CT signs are associated with bowel ischemia, they are not very frequent nor are they specific. Visualized occluded mesenteric arteries or venous thrombus is a clear sign of mesenteric ischemia (Fig. 8). The bowel wall may be thickened (>3 mm) because of mural edema, hemorrhage, congestion, or superinfection. Thickening owing to edema, congestion, or hemorrhage is a frequent manifestation of venous obstruction (Fig. 9). Bowel-wall hypoattenuation (edema), hyperattenuation (hemorrhage), abnormal enhancement (target sign), and absence of enhancement are features of bowel ischemia. The absence of bowel-wall enhancement is highly specific but is often missed (Stoker et al. 2009). The wall may become paper thin, which may indicate impending perforation. Luminal dilatation and fluid levels (fluid exudation of the ischemic bowel segments) are common in irreversible bowel ischemia, whereas mesenteric stranding and ascites are

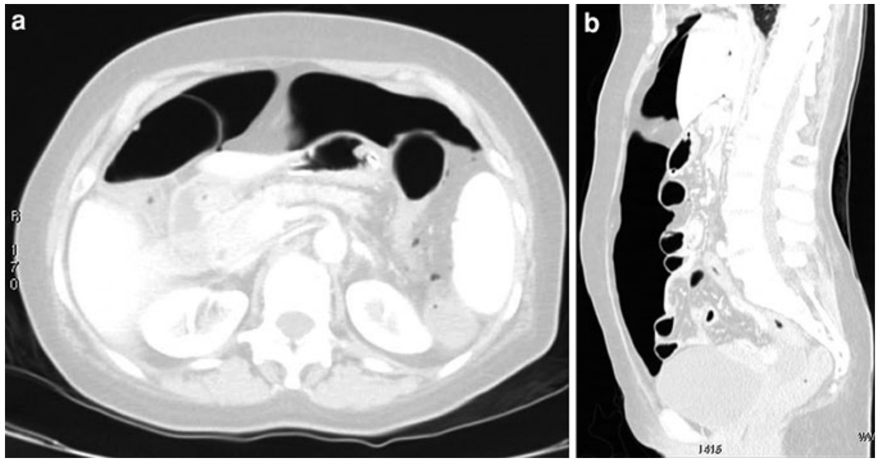

Fig. 10 Intestinal perforation. Axial CT scan (**a**) and multiplanar sagittal reconstruction (**b**) show the presence of pneumoperitoneum, which is more evident with a lung window

non-specific CT findings of this condition. Pneumatosis cystoides intestinalis can be present, manifesting as a single gas bubble or a broad rim of air dividing the bowel wall into two layers.

When pneumatosis cystoides intestinalis occurs in combination with portal-venous gas, especially in the liver periphery, it is definitely associated with bowel ischemia but is not a pathognomonic finding (Stoker et al. 2009). Portal-venous gas is an ominous sign that is generally seen in patients with a poor prognosis.

In patient with clinically suspected GI-tract perforation, pneumoperitoneum can be recognized by the presence of subdiaphragmatic air on an erect chest radiograph or an erect or left lateral decubitus radiograph of the abdomen (Grassi et al. 1996; Cho and Baker 1994; Levine et al. 1991). An abundant pneumoperitoneum is indicative of a perforation complicating a large-bowel obstruction. With perforation of the small bowel, only small quantities of gas escape because the small bowel usually does not contain gas (Grassi et al. 1998). The detection of subtle pneumoperitoneum is often difficult. MDCT is far more sensitive than conventional radiography in identifying a small pneumoperitoneum and has thus become the modality of choice in cases that are unclear on a conventional radiograph (Grassi et al. 2004; Pinto et al. 2000, 2004; Imuta et al. 2007). To enhance the sensitivity of CT for extraluminal gas, the scans are also viewed at "lung window" settings (Fig. 10).

Acute flank or epigastric pain is commonly a manifestation of retroperitoneal pathology, especially urinary colic, acute pancreatitis, or leaking abdominal

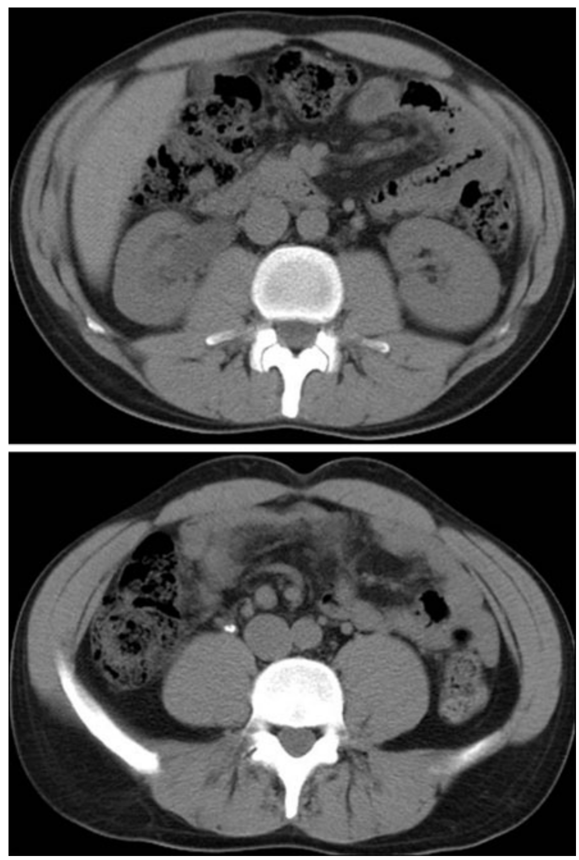

Fig. 11 Urolithiasis. Axial CT sections, without intravenous contrast material, at the levels of the kidneys and the ureteral abdominal tract. Multiplanar coronal reconstruction performed with low-dose technique show a right hydro-uretero-nephrosis with evidence of an obstructing calculus located at the level of the ureteral abdominal portion

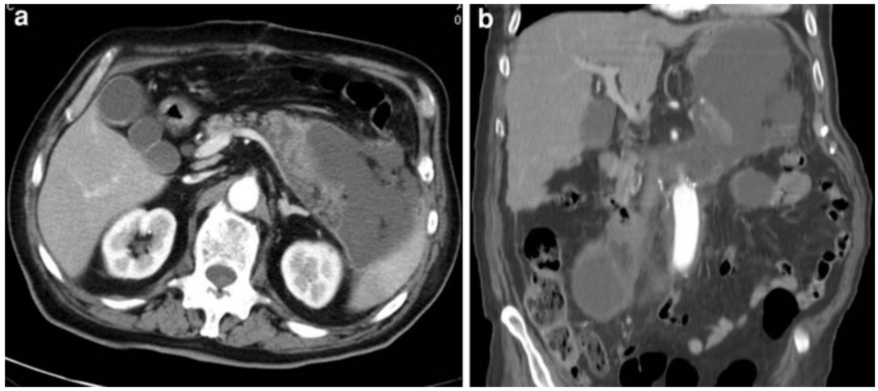

Fig. 12 Necrotizing pancreatitis. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show a pancreatic parenchymal distruction with pancreatic exudate extending at the level of the perisplenic space

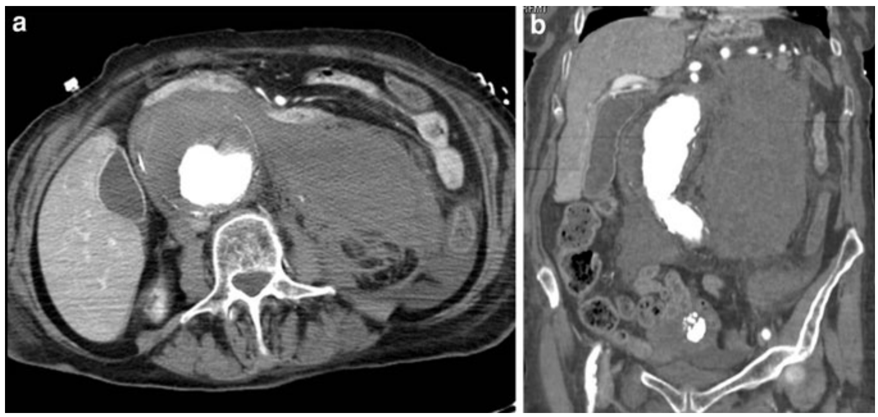

Fig. 13 Abdominal aortic aneurysm. Axial CT scan (**a**) and multiplanar coronal reconstruction (**b**) show the rupture of an abdominal aortic aneurysm, with a large hemoretroperitoneum

aortic aneurysm. For several decades, intravenous urography has been the primary imaging technique used in patients with flank pain caused by a suspected urolithiasis-induced urinary colic. Abdominal US is considered useful in patients with contraindications to irradiation or contrast media. However, because of the low sensitivity of US for urinary-tract calculi, the role of unenhanced CT has grown rapidly (Smith et al. 1995, 1996) (Fig. 11). MDCT examination at reduced exposure factors maintains the diagnostic accuracy. Unenhanced, low-dose MDCT provides a rapid and accurate diagnosis of ureteral stones, because almost all calculi are radio-opaque at CT (Leschka et al. 2005). Obstructing ureteral calculi are typically located at the ureteropelvic or ureterovesical junction. Subtle calculi may be detectable by the presence of focal peri-ureteral stranding. Secondary CT signs of urolithiasis include hydro-ureter, hydronephrosis, peri-nephric stranding, and renal enlargement. The use of oblique–coronal reconstructions is more effective for precise stone localization and measurement than axial slices (Leschka et al. 2005). With MDCT, high-resolution, cine-viewing reconstructions can be obtained from thin-collimation acquisitions. The use of curved reformations provides unequivocal images focused on the ureteral stone.

An important disease causing epigastric pain is acute pancreatitis. US is helpful for the demonstration of gallstones as a cause of acute pancreatitis and for the follow-up of known fluid collections. The CT findings correlate well with the clinical severity of acute pancreatitis, such that MDCT has become the imaging modality of choice to stage the extent of disease and to detect complications (Marincek 2002). Pancreatic enlargement due to interstitial parenchymal edema may progress to pancreatic exudate collecting in the anterior pararenal space, the transverse mesocolon, the mesenteric root, and the lesser sac. Necrosis or hemorrhage may develop within the pancreas itself, in addition to extending to adjacent organs, which can be further compromises by thrombosis of the splenic and portal veins (Marincek 2002) (Fig. 12).

One of the most life-threatening alternative diagnoses in acute flank pain is a leaking aneurysm of the abdominal aorta. In a suspected rupture of an abdominal aortic aneurysm, US is the initial imaging technique. The examination can be performed rapidly with portable equipment in the emergency room. In hemodynamically stable patients, contrast-enhanced MDCT accurately delineates the para-aortic hemorrhage and can directly visualize the actual site of the leaking aortic aneurysm (Fig. 13).

Even though the ACR Appropriateness Criteria still rate MRI below CT and US for the evaluation of acute abdominal and pelvic conditions (Miller et al. 2008), MRI is an excellent alternative to CT in patients in whom the use of iodinated contrast agents or radiation is not desirable (Heverhagen and Klose 2009). In addition, when US findings are non-diagnostic or equivocal, MRI is an appropriate modality for the evaluation of acute lower abdominal and pelvic pain, especially in pregnant or younger patients. Depending on local availability, MRI may be considered as the modality of first choice in all patients with acute lower abdominal and pelvic pain. In general, high costs, long imaging times, and limited availability are considered to be its major drawbacks in this setting. However, its value has been assessed in many acute conditions of the lower abdomen and pelvis, for example, appendicitis, diverticulitis, bowel obstruction, chronic inflammatory disease (Crohn disease and ulcerative colitis), vascular disease, and gynecologic disorders (Patel et al. 2007). The body of scientific research on the use of MRI in patients with acute abdominal pain is relatively limited. Therefore, the availability of and expertise with this examination are limited, and the cost-effectiveness has not been studied. Further research should be directed toward better defining the role of MRI in the setting of acute abdominal pain, especially compared with US and CT. Attention to proper technique and the use of tailored protocols are essential for optimizing the effectiveness of the MRI examination and maximizing its diagnostic accuracy. The recently increased awareness and attending concern regarding radiation-related health risks warrant the adoption of a flexible approach to imaging in the emergency setting, particularly in pregnant and pediatric patients.

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