RADIOLOGY FOR PRACTITIONERS

EMERGENCY ABDOMINAL RADIOLOGY: THE ACUTE ABDOMEN

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I. DEFINITION

The clinical entity of the acute abdomen, from a practical standpoint view, describes a patient with acute abdominal pain of rapid or sudden onset, requiring surgical or immediate action [1]. It is assigned as preliminary diagnosis until a specific diagnosis is established.

II. CAUSES

Based on studies of approximately 30,000 patients, de Dombal [2] noted that in one third of these cases, cause was never established hence so-called unspecified abdominal pain. In those patients in whom a diagnosis became evident, 28% had appendicitis, 9.7% acute cholocystitis, 4.1% small bowel obstruction, 4% acute gynecologic disease, 2.9% acute pancreatitis, 2.9% renal colic, 2.5% perforated peptic ulcer, 1.5% cancer, and 1.5% diverticulitis. Of course, several other causes not mentioned in this section may be responsible for acute abdominal pain, some of which will be discussed in this article. Grossly, acute abdominal conditions can be divided into traumatic and non traumatic conditions, in adults and elderly and in pediatric patients with some inevitable overlap.

III. CLINICAL ASSESSMENT

The majority of patients with acute abdominal conditions present to the Emergency Unit. It is of great importance that the preliminary clinical assessment and the radiology request form state the working presumptive/provisional clinical or differential diagnosis, specify the rapid or insidious onset and the duration of the pain and whether the abdominal pain is diffuse or localized to a quadrant i.e. to the epigastrium, right upper quadrant (RUQ), left upper quadrant (LUQ), right lower quadrant (RLQ), left lower quadrant (LLQ), or pelvic pain; and whether there are associated symptoms such as fever, tachycardia, nausea and vomiting, hematuria, gastrointestinal bleeding, leucocytosis, hemodynamic status i.e. stable or unstable patient in shock, and others that can help in short listing the diagnostic possibilities towards "ruling out" one or more acute abdominal conditions. In terms of differential diagnosis of acute abdominal emergencies, the authors of this article adopted a simple classification based on the following terminology: the **"itis"** i.e. inflammatory and infectious conditions such as appendicitis, diverticulitis, cholecystitis, and many other diseases, the **"tion"** such as bowel perforation, bowel, renal, biliary, and vascular obstruction, aortic dissection, and intestinal or ovarian torsion, and the "nonspecific" abdominal pain. A provisional working or presumptive diagnosis is made in approximately 50% of cases, otherwise a clinical differential diagnosis is provided depending on history, physical examination, basic blood tests including a full blood count and a serum creatinine level, urine analysis, and other laboratory tests of relevance. Requests for cross-sectional imaging namely ultrasound and CT scan will follow if immediate surgery is not indicated. Immediate surgery is indicated in patients with a large pneumoperitoneum diagnosed on plain abdominal radiographs (PAR), hemodynamically unstable patient with spontaneous intraabdominal hemorrhage detected on a bedside portable ultrasound examination. Selection of an appropriate imaging strategy is essential to ensure prompt treatment.

IV. CLINICAL SCENARIOS AND IMAGING TECHNIQUES

With regard to the selection of imaging strategies in the emergency room, two clinical scenarios should be considered at presentation. First, the patient presenting with abdominal pain and hemodynamically unstable condition with hypotension i.e. shock state. If the hematocrit level is low a hemorrhagic shock state should be suspected. For this clinical scenario, a fast chest and abdominal sonography using hand held portable ultrasound equipment at the bedside in the emergency room should be carried out in 20 to 30 seconds looking for four major abnormalities: 1/ Retroperitoneal hemorrhage from a leaking abdominal aortic aneurysm (AAA) or ruptured angiomyolipoma of the kidney or hemorrhagic pancreatitis. 2/ Presence of intraperitoneal hemorrhage or fluid from a ruptured visceral aneurysm, liver tumor, ectopic pregnancy, or other conditions. 3/ Hemopericardium or hemothorax from aortic dissection or rupture. 4/ Pyonephrosis from renal obstruction and urosepsis. Second, the patient presenting with abdominal pain and hemodynamically stable con-

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dition. In this clinical scenario imaging is important because the physical findings and laboratory studies are often nonspecific, and abnormalities that may cause an acute abdomen are extraordinarily diverse and range from benign self-limited disorders such as gastroenteritis, mesenteric adenitis and others that may not require admission to hospital, to life-threatening illnesses such as bowel infarction or perforation, strangulated hernia, necrotizing pancreatitis requiring immediate surgical action i.e. a surgical emergency. Diagnostic imaging plays a pivotal role in triaging these patients rapidly, safely, and decisively towards optimal therapy i.e. surgical versus nonsurgical. In this regard, several imaging techniques can be used that have practically replaced the physical examination starting with the simple conventional radiographs as the initial radiological investigation i.e. **"three-view acute abdominal series"** consisting of a combination of chest and abdominal radiographs in the erect and supine positions looking for intestinal obstruction or perforation with extraluminal air, radiopaque urinary calculi or appendicolith. The use of cross-sectional imaging techniques such as computed tomography (CT) and color Doppler ultrasound (CDUS) has superseded at large the conventional radiographs because of their higher diagnostic accuracy. Because of major concern about exposure to high radiation doses and potential adverse allergic and toxic effects of intravenous contrast material administered to patients undergoing CT examinations, CDUS and magnetic resonance imaging (MRI) are noninvasive imaging techniques that should be considered as the modalities of first choice in children, and in pregnant women where exposure to ionizing radiation is considered unacceptable, and in patients at higher risk for developing allergic and toxic reactions to iodinated contrast media. Present data have not conclusively documented any deleterious effects of MR imaging on the developing fetus. Therefore, no special consideration is recommended for the first, versus any other, trimester in pregnancy. Pregnant patients can be accepted to undergo MR scans at any stage of pregnancy. MR contrast agents should not be routinely provided to pregnant patients [3]. However, low dose CT scan examination is increasingly used in the United States for the primary diagnosis of acute abdominal conditions in pregnant women and children. When performing an ultrasound examination of a patient with acute abdominal pain, it is essential that the operator ask the patient to point out with one index finger the point of maximum tenderness, where the operator will apply the transducer for an optimal examination.

A variety of CT techniques that can be applied and tailored to each clinical scenario are listed in Table I, to answer specific clinical questions. An algorithmic imaging approach to acute abdominal pain is suggested in Table II.

Magnetic resonance and nuclear medicine imaging studies have a limited selective role in the acutely ill-patient. The use of MRI in the emergency setting is evolving [4]. Abdominopelvic MRI is often used in a problem-solving capacity as an adjunct second-line investigation in those patients with an unclear diagnosis on cross-sectional CDUS or CT imaging techniques, prior to laparoscopy.

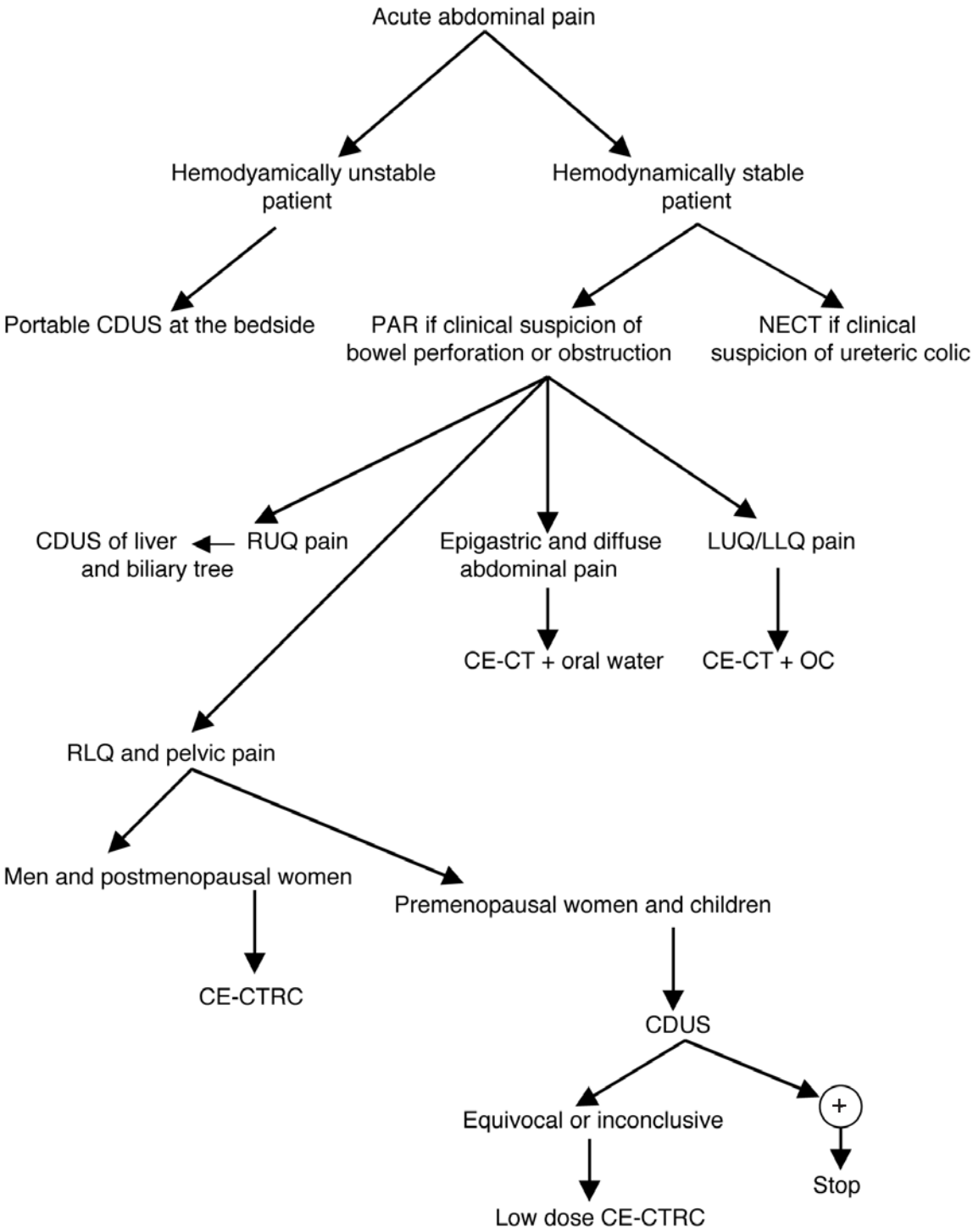
TABLE I
VARYING AND TAILORED CT TECHNIQUES TO CLINICAL SCENARIOS

NECT/Plain CT without IV or oral CM	**NECT & CECT + delayed images without oral CM**
1. Renal or ureteric colic	**1.** Acute flank pain with normal kidneys on NECT → CECT to R/O renal infarction or acute pyelonephritis or equivocal renal or ureteric obstruction.
2. Renal failure i.e. elevated serum creatinine level	
Biphasic CECT with arterial and venous phases **+ oral water**	**Monophasic CT angio with arterial phase only – without oral CM**
1. Acute pancreatitis	**1.** Suspected acute abdominal spontaneous hemorrhage
	2. Suspected leaking AAA
	3. Polytrauma patient
	4. Intrapelvic postpartum hemorrhage with uterine rupture
CECT – without oral CM	**CE/CTRC i.e. with rectal contrast**
1. Suspected high grade SBO on PAR	**1.** Suspected acute appendicitis
2. Suspected acute mesenteric ischemia → Biphasic CT angio with arterial & venous phases	**2.** Suspected colonic obstruction → Instant contrast enema
CECT + oral CM	**CECT with delayed urinary excretory phase**
1. Diverticulitis	**1.** Suspected urine leakage after blunt trauma to the urinary tract or post surgical injury to the urinary tract with urinary ascites or urinoma formation
2. PEA	
3. Low grade/intermittent/partial or incomplete SBO	
4. Small pneumoperitoneum	

NECT : non enhanced CT — **IV** : intravenous ; **CM** : contrast media — **CECT** : contrast enhanced CT
R/O : rule out — **AAA** : abdominal aortic aneurysm — **SBO** : small bowel obstruction
PAR : plain abdominal radiographs — **CE/CTRC** : contrast enhanced CT with rectal contrast — **PEA** : primary epiploic appendagitis

TABLE II

SUGGESTED ALGORITHMIC IMAGING APPROACH FOR THE DIAGNOSTIC WORKUP OF ACUTE ABDOMINAL PAIN



CDUS : color Doppler ultrasound **PAR** : plain abdominal radiographs **NECT** : non-enhanced CT scan **RUQ** : right upper quadrant
LUQ : left upper quadrant **LLQ** : left lower quadrant **RLQ** : right lower quadrant
CE-CT + OC : contrast enhanced CT scan with oral contrast **CE-CTRC** : contrast enhanced CT scan with rectal contrast

Hepatobiliary scintigraphy [5] is indicated in patients with suspected acute cholecystitis and equivocal CDUS or CT findings, and in patients with suspected bile leak or biloma formation from bile ducts injury following abdominal trauma or iatrogenic injury.

Invasive angiographic and interventional transcatheter procedures performed percutaneously by interventional radiologists under imaging guidance play an important role in the management of acute abdominal conditions in some selected cases with appropriate indications.

V. DIAGNOSTIC IMAGING & PATHOLOGY IN ADULTS

For all practical purposes, the authors based on personal experiences and review of the literature, have preferably adopted the classification of traumatic versus non traumatic abdominal conditions, an imaging approach based on the localization of pain to an abdominal quadrant, taking also in consideration the age of the patient. A brief discussion of the common causes of acute abdominal emergencies with the appropriate and up-to-date usage of imaging diagnostic strategies and techniques with illustrative examples is presented.

A. ABDOMINAL TRAUMA

Abdominal trauma will be discussed here in the context of polytraumatized patients, because abdominal trauma is often associated with trauma to other parts of the body, especially in severely injured patients involved in road traffic accidents or fall from a height. Few important points should be addressed regarding the management of a polytraumatized patient i.e. transport, resuscitation, investigation, and treatment action or therapeutic options of a critically injured individual [6-8].

First, **"time is life"** i.e. a quick transport from the field of injury to the emergency room is of crucial importance. Ambulances for short distances and helicopters for long distances play an important role in patient's survival by applying the **"load and go"** principle, of course after adequate immobilization of the victim of injury on a brancard and applying "first aid" resuscitation.

Second, upon arrival to the emergency room (ER) the principle of the **"Golden Hour"** should be applied i.e. in the first 30 minutes the patient is resuscitated and hemodynamically stabilized in the resuscitation room (RR) and his conscious status assessed, and in the second 30 min the patient should be investigated for a diagnosis and immediately treated. In the second 30 min of the "Golden Hour" principle, two different scenarios can be observed depending on availability of local facilities and expertise:

1. In advanced "Specialized Trauma Centers" in Europe & the United States where an integrated multidetector CT (MDCT) and angiography units are available on-site in the ER with dedicated trauma and interventional radiologists staff on-duty available 24 hours, no mobilization of the patient or the resuscitation team or ancillary equipment is required. In a conscious patient a total body MDCT angiography is performed even if the patient is hypotensive and hemodynamically unstable, looking for surgically treatable conditions that can be treated by interventional radiologists such as active arterial bleeding with extravasation of the contrast medium i.e. contrast blush detected on MDCT images, treatable by immediate transcatheter embolization at admission. Lack of renal enhancement indicates renal artery injury treatable with stenting within the first 6 hours following trauma. If the patient is unconscious a nonenhanced head CT scan should be also performed.
2. In non specialized trauma centers, as in the case of practically all emergency centers in Lebanon including our emergency unit, the scenario is different. If the patient is hymodynamically unstable i.e. with a blood pressure < 80 mmHg the patient should not be moved from the RR, and a **"focused assessment sonography for trauma (FAST)"** is performed using a hand held portable ultrasound machine at the bed-side looking for a hemopericardium, hemothorax, or a hemoperitoneum [9], together with portable chest and pelvis radiographs and lateral projection of the cervical spine to exclude an unstable cervical spine fracture, prior to surgery. If the patient is hemodynamically stable i.e. blood pressure > 80 mmHg or marginally stable BP = 80 mmHg, he can be moved to the Radiology Department for investigation. A helical CT angiography (with delayed image acquisition at 10 minutes if there is suspicion of upper urinary tract injury to the pelvicalyceal system with urine extravasation, or with a conventional retrograde urethro-cystography if there exists suspicion of lower urinary tract injury) is usually performed looking for ongoing active arterial hemorrhage with extravasation of contrast medium that can be treated by transcatheter embolization at the angiography suite (Fig. 1a). With regard to transcatheter therapy the aim is to achieve hemostasis by either embolization or balloon vessel occlusion prior

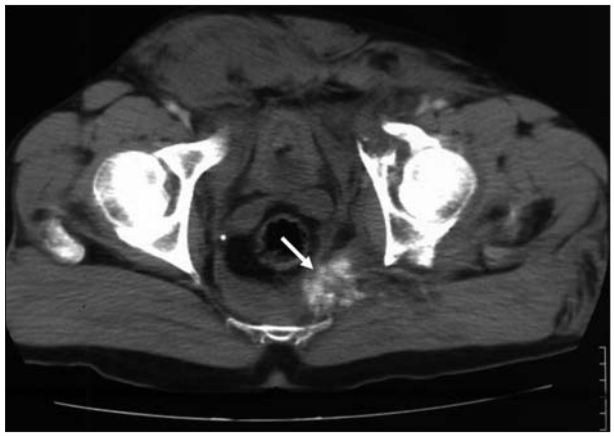


FIGURE 1a
Contrast enhanced helical CT angiography showing extravasation of contrast material (arrow) (131 HU) compatible with active bleeding secondary to a pelvic fracture.

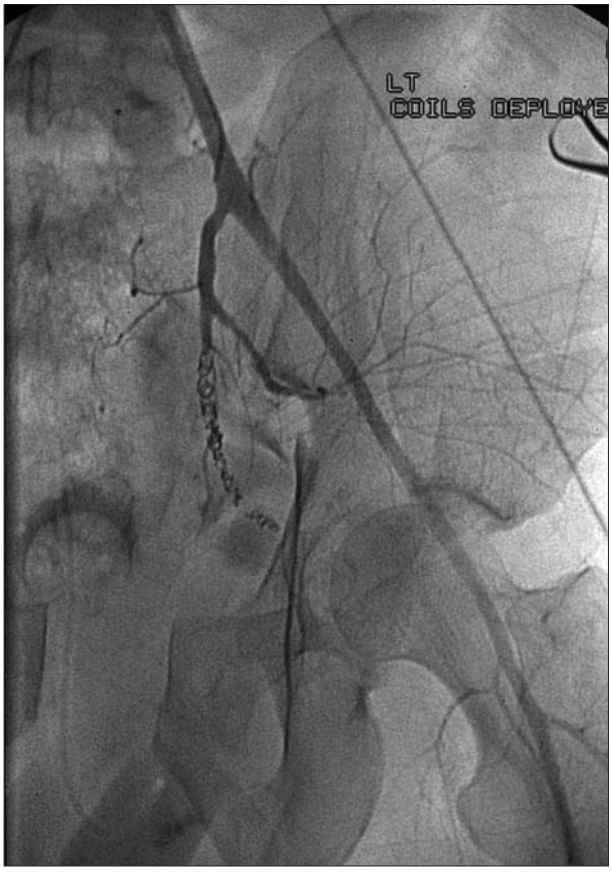


FIGURE 1b. Selective transcatheter coil embolization of the bleeding vessel shown in 1a, a branch of the left internal iliac artery, was successfully performed achieving hemostasis.

to definitive surgery (Fig. 1b). A superselective distal or peripheral embolization using microcoils through a coaxial system i.e. an outer 5F catheter or 6F guiding catheter with an inner 3F microcatheter, is usually required and preferable. However, emergency hemostatic selective embolization with a 4F or 5F catheter is also desirable, performed as a life-saving procedure by general radiologists. Embolization should be performed quickly and as soon as possible for hemorrhage control i.e. hemostasis for two reasons: first, patients receiving multiple or massive blood transfusions usually develop wash-out coagulopathy, in this instance it may become difficult to stop bleeding or achieve hemostasis with distal embolization and microcoils therefore a more proximal embolization of the main feeding trunk with compact coils may be necessary; second, in patients with hypovolemic state and pre-shock vasoconstriction or vasospasm occurs, it prevents distal catheterization for embolization.

A special circumstance may occur with terror attacks consisting of suicide bombers and massive explosions, resulting in a large number of injured individuals arriving to Emergency Unit in a very short period of time, so-called mass casualty incidents (MCI's). Radiologists became crucial members of the fist-line team of doctors in the management of MCI's. Fast imaging plays an important role in the secondary triage process of critically injured individuals who need further management and hospitalization, thus improving mortality or death-to-injury rates. A disaster plan with emergency radiology preparedness and a bomb threat plan with regular drill tests should be developed as part of every hospital's policies and procedures [10].

B. NON TRAUMATIC CONDITIONS

1. Acute Right Upper Quadrant (RUQ) Pain

a. ***Acute cholecystitis*** • In the right upper quadrant, acute cholecystitis and biliary colic or acute cholangitis are by far the most common diseases, other less important and frequent diseases that cause RUQ pain include: liver abscess and spontaneous rupture of a hepatic neoplasm. CDUS is the preferred imaging method for evaluating patients with acute RUQ pain. It is a reliable technique for establishing the diagnosis of acute cholecystitis with a high accuracy of 92% [11]. The imaging findings consist of primary signs or major criteria for diagnosis such as detection or visualization of gallstones obstructing the gallbladder neck or cystic duct, a positive Murphy's sonographic sign, and minor criteria or secondary diagnostic signs such as gallbladder wall thickening of 3 mm or greater, overdistension of the gallbladder with a largest diameter of 4 cm or greater, and evidence of pericholecystic fluid or biliary sludge (Fig. 2). In patients with suspected emphysematous cholecystitis i.e. diabetic, HIV and immunosuppressed individuals, a plain abdominal radiograph or better a nonenhanced CT scan may supplement the CDUS in order to confirm the diagnosis of emphysematous cholecystitis. In patients with suspected gangrenous cholecystitis, the pain is usually absent with a negative Murphy's sonographic

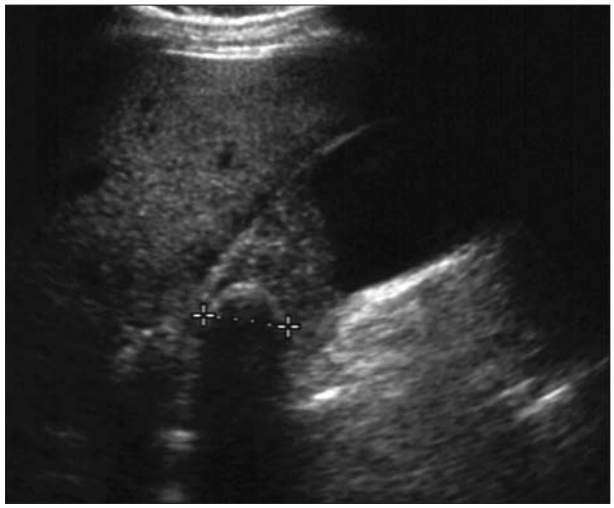


FIGURE 2.. Sonography showing an impacted large 2.4 cm stone in the gallbladder neck, gallbladder distension and biliary sludge in a patient with acute cholecystitis.

sign, color Doppler flow imaging or contrast enhanced CT scan show absence of vascularity or enhancement in the gallbladder wall and sloughing of the mucosa. CT and Tc-HIDA hepatobiliary scintigraphy may be helpful as second-line investigations for confirmation of the diagnosis if the sonographic diagnosis of acute cholecystitis is equivocal.

Acute acalculous cholecystitis (AAC) occurs in patients who are critically ill in intensive care units. It is thought to be secondary to a functional obstruction of the cystic duct. The sonographic findings may be nonspecific, therefore the sonographic diagnosis of AAC can be difficult. Diagnostic percutaneous needle aspiration of bile from the gallbladder for Gram stain and culture, and a percutaneous transhepatic cholecystostomy performed at the bedside under sonographic guidance are valuable methods for confirming the diagnosis of AAC and relieving obstructive and inflammatory changes.

b. ***Biliary colic and acute cholangitis*** • Choledocholithiasis is seen at the time of cholecystectomy in 8% to 15% of patients younger than 60 years old, and 15% to 60% of patients older than 60 years of age [12]. Patients with or without cholecystectomy presenting with common bile duct stones, may have a biliary colic with or without cholangitis, pancreatitis, jaundice, and abnormal liver function tests (LFT's) especially an elevated serum alkaline phosphatase level due to biliary obstruction.

Diagnosis of choledocholithiasis may be difficult especially with sonography because more than one third of patients with choledocholithiasis have no biliary ductal dilatation that usually makes detection of bile duct stones much easier (Fig. 3). The overall reported sensitivity of sonography for detection of choledocholithiasis is low estimated at 70% (range 22-85%) [13-14]. The main application for sonography in patients with suspected biliary sepsis, jaundice, and abnormal LFT's is the detection of bile duct dilatation and differentiation of obstructive jaundice from hepatitis which enters in the differential diagnosis. Magnetic resonance cholangiopancreatography (MRCP) is a totally noninvasive imaging technique capable of detecting choledocholithiasis in patients with no biliary sepsis with a high sensitivity approaching 96% [15]. However, it is not widely used because of some technical limitations: a minimal cooperation from the patient remains necessary to obtain optimal quality images, low availability of MR imaging especially with non scheduled appointments for emergency patients with biliary sepsis, some pitfalls in image interpretation i.e. stones smaller than 5 to 6 mm may be overlooked, and a final major limitation of MRCP which represents only a diagnostic and not a therapeutic procedure. This is why endoscopic ultrasound (EUS) and endoscopic retrograde cholangiopancreatography (ERCP) have gained wide acceptance and became the procedure of choice for diagnosis and treatment of choledocholithiasis, as an emergency procedure especially in patients with biliary obstruction and sepsis requiring emergency drainage by sphincterotomy and balloon or Dormia basket extraction of stones, with a success rate of 87% [16]. If the stones cannot be removed, a nasobiliary tube or preferably an internal stent may be left in place for drainage. In a few instances, when endoscopy is not feasible especially in patients with previous surgery and biliary-enteric anastomosis, percutaneous transhepatic management is useful. In critically-ill or high-risk elderly patients with multiple medical problems, presenting with cholangitis secondary to biliary obstruction and sepsis, and considered at risk i.e. not candidates for surgery, ERCP, or percutaneous transhepatic cholangiography (PTC), a percutaneous cholecystostomy (Fig. 4) under CT guidance or at bedside under ultrasound guidance can be performed. This is usually performed as a simple first stage procedure and temporizing measure to relieve obstruction and culture the aspirated bile specimen, prior to a definitive second stage procedure consisting of balloon dilatation of the sphincter of Oddi and

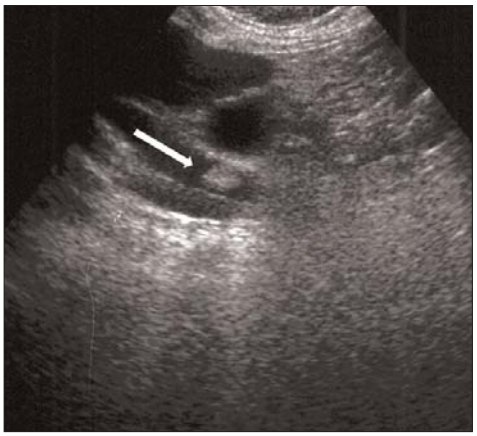


FIGURE 3

Dilated common bile duct measuring 1.3 cm in diameter containing a large 1.2 cm stone (arrow) on sonography.

FIGURE 4

Cholecystostomy tubogram showing complete obstruction of the common bile duct by a stone (arrow).

biliary stenting of the common bile duct over a guide wire manipulated across the cystic duct.

2. Acute Right Lower Quadrant (RLQ) Pain

a. ***Acute appendicitis (AA)*** • It is the most frequent cause of acute RLQ pain. Other less common causes include: mensenteric adenitis, primary epiploic appendagitis, caecal diverticulitis, right lower lobe pneumonia with referred pain to the RLQ, infectious and inflammatory enterocolitides, torsion of Meckel's diverticulum, and neutropenic typhlitis in immunosuppressed and cancer patients. Classically, the diagnosis of AA is primarily a clinical diagnosis in approximately 70 to 78% of patients with typical clinical and laboratory findings, they undergo surgery without preoperative imaging. In about 20% of clinically equivocal patients with atypical findings or clinical presentation, the clinical diagnosis of AA may be uncertain, therefore appendiceal cross-sectional imaging is required to confirm or exclude the diagnosis of AA [17].

Plain abdominal radiograph has a limited diagnostic value in the diagnosis of AA; it may show an appendicolith which is only present in 15% of patients with AA. It is important to mention that appendicoliths can also be seen in the absence of appendicitis. The most widely used imaging techniques for diagnosis of AA are graded compression ultrasound (US) using a high frequency 5-12 MHz linear probe and CT scan. US has become an important imaging option in the evaluation of AA, particularly in children and pregnant women because of radiation concern. If the results of US are equivocal or indeterminate, further evaluation by MRI or contrast enhanced low dose CT with intravenous and rectal contrast may be required in a small minority of patients. On sonography, the identification of a swollen and thickened, noncompressible appendix greater than 6 mm in diameter is diagnostic of AA. Because of its exceptional accuracy CT scan has emerged in many centers including our institution as the primary imaging modality for patients with suspected AA especially those presenting outside working hours and examined by junior housestaff. At our institution, multislice helical CT scan with intravenous and rectal contrast administration (CTRC) proved to be a highly useful and effective technique allowing a quick and accurate diagnosis for appropriate management of AA and avoiding unnecessary surgery for nonsurgical conditions. The use of helical CTRC with its high accuracy of 94.7% in the diagnosis of AA [18], has resulted since its introduction in the year 2002 in a significant reduction of negative appendectomy rate to 4% as compared to a previous negative appendectomy rate of 16% prior to the year 2002 according to a study of Performance Indicator (PI) conducted in our hospital (Dr. Ayman Tawil, personal communication), and allowed identification of alternative diagnoses or mimickers of AA in 32% of patients investigated with helical CTRC to rule out AA in whom a normal appendix is identifiable [19]. On helical CTRC, a thickened appendix, with nonopacification of its lumen with contrast material, enhancement of its wall and periappendiceal fat streaking, are diagnostic signs of noncomplicated AA (Fig. 5), even a tip appendicitis can be easily diagnosed with CTRC. In complicated AA by rupture or perforation, free fluid in the abdomen and pelvis, periappendiceal abscess formation, ureteric or intestinal obstruction may be observed. In the recent literature, there is an emerging consensus for routine use of CT for most if not all adult patients with suspected AA.

b. ***Ureteric colic*** • Ureteric colic caused by acute right ureteric calculus obstruction may cause RLQ pain radiating to the flank, or inguinal region and scrotum. Similarly, an acute left ureteric calculus obstruction may cause left lower quadrant pain. For several years intravenous urography has been the primary cornerstone investigation used in patients with suspected urolithiasis induced urinary colic. Nowadays, nonenhanced CT scan of the abdomen and pelvis (Fig. 6) is universally considered including at our institution [20-21] as the imaging modality of first choice for patients suspected with urinary calculus obstruction. Virtually all ureteral calculi are radiopaque and dense on CT, regardless of their chemical composition. Uric

FIGURE 5. Contrast enhanced CT scan with rectal contrast showing an inflamed thickened nonopacified appendix compatible with a noncomplicated acute appendicitis (arrow).

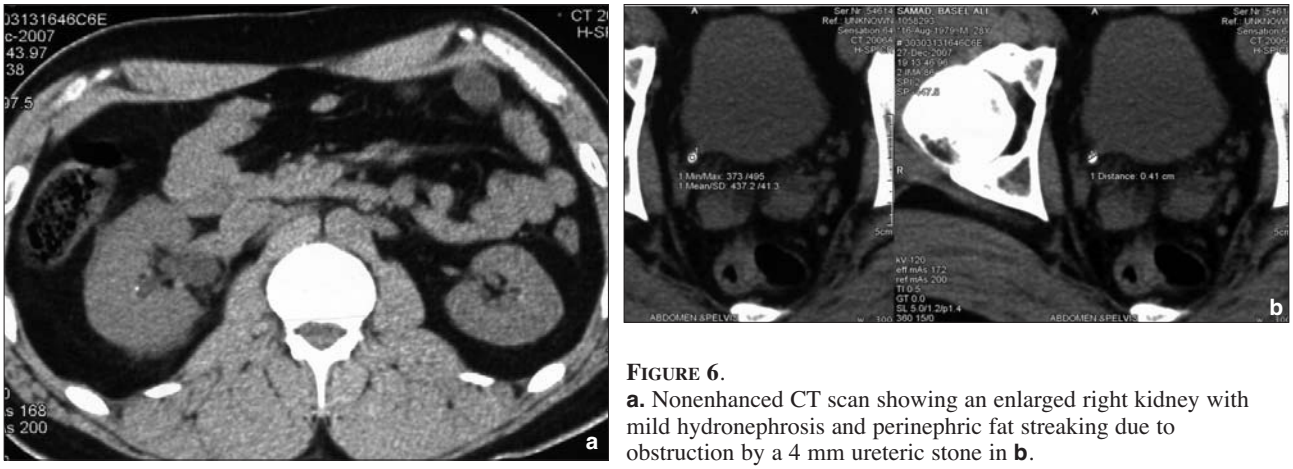


FIGURE 6.
a. Nonenhanced CT scan showing an enlarged right kidney with mild hydronephrosis and perinephric fat streaking due to obstruction by a 4 mm ureteric stone in **b**.

acid stones have attenuation values of 300-500 HU, and calcium-based calculi have attenuation values higher than 1000 HU [22]. When no ureteric calculus is detected, a search for an alternative diagnosis should be instituted. Noncalculous urinary tract abnormalities causing symptoms of renal colic or acute flank pain with or without microscopic hematuria include acute pyelonephritis and renal infarction. In this clinical context, a repeat of CT examination with intravenous contrast material administration is required to establish a diagnosis. Also, in approximately 3% of cases differentiation of a ureteric calculus versus a calcified phlebolith in the pelvis may be difficult on nonenhanced CT scan, therefore a repeat CT examination with intravenous contrast material and delayed imaging at excretory phase is necessary to ascertain a diagnosis of ureteric calculous obstruction. In pregnant women with suspected ureteric colic, CDUS can be helpful for the diagnosis of acute ureteric calculous obstruction [23]. In children with suspected ureteral calculous obstruction, PAR coupled with CDUS are usually diagnostic. If the combination of PAR and CDUS is negative i.e. no dilatation of the upper renal tract exists and the calculus not visualized by PAR, a limited single-shot urography intravenous film taken 10-15 minutes after injection of contrast is still a good examination for confirmation or exclusion of the diagnosis in children [24]. Gadolinium enhanced MR urography will achieve the same result, however nonenhanced low dose CT scan examination (80-100 mA, at 120-140 kV) is increasingly used in the United States for the primary diagnosis of ureteric calculous obstruction in pregnant women and children [25], and even in adults with a reduction in effective radiation dose by 38-56% [26].

Figure 7
Contrast enhanced CT scan showing a large wedge shape splenic infarct.

3. Acute Left Upper Quadrant (LUQ) Pain

Acute abdomen with LUQ pain is not frequent. Splenic infarction (Fig. 7) or abscess, gastritis or gastric ulcer and irritable colon or constipation are the most important causes of acute LUQ pain. The diagnosis of gastric or colonic pathology is established by endoscopy, with imaging playing a minor role. However, CT enables accurate evaluation of splenic pathology.

4. Acute Left Lower Quadrant (LLQ) Pain

a. ***Diverticulitis*** • In the LLQ, diverticular disease is the most common cause of acute abdominal pain. Diverticulitis occurs in up to 25% of patients with known colonic diverticulosis. It can also affect the caecum causing caecal diverticulitis with RLQ pain simulating AA or a colonic malignancy especially in elderly people, the clue to the diagnosis is clinical with identification of diverticulae in other segments of the large bowel on CT scan. Contrast enhanced CT with intravenous and oral contrast material reaching the large bowel is very sensitive and approaches 100% specificity and accuracy in the diagnosis or exclusion of diverticulitis [27-28].

The CT diagnosis of diverticulitis relies on the identification of colonic diverticulae, segmental colonic wall thickening, and pericolonic mesenteric

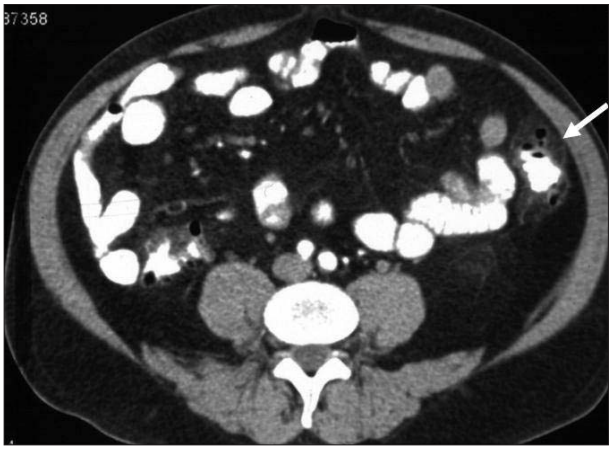


Figure 8. Contrast enhanced CT scan with oral contrast reaching the large bowel, showing diverticulitis of the descending colon (arrow).

Figure 9

a. Contrast enhanced CT scan with oral contrast showing a pericolonic abscess (arrow) due to sigmoid diverticulitis.

b. Percutaneous catheter drainage of the pericolonic abscess was performed. Tubogram showing opacification of the large bowel secondary to a communication between the pericolonic diverticular abscess and the large bowel.

inflammatory changes (Fig. 8). Occasionally, patients with diverticulitis may present with a pericolic abscess that can be drained percutaneously by a draining catheter under CT guidance, as a temporizing measure prior to elective surgery as a definitive treatment (Fig. 9). The use of contrast enhanced CT scan with rectal contrast in patients with suspected diverticulitis is to be avoided because of the risk of perforation and inducing blood septicemia. However, we have observed cases of caecal diverticulitis diagnosed by contrast enhanced CT with rectal contrast in patients presenting with RLQ pain in the emergency setting without any complications (Fig. 10).

b. ***Primary epiploic appendagitis (PEA)*** • Contrast enhanced CT with intravenous and oral contrast medium is very useful for detecting other causes of LLQ pain such as PEA which is a nonsurgical self-limiting condition managed with conservative treatment [29]. PEA is caused by torsion of the epiploic appendage with resultant ischemia and fat necrosis. CT shows a pericolonic fat attenuating mass located adjacent to the anterolateral serosal surface of the colon (Fig. 11). PEA can affect any segment of the colon including the ascending and transverse colon causing localized pain.

5. Acute Epigastric, Central and Diffuse Abdominal Pain

Any disorder that irritates a large portion of the gastrointestinal tract and/or the peritoneum causes diffuse abdominal pain. The most common disorders are infectious gastroenterocolitis, acute pancreatitis, acute mesenteric ischemia, bowel obstruction and pseudoobstruction, gastrointestinal tract perforation, leaking abdominal aortic aneurysm, spontaneous intraperitonal hemorrhage, and others.

a. ***Acute pancreatitis*** • An important cause of epigastric pain is acute pancreatitis. Ultrasound (US) is helpful for the demonstration of gallstones as a cause of gallstone pancreatitis and for follow-up of known peripancreatic fluid collections occurring in patients with pancreatitis. US is not helpful for the radiologic diagnosis of acute pancreatitis. In patients with elevated serum amylase and lipase levels suspected to have acute pancreatitis, contrast enhanced CT scan with oral water administration (Fig. 12) is the modality of choice for early diagnosis of acute pancreatitis and assessment of the severity of acute pancreatitis using a CT severity index developed by Balthazar et al. [30-31] to stage the extent of the disease, and for detection of complications that may develop in patients with pancreatitis such as pancreatic tissue necrosis and peripancreatic fluid collections, splenic or portal vein thrombosis and splenic artery pseudoaneurysm. Surgical debridement i.e. necrosectomy is the treatment of choice of necrotizing pancreatitis associated with greater than one third of pancreatic tissue necrosis. However, the percutaneous catheter drainage of peripancreatic fluid collections may be attempted to alleviate infection as a temporizing measure to improve a critically ill high-

Figure 10

a. Contrast enhanced CT scan with rectal contrast showing ascending colon and caecal diverticulitis in an adult patient with right lower quadrant pain clinically suspected to have acute appendicitis.

b. A lower CT section showing caecal diverticulitis, a normal appendix opacified with contrast (straight arrow), and a diverticulum of the sigmoid colon (curved arrow).

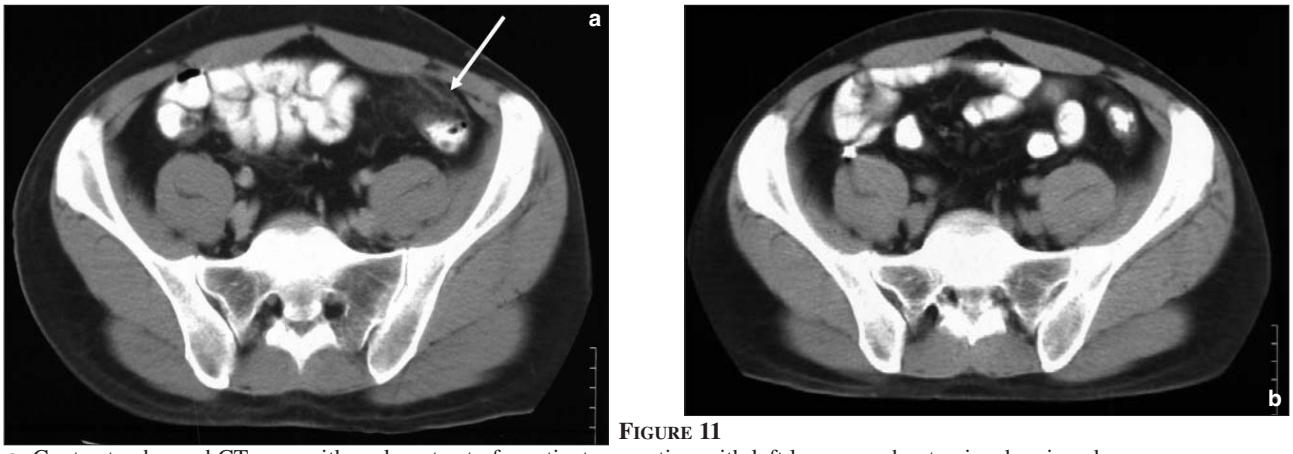


Figure 11

a. Contrast enhanced CT scan with oral contrast of a patient presenting with left lower quadrant pain, showing absence of diverticular disease but the presence of fat streaking and thickening anterior and adjacent to the descending colon (arrow) compatible with primary epiploic appendagitis.

b. Follow-up CT scan after conservative management, showing complete healing of the pericolonic inflammatory changes.

risk operative patient prior to definitive surgical debridement. In patients with acute pancreatitis and no pancreatic tissue necrosis or with less than one third of pancreatic tissue necrosis, antibiotherapy coupled with percutaneous catheter drainage using multiple large bore 14F catheters is a viable therapeutic option with a success rate ranging from 50% to 80%; however, if no improvement or any deterioration in the clinical course are observed, then surgery becomes mandatory.

b. ***Acute mesenteric ischemia*** • Two important causes are responsible for acute mesenteric ischemia: 1/ Occlusive diseases i.e. embolic in cardiac patients with atrial fibrillation or left ventricular aneurysm and a mural thrombus, thrombosis of mesenteric artery or vein in patients with hypercoagulable states, and dissection; 2/ Non-occlusive diseases i.e. due to hypoperfusion in the mesenteric territories from low flow states in elderly cardiac patients with decompensated congestive heart

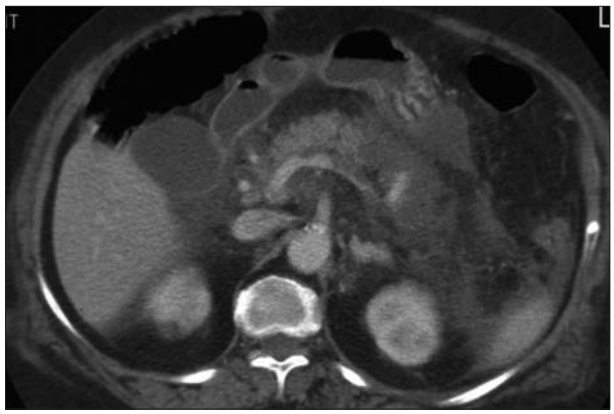


Figure 12. Contrast enhanced CT scan with water oral intake showing acute pancreatitis with pancreatic necrosis of the tail of the pancreas demonstrating lack of pancreatic tissue enhancement with contrast material.

Figure 13
a. Contrast enhanced helical CT angiography without oral contrast showing an occluding thrombus of the superior mesenteric artery.
b. Maximum intensity projection (MIP) reconstructed sagittal image of the aorta and superior mesenteric artery trunk, showing the occluding thrombus (arrow).

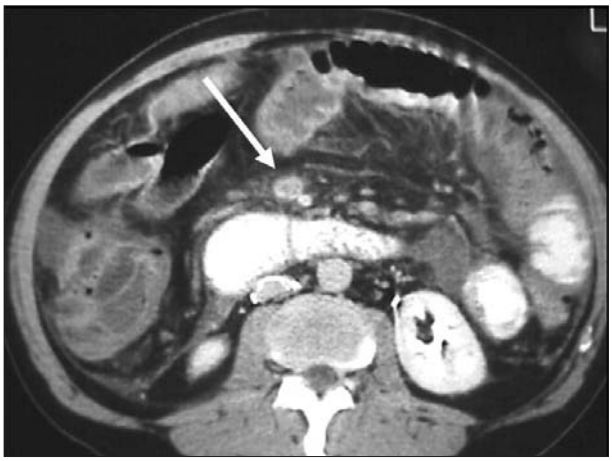


Figure 14. Contrast enhanced CT scan showing superior mesenteric vein thrombosis (arrow). Note thickened edematous small bowel loops and free fluid in the abdomen due to bowel ischemia.

failure, low cardiac output and ejection fraction, and patients receiving vasoconstrictive drugs. Clinically, patients present with abdominal pain, bloody diarrhea, peritonitis, fever and leukocytosis, metabolic acidosis and elevated LDH serum level. Diagnostic imaging plays an essential role in identification of the cause of intestinal ischemia, and in the differentiation of reversible bowel ischemia with damage only to the mucosal layer from irreversible bowel infarction with transmural necrosis of all layers of the bowel wall. The assessment of bowel viability by imaging studies represents an important decision-making step towards institution of an appropriate therapy of optimal choice. In this regard, contrast enhanced biphasic CT angiography with arterial and venous phases and without oral contrast media is capable of providing a quick diagnosis with a sensitivity greater than 90% [32]. A specific CT sign of bowel ischemia consists of the visualization of an embolus or thrombus in a mesenteric artery or vein (Fig. 13 & 14); whilst bowel dilatation of more than 2.5 to 3 cm in diameter reflecting the interruption of peristaltic activity in ischemic bowel segments, and bowel wall thickening of more than 3 mm due to edema and submucosal hemorrhage are nonspecific CT findings that can be seen with other inflammatory or infectious diseases of the gastrointestinal tract. CT findings that suggest subsequent bowel infarction and necrosis include: nonenhancement or poor enhancement of the mucosa or the thickened bowel wall, intramural gas or air in the mesenteric and portal venous system, free intraperitoneal air indicating bowel perforation, and ascites. In general, the treatment of acute mesenteric ischemia is surgical, however interventional radiology procedures such as local intra-arterial catheter infusion of fibrinolytic and vasodilating drugs, percutaneous transluminal balloon angioplasty and stenting may be considered as alternative options to surgery in patients not candidates for surgery, with symptoms of intestinal ischemia of less than six hours and presence of a viable bowel with good enhancement on helical CT angiography or blood flow on CDUS, in the thickened bowel wall.

c. ***Bowel obstruction*** • When there is a clinical suspicion of mechanical bowel obstruction, the diagnosis can be confirmed by imaging studies namely plain abdominal radiographs which have a limited sensitivity of 66% in surgically proven cases of small bowel obstruction [33], however, CT is increasingly used. Contrast en-

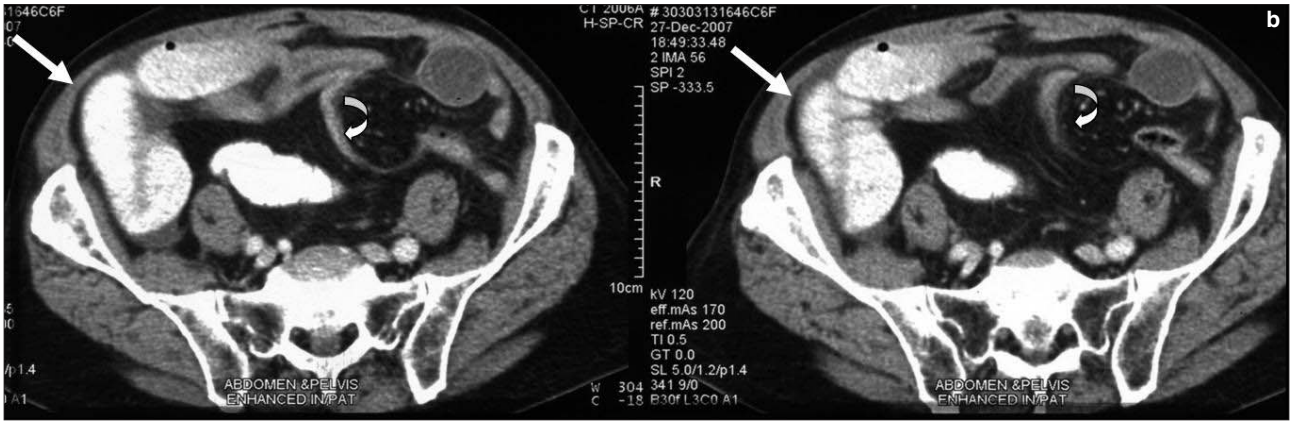


FIGURE 15

a. Plain abdominal radiograph in the erect position, showing dilated small bowel loops with multiple air fluid levels, air is seen reaching the descending colon, compatible with partial or incomplete small bowel obstruction.

b. Contrast enhanced CT scan with oral contrast images showing the transition zone between dilated bowel loops opacified with contrast (straight arrows) and the nondilated or collapsed bowel loops in the pelvis (curved arrows).

hanced CT scan without oral contrast material is usually performed in patients with suspected high grade or complete small bowel obstruction (SBO) on plain abdominal radiographs, while a contrast enhanced CT scan with oral contrast material administration is preferred in patients with low grade or incomplete intermittent or partial SBO. When interpreting CT scan findings, the radiologist should answer the following questions [34]: 1/ Whether the bowel dilatation is secondary to a mechanical obstruction or pseudointestinal obstruction i.e. a paralytic ileus; 2/ The site of the obstruction i.e. small versus large bowel obstruction; 3/ The severity of the obstruction i.e. high-grade complete obstruction versus low-grade intermittent or partial obstruction; 4/ Identify the cause of obstruction i.e. adhesions, hernia, volvulus, tumor, and others; 5/ To determine the presence or absence of associated complications particularly bowel ischemia or infarction from bowel strangulation or incarceration.

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. 15). Bowel dilatation is diagnosed when the small bowel diameter exceeds 2.5 cm and when the large bowel exceeds 8 cm in diameter. With pseudointestinal obstruction or paralytic ileus that can be secondary to many causes, no transition zone is identifiable and both small and large bowel show gaseous distension. The commonest cause for small bowel obstruction (SBO) is post surgical adhesions. A diagnosis of adhesion is assumed when there is no identifiable lesion at the trasition zone because the adhesive band itself is not visualized on CT; therefore it is a diagnosis of exclusion. Other less common causes of SBO include hernias, intussusception, volvulus, and gallstone ileus. For large bowel obstruction the commonest causes are colonic tumors, sigmoid volvulus, and diverticulitis.

CT scan can be useful for differentiating between simple uncomplicated mechanical bowel obstruction and closed loop or complicated bowel obstruction [35-37]. This differentiation is important because with simple mechanical bowel obstruction without evidence of CT signs of intestinal ischemia conservative management can be applied by placement of a nasogastric tube and close monitoring or observation of the patient. While in patients with closed loop obstruction, there is bowel strangulation leading to reversible intestinal ischemia or irreversible bowel infarction that need immediate surgical action. CT signs of intestinal ischemia or infarction in strangulated or incarcerated **"unhappy or angry bowel"** include: U-shaped or

FIGURE 16. Contrast enhanced CT scan with rectal contrast in a patient with colonic obstruction. Note the "beak sign" (curved arrow) indicative of volvulus of the large bowel.

C-shaped dilated bowel loop, "whirling sign" indicative of torsion and "beak sign" indicative of volvulus (Fig. 16), bowel wall thickening, mesenteric edema and ascites, abnormal enhancement of bowel wall, and pneumatosis intestinalis.

Pregnant women with suspected SBO may be investigated by CDUS and MRI, prior to laparoscopy.

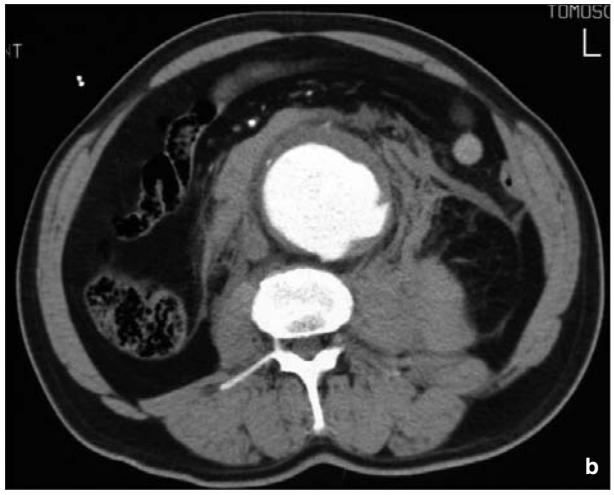
d. ***Bowel perforation*** • Pneumoperitoneum usually starts with localized pain and culminates in diffuse pain after peritonitis has developed. Abundant pneumoperitoneum can be recognized by the presence of subdiaphragmatic air on an erect chest radiograph, on supine or erect or a cross-table left lateral decubitus radiographs of the abdomen. An abundant pneumoperitoneum (Fig. 17) is indicative of a perforation complicating a gastro-duodenal ulcer or large bowel obstruction. Detection of subtle or small localized pneumoperitoneum is often difficult on plain abdominal radiographs. CT is far more sensitive than conventional radiography in the detection of a small localized pneumoperitoneum usually seen in the falciform ligament or in the mesentery adjacent to the perforated bowel secondary to bowel necrosis [38]. To enhance the sensitivity of CT for detection of extraluminal air or gas, the scans are also viewed at "lung window" settings.

e. ***Leaking abdominal aortic aneurysm*** • Leaking abdominal aortic aneurysm (AAA) is a life-threatening condition. Patients present with abdominal pain radiating to the back and flanks with or without a hypovolemic shock state and a low hematocrit level. In a suspected rupture of AAA, CDUS is the initial imaging technique which can be performed rapidly especially in patients with hemodynamically unstable condition with a portable hand held ultrasound equipment at the bedside in the emergency room, in order to rule out or confirm the presence of an AAA. However, the diagnosis of a

FIGURE 17

a. Plain abdominal radiograph in the supine position showing a pneumoperitoneum.

b. Nonenhanced CT scan with oral contrast in an elderly patient with impaired renal function showing a large pneumoperitoneum and free fluid in the abdomen.



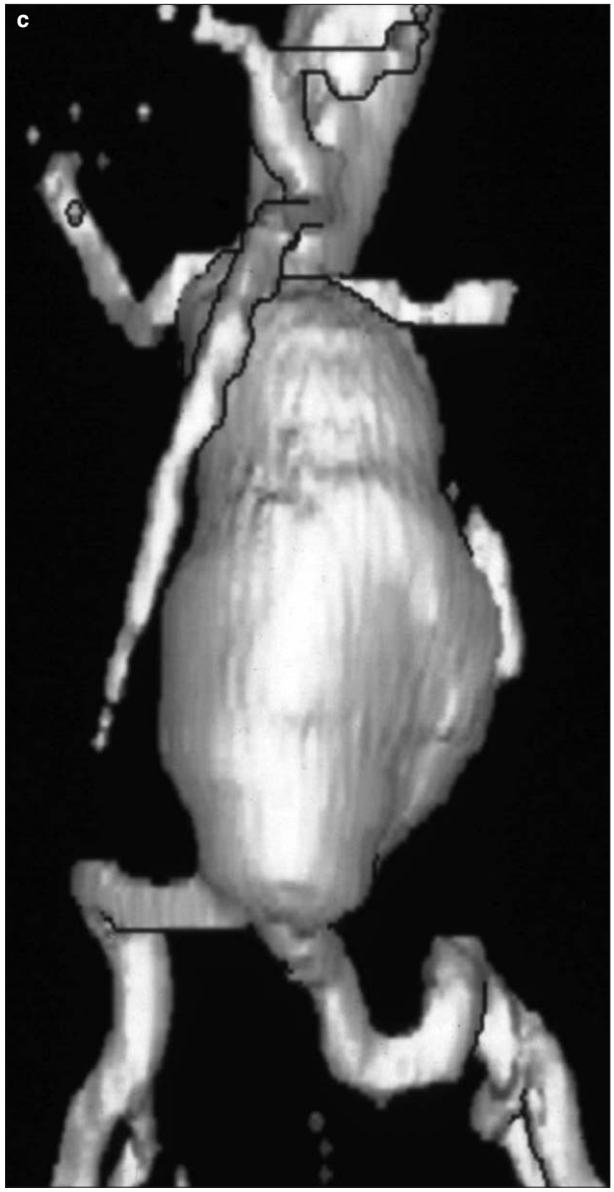


FIGURE 18

a. Plain abdominal radiograph in the supine position showing loss of the outline of the left psoas muscle as compared to the normal controlateral outline of the right psoas muscle.

b. Contrast enhanced helical CT angiography without oral contrast in a hemodynamically stable patient, showing a large abdominal aortic aneurysm with paraaortic hemorrhage compatible with a leaking abdominal aortic aneurysm (AAA).

c. SSD reconstructed coronal image of the aorta showing the relationship of the AAA to the major branches of the abdominal aorta prior to surgery.

paraaortic hemorrhage or leak by CDUS is poor. In hemodynamically stable patients, the diagnosis of paraaortic hemorrhage or leak is best achieved by contrast enhanced MDCT angiography without oral contrast material administration (Fig. 18), which is capable of demonstrating a retroperitoneal hematoma and the site of active arterial extravasation of blood opacified with contrast material. Some authors recommend that a noncontrast CT study should always be obtained first prior to contrast enhanced helical CT angiography [39]. Noncontrast or nonenhanced CT scan images are used to identify high attenuation in the aortic wall i.e. an intramural hematoma, which in the setting of an aneurysm may indicate early or impending rupture [40]. If a plain abdominal radiograph is obtained prior to CT angiography, it may show loss or obliteration of the psoas muscles outlines.

Emergency surgery is required for a ruptured AAA. However, in hemodynamically stable patients the endovascular repair with insertion of a stent graft is

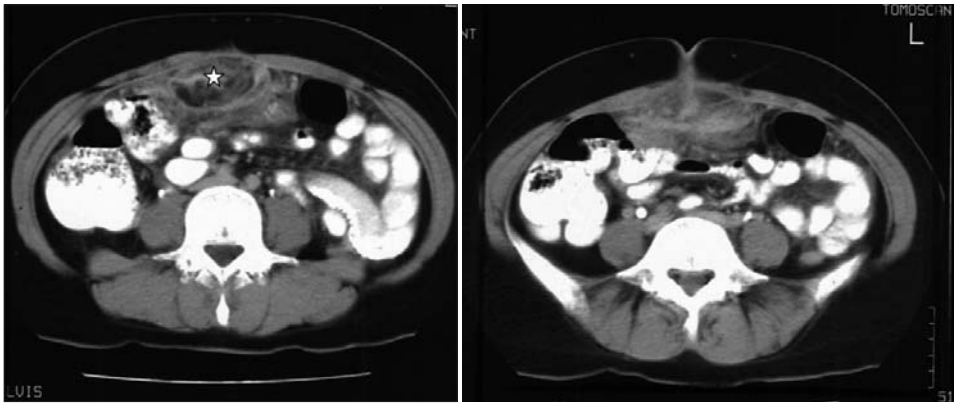


FIGURE 19
Contrast enhanced CT scan with oral contrast images show evidence of omental torsion (★).

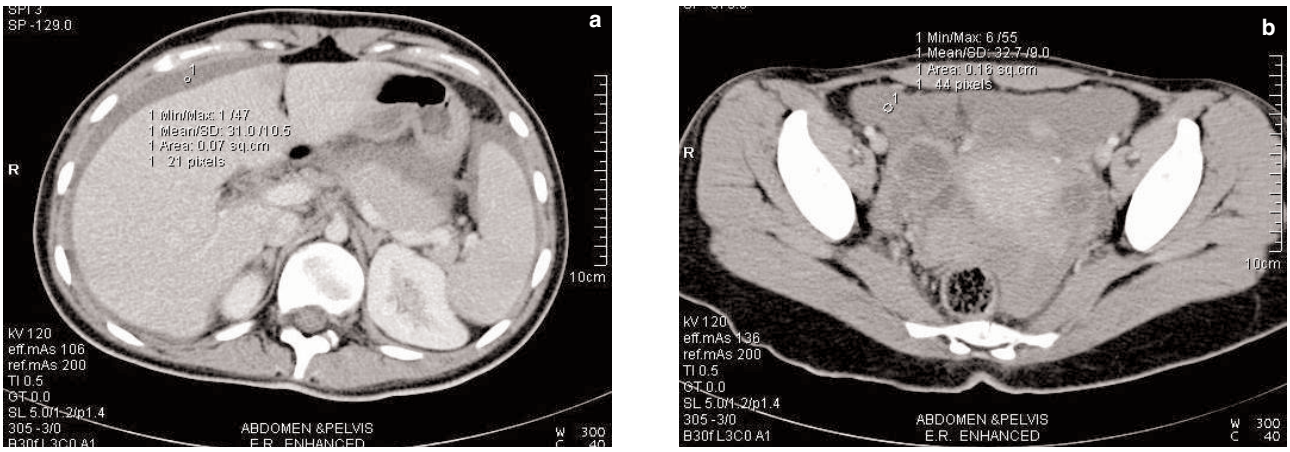


FIGURE 20
Axial contrast enhanced CT scan images at the level of the liver (**a**) and pelvis (**b**) showing free fluid in the pelvis and surrounding the liver with a CT density reaching 32HU (circle) confirming hemoperitoneum.

considered as a viable alternative therapeutic option to standard open surgery. In few hemodynamically unstable patients with contraindication to surgery i.e. presence of significant comorbid disease or conditions, transbrachial aortic balloon occlusion and endovascular repair by a stent graft may be performed if the vascular anatomy on angiography is suitable and favorable for stent graft application [41-43].

f. ***Omental torsion and infarction*** • Torsion of the greater omentum is a relatively rare clinical event, the causes of which remain elusive. Patients present with progressive diffuse abdominal pain. Contrast enhanced CT scan with oral contrast material administration (Fig. 19) shows diffuse streaking of the greater omentum with a mass of fat density located anteriorly adjacent to the abdominal wall just below the umbilicus, showing a whirling pattern of concentric streaks indicative of torsion. Torsion leads to omental infarction that can be treated by conservative management in the absence of complications such as peritoneal fluid and irritation [44].

g. ***Spontaneous abdominal hemorrhage*** • Spontaneous intraperitoneal hemorrhage (SIH) or hemoperitoneum is a potentially lethal or life-threatening entity that may result from a bleeding diathesis including HELLP syndrome, blunt or penetrating abdominal trauma, rupture of a visceral aneurysm or a vascular neoplasm such as hepatocellular carcinoma, hepatocellular adenoma, focal nodular hyperplasia, hemangiomas, and metastases, ovarian hemorrhagic cyst or ectopic pregnancy, perforation of a duodenal ulcer or other gastrointestinal pathologies, inflammatory erosive processes such as pancreatitis with subsequent pseudoaneurysm formation, and post surgical especially in patients who underwent pancreatic surgical resection.

Patients with SIH present with sudden abdominal pain and distension, an acute drop in hematocrit level, with or without a hypovolemic shock or a discoloration around the umbilicus and flanks (Cullen's sign) that can appear with a variable delay after intraabdominal hemorrhage [45]. Blood is a peritoneal irritant and the intensity and localization of abdominal pain is usually related to the volume and site of blood extravasation.

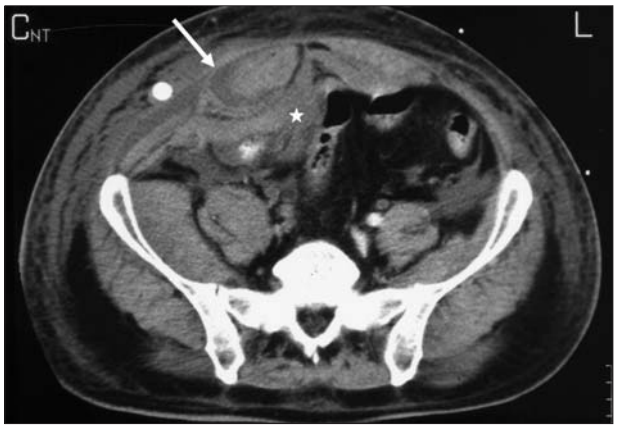


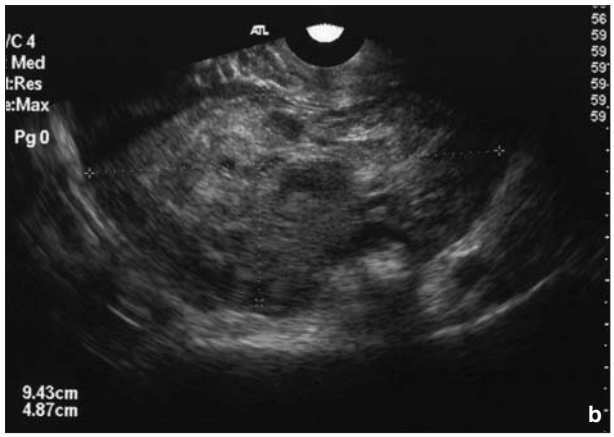
FIGURE 21. Contrast enhanced helical CT angiography without oral contrast in a patient on anticoagulation, showing spontaneous intraabdominal (★) and rectus sheath muscle (arrow) hemorrhage.

Helical MDCT angiography of the abdomen and pelvis without oral contrast administration is an effective method for detecting intraabdominal hemorrhage i.e. a hemoperitoneum and active extravasation of blood in active arterial bleeding. The CT appearance of a hemoperitoneum depends on the age of the hemorrhage [45]. During the hyperacute phase, the attenuation value of intraperitoneal blood ranges from 20 or even 30 HU to 90 HU compatible with an acute hematoma of less than 48 hours of age (Fig. 20). In most cases, the attenuation begins to decrease within several days as clot lysis and liquefaction take place, the attenuation values decrease steadily with time and often approach that of water (0 to 20 HU) after 2 to 4 weeks. Occasionally, a hematocrit effect with sedimented erythrocytes producing a dependent layer of high attenuation can be observed on CT scan images.

Ultrasound has become the imaging modality of choice in evaluating women with intrapelvic hemorrhage secondary to ruptured ectopic pregnancy or ruptured ovarian hemorrhagic cyst.

In stable patients with SIH and active extravasation of blood or arterial bleeding, percutaneous transcatheter embolization therapy may be considered as an alternative option to surgery if the patient is not a surgical candidate or as an adjunct treatment to overcome a life-threatening bleeding prior to definitive surgical treatment. Unstable patients require immediate surgical laparotomy.

Other causes of spontaneous abdominal hemorrhage that may cause abdominal pain include: spontaneous retroperitoneal hemorrhage, and anterior abdominal wall musculature hemorrhage especially in patients on anticoagulation (Fig. 21). Spontaneous retroperitoneal hemorrhage (SRH) in the absence of AAA is usually secondary to rupture of a microaneurysm in a kidney lesion in patients with vasculitis (periarteritis nodosa), angiomyolipoma, renal cell carcinoma, and renal artery aneurysm rupture in patients with neurofibromatosis. An immediate CT angiography for diagnosis of SRH, and catheter angiography with embolization to achieve hemostasis are mandatory.



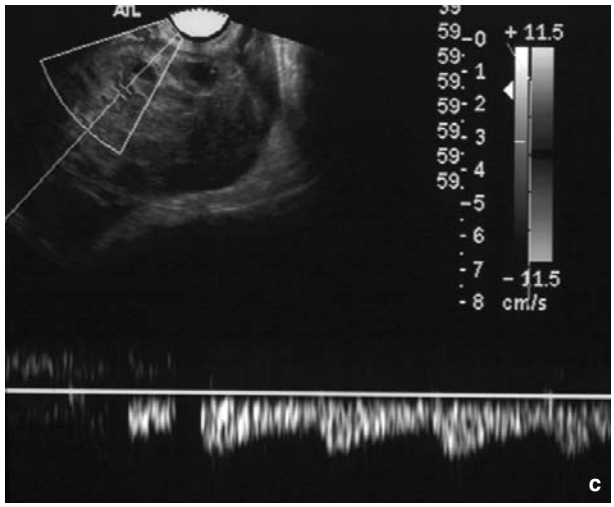


FIGURE 22. Tuboovarian abscess.
Axial contrast enhanced CT scan (**a**) and axial transvaginal ultrasound (**b**) images at the level of the pelvis showing a heterogeneous mass lying posterior to the uterus (cursors). The ovaries are embedded in the process, and the presence of flow on color Doppler examination excluded torsion (**c**).

6. Acute Pelvic Pain in Women

This section will be divided into acute gynecologic and obstetrical emergencies [46-47].

■ Gynecologic emergencies

a. ***Pelvic inflammatory disease (PID)*** • PID is the most common cause of acute pelvic pain in women. It incorporates a spectrum of processes, ranging from an isolated or localized endometritis to tuboovarian abscesses and disseminated or diffuse peritonitis. Placement of intrauterine contraceptive devices increases the susceptibility to PID. On transabdominal in the virginal or transvaginal sonography in the nonvirginal patient, tuboovarian abscesses can appear as complex masses with cystic and solid components, internal echoes, fluid-debris levels, thickened septation, and occasionally intraluminal or mural air. CT scanning may be useful in those cases in which CDUS is equivocal (Fig. 22).

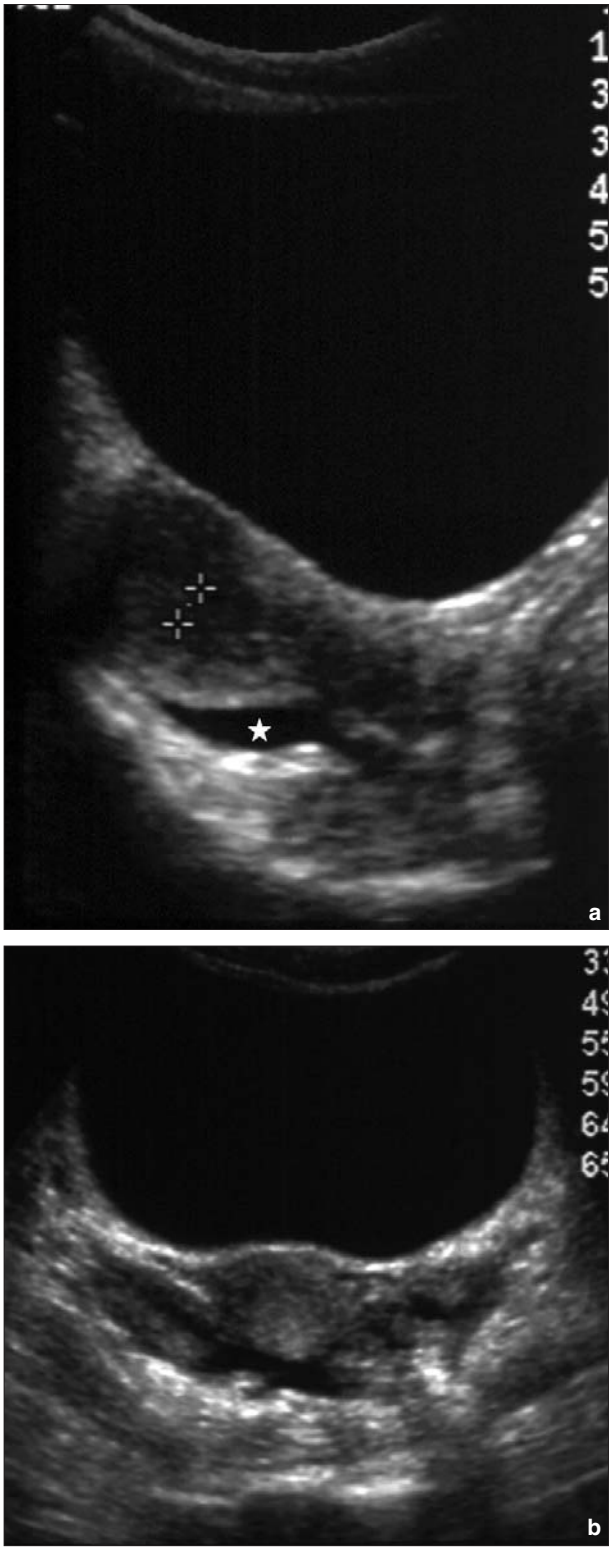


Figure 23
Sagittal (**a**) and axial (**b**) ultrasound images of the pelvis in a premenopausal woman showing small amount of free fluid in the cul-de-sac of Douglas (*) without evidence of uterine or adnexal pathology.

b. ***Ruptured corpus luteum or follicular cyst and hemorrhagic ovarian cyst*** • Abrupt onset of pelvic pain may be commonly caused by a ruptured corpus luteum or follicular cyst, or less commonly by acute bleed into a physiologic ovarian cyst so-called hemorrhagic ovarian cyst, occurring mostly in women under 40 years of age. Ruptured corpus luteum follicular cyst occurs in the second half of the menstrual cycle. On sonography there may be a crenated thick-walled cyst contained within the ovary, or debris within the cyst, or more frequently a small amount of free fluid in the pelvis (Fig. 23), or a complicated hemopritoneum. We prefer to examine premenopausal women with pelvic pain by two transducers using first a sector 2-5 MHz probe, if no abnormality was identified then we proceed with a second pelvic examination using a linear 5-12 MHz probe that may be helpful in few instances to detect acute appendicitis or a small amount of free fluid (Fig. 24) interspersed in between bowel loops outside the cul-de-sac of Douglas and undetectable by the sector probe. The free fluid especially hemorrhagic fluid is irritant to peritoneum and induces severe abdominal or pelvic pain.

Hemorrhagic ovarian cysts have variable sonographic appearances (Fig. 25) depending on the age of intracystic blood. Increased through transmission is present in the majority of cases and confirms the cystic nature of the lesions. Initially, the hemorrhage can be isoechoic to the adjacent ovarian parenchyma. Subsequently, this may transform into a heterogenous hyperechoic or hypoechoic complex mass with internal septations of varying thickness, fluid debris levels or low levels internal echoes, intraluminal echogenic retracting clot, and irregular mural nodularity. Hemorrhagic ovarian cyst may mimic other ovarian pathologies, and the differential diagnosis in a premenopausal woman with a negative pregnancy test and a complex cystic mass is that of an endometrioma, ovarian neoplasm most commonly an ovarian dermoid, ovarian torsion, or a tuboovarian abscess. Although CDUS is the primary imaging modality for assessment of hemorrhagic ovarian cysts, low dose contrast enhanced CT scan with intravenous and rectal contrast and/or MRI may be useful in confirming the presence of hemorrhage when the sonographic findings are atypical. CT findings include high attenuation within an ovarian cyst with intracystic attenuation values ranging from 45 to 100 HU and a fluid/hematocrit level. Hemorrhagic ovarian cysts can be complicated by rupture into the peritoneal cavity, or by adnexal torsion necessitating surgical intervention. If a noncomplicated hemorrhagic ovarian cyst is suspected in a premenopausal woman, intervention may be avoided and the diagnosis may be confirmed by repeating the ultrasound examination at the next menstrual cycle to demonstrate a decrease in the size of the cyst or complete resolution (Fig. 25). In older and postmenopausal women, surgery is indicated due to the increased incidence of underlying neoplasm.

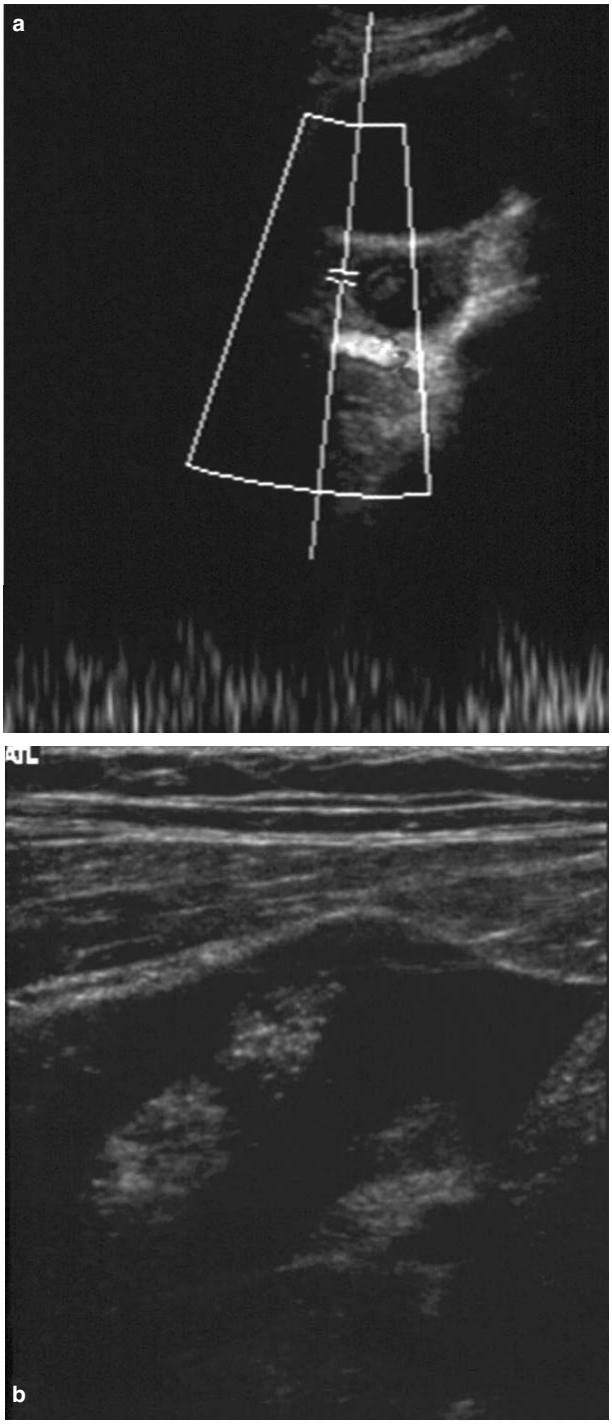


Figure 24
a. Color Doppler ultrasound images of the pelvis in a premenopausal woman presenting with pelvic pain, showing a hemorrhagic right ovarian cyst and presence of blood flow excluding ovarian torsion. There was no visualization of free fluid in the pelvis on the initial examination by the sector 2-5MHz transducer.
b. Real-time ultrasound image of the pelvis using a high-frequency 5-12MHz linear transducer, shows evidence of free fluid interspersed in between bowel loops.

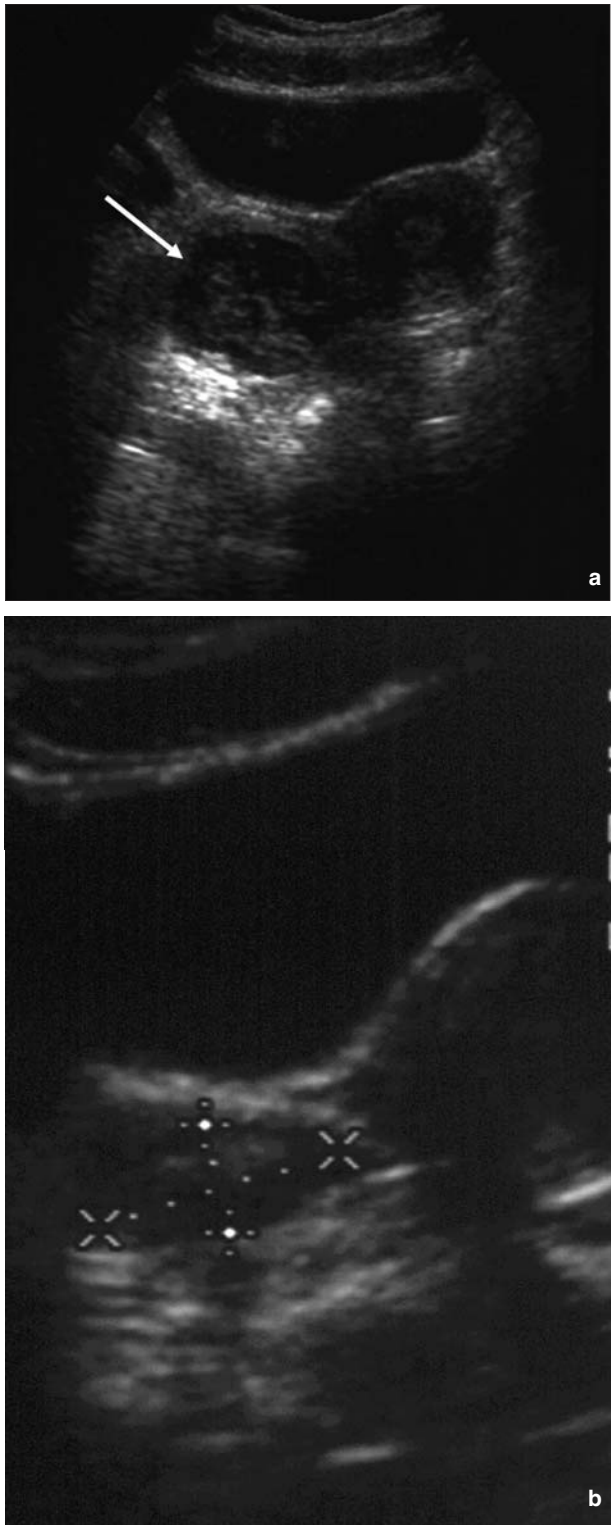


FIGURE 25
a. Transverse ultrasound image of the pelvis in a premenopausal woman showing a right hemorrhagic ovarian cyst (arrow).
b. Follow-up ultrasound examination showing complete resolution of the right ovarian hemorrhagic cyst.

FIGURE 26. Transverse ultrasound image of the pelvis showing an enlarged right ovary (★) due to torsion.

c. ***Adnexal torsion*** • Patients with adnexal torsion present with acute onset of pelvic pain, nausea and vomiting, fever and leukocytosis. It usually involves the ovary and fallopian tube and can occur at all age groups even in utero. Torsion is due to adnexal rotation with the vascular pedicle on its axis with resultant venous and lymphatic stasis or obstruction, followed by arterial thrombosis leading to diffuse ovarian enlargement, oedematous change and infarction. Primary torsions are less common and occur in the absence of an ovarian lesion, seen mainly in premenarchal girls and children in whom the ovary may be present in a normal pelvic position or herniating into the inguinal canal. Secondary torsions are more common and occur in the presence of an ovarian lesion. Commonly associated predisposing lesions are benign and include benign ovarian neoplasms such as dermoids, and non-neoplastic ovarian and paraovarian cysts.

Ovarian enlargement with or without small peripheral cysts is the most consistent finding on ultrasound examination (Fig. 26), the ovarian volume is usually above 25 cc. The mean ovarian volume in the normal menstruating female as defined by Cohen et al. [48] is 9.8 cc, with a range of 2.5 cc to 21.9 cc. Because of this variation in the volume of a normal ovary, it is always important to compare with the normal contralateral ovary. The sonographic appearance of most adnexal torsions, particularly secondary torsions, will depend on the morphology of the underlying lesion. The varied appearances of ovarian torsion make the sonographic gray-scale diagnosis rather difficult. Color Doppler flow imaging is very helpful in documenting venous flow within the affected ovary, an important finding to determine ovarian viability. Low dose contrast enhanced CT scan with intravenous and rectal contrast or gadolinium enhanced MRI may also suggest the diagnosis of adnexal torsion if the sonographic diagnosis remains equivocal or inconclusive.

Because the clinical presentation of torsion is not specific and prompt intervention is required to preserve the affected ovary, laparoscopy may be required to make a definitive diagnosis. At this time, the ovary may be untwisted and left in position after fixation in primary torsion, or may be excised if an underlying neoplasm is suspected in secondary torsion.

■ Obstetrical emergencies/ Acute abdomen in pregnancy

Pregnant women may be affected by acute abdominal conditions similar to nonpregnant women such as renal colic, appendicitis, pancreatitis, cholecystitis and others. CDUS is the imaging modality of first choice for investigation of pregnant women with acute abdominal pain. If the CDUS results remain equivocal or inconclusive, then a low dose CT scan examination (Fig. 27) or MRI are justifiable as second line examinations for further investigation.

Some conditions of particular interest that can occur in pregnant women are discussed in this section.

a. ***Ectopic pregnancy*****:** The introduction of sensitive assays for ß-hCG levels and the use of transvaginal ultrasound have significantly improved detection of ectopic pregnancy, that should be considered in every woman in the reproductive age group with a positive serum ß-hCG (greater than 1,000 IU/L) and non-visualization of an intrauterine gestational sac. Sonographic findings of ectopic pregnancy (Fig. 28) include

FIGURE 27. Low dose contrast enhanced CT scan with rectal contrast (mA 160, Kv 160) in a pregnant woman with right sided abdominal pain in whom the ultrasound examination was inconclusive. It shows an inflamed thickened non opacified appendix (arrow) with rectal contrast and periappendiceal fat streaking compatible with acute appendicitis confirmed at surgery.

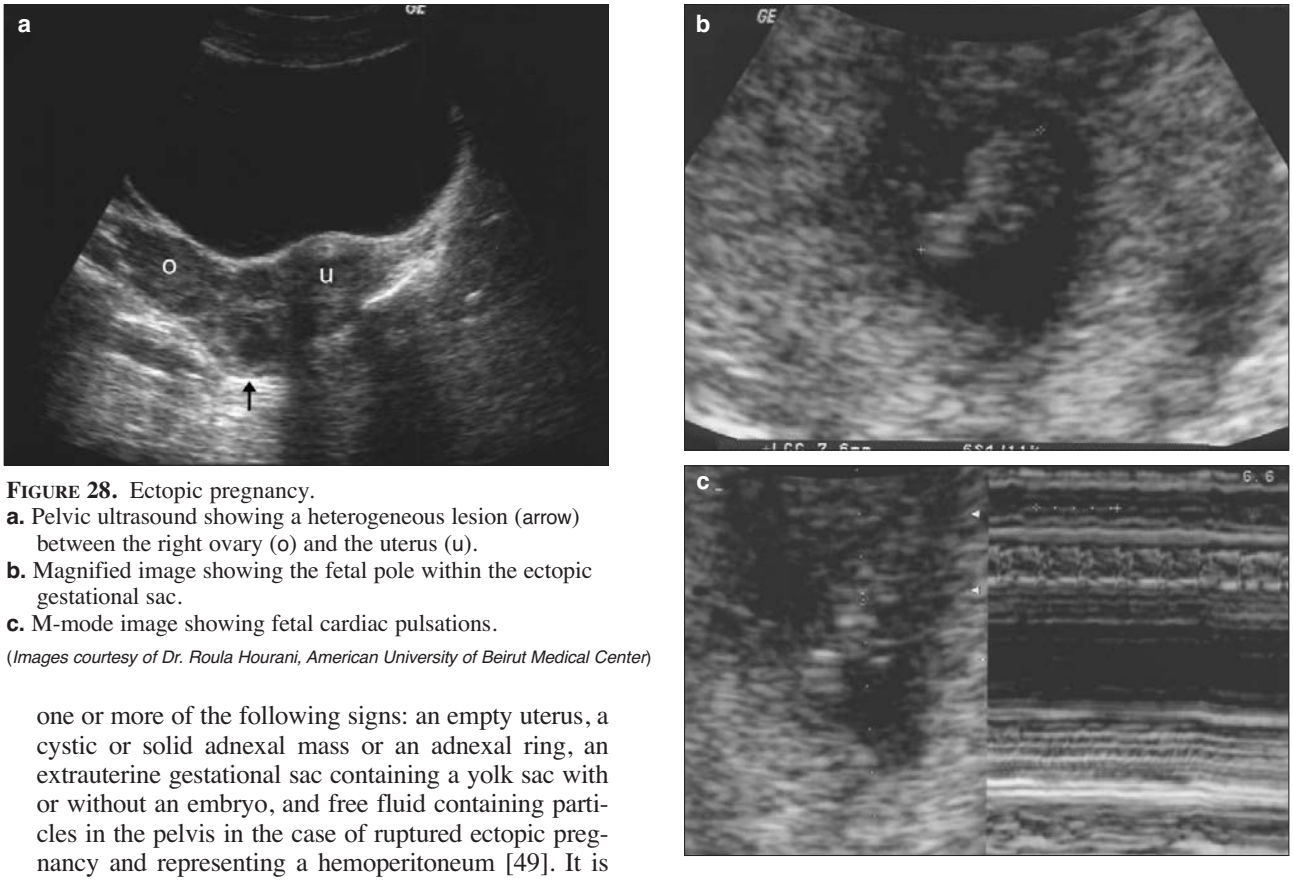


Figure 28. Ectopic pregnancy.
a. Pelvic ultrasound showing a heterogeneous lesion (arrow) between the right ovary (o) and the uterus (u).
b. Magnified image showing the fetal pole within the ectopic gestational sac.
c. M-mode image showing fetal cardiac pulsations.
(*Images courtesy of Dr. Roula Hourani, American University of Beirut Medical Center*)

one or more of the following signs: an empty uterus, a cystic or solid adnexal mass or an adnexal ring, an extrauterine gestational sac containing a yolk sac with or without an embryo, and free fluid containing particles in the pelvis in the case of ruptured ectopic pregnancy and representing a hemoperitoneum [49]. It is important to differentiate a normal early intrauterine gestational sac that has two concentric trophoblastic rings of the double decidual sign from a decidual sac or pseudogestational sac of ectopic pregnancy which is an intrauterine fluid collection surrounded by a single decidual layer.

b. ***Placental abruption*** • It is a result of premature separation of the placenta. It may be classified into three types according to the location of the hemorrhage: subchorionic, retroplacental, and preplacental. Patients may present with painless or painful vaginal bleeding accompanied by cramping abdominal pain. Sonography will detect the extrachorionic fluid collection indenting the gestational sac.

c. ***Postpartum complications***

Ovarian vein thrombophlebitis (OVT) • It is an uncommon complication that may be seen in the postpartum period. Patients present with abdominal pain and fever. It is potentially fatal due to an increased risk of pulmonary embolism; it requires prompt diagnosis and treatment with antibiotics and anticoagulation. Although the diagnosis of OVT can be made with CDUS, CT (Fig. 29) or MRI are the techniques of choice. The diagnostic feature of OVT is visualization

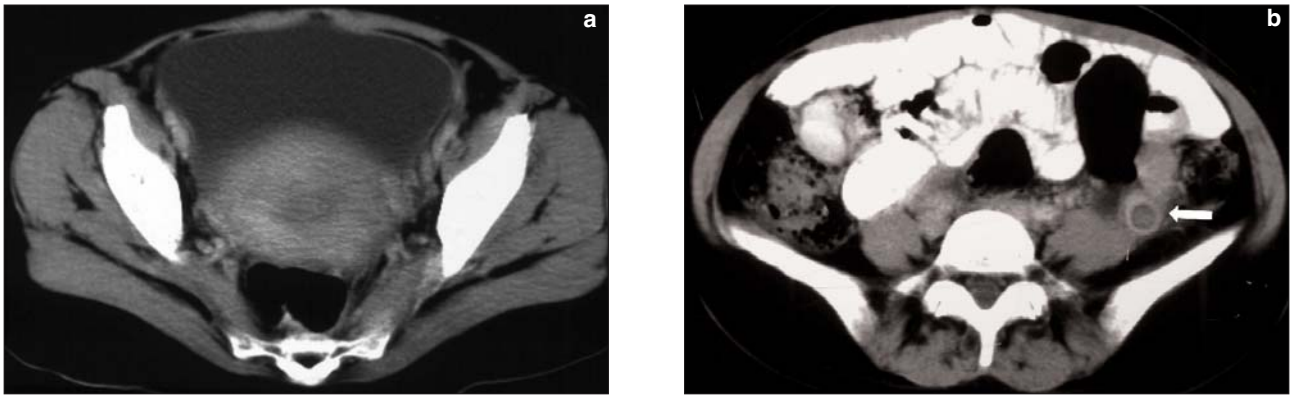


Figure 29. Contrast enhanced CT scan with oral contrast images showing an enlarged postpartum uterus (**a**) and left ovarian vein thrombophlebitis (arrow) (**b**).

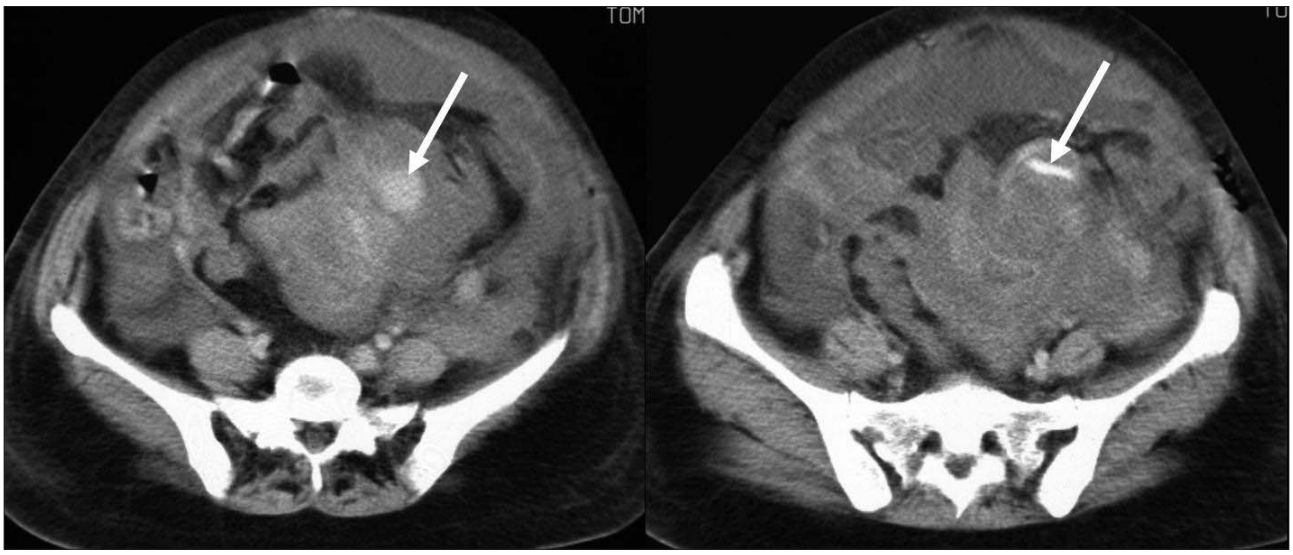


FIGURE 30. Contrast enhanced helical CT angiography without oral contrast in a patient with postpartum hemorrhage showing large intrapelvic hematoma and extravasation of contrast material (arrows) due to active bleeding. She underwent hysterectomy.

of tubular retroperitoneal structure or mass extending from the pelvis to the inferior vena cava and paralleling the course of the psoas muscle and ureter.

Intrapelvic hemorrhage • Hematomas may occur in a number of locations and should be considered in the differential diagnosis of pain or fever during the postpartum period. Bladder-flap hematomas occur after low transverse incisions for Cesarian section. They are seen sonographically as solid or complex collections located between the lower anterior myometrium and the posterior bladder wall. Subfascial hematomas occur as a result of disruption of the inferior epigastric artery and may occur after Cesarian section or traumatic vaginal delivery. They are found anterior to the bladder and may extend beneath the pubis or superiorly, posterior to the rectus muscle. Deep pelvic hematomas usually arise secondary to vaginal or cervical laceration. They are located laterally in the supralevator or infralevator compartments and are best evaluated with CT.

Postpartum uterine hemorrhage • Although there are several causes of postpartum hemorrhage within the first 24 hours of delivery, the most common reason for referral to sonography is to differentiate blood loss from uterine atony and that from retained products of conception. Most postpartum pelvic hematomas resolve spontaneously or respond to transcatheter embolization.

Uterine rupture or dehiscence • Intraperitoneal i.e. a gross hemoperitoneum or extraperitoneal hemorrhage is usually associated with this catastrophic event that can be seen on helical CT angiography without oral contrast (Fig. 30) capable of demonstrating extravasation of blood opacified with contrast material.

7. Rare intra- and extraabdominal causes of acute abdominal pain

In approximately 20% of patients presenting with acute abdominal pain to the emergency room, no cause could be identified on clinical and radiological grounds and the pain is labeled as a nonspecific or unspecified abdominal pain [50].

In a minority of patients, some other rare intraabdominal conditions such as familial Mediterranean fever, lupus peritonitis, scleroderma, sickle cell sequestration crisis, angioneurotic edema, anisakiasis and others may cause an acute abdominal pain. In these conditions, the correct radiologic diagnosis is rarely considered because the imaging findings are nonexisting or subtle and nonspecific often unrecognized and misinterpreted for other diagnosis [51].

In some rare instances, extraabdominal causes of acute abdominal pain may be identified on imaging such as lower lobe pneumonia (Fig. 31). Pneumonia is notorious for causing referred abdominal pain and vomiting in children and elderly with subtle or no signs or symptoms of pulmonary disease. This is not to forget other extraabdominal causes such as myocardial infarction.

VI. ACUTE ABDOMEN IN THE IMMUNOSUPPRESSED PATIENTS

With the increasing prevalence of AIDS and intravenous drug users, and the increasing use of immunosuppressive drugs in cancer and transplant patients, we are constantly faced with the diagnostic challenge in the symptomatic immunosuppressed or neutropenic patient presenting with acute abdominal disease. Clinically, the symptoms may be deceiving with little elevation of the white blood cell count or temperature, and the localizing signs may be

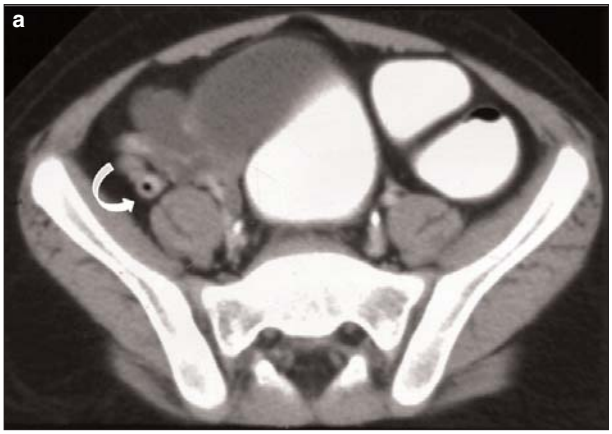


FIGURE 31
a. Low dose contrast enhanced CT scan with rectal contrast in a child with right lower quadrant pain showing a normal appendix (curved arrow).
b. A higher CT scan section demonstrated pneumonic infiltrates in the right lower lobe.
c. Chest radiograph obtained prior to CT scan was unrevealing.

also obscured by immunosuppression, debilitation, and prior or current antibiotic use. Cross-sectional imaging techniques namely CDUS for diagnosis of AIDS-related cholangiopathy, and CT scan with intravenous and oral contrast material is the modality of choice for the diagnosis of acute abdominal disease that occur in immunosuppressed patients such as opportunistic infections of the gastrointestinal tract, liver and spleen i.e. infectious gastroenterocolitis, typhlitis (Fig. 32), pseudomembranous colitis, fungal microabscesses of the liver and spleen, bacillary angiomatosis or peliosis of the liver and spleen, and septic emboli in drug users [52].

It is also important to remember that patients with AIDS are also particularly prone to develop AIDS-related malignancies such as Kaposi's sarcoma and lymphoma that enter in the differential diagnosis of AIDS-related infections, and differentiation may require a biopsy for tissue diagnosis and culture for isolation of the organism.

VII. NON TRAUMATIC ACUTE ABDOMINAL DISEASES IN THE PEDIATRIC PATIENT

The purpose of this section is to draw attention to those areas where children differ from adults [24, 53-57]. The causes of acute abdominal pain in children are numerous and dependent in part on the age of the child. They can be divided into those related to congenital abnormalities at whatever age they present, and acquired diseases. Children are poor historians, and pain localization in young children is also poor, therefore the site of the pain is unhelpful in reaching a provisional working diagnosis. For these reasons, imaging has become increasingly popular with primary care physicians, pediatricians and surgeons to help with clinical management of this common pediatric problem.

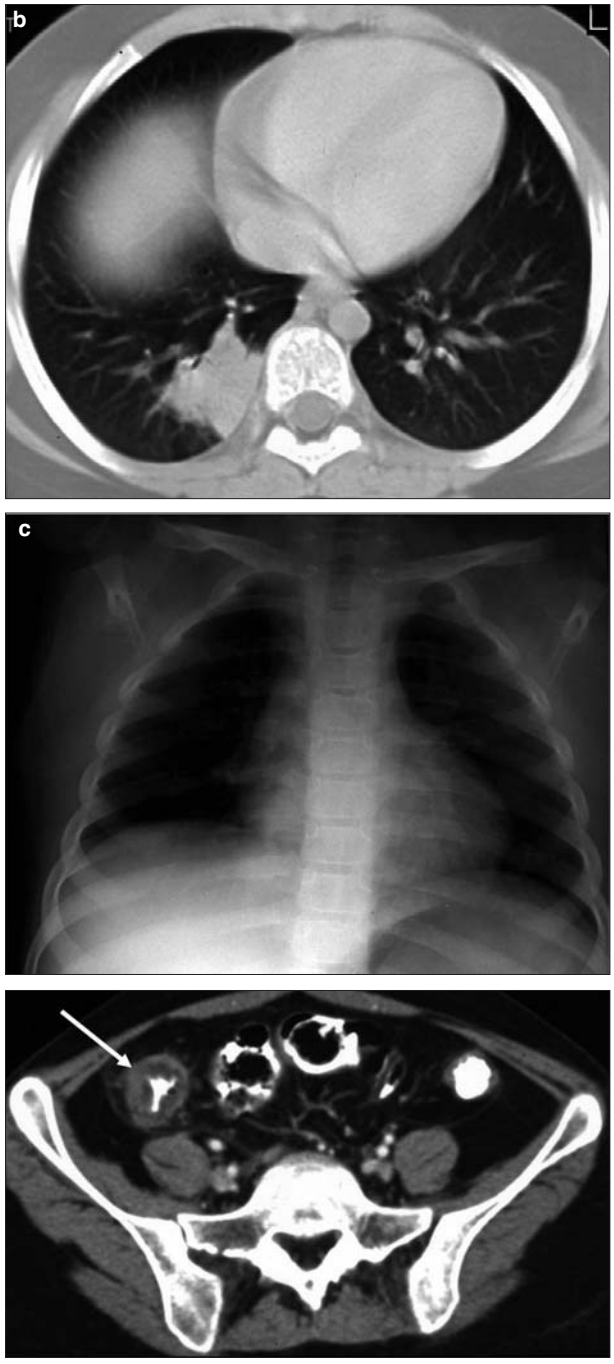


FIGURE 32
Contrast enhanced CT scan with oral contrast showing typhlitis (arrow) of the caecum in an immunosuppressed cancer patient with neutropenia.

Although plain abdominal radiograph is of limited diagnostic value in many cases, it is still used as primary imaging modality of abdominal emergencies in childhood followed by or coupled with ultrasound examination. Imaging usually starts with a supine plain abdominal radiograph. If there is doubt about free intraperitoneal air or a need to identify air-fluid levels, an erect or a cross-table

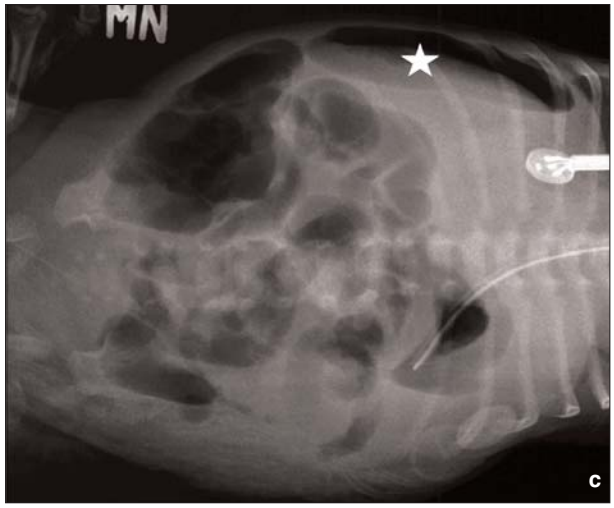


FIGURE 33. Necrotizing enterocolitis complicated by bowel necrosis and perforation.
a. Plain abdominal radiograph showing distended featureless bowel loops with bowel wall edema.
b. Follow-up examination showing air into the portal venous system (arrow) compatible with bowel mural necrosis.
c. Another follow-up examination by plain radiograph in the left lateral decubitus position showing a pneumoperitoneum (*) due to bowel perforation.

left lateral decubitus radiograph may be indicated.

Ultrasound (US) is the most commonly used cross-sectional imaging technique in children to a point that pediatric radiologists are now called echo-pediatricians. US of the abdomen is extremely helpful in both establishing and excluding pathology. Abdominal US should include both examinations of the solid organs by a sector 4-7 MHz transducer and by a linear high-frequency 5-12 MHz transducer for the bowel, the low dose computed tomography is required in selected circumstances but should be agreed on an individual basis. It is used more frequently in the U.S.A. than in Europe but it is invaluable in appropriate circumstances. It is recommended to use low dose CT examination with low mA & kV (80 mA or even lower to 30 mA depending on size of patient, and 80 to 120 kV) adjusted to answer the clinical questions. Magnetic resonance imaging is seldom required as a primary imaging technique but supplements low dose CT and US in selected cases.

1. Neonates and infants (under 3 years)

a. ***Necrotizing enterocolitis (NEC)*** • NEC remains one of the most common abdominal emergencies in premature neonates. The diagnosis is usually made when pneumatosis intestinalis is observed on abdominal radiographs, but pneumatosis is not visible in all cases. Acute intestinal dilatation is an early nonspecific sign, that should suggest the diagnosis especially when intestinal wall thickening is present. After initiation of therapy (bowel rest for 10-15 days, antibiotics) and on serial daily follow-up plain abdominal radiographs, beware of the abdomen that becomes gasless but remains distended. These findings herald perforation in many cases, and the perforation is not detectable by the presence of free intraperitoneal air because of the lack of air in the gastrointestinal tract. US can be used to identify bowel wall thickening due to edema, the visualization of small bubbles of air in the portal venous system that are too small to be detected on plain abdominal radiographs, and detection of free fluid in the abdomen.

Color Doppler sonography of the abdomen using a high frequency 5-12 MHz linear transducer is indicated in babies with equivocal clinical and plain abdominal radiographs findings for the diagnosis of NEC. Thinning of the bowel wall and lack of perfusion at color Doppler flow imaging are highly suggestive of nonviable bowel and may be seen before visualization of a pneumoperitoneum at plain abdominal radiography [56]. Surgery is indicated when bowel perforation occurs (Fig. 33).

b. ***Midgut volvulus/Malrotation*** • This is a serious abdominal emergency that occurs in the neonatal period or later in life, and requires immediate emergency surgery because of its life-threatening implications. The symptoms are abdominal pain and bilious vomiting. The plain abdominal radiograph may be normal. CDUS can show the spiral configuration of the bowel known as the "whirlpool" sign, and reverse of the normal relationship of the superior mesenteric artery and vein, when the vein comes to lie in front or to the left of the artery (Fig. 34). The diagnosis is confirmed by upper gastrointestinal contrast studies which should be performed in all suspected cases. On upper gastrointestinal contrast study, in normal rotation the duodeno-jejunal (DJ) flexure lies to the left of the midline at the level of L3 or above, and should lie under the gastric antrum. In malrotation or midgut volvulus the duodenum shows on upper gastrointestinal contrast study a spiral configuration, descends downwards and the DJ flexure with the jejunum pass to the right side of the left pedicles of the spine on the anteroposterior projection of the abdomen.

c. ***Intussusception*** • Intussusception occurs when a segment of bowel, the intussusceptum, prolapses and invaginates into another segment, the intussuscipiens. In young children between the ages of 3 months and 3 years, the presence of abdominal pain and vomiting should always raise clinical suspicion of intussusception, even in the absence of bloody redcurrant jelly stools. It is often seasonal, being common in the late spring and autumn, rather than summer or winter. In the vast majority of children, the cause is unknown but is probably related to inflammation of Peyer's patches during a generalized viral infection; a preceding history of sore throat and upper respiratory tract infection is frequent. In a small minority of children, approximately 5%, a pathological lead point, e.g. a Meckel's diverticulum, duplication cyst and Burkitt's lymphoma of bowel may be the cause of intussusception. There is an increased incidence of intussusception in children with celiac disease and cystic fibrosis.

At presentation the child may be in shock with peripheral shut down. Failure to respond to resuscitation i.e. child in shock or peritonitis, or evidence of bowel perforation i.e. presence of a pneumoperitoneum on plain abdominal radiograph, are the only absolute contraindications to attempt nonoperative reduction.

CDUS is the primary modality of choice, it is performed with a high frequency 5-12 MHz linear probe, highly sensitive for diagnosis of intussusception, and has a negative predictive value approaching 100% [57].

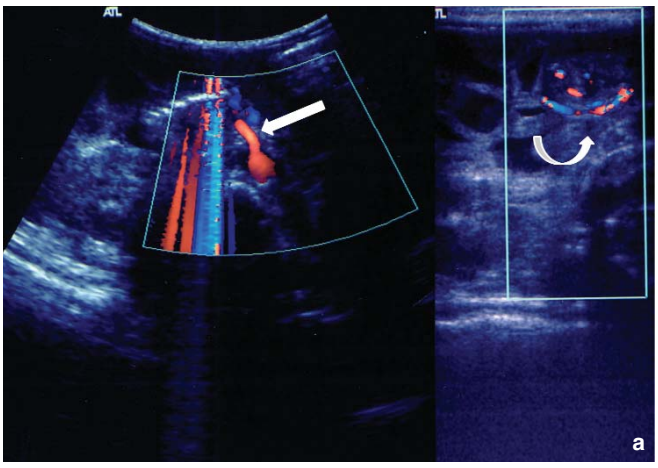


FIGURE 34
Midgut volvulus

a. Color Doppler ultrasound images of the abdomen showing a reversed position of the mesenteric vessels with the superior mesenteric artery (straight arrow) lying to the right side of the superior mesenteric vein, and the "whirlpool sign" (curved arrow) of the bowel indicative of volvulus.

b. Upper gastrointestinal tract contrast study showing the spiral configuration of the small bowel confirming the diagnosis of midgut volvulus, a surgical emergency condition requiring immediate surgery.

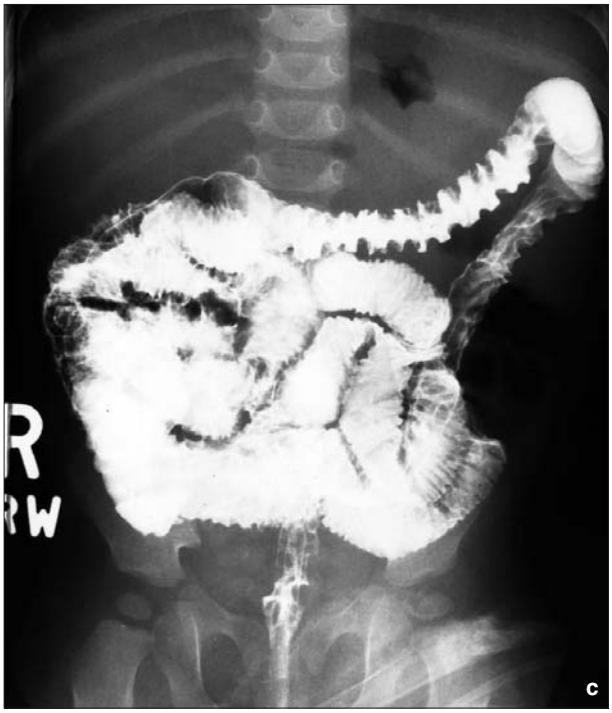


FIGURE 35
Nonsurgical reduction of intussusception.
a. Plain abdominal radiograph showing no evidence of free intraperitoneal air.
b. Hydrostatic reduction of intussusception using water-soluble iodinated contrast enema. Note the "meniscus sign" (arrow) of intussusception.
c. Successful reduction was achieved.

On sonography, the intussusception shows a classical or typical "target or doughnut sign" on a transverse scan, and a "pseudokidney or sandwich" appearance on longitudinal sections. The plain abdominal radiograph is only performed after a positive CDUS examination as the plain radiograph findings of intussusception are unreliable in many cases, but it should be carefully scrutinized for the presence of a pneumoperitoneum, the identification of which leads to direct surgical therapy. The degree and severity of bowel distension on the plain abdominal radiograph, the absence of color flow in the intussusception, the presence of a hypoechoic rim greater than 10 mm in the intussusception or a large amount of fluid trapped within the intussusception are said to be predictors of a poor prognosis or chance for nonoperative reduction. However, these sonographic findings should not dissuade the radiologist from attempting pressure reduction which is the treatment of preference. When intussusception is confirmed by CDUS, one should proceed with nonsurgical reduction unless free intraperitoneal air is seen on plain radiograph, or there is evidence of clinical signs of peritonitis i.e. peritoneal signs accompanied with fever and leucocytosis identified by a pediatric surgeon, for whom the nonsurgical reduction is contraindicated and the surgical approach is recommended. Prior to the nonsurgical treatment by rectal enema pressure reduction, the child should be examined by a pediatric surgeon and receive adequate sedation and hydration with an intravenous line placement in the emergency room before arrival to the Radiology Department.

Considerable research had been undertaken in recent years to improve the safety and success of non-surgical reduction of intussusception. The old technique of hydrostatic pressure reduction using barium sulphate is associated with lower reduction rates, primarily because of less aggressive reduction techniques used to avoid perforation and spillage of barium into the peritoneal cavity. When perforation occurs using barium, the complication and mortality rates are high, and therefore the use of barium for enema reduction of intussusception should be abandoned. The most popular techniques for intussusception reduction are hydrostatic reduction using water-soluble contrast (Fig. 35) or air enema reduction performed under fluoroscopic guidance. The success rates of either technique should be at least 70%. Advocates of air reduction cite reduction rates that are significantly greater than those with barium reduction and have shown that reduction occurs faster with air, decreasing the radiation exposure. Studies have also shown that when perforation occurs with air, the hole is smaller and fecal spillage is minimal. The disadvantage of air is the relative lack of contrast for identifying lead points and small perforations, and thus air or pneumatic reduction of intussusception has not received universal acceptance. Hydrostatic reduction using water under ultrasound guidance has gained popularity in some parts of the world for treatment of intussusception. The greatest merit of this technique is the avoidance of exposure to ionizing radiation, which can be considerable with the pressure reduction techniques. Nevertheless, concerns about detection of perforation and greater fecal spillage using this latter technique keep it from widespread use.

Successful reduction of the intussusception is confirmed radiologically and by relief of pain. If symptoms or intussusception persist, repeat with three attempts at reduction may be successful.

d. ***Small bowel obstruction and bowel distension*** • Neonatal causes of small bowel obstruction are related to varying congenital abnormalities such as intestinal atresia, or due to an incarcerated inguinal hernia (Fig. 36). Plain abdominal radiograph is usually diagnostic, and the treatment is surgical.

In neonates with non resolving abdominal distension and failure to pass meconium, intolerance to feeding and requiring anal stimulation to evacuate, Hirschprung's disease (HD) which is a functional obstruction of the large bowel due to lack of enteric ganglion cells should be suspected. In HD there is a narrow aganglionic distal segment demonstrable on a lateral projection without inflation of a balloon catheter

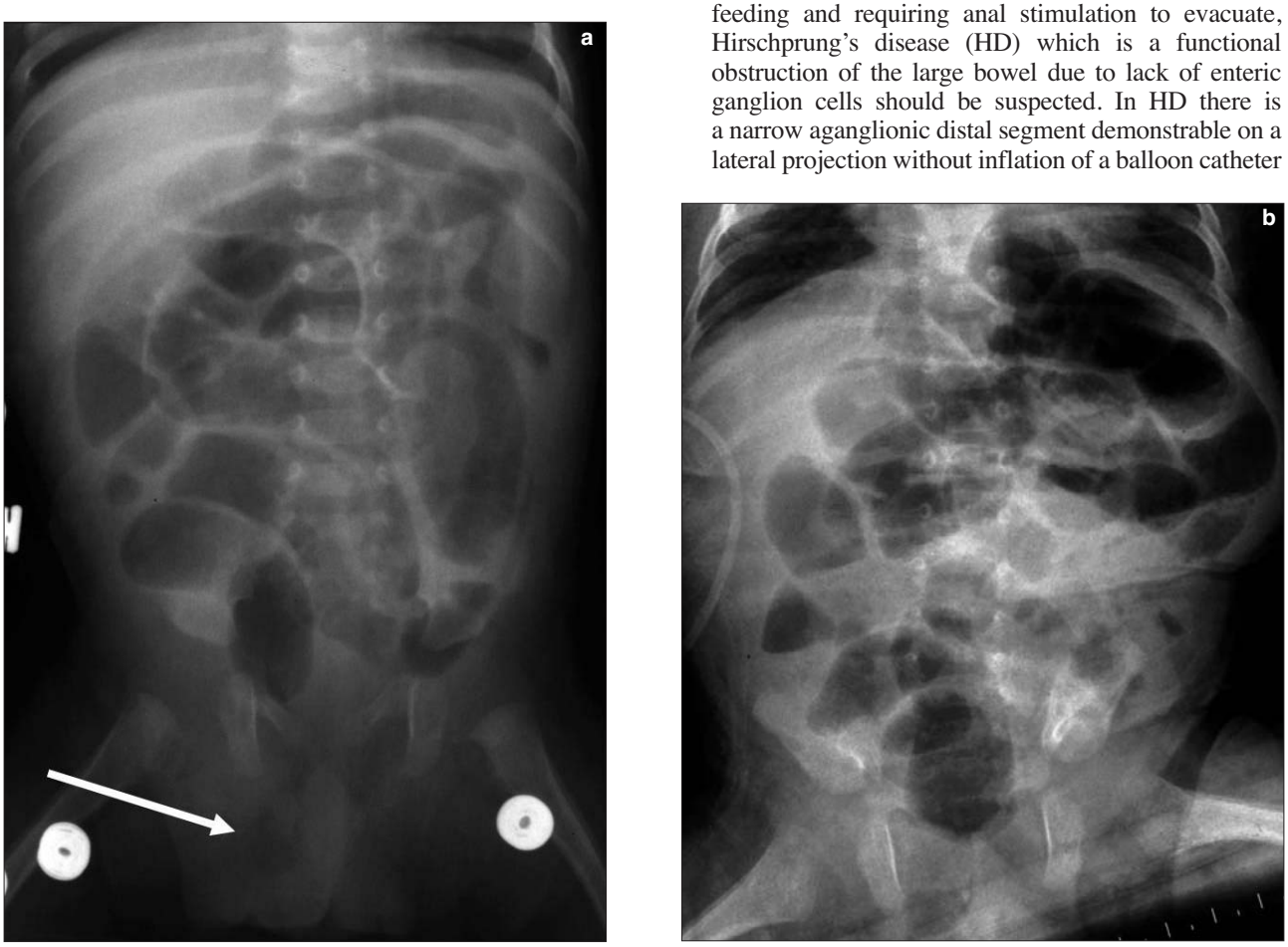


FIGURE 36. Plain abdominal radiographs in the supine (**a**) and erect (**b**) positions, showing bowel distension due to intestinal obstruction caused by a right inguinal hernia (arrow) resulting from a patent processus vaginalis.

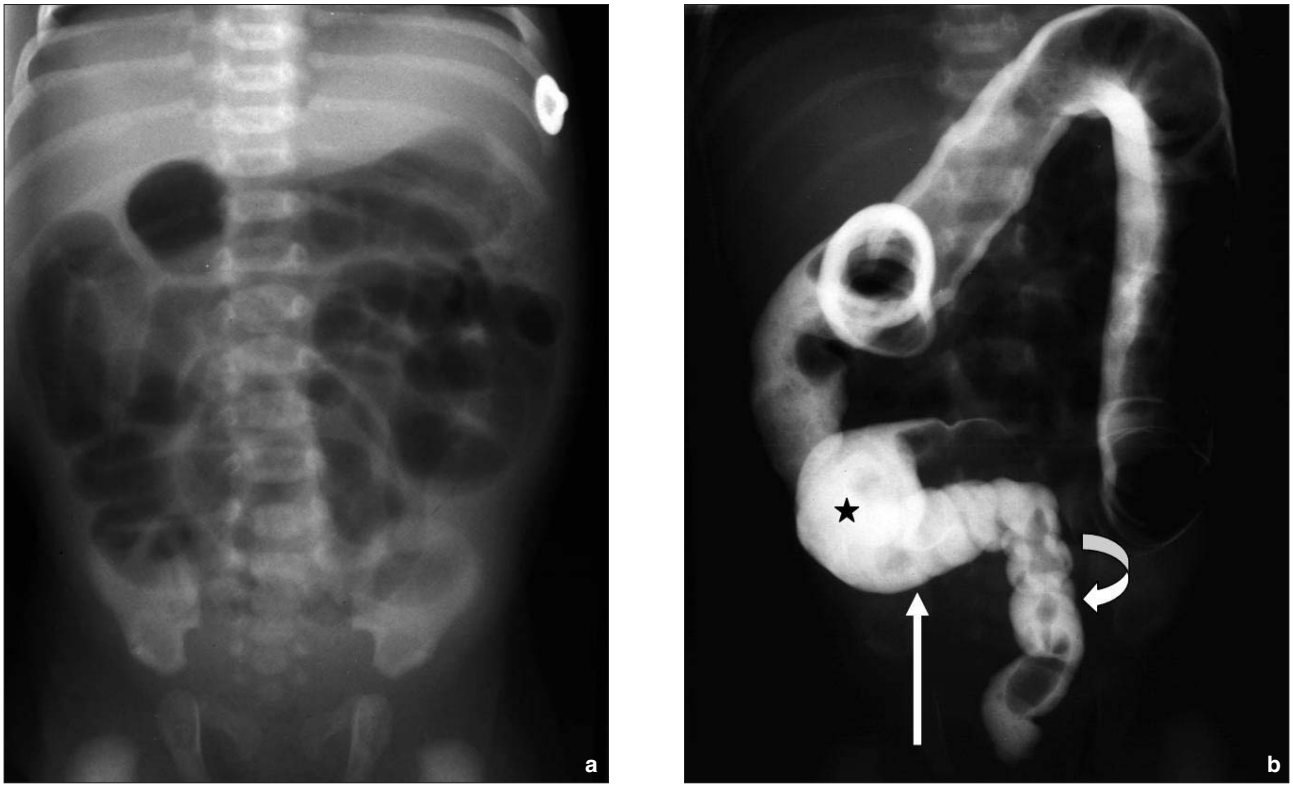


FIGURE 37. Hirschprung's disease in a neonate.
a. Plain abdominal radiograph showing abdominal bowel distension.
b. Water-soluble iodinated contrast enema demonstrating a long narrow segment of aganglionic large bowel involving the rectum and sigmoid colon with a transition zone (straight arrow) between normal caliber colon (★) and narrowed segment (curved arrow). Note also malrotation of the large bowel with the caecum and ascending colon located in the left side of the abdomen, filled with meconium.

of a water-soluble contrast enema (Fig. 37) in most patients but this is not invariable. The identification of a transition zone and a rectosigmoid index of less than one are specific signs diagnostic of HD. If barium has been used as the contrast agent, films obtained after 24 hours may show retention of barium which is abnormal. However, a normal contrast enema does not exclude HD and children with persistent symptoms without identifiable other causes should have a rectal biopsy to exclude HD.

e. ***Meconium ileus and meconium peritonitis*** • In neonates, meconium ileus can be complicated or uncomplicated. In approximately half of the cases meconium ileus is complicated by secondary bowel obstruction due to stenosis, atresia and volvulus. The presence of calcifications on plain abdominal radiographs (Fig. 38) indicate meconium peritonitis which is the result of in utero bowel perforation. Occasionally, twisted loops of bowel in utero do not perforate but undergo resorption forming cysts, the so-called intestinal pseudocyst. The

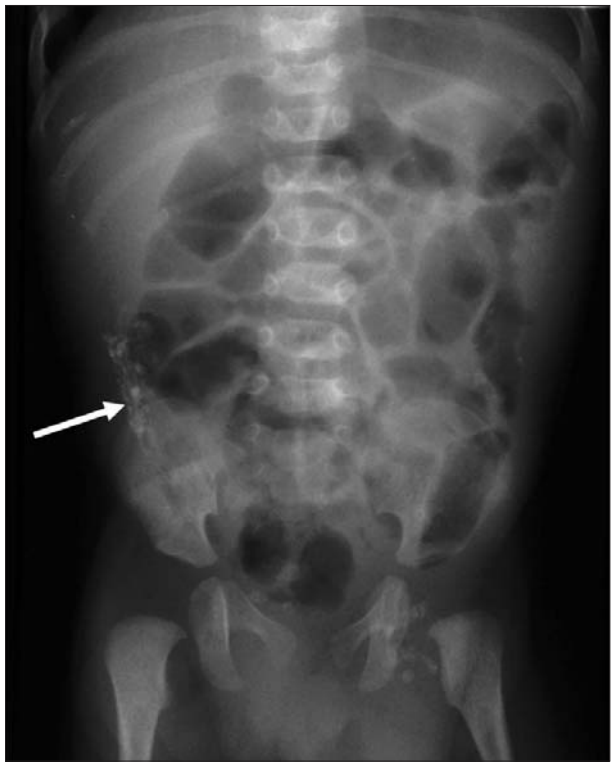


FIGURE 38. Meconium peritonitis.
Plain abdominal radiograph showing intraperitoneal calcifications (arrow). Note also the presence of a calcification projecting over the left inferior pubic ramus due to the presence of a patent processus vaginalis.

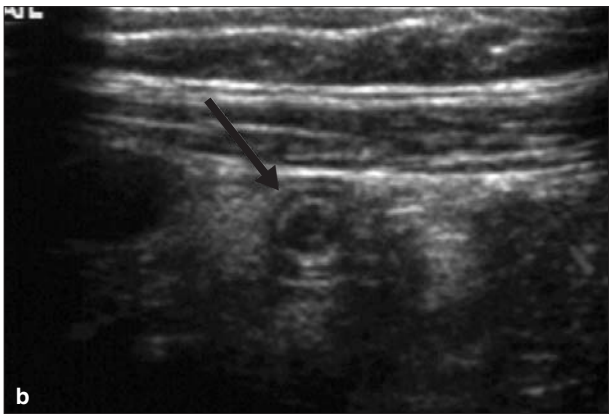
treatment for uncomplicated meconium ileus consists of gastrografin enema, whereas the treatment for complicated meconium ileus is surgical.

2. Toddlers (above 3 years) and teenagers

a. ***Acute appendicitis (AA)*** • The condition is rare in children under 3 years of age. Based on a literature survey conducted by Rosendahl et al. [58], imaging should be performed in all children with suspected AA, CDUS performed by an experienced person should be the initial imaging procedure, with CT scan reserved as a complementary tool. The plain abdominal radiographs (PAR) findings of appendicitis, when present, include a fecalith in the right lower quadrant (Fig. 39) seen only in 15% of cases of AA, and a sentinel loop due to a localized paralytic ileus. In the majority of children with suspected AA, the plain abdominal radiograph is typically normal, and PAR should not be obtained routinely in children with clinically suspected AA if CDUS is available.

Children with suspected AA should undergo abdominopelvic CDUS performed by an experienced sonographer (Fig. 40) using a graded compression technique performed with a high frequency 5 to 12 MHz linear

FIGURE 39. Plain abdominal radiograph showing calcified appendicoliths (arrow) in the right side of the pelvis.



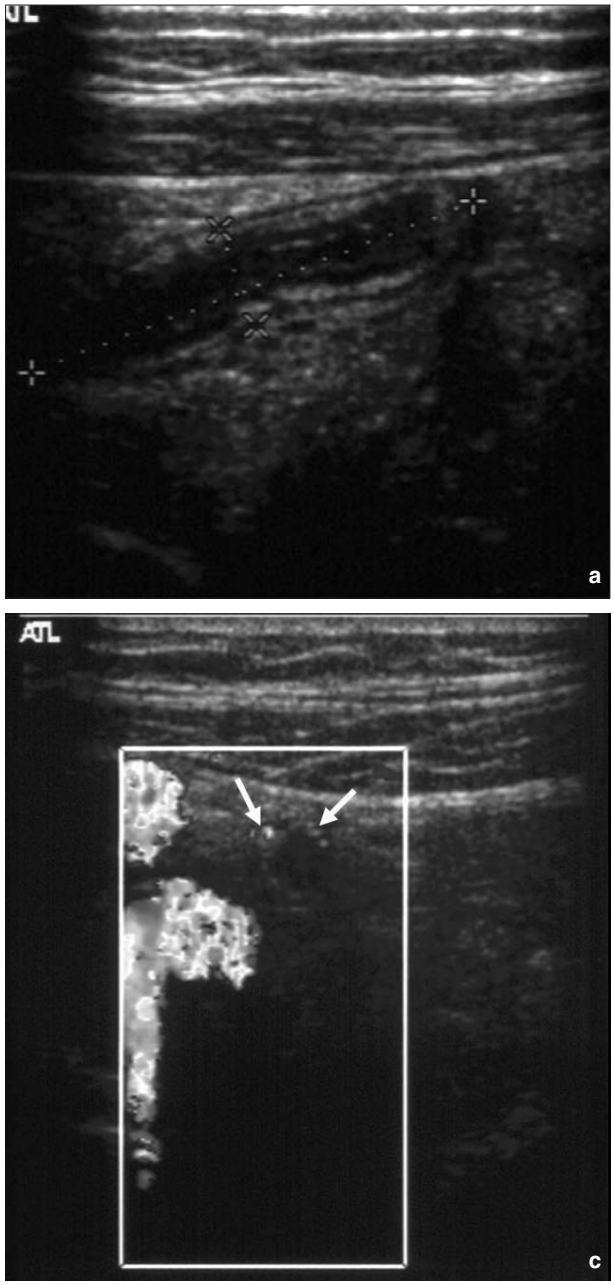


FIGURE 40. Acute appendicitis in a child.
Longitudinal (**a**), transverse (**b**), and color Doppler flow (**c**) images of graded compression ultrasound examination using a linear high-frequency 5-12 MHz transducer, showing a thickened noncompressible inflamed appendix (black arrow) with increased vascularity (white arrows) of its wall due to inflammation.

array probe and supplemented by color Doppler flow imaging which can be helpful in the diagnosis of gangrenous appendicitis showing no appendical wall blood flow on color Doppler flow imaging. In a study performed by Haddad-Zebouni et al. [59], sonography proved to have high accuracy of 94% in the diagnosis of AA in children. If the sonographic diagnosis remains doubtful or equivocal, it is preferable to perform an abdominal and pelvic low dose contrast enhanced CT scan with intravenous and rectal contrast enema and not proceed with repeated equivocal ultrasound examinations. Visualization of a normal appendix by CDUS is possible in only less than half of the patients examined by CDUS. When CDUS result is equivocal, low dose CT scan is justifiable because delaying a diagnosis of acute appendicitis or misdiagnosing or even overlooking AA increases the risk of morbid complications such as ureteral obstruction, appendiceal perforation with subsequent abscess formation. Early diagnosis is essential and full imaging is justified to resolve difficult problematic cases. In some major American centers and in our center, low dose contrast enhanced CT with intravenous and rectal contrast has become the modality of choice in the evaluation of children suspected of having appendicitis and presenting outside working hours.

In girls and young women with deep pelvic perforated appendicitis, differentiation of complicated acute appendicitis with inflammatory mass or abscess formation from ovarian neoplastic pathology may be difficult with CDUS and CT scan, it is best performed by means of MRI with gadolinium enhancement which is capable of demonstrating a normal ovary on T_2-weighted MR images.

FIGURE 41. Mesenteric adenitis in a child.
Ultrasound image using a linear high-frequency 5-12 MHz transducer, showing an enlarged mesenteric lymph node (cursors) in a child with right lower quadrant pain clinically suspected to have acute appendicitis.

b. ***Mesenteric adenitis*** • Normal mesenteric lymph nodes are less than 10 mm in longitudinal diameter. Inflammatory lymph nodes in patients with mesenteric adenitis measure almost always 10 mm or more, are homogenously attenuating, and are clustered in the right lower quadrant, small bowel mesentery or ventral to the psoas muscle. Mesenteric adenitis can be divided into two distinct groups: primary and secondary. On imaging, primary mesenteric adenitis has been defined as right-sided mesenteric lymphadenopathy without an identifiable acute inflammatory process or with only minimal wall thickening of the terminal ileum; it is usually a consequence of a viral infection. Secondary mesenteric adenitis is defined as lymphadenopathy associated with a detectable intraabdominal process such as Crohn's disease, acute appendicitis, celiac disease, familial Mediterranean fever and many other causes of enlarged mesenteric lymph nodes. CDUS (Fig. 41) and contrast enhanced CT with intravenous and rectal contrast help in establishing a positive diagnosis and avoiding unnecessary surgery because mesenteric adenitis causes right lower quadrant pain and enters in the differential diagnosis of AA.

c. ***Infectious and inflammatory enterocolitis*** • Abdominal pain in children with enterocolitis may be very severe and children may present with fever and blood-stained diarrhea. It may be viral or bacterial. Infecting organisms include *Rotavirus, Campylobacter, Yersinia, Salmonella, Cryptosporidium,* and *Escherichia coli*. The *E. coli* infection with the 0157: H7 strain may precede the onset of hemolytic uremic syndrome, which itself may present as an acute abdominal pain or with acute renal failure and oliguria as a dominant clinical presentation. The diagnosis is established by serology, endoscopy and biopsy with culture; imaging has a limited role and it is used to exclude other causes of abdominal distension. On plain abdominal radiograph, gaseous bowel distension with multiple air-fluid levels is usually present. On sonography, either an excessive peristalsis or ileus with some free fluid between bowel loops are observed.

In children with hemolytic uremic syndrome, a thickened narrow colon with thumbprinting is a described radiological finding on PAR, and the kidneys may be normal or hyperechoic with preserved corticomedullary differentiation on sonography indicating renal parenchymal disease. When localized transmural small bowel thickening is found in conjunction with increased echogenicity of the renal parenchyma on sonography, Henoch-Schönlein purpura or hemolytic uremic syndrome should be considered. Henoch-Schönlein purpura is a vasculitis that can be associated with intramural hemorrhage leading to duodenal (Fig. 42) or small bowel intussusception.

The two major inflammatory bowel lesions seen in children are ulcerative colitis and Crohn's disease (Fig. 43). Usually neither disease presents primarily as an acute abdominal emergency but may present acutely due to complications in a child with known disease such as abscess formation due to diseased bowel perforation or fistula.

Occasionally, with both infectious and inflammatory bowel diseases, a toxic megacolon can occur, which is an emergency condition.

d. ***Urinary tract infection*** • Urinary tract infection (UTI) in children is a common problem that may cause abdominal discomfort accompanied with or without fever. Children with nonfebrile UTI i.e. cystitis need no radiologic investigation. Children with febrile UTI under the age of one year will undergo systematically sonography of the urinary tract coupled with a voiding cystourethrogram (VCUG) from the first episode of febrile UTI. While in children above one year of age with a documented first episode of febrile UTI they will undergo an ultrasound examination of the urinary tract and a Tc-DMSA renal scintigraphy. A VCUG is an invasive imaging technique that is usually kept as a second line investigation if the sonography or scintigraphy of the urinary tract at first episode of UTI are abnormal, or a second episode of UTI or reinfection occur i.e. recurrent UTI.

The sonographic and scintigraphic abnormalities are present in approximately 12% of patients examined at the first episode of UTI and consist of: renal pelvicalyceal system dilatation or hydroureteronephrosis, parenchymal scarring on Tc-DMSA scintigraphy, irregular unstable bladder, postvoid urine residue and urinary stasis, debris in the bladder. The VCUG is performed to detect vesico-ureteric reflux.

e. ***Constipation*** • Investigation of a child presenting with an abdominal emergency due to constipation should

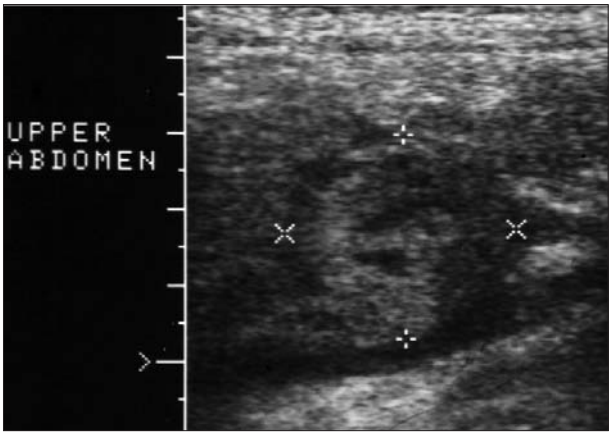
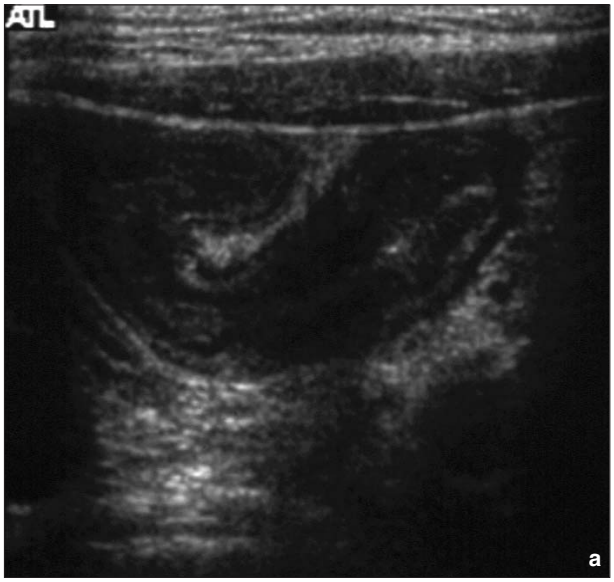


FIGURE 42. Ultrasound image using a linear high-frequency probe of a duodenal intussusception (cursors) in a child with known Henoch-Schönlein purpura.



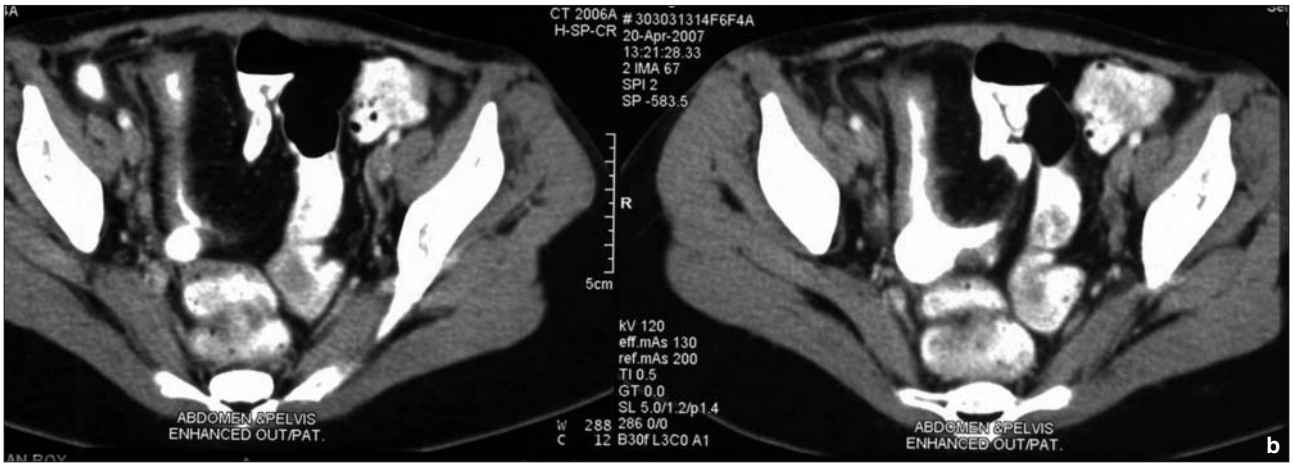


FIGURE 43. Crohn's disease in a child.
Note the transmural bowel wall thickening of the terminal ileum on linear ultrasound examination (**a**) and contrast enhanced CT scan with oral contrast material (**b**) with a typical "comb's sign" on CT scan due to dilated engorged vasa recta.

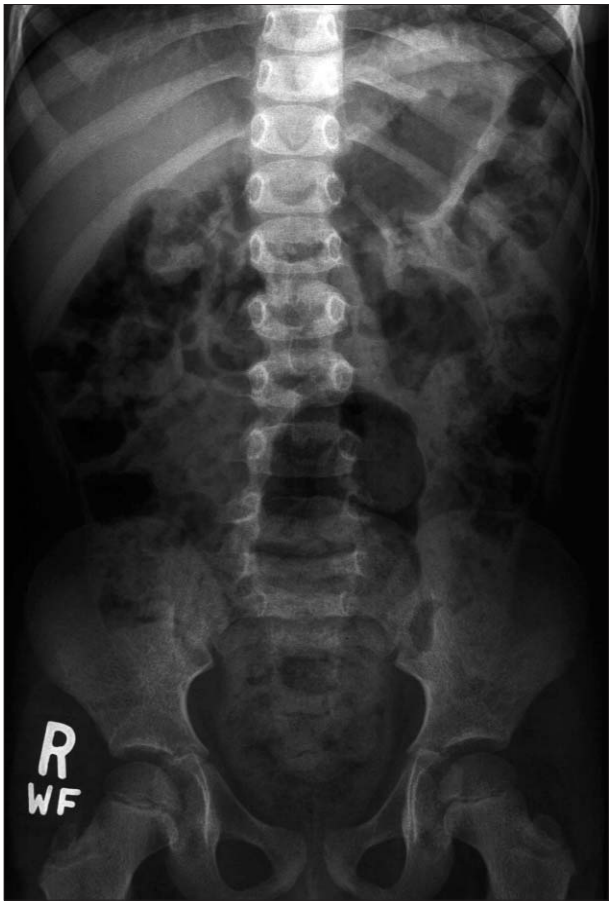


Figure 44. Plain abdominal radiograph showing fecal loading of the large bowel and rectum due to constipation with fecal impaction.

include a plain abdominal radiograph (Fig. 44). In a few patients with nonresolving symptoms of constipation contrast enema using water soluble contrast and not barium sulphate to avoid impaction is usually performed with delayed images at 24 & 48 hours to exclude two possible diagnoses such as missed Hirschprung's disease, and functional constipation with megarectum or megacolon that may also cause secondary urinary tract obstruction and hydronephrosis so-called Heinman's or elimination syndrome. In some cases with fecal impaction, organic diseases such as a stenosis following anorectal surgery or a spinal cord lesion should be suspected. If spinal cord pathology is suspected a spinal MRI is indicated to rule out a neuromuscular disorder.

VIII. ACUTE ABDOMEN IN THE ELDERLY INDIVIDUALS

Acute abdominal pain generally defined as pain of less than one week's duration is a common presenting or chief complaint among elderly patients. Approximately one fourth of patients who present to the emergency department are older than 60 years and 75% of them are usually admitted to hospital for further management. The presentation of an older patient with abdominal pain may be very different from that seen in a younger patient. Older patients tend to present later in the course of their illness and have more nonspecific symptoms and physical findings. Older patients may delay seeking care because of many reasons: they fear losing independence, they lack health insurance, transportation, a secondary caregiver for their spouse or pet, or are afraid of hospitals or death [60]. Elderly patients are often unresponsive and therefore imaging is mandatory.

Figure 45. Gallstone ileus in an elderly patient. Note the presence of a large stone obstructing the jejunum (**a**) and presence of air in the biliary tree and within the gallbladder (arrows) (**b**) on CT sections.

The causes of acute abdominal pain in older patients are not greatly dissimilar from the causes in younger patients; however, certain disease processes occur more often in older patients such as cholecystitis and cholangitis, appendicitis, pancreatitis, peptic ulcer disease and perforation, diverticular disease, small bowel obstruction

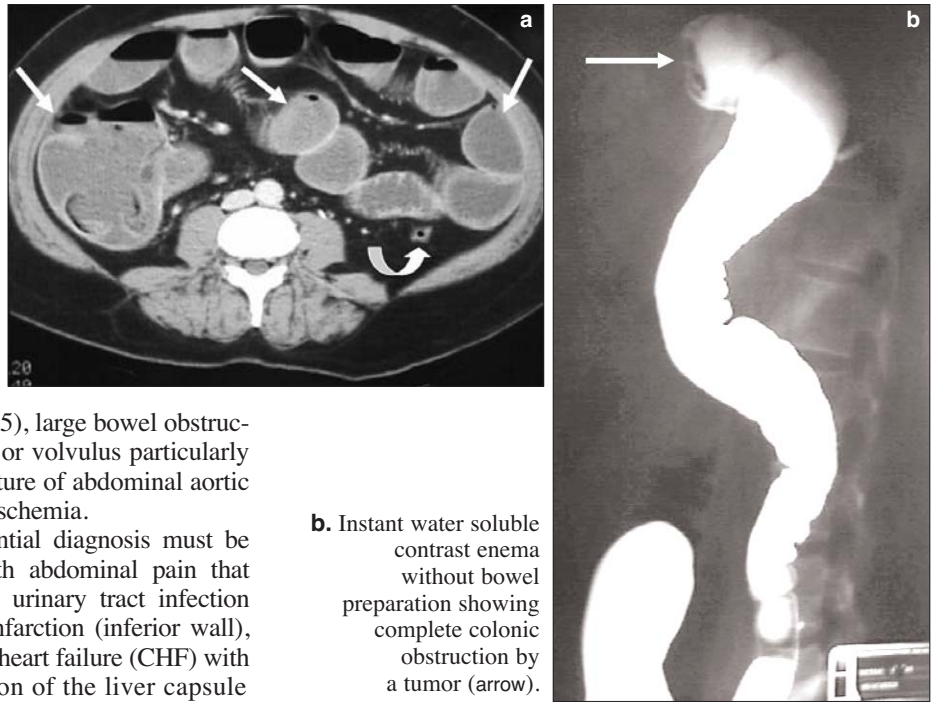


FIGURE 46
Large bowel obstruction.

a. Contrast enhanced CT scan without oral contrast showing dilated small bowel loops, ascending and transverse colon (straight arrows). The descending colon is completely collapsed (curved arrow). The findings indicate high grade distal colonic obstruction in an elderly patient.

b. Instant water soluble contrast enema without bowel preparation showing complete colonic obstruction by a tumor (arrow).

particularly gallstone ileus (Fig. 45), large bowel obstruction due to malignancy (Fig. 46) or volvulus particularly a sigmoid volvulus (Fig. 47), rupture of abdominal aortic aneurysm, and acute mesenteric ischemia.

In addition, a broader differential diagnosis must be considered in older patients with abdominal pain that include atypical causes such as: urinary tract infection and pyelonephritis, myocardial infarction (inferior wall), pulmonary embolism, congestive heart failure (CHF) with hepatic congestion and distension of the liver capsule

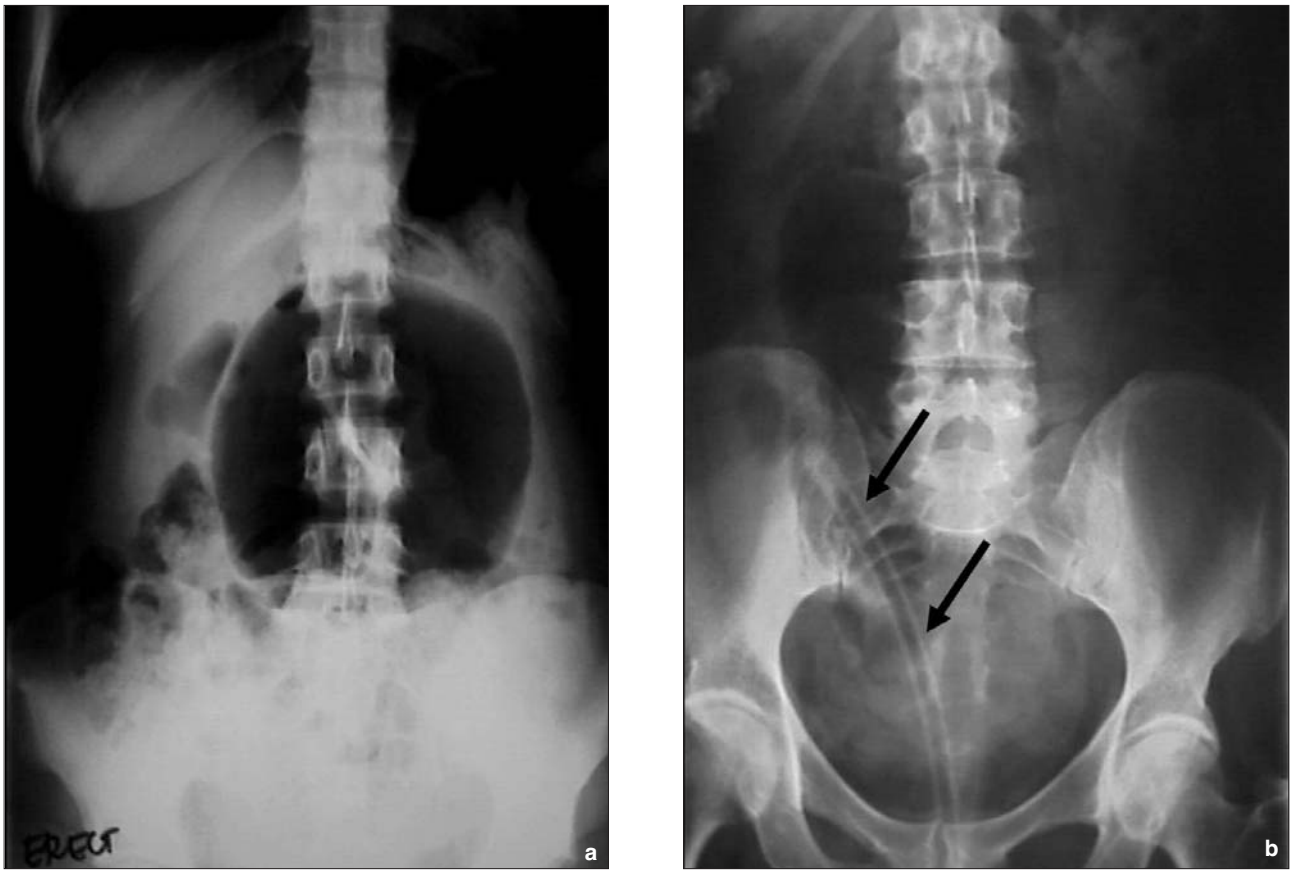


FIGURE 47. Sigmoid volvulus
a. Plain abdominal radiograph in the supine position showing an inverted-U or a coffee-bean appearance of the sigmoid colon compatible with a volvulus.
b. The sigmoid volvulus was successfully reduced following insertion of a long rectal tube (arrows).

causing right upper quadrant pain, or CHF causing diffuse abdominal pain due to low flow state nonocclusive mesenteric ischemia, pneumonia, constipation, urinary retention from urinary bladder outflow obstruction caused by prostatic enlargement in men and pelvic organs prolapse in women, gallbladder torsion, diabetic ketoacidosis, pyometra associated with uterine obstruction by cervical cancer, rupture of an infected urachal cyst causing peritonitis, rupture of a visceral aneurysm causing hemoperitoneum, and abdominal pain caused by intestinal intramural hematoma or anterior abdominal wall muscle hematoma in patients on oral anticoagulation.

Older patients especially those above 70 years of age may also have coexistant or concomitant illnesses and decreased renal function, they generally have a substantial operative risk.

IX. CONCLUSIONS

The practice of radiology or imaging of patients with acute abdomen has changed dramatically over the past few years and some general conclusions can be drawn. First, the topographic classification of pain facilitates the radiological assessment by tailoring specific cross-sectional imaging examinations to answer specific clinical questions. Therefore, close cooperation with the referring physician prior to imaging remains essential for rapid and accurate diagnosis. Second, the PAR have a limited diagnostic value, they show an abnormality in less than 50% of patients presenting with an acute abdominal condition. However, they are still valuable as a diagnostic imaging modality in adult patients with bowel perforation and a large pneumoperitoneum, as an initial preliminary study prior to CT scan in adult patients with suspected high grade small bowel obstruction, PAR coupled with sonography in children, and in adults with suspected emphysematous cholecystitis. Third, because of their limited diagnostic value and low accuracy inferior to 50%, the time honored plain abdominal radiographs have been largely replaced with cross-sectional imaging techniques namely CDUS and CT scan which have high diagnostic accuracy exceeding 90%. CDUS remains a primary imaging modality of choice in the evaluation of patients with suspected acute cholecystitis, gynecologic and obstetric emergencies, children with suspected AA or other abdominal emergencies, and as a fast triage technique in the emergency room at the bedside for abdominal trauma and leaking AAA in hemodynamically unstable patients. Helical CT scan with varying tailored techniques and in particular MDCT – the latest technical development – with its capability of multiplanar reconstruction of images permit the examination to be performed in a very short time with a great diagnostic accuracy, and with less patient discomfort. Fourth, there is an increasing usage of low dose CT scan and MR imaging as adjunct second line investigations in children and young women after an equivocal ultrasound result, because of increasing awareness and concern about radiation exposure and its potential risks when using standard CT scan examinations. The use of nonenhanced CT scan is justifiable in elderly and adults at risk for developing allergic and toxic reactions to intravenous administration of iodinated contrast material. Fifth, there is a shift towards usage of water soluble iodinated contrast media substituting barium sulphate in the study of the gastrointestinal tract in children. Sixth, minimally invasive interventional procedures performed by specialized interventional radiologists under imaging guidance such as percutaneous catheter drainage of a diverticular or periappendiceal abscess or peripancreatic fluid collections as a temporizing measure prior to definitive surgery, percutaneous nephrostomy in renal obstruction and urosepsis with fever due to pyonephrosis, percutaneous cholecystostomy, percutaneous transcatheter or endovascular treatment of intestinal ischemia in the first golden 6 hours of reversible ischemia, and percutaneous transcatheter embolization of life-threatening bleeding are very helpful in the management of patients with acute abdominal conditions. Seventh, the radiologist should be familiar with the treatment of acute abdominal diseases, be alerted to ominous diagnostic signs that need immediate intervention, and capable of differentiating nonsurgical conditions i.e. **"leave me alone lesions"** treatable with conservative management from surgical conditions i.e. **"take me out lesions"** that need surgical intervention.

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