SYLLABUS IDKD

# Diseases of the Abdomen and Pelvis 2010-2013

*Diagnostic Imaging and Interventional Techniques*

**Editors**

J. Hodler
G.K. von Schulthess
Ch.L. Zollikofer

Springer

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*Diagnostic Imaging and Interventional Techniques*

J. Hodler • G.K. von Schulthess • Ch.L. Zollikofer (Eds)

# DISEASES OF THE ABDOMEN AND PELVIS 2010-2013

## DIAGNOSTIC IMAGING AND INTERVENTIONAL TECHNIQUES

**42nd International Diagnostic Course in Davos (IDKD)**
***Davos, March 21-26, 2010***

*including the*
Nuclear Medicine Satellite Course "Diamond"
Davos, March 20-21, 2010

Pediatric Satellite Course "Kangaroo"
Davos, March 20-21, 2010

IDKD in Greece

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# Preface

The International Diagnostic Course in Davos (IDKD) offers a unique learning experience for imaging specialists in training as well as for experienced radiologists and clinicians wishing to be updated on the current state of the art and the latest developments in the fields of imaging and image-guided interventions.

This annual course is focused on organ systems and diseases rather than on modalities. This year's program deals with diseases of the abdomen and pelvis. During the course, the topics are discussed in group workshops and in plenary sessions with lectures by world-renowned experts and teachers. While the workshops present state-of-the-art summaries, the lectures are oriented towards future developments. Accordingly, this Syllabus represents a condensed version of the contents presented under the 20 topics dealing with imaging and interventional therapies in abdominal and pelvic diseases. The topics encompass all the relevant imaging modalities including conventional X-rays, computed tomography, nuclear medicine, ultrasound and magnetic resonance angiography, as well as image-guided interventional techniques.

The Syllabus is designed to be an "*aide-mémoire*" for the course participants so that they can fully concentrate on the lecture and participate in the discussions without the need of taking notes.

Additional information can be found on the IDKD website: www.idkd.org

J. Hodler
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# WORKSHOPS

# Emergency Radiology of the Abdomen: The Acute Abdomen

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## Introduction

The term "acute abdomen" defines a clinical syndrome characterized by a history of hitherto undiagnosed abdominal pain lasting less than one week. A large range of disorders, from benign, self-limited diseases to conditions that require immediate surgery, can cause acute abdominal pain. Eight conditions account for over 90% of patients who are referred to the hospital and who are seen on surgical wards with acute abdominal pain: acute appendicitis, acute cholecystitis, small bowel obstruction (SBO), urinary colic, perforated peptic ulcer, acute pancreatitis, acute diverticular disease, and non-specific, non-surgical abdominal pain (dyspepsia, constipation).

## Imaging Techniques

Clinical assessment of the acute abdomen is often difficult because the findings of the physical examination and laboratory investigations are often non-specific. Traditionally, *plain abdominal radiographs* have served as the initial imaging approach; however, because of their diagnostic limitations, plain radiographs now play only a limited role in this clinical setting. Currently, the major indications for plain radiography are to determine the presence of bowel obstruction, perforated viscus, urinary tract calculi, or a foreign body. The conventional radiographic examination consists of supine and either upright or left lateral decubitus images. *Computed tomography* (CT) now serves as the imaging test of choice for most adult patients with acute abdominal pain. It has been shown to be superior to plain radiography for diagnosing nearly all causes of acute abdominal pain. Several studies have demonstrated that the use of CT to evaluate patients with acute abdominal pain increases the accuracy of clinical diagnosis by >20% and results in management changes in up to 60% of patients. The major obstacles to replacing plain abdominal radiography with CT are its higher cost, more limited availability, and higher radiation dose. The use of CT in patients with an acute abdomen requires careful attention to the CT protocol.

1. The multidetector CT (MDCT) image data volume should be obtained from the dome of the diaphragm to the inferior aspect of the pubic symphysis (with thin collimation and a short acquisition time). CT data are reconstructed with thin, overlapped slices for multiplanar (coronal and sagittal planes) reformation and 3- to 5-mm thick contiguous axial slices. The image series is sent to a dedicated workstation and/or PACS.
2. Vascular enhancement by iodinated contrast medium (CM) is mandatory in most cases, unless contraindicated. Special attention should be paid to older patients and those with metabolic disorders (dehydration in SBO) in assessing the renal impact of CM administration. In general, the most helpful scanning phase is the late portal phase (70 s), but other scanning phases are useful in selected circumstances: arterial phase in bowel ischemia, bleeding, or visceral infarction; delayed phase (3 min) for assessing the lack of enhancement in a patient with suspected acute mesenteric ischemia. A pre-contrast CT scan allows demonstration of calcifications, lithiasis, and acute or subacute hemorrhage; multiphasic scanning should be used only for specific indications in order to limit radiation dose.
3. Changes in the CT protocol should be decided according to the clinical conditions and/or the preliminary results of the CT examination. In selected cases, colorectal opacification and/or image acquisition with the patient in the prone position may be helpful to clarify equivocal findings. In most cases, the systematic use of ingested oral contrast is not recommended.
4. The method of image evaluation is critical to optimize interpretation. Additional window level (M) and width (W) settings are useful to identify tiny bubbles of extraluminal gas (CT lung windows) or hyperattenuation from recent hemorrhage (narrow CT windows). The systematic use of multiplanar reformation (MPR), particularly in the coronal plane, is recommended, and 3D imaging may be helpful.

*Ultrasonography* (US) is the initial imaging technique of choice for patients with suspected acute cholecystitis or acute gynecological abnormalities. It also is the primary method for evaluating pregnant women and pediatric patients. Although less sensitive and specific than CT, US is an excellent imaging test for diagnosing acute appendicitis, when employed by experienced individuals. It can also be used to evaluate the presence or absence of the layered structure of the digestive tract wall or to assess the structure of a lesion identified at CT.

Until recently, *magnetic resonance imaging* (MRI) has played a very limited role in patients with acute abdominal pain; however, it is now established in the imaging of pregnant women with abdominal pain who have had a negative or equivocal US examination. Recent studies assessing the use of MRI to evaluate all patients with acute lower abdominal pain have shown promising results. MRI may also have a role in patients with biliary diseases and/or pancreatitis.

The differential diagnosis in a patient with an acute abdomen is influenced greatly by the nature and location of the pain. Therefore, the imaging strategies for acute pain localized to an abdominal quadrant should be discussed separately from those for acute pain that is diffuse or localized to the flank or epigastric region.

## Acute Pain in an Abdominal Quadrant

In many cases, acute abdominal pain can be localized to one either the right upper, left upper, right lower, or left lower abdominal quadrant.

### Right Upper Quadrant

Acute cholecystitis is by far the most common disease to involve the right upper quadrant. Other important diseases that can have a clinical presentation similar to that of acute cholecystitis are pyogenic or amebic liver abscess, spontaneous rupture of a hepatic neoplasm (usually hepatocellular adenoma or carcinoma), hepatitis, and myocardial infarction.

The preferred imaging method for evaluating patients with acute right upper abdominal pain is US. It is a reliable technique for establishing the diagnosis of acute calculous cholecystitis. The imaging criteria include the detection of gallstones, the sonographic Murphy sign, gallbladder wall thickening ≥3 mm, and pericholecystic fluid. The association of three of these signs is highly suggestive of acute cholecystitis. Isolated gallbladder wall thickening may be secondary to other conditions, such as gallbladder adenomyomatosis, gallbladder carcinoma, HIV cholangitis, sclerosing cholangitis, acute hepatitis, cirrhosis, ascites, portal hypertension, hypoproteinemia, pancreatitis, and cardiac failure. In acute calculous cholecystitis, typically a calculus obstructs the cystic duct. The trapped concentrated bile irritates the gallbladder wall, causing increased secretion, which in turn leads to distention and edema of the wall. The rising intraluminal pressure compresses the vessels, resulting in thrombosis, ischemia, and subsequent necrosis and perforation of the wall. Gallbladder perforation and complicating pericholecystic abscess typically occur adjacent to the gallbladder fundus because of the sparse blood supply. CT may be useful for confirmation of the sonographic diagnosis, but usually is not necessary. Emphysematous cholecystitis is a rare complication of acute cholecystitis that generally is associated with diabetes mellitus. US or CT demonstrates gas in the wall and/or lumen of the gallbladder, which implies underlying gangrenous changes (Fig. 1). Acalculous acute cholecystitis accounts for only approximately 5% of cases of acute cholecystitis but is especially common in patients in the intensive care unit. Prolonged bile stasis results in increased viscosity of the bile that ultimately leads to functional cystic duct obstruction.

Both US and CT are accurate techniques for diagnosing liver abscesses. US usually demonstrates a round or oval hypoechoic mass with low-level internal echoes. Although the lesion may mimic a solid hepatic mass, the presence of through transmission is a clue to its cystic nature. Pyogenic liver abscesses most commonly are the result of seeding from appendicitis or diverticulitis or direct extension from cholecystitis or cholangitis. Amebic abscesses result from primary colonic involvement, with seeding through the portal vein. In most cases, the US appearances of pyogenic and amebic abscess are indistinguishable. The CT appearances of pyogenic and amebic abscesses also overlap substantially. Amebic abscesses are cystic masses of low attenuation. An enhancing wall and a peripheral zone of edema surrounding the abscess are common but not universally present. Extrahepatic extension of the amebic abscess with involvement of the chest wall, pleura, or adjacent viscera is a frequent finding. Whereas amebic abscesses usually are solitary and unilocular, pyogenic abscesses may be multiple or multi-

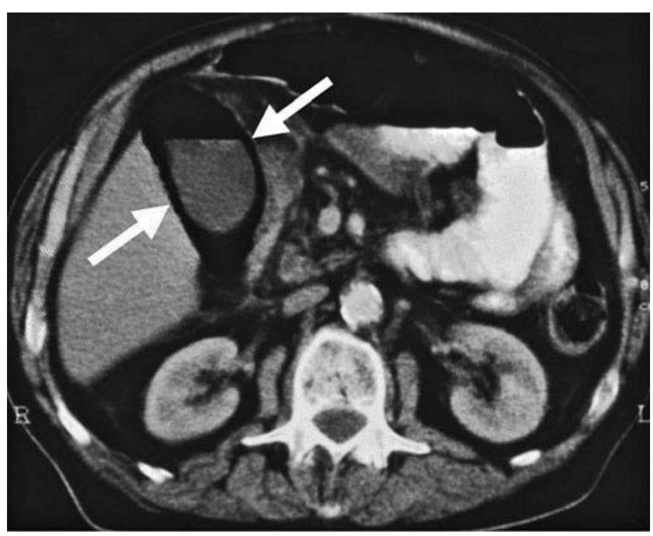

**Fig. 1.** Diabetic patient with emphysematous cholecystitis and gangrene of the gallbladder. CT shows air-fluid level in the gallbladder lumen and air in the gallbladder wall (*arrows*)

loculated and may demonstrate an irregular contour. Some pyogenic abscesses have a mixed cystic and solid appearance on US, CT, or MRI; rarely, they appear completely solid. A small percentage of hepatic abscesses, particularly those secondary to *Klebsiella* infection, are associated with portal vein thrombosis.

Spontaneous rupture of a hepatocellular carcinoma with subsequent hemoperitoneum is a frequent complication in countries with a high incidence of this tumor, but is less commonly seen in Western countries. Subcapsular location and tumor necrosis have been implicated in the pathogenesis. US, and especially CT, are the most useful techniques for diagnosing a ruptured hepatocellular carcinoma, which appears as a peripheral or subcapsular mass. Transcatheter embolization of either the tumor or the bleeding hepatic artery is the treatment of choice. Spontaneous hemorrhage within a hepatocellular adenoma occurs most commonly in women taking oral contraceptives. Capsular rupture with subsequent hemoperitoneum is an uncommon complication. On CT, high-density intraperitoneal fluid confirms the diagnosis of hemoperitoneum. Extravasation of CM, when present, is indicative of active bleeding.

### Left Upper Quadrant

Although infrequent, acute left upper quadrant pain is most often seen in splenic infarction, splenic abscess, gastritis, and gastric or duodenal ulcer. US is most frequently used for screening, while CT enables accurate further evaluation. The diagnosis of gastric pathology is established by endoscopy, with imaging playing a minor role.

Common causes of splenic infarction include bacterial endocarditis, portal hypertension, and marked splenomegaly. Pancreatitis or tumors that extend into the splenic hilum can also result in infarction. Splenic infarction may be focal or global. Typical focal splenic infarcts appear as peripheral wedge-shaped defects, hypoechoic or isoechoic at US and hypoattenuating at CT. Most splenic abscesses are secondary to hematogenous dissemination of infection, e.g., bacterial endocarditis or tuberculosis. Intravenous drug abusers and immunocompromised individuals are predominantly affected. US and CT are sensitive, but the specificity of either one is low. On US, most abscesses appear as hypo- or anechoic, poorly defined lesions; on CT, they typically appear as rounded lesions of low attenuation and with rim enhancement. Spontaneous splenic rupture can occur in patients with hematological malignancy or secondary to rapid splenic enlargement from viral infections such as mononucleosis.

### Right Lower Quadrant

Acute appendicitis is not only the most frequent cause of acute right lower quadrant pain, it is also the most commonly encountered cause of an acute abdomen. Other diseases that can present with acute right lower quadrant pain include acute terminal ileitis (Crohn's disease), typhlitis, right-sided colonic diverticulitis and, in women, pelvic inflammatory disease, complications of ovarian cyst (hemorrhage, torsion, and leakage), endometriosis, or ectopic pregnancy. Less common causes of right lower quadrant pain include segmental infarction of the greater omentum, mesenteric adenitis, epiploic appendagitis, perforated cancer, and ileal or Meckel's diverticulitis.

The diagnosis of acute appendicitis is uncertain in up to one-third of patients. Thus, pre-operative imaging plays an important role in confirming or excluding the diagnosis. With the increasing use of medical imaging to evaluate patients with suspected acute appendicitis, the rate of both false-positive (unnecessary appendectomy) and false-negative (leading to complications from perforated appendicitis) diagnoses has decreased. The standard surgical teaching is that patients with typical clinical findings should undergo immediate appendectomy without pre-operative imaging. Nevertheless, at most medical centers pre-operative imaging is obtained even when the clinical presentation is typical. The most specific CT finding of acute appendicitis is a thick-walled appendix that contains an appendicolith (Fig. 2). The inflamed appendix often is dilated and fluid-filled. Additional helpful findings are stranding of the periappendiceal fat and thickening of the cecal apex. Findings that indicate appendiceal perforation include periappendiceal abscess, extraluminal gas, a right lower quadrant inflammatory mass, a defect in the appendiceal wall, and SBO.

In the evaluation of suspected acute appendicitis in children, pregnant women, and women of reproductive age, US is an important imaging option. Demonstration of a swollen, noncompressible appendix >7 mm in diameter with a target configuration is the primary sonographic criterion (Fig. 3). Additional helpful US findings are "MacBurney's sign" (maximum tenderness found with graded compression of the inflamed appendix) and demonstration of an appendicolith. These US signs may also be demonstrated by transvaginal high-resolution US. The advantages of US include the lack of ionizing radiation, relatively low cost, and widespread availability. However, US requires considerable skill and is difficult to perform in obese patients, patients with severe pain, and patients likely to have a complicating periappendiceal abscess. When the sonographic findings are unclear, CT can provide a rapid and definitive diagnosis. Due to its exceptional accuracy, CT has emerged in many centers as the primary imaging test for patients with suspected acute appendicitis.

In a small percentage of patients, diverticulitis manifests itself as a right-sided condition. Right-sided colonic diverticula are often congenital, solitary, and true diverticula, unlike sigmoid diverticula. In right-sided diverticulitis the normal appendix should be visible.


**Fig. 2 a-c.** Acute appendicitis. Axial (**a**, **b**) and sagittal (**c**) views of multidetector CT demonstrate a dilated appendix in retrocecal position, a calcified appendicolith at the base of the appendix (*arrowheads*), and inflammatory changes of the mesenteric fat (*arrow*)


**Fig. 3 a-c.** Ultrasonography of acute appendicitis in a 12-year-old girl. Oblique (**a**, **b**) and transverse (**c**) views show swollen appendix (diameter 10 mm, *arrowheads*) with a target configuration

## Left Lower Quadrant

Diverticulitis is the most common cause of acute left lower quadrant abdominal pain. The condition occurs in 10–20% of patients with diverticulosis and most commonly involves the sigmoid colon. CT is very sensitive and approaches 100% specificity and accuracy in the diagnosis or exclusion of diverticulitis; it has therefore largely replaced barium enema examinations. CT is also very useful in establishing the presence of pericolic complications. The CT diagnosis of acute diverticulitis is based on the identification of segmental colonic wall thickening and pericolic inflammatory changes, such as fat stranding, inflammatory mass, gas bubbles, or free fluid (Figs. 4, 5). Complications of acute diverticulitis include abscess, fistula (most commonly colovesical), SBO, peritonitis, septic thrombophlebitis, colonic obstruction, and ureteral obstruction. In patients with left lower quadrant pain, alternative diagnoses that should be considered are colitis (infectious/inflammatory or ischemic), colonic carcinoma, epiploic appendagitis, neutropenic colitis, functional colonic disorders, and extragastrointestinal disorders (pyelonephritis or gynecological diseases). Epiploic appendagitis is a clinical condition mimicking acute colonic diverticulitis, with focal

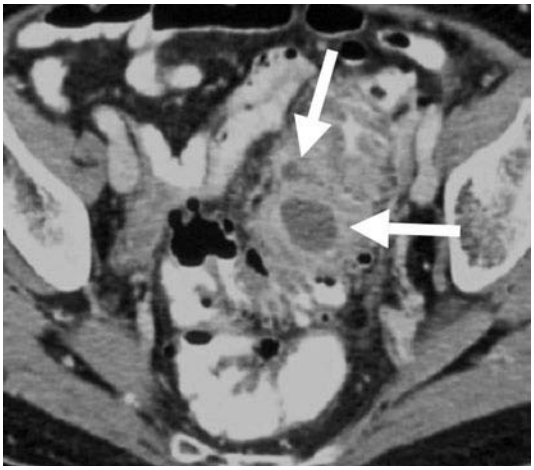

**Fig. 4.** Sigmoid diverticulitis with pericolic abscesses. CT shows fine linear strands within pericolic fat, diverticula filled with air, barium, or fecal material, circumferential bowel thickening, and frank abscesses (*arrows*)

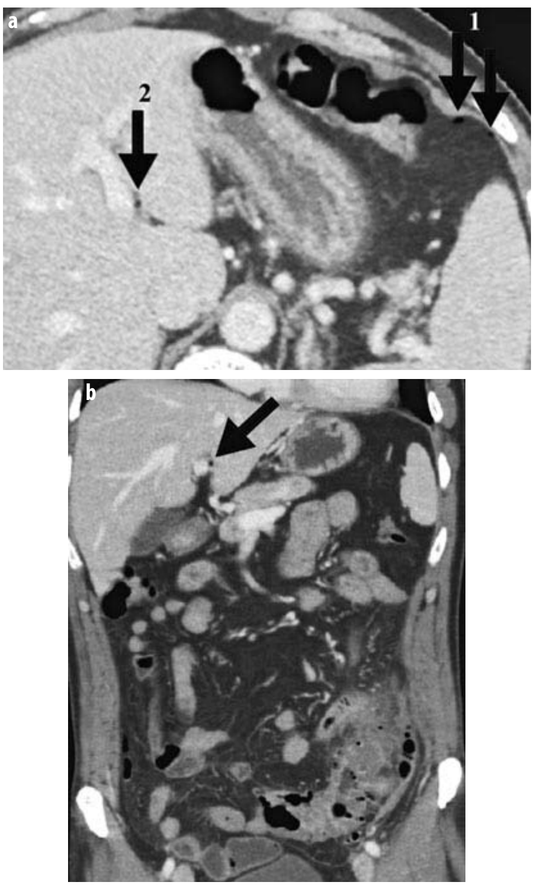


**Fig. 5 a, b.** Perforated sigmoid diverticulitis. **a** CT demonstrates tiny bubbles of extraluminal gas within the left subphrenic space (*arrows, 1*) and hepatic pedicle (*arrow, 2*). The determination of a pneumoperitoneum from the perforated sigmoid diverticulitis (**b**) requires dedicated window settings. **b** Coronal reformat shows the patterns indicating the severity of the local extent of this case of sigmoid diverticulitis: thickened bowel wall with diverticula associated with dramatic changes of the pericolic fat and thickened root of the sigmoid mesocolon. Note the tiny bubble of extraluminal gas (*arrow*) within the hepatic pedicle

exquisite lower abdominal pain. It is diagnosed with CT (or US) by the demonstration of an ovoid lesion within the pericolonic fat, surrounded by inflammatory changes and abutting the colonic wall. As this disease resolves spontaneously within a few days, its correct diagnosis on CT images is important to avoid unnecessary surgery.

Distinguishing sigmoid diverticulitis from carcinoma is a major differential diagnostic consideration but is often difficult on CT images despite CT findings suggestive of colon carcinoma, such as marked thickening of the colonic wall, focal thickening (length <5 cm), and the presence of pericolonic lymph nodes. The distinction between perforated colon carcinoma and diverticulitis may be especially difficult because many patients with colon carcinoma also have diverticulosis. Therefore, it is crucial to perform colonoscopy 3-4 weeks after the onset of acute diverticulitis to rule out a colonic carcinoma.

## Gynecological Disorders

These are important causes of acute lower abdominal pain (right lower quadrant, left lower quadrant, or central pelvic) in female patients, particularly young women. Acute uterine and ovarian disorders, pelvic inflammatory disease, endometriosis, and ectopic pregnancy are diagnostic considerations in women of child-bearing age who present with an acute abdomen.

Pelvic inflammatory disease (PID) is the most frequent gynecological cause of an acute abdomen. Its manifestations may include salpingitis, tubo-ovarian abscess, and peritonitis. The most common causative organisms are *Neisseria gonorrhoeae* and *Chlamydia trachomatis*. Since PID most commonly results from an ascending infection, it usually involves both adnexa. US is the imaging test of choice for patients with suspected PID; however, CT is helpful when the clinical diagnosis is equivocal. CT findings may include fluid within the cul-de-sac, endometrial thickening, fluid within the uterine cavity, and thickening and dilation of the fallopian tubes (pyosalpinx) (Fig. 6).

**Fig. 6.** Pelvic inflammatory disease. Transaxial CT image shows thickened, dilated fluid-filled fallopian tubes indicative of bilateral pyosalpinx

With progression to tubo-ovarian abscesses, unilateral or bilateral cystic adnexal masses may be seen, usually in association with pyosalpinx. In advanced cases of PID, the intrapelvic spread of purulent material may result in peritonitis. Patients with Fitz-Hugh-Curtis syndrome present with right upper quadrant pain due to perihepatic inflammation from intraperitoneal exudates stretching between the liver capsule and the peritoneum, which can mimic carcinomatosis on CT.

In adult patients, ovarian torsion (adnexal torsion) usually occurs in association with an ovarian mass, which acts as a fulcrum to potentiate torsion. Teratoma is the most common cause of ovarian torsion. The typical presentation is non-specific, consisting of acute lower abdominal pain associated with nausea, vomiting, and leukocytosis. If ovarian torsion is suspected, Doppler US is the initial imaging test of choice; however, because the clinical presentation usually is non-specific, CT is often the first imaging test requested. A CT finding helpful in making the diagnosis of ovarian torsion is an enlarged ovary that is displaced from its normal location. Secondary signs include a thickened fallopian tube, a twisted vascular pedicle, hemoperitoneum, and deviation of the uterus toward the affected side.

Complications of ovarian cysts such as hemorrhage and rupture also can cause acute lower abdominal pain. Hemorrhagic cysts contain fluid that is high in attenuation, sometimes with a fluid-fluid level. In a small percentage of patients, the cyst may rupture, resulting in hemoperitoneum. Correlation with β-human chorionic gonadotropin (hCG) levels is important as a ruptured ectopic pregnancy may present with similar clinical and imaging features.

Endometriosis is characterized by the presence of functioning endometrial tissue outside of its normal intrauterine location. It presents as acute abdominal pain in only a small percentage of women and is usually caused by rupture or hemorrhage of an endometrioma or by torsion of an ovary that contains endometrial implants. On CT, endometriomas have a variable appearance, ranging from cystic to solid adnexal masses.

Ectopic pregnancy remains the leading cause of death during the first trimester of pregnancy, with a mortality of 9-14%. The main risk factors for ectopic pregnancy include a history of ectopic pregnancy, tubal surgery, and PID. The initial evaluation of patients suspected of having an ectopic pregnancy requires quantitative measurement of serum β-hCG level and transvaginal US. The latter should be used to search for the presence of an adnexal mass (with or without highly specific signs such as adnexal gestational sac with a live embryo, suggested by the demonstration of cardiac activity and/or a "tubal ring sign"), hematosalpinx, pelvic free fluid (highly suggestive if heterogeneous), and hemoperitoneum, enlarged uterus (with a pseudo-gestational sac), and symmetrically enlarged ovaries. The diagnosis of ectopic pregnancy often is difficult, since transvaginal US may be normal in up to 25% of these patients and adnexal abnormalities may be found in numerous alternative diagnoses. The diagnosis of ectopic pregnancy is based on an association of the β-hCG level with the transvaginal US findings:

1. a normal β-hCG level rules out an ectopic pregnancy;
2. an intrauterine gestational sac with a live embryo (cardiac activity) rules out an ectopic pregnancy (but in patients with assisted reproduction by ovulation induction the rate of "heterotopic pregnancy", defined as the simultaneous occurrence of an intrauterine and an extrauterine pregnancy, has been reported to be 1–3%);
3. an elevated β-hCG level (>1000 IU/L) without an intrauterine gestational sac, associated with an abnormal adnexal pattern and/or heterogeneous pelvic fluid, indicates an ectopic pregnancy.

## Acute Abdomen with Diffuse Pain

Any disorder that irritates a large portion of the gastrointestinal (GI) tract and/or the peritoneum can cause diffuse abdominal pain. The most common disorder is gastroenterocolitis. Other important disorders are bowel obstruction, ischemic bowel disease, and GI tract perforation.

### Bowel Obstruction

Bowel obstruction is a frequent cause of abdominal pain and accounts for approximately 20% of surgical admissions for acute abdominal conditions. The small bowel is involved in 60-80% of cases. Frequent causes of SBO are postoperative adhesions, hernias, and neoplasms. Mechanical large bowel obstruction is most commonly due to colorectal carcinoma, but volvulus and diverticulitis are also important causes. Colonic volvulus most commonly involves the sigmoid region, followed by the cecum.

The diagnosis of bowel obstruction is established on clinical grounds and usually confirmed with plain abdominal radiographs. Due to the diagnostic limitations of plain radiography, CT is increasingly used to establish the diagnosis, identify the site, level, and cause of obstruction, and determine the presence or absence of associated bowel ischemia. CT can be useful for differentiating between simple and closed-loop obstruction. Closed-loop obstruction is a form of mechanical bowel obstruction in which two points along the course of the bowel are obstructed at a single site. It is usually secondary to an adhesive band or a hernia. Since a closed loop tends to involve the mesentery and is prone to produce a volvulus, it represents the most common cause of strangulation. However, only colonic volvulus is associated with classic features on plain abdominal radiography.

CT is particularly reliable in higher grades of bowel obstruction. It has proved useful in characterizing bowel obstruction from various causes, including adhesions, hernia, neoplasm, extrinsic compression, inflammatory bowel disease, radiation enteropathy, intussusception, gallstone ileus, or volvulus. The essential CT finding of bowel obstruction is the delineation of a transition zone between the dilated and decompressed bowel. Careful inspection of the transition zone and luminal contents usually reveals the underlying cause of obstruction. However, the presumed point of transition from dilated to non-dilated bowel can be difficult to determine in the transaxial plane. MDCT facilitates this task by providing the radiologist with a volumetric data set that can be viewed in the transaxial, sagittal, or coronal plane or any combination of the three. These MPR views centered on the anticipated transition point help to determine the site, level, and cause of obstruction.

Mechanical obstruction of the small bowel (SBO) has to be differentiated from paralytic ileus, large bowel obstruction (LBO), and non-obstructive massive distention of the colon.

Paralytic ileus is a common problem after abdominal surgery. It may be diffuse or localized and has numerous causes, e.g., secondary to ischemic conditions, inflammatory or infectious disease, abnormal electrolyte, metabolite, drug or hormonal levels, or innervation defects.

In LBO, CT demonstrates distension of the large bowel to the point of obstruction, with collapse of the distal large bowel. The distal small bowel loops may also be distended if the ileocecal valve is incompetent. Luminal obstruction by a colonic carcinoma and colonic volvulus (Fig. 7) are the main causes of LBO. Perforation of the cecum, due to gross distention resulting in ischemia of the cecal wall, is the main complication of severe LBO.

A massively dilated colon may be seen in toxic megacolon and Ogilvie's syndrome. In toxic megacolon secondary to severe colitis, CT demonstrates a thickened wall with "thumbprinting" caused by wall edema and inflammation. Ogilvie's syndrome is an acute pseudo-obstruction with dilation of the colon in the absence of a colonic transition zone. It may occur in severely ill patients after surgery and/or with neurological disorders, serious infections, cardiorespiratory insufficiency, and metabolic disturbances. Drugs that disturb colonic motility (e.g., anticholinergics or opioid analgesics) contribute to the development of this condition.

## Ischemic Bowel Disease

Predominant causes of bowel ischemia are arterial or venous occlusion and hypoperfusion. Occlusive disease involves the mesenteric arteries, most commonly the superior mesenteric artery, in the large majority of cases. Bowel ischemia secondary to venous thrombosis is much less common. The only direct sign of vascular impairment of the bowel is diminished bowel wall enhancement, which is due to inadequate arterial inflow to the bowel. Increased bowel wall enhancement may be seen in some cases secondary to reactive hyperemia or compromised venous outflow. Other CT findings are direct visualization of a thrombus in the superior mesenteric artery or vein. Bowel distention and bowel wall edema are non-specific findings and may accompany inflammatory or infectious causes. Bowel distention reflects the interruption of peristaltic activity in ischemic segments. Non-occlusive acute mesenteric ischemia usually is due to hypoperfusion secondary to severe cardiac disease, but also occurs in patients with end-stage renal or hepatic disease. An important radiographic manifestation of non-occlusive acute mesenteric ischemia due to low arterial flow is mesenteric arterial vasoconstriction. A less common form of non-occlusive acute mesenteric ischemia is severe vasculitis, which often affects younger individuals. Mesenteric vasculitis usually results in bowel edema and mucosal hyperenhancement. The small and the large bowel often are both involved. The duodenum is involved in approximately one-quarter of patients.

The most common mechanical cause of bowel ischemia is obstruction. A closed-loop SBO is more likely than other types of obstruction to result in vascular compromise (strangulation obstruction). Strangulation obstruction has a reported prevalence of 5-40% and is a predominantly venous disease. The most frequent abnormality seen on CT is bowel wall thickening. The thickened bowel wall sometimes is associated with a target sign, consisting of alternating layers of high and low attenuation within the thickened bowel wall, which results from submucosal edema and hemorrhage. The bowel segment proximal to an obstruction can become ischemic

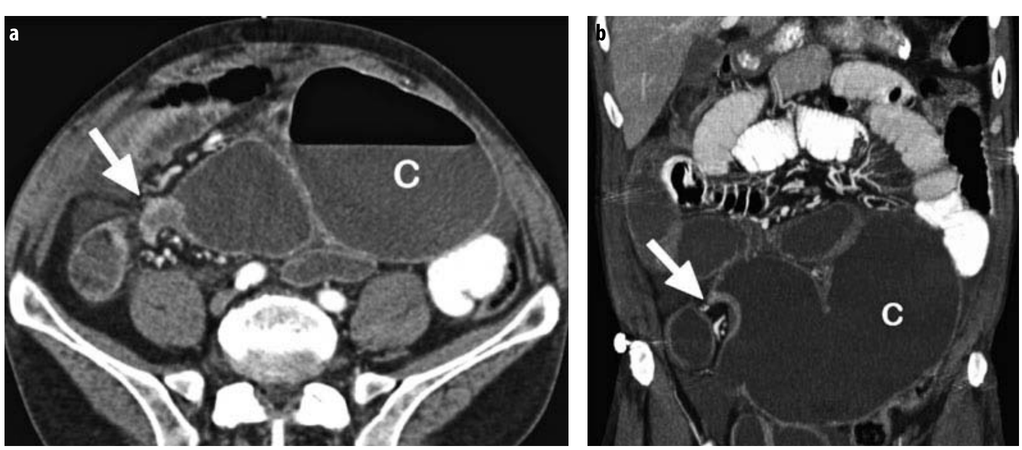


**Fig. 7 a, b.** Cecal volvulus. Transaxial CT (**a**) and coronal volume-rendered (**b**) CT demonstrate a markedly dilated cecum (*C*) in the left side of the pelvis. The *arrow* points to the area of twist of the ascending colon. Note the dilated small bowel loops due to the proximal colonic obstruction due to severe distention. CT findings that suggest subsequent infarction are non-enhancement of the bowel wall, gas in the bowel wall, mesenteric or portal veins, edema/hemorrhage in the mesentery adjacent to thickened and/or dilated bowel loops, and ascites (Fig. 8).

### Perforation of the Gastrointestinal Tract

Gastrointestinal perforation usually causes localized pain initially, and culminates in diffuse pain if peritonitis develops. Gastroduodenal perforation associated with peptic ulcer disease or a necrotic neoplasm has become less frequent in recent decades due to earlier diagnosis and improved therapy. At the same time, the incidence of gastroduodenal perforation resulting from endoscopic instrumentation has increased. Perforation of the small bowel is relatively uncommon but may be secondary to a foreign body, small bowel diverticulitis, or trauma. Spontaneous rupture of the colon is more frequent and can occur when the colon becomes markedly dilated proximal to an obstructing lesion (tumor, volvulus) or when the bowel wall is friable (ischemic or ulcerative colitis, necrotic neoplasm). Fiberoptic colonoscopy with or without biopsy is another cause of colonic perforation.

Pneumoperitoneum can be recognized by the presence of subdiaphragmatic gas on an upright chest radiograph or an upright or left lateral decubitus abdominal radiograph. A large pneumoperitoneum generally is indicative of colonic perforation, whereas moderate quantities of free gas are seen with gastric perforation. Small bowel perforation usually results in either a limited amount of peritoneal gas or none, because the small bowel usually does not contain gas. Detection of subtle pneumoperitoneum is often difficult. As CT is far more sensitive than conventional radiography in demonstrating a small pneumoperitoneum, it has become the imaging test of choice when the results of conventional radiography are equivocal. Viewing the CT images at "lung window" settings improves the demonstration of small amounts of extraluminal gas.

Retroperitoneal perforations (duodenal loop beyond the bulbar segment, or involving the appendix; posterior aspect of the ascending and descending colon, or the rectum below the peritoneal reflection) tend to be contained locally and remain clinically silent for several hours or days. Retroperitoneal gas has a mottled appearance and may extend along the psoas muscles. In contrast to intraperitoneal gas, retroperitoneal gas does not move freely when the patient's position is changed from supine to upright for plain abdominal radiographs.

## Acute Abdomen with Flank or Epigastric Pain

Acute flank or upper abdominal pain radiating to the back is commonly a manifestation of retroperitoneal pathology, especially urinary colic, acute pancreatitis, or leaking abdominal aortic aneurysm.

### Urinary Colic

For decades, intravenous urography was the primary imaging technique used to evaluate patients with suspected urinary colic. Plain abdominal radiography and US may be useful for patients with a contraindication to radiation or iodinated intravenous CM. However, because

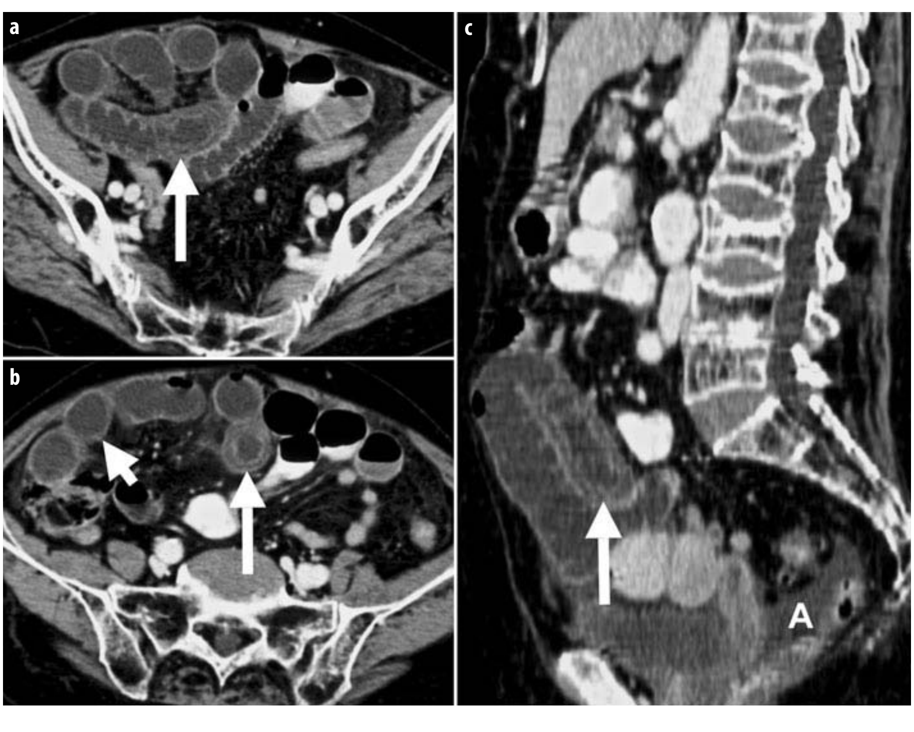


**Fig. 8 a-c.** Strangulating small bowel obstruction due to an adhesive band that developed after cholecystectomy and appendectomy. Axial (**a**, **b**) and sagittal (**c**) views of multidetector CT show bowel wall thickening, enhancing bowel wall with submucosal edema, and/or hemorrhage giving a target sign (*long arrows*), indicating ischemia. Non-enhancement of the bowel wall of the jejunum (*short arrow*) corresponds to segmental infarction. *A* Ascites of the low sensitivity of abdominal radiographs and US in the detection of urinary tract calculi, the role of unenhanced CT has become well established over the past 15 years. On CT, virtually all ureteral stones are radiopaque, regardless of their chemical composition. Uric acid stones have attenuation values of 300-500 Hounsfield units (HU), and calcium-based stones >1000 HU. In addition to the direct demonstration of a ureteral stone, secondary signs of ureterolithiasis, including hydroureter, hydronephrosis, perinephric stranding, and renal enlargement, may be visible (Fig. 9). Perinephric stranding and edema result from reabsorbed urine infiltrating the perinephric space along the bridging septa of Kunin. The more extensive the perinephric edema shown on unenhanced CT, the higher the degree of urinary tract obstruction. Focal periureteral stranding resulting from a local inflammatory reaction or irritation and induced by the passage of a stone helps to localize subtle calculi. Occasionally, a repeat CT examination using intravenous CM may be required, particularly if infectious complications are suspected. For the diagnosis of such complications (pyelonephritis), CT is helpful as it reveals a "striated nephrogram" after CM administration, as well as global enlargement of the kidney, renal and/or perirenal abscesses, or emphysematous pyelonephritis.

When no stone is detected, an alternative diagnosis must be established. Non-calculus urinary tract abnormalities causing symptoms of colic include acute pyelonephritis, renal cell carcinoma, acute renal vein thrombosis, spontaneous dissection of the renal artery, and renal infarction. Extraurinary diseases, such as retrocecal appendicitis, diverticulitis, SBO, pancreatitis, gynecological disorders, and retroperitoneal hemorrhage, may also simulate acute urinary colic.

### Acute Pancreatitis

An important disease causing upper abdominal pain is acute pancreatitis. US may be helpful for the demonstration of choledocolithiasis as a cause of acute pancreatitis and for the follow-up of known fluid collections.

Since the CT findings correlate well with the clinical severity of acute pancreatitis, CT has become the imaging test of choice to stage the extent of disease (CT severity index of Balthazar) and to detect complications. The initial CT should be performed 48-72 h after disease onset (a CT examination performed too early in the course of the disease may not demonstrate any abnormality). Pancreatic enlargement due to interstitial parenchymal edema may progress to pancreatic exudate collecting in

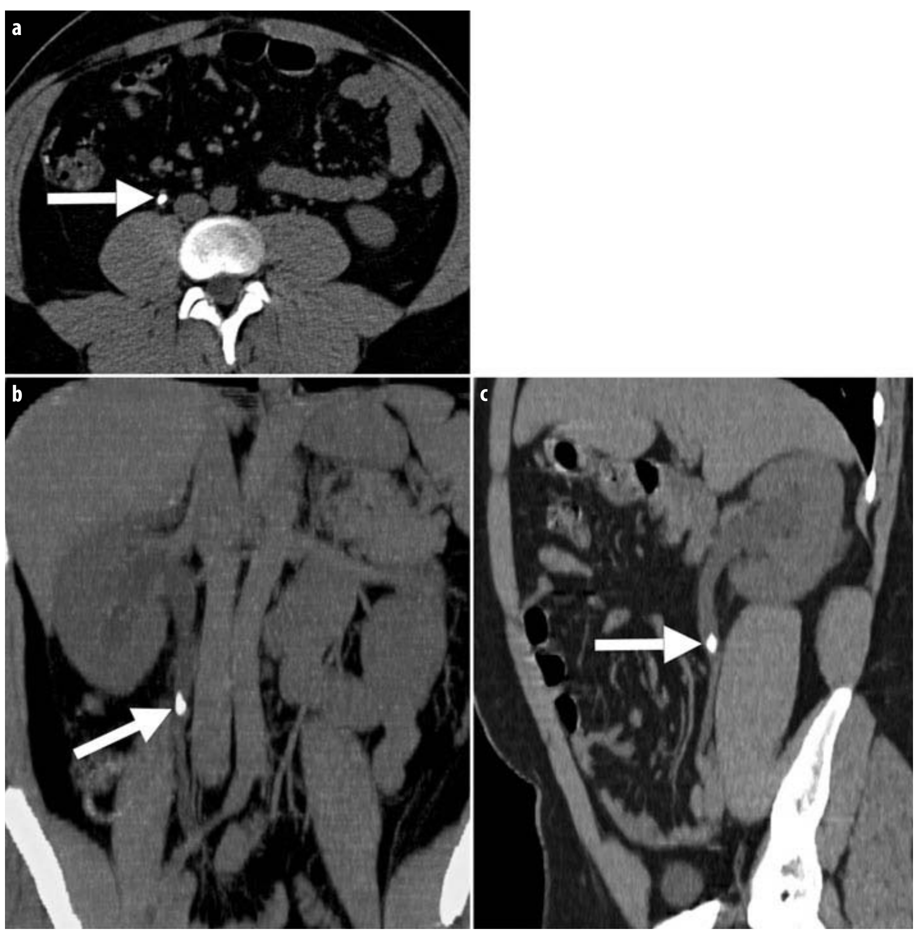


**Fig. 9 a-c.** Right-sided urinary colic. Axial (**a**), coronal (**b**), and oblique (**c**) views of multidetector CT show dilatation of the proximal urinary tract due to a ureteral stone (*arrow*). Note slight secondary periuretral and perinephric stranding

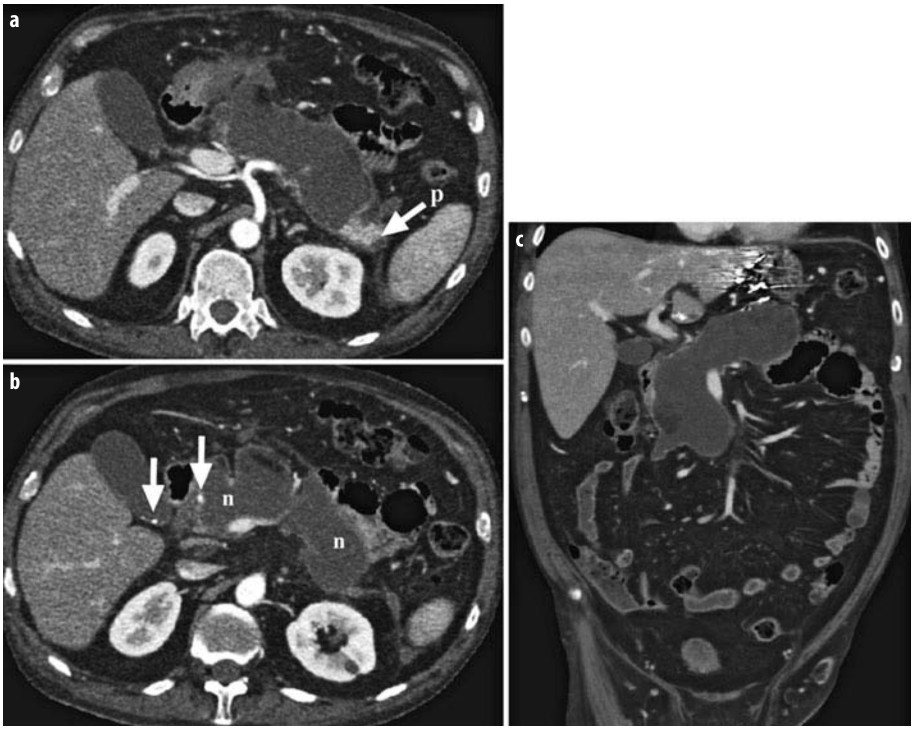


**Fig. 10 a-c.** Severe acute pancreatitis. Axial (**a**, **b**) and coronal (**c**) views of MDCT demonstrate an enlarged pancreatic area. **a** Only small areas of enhanced pancreatic parenchyma (*p*) remain within **b** extensive pancreatic necrosis (*n*). Note the tiny hyperattenuating calculi within the gallbladder and the lower bile duct (*arrows*). **c** The large amount of pancreatic necrosis contrasts sharply with the minimal extra-pancreatic changes at this phase

the abdominal ligaments and potential spaces surrounding the pancreas. The pancreatic parenchyma may undergo necrosis or hemorrhage (Fig. 10). Severe pancreatitis is often complicated by infection of the necrotic site and/or thrombosis of the splenic and portal vein. Identifying infectious complications in patients with pancreatitis may be difficult; the demonstration of gas bubbles within peripancreatic collections is neither sensitive nor specific. CT-guided fluid aspiration for bacteriological examination is often the best technique to establish the presence of infection.

Acute pancreatic and peripancreatic fluid collections may evolve into pseudocysts, which exhibit defined walls. A pseudocyst can erode peripancreatic vessels, thus causing bleeding or the formation of a pseudoaneurysm (Fig. 11).

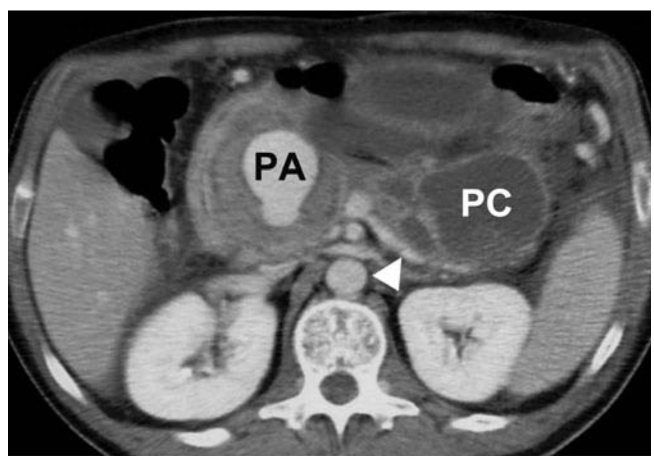


**Fig. 11.** Recurrent pancreatitis. CT shows a pseudocyst of the pancreatic tail (*PC*) and a pseudoaneurysm of the gastroduodenal artery (*PA*). The splenic vein is indicated by the *arrowhead*

### Leaking Abdominal Aortic Aneurysm

One of the most life-threatening diagnoses in patients with acute flank pain is a leaking abdominal aortic or iliac artery aneurysm. When a patient with suspected rupture of an abdominal aortic aneurysm is hemodynamically unstable, US is the initial imaging technique. The examination can be performed rapidly with portable equipment in the emergency room. However, para-aortic hemorrhage is poorly diagnosed by US. Instead, in hemodynamically stable patients, non-contrast-enhanced CT is the initial imaging test of choice as it is almost always able to demonstrate a para-aortic hematoma, if present, and may show additional findings helpful in establishing the diagnosis, such as a high-attenuating crescent sign. If endoluminal stent graft repair of the aorta is planned, contrast-enhanced CT should be performed.

## Conclusions

The imaging evaluation of patients with an acute abdomen has changed dramatically in the past decade. Plain abdominal radiographs largely have been replaced with US and CT. MDCT permits a rapid examination with high diagnostic accuracy. Close cooperation with the referring physician prior to imaging remains essential for rapid and accurate diagnosis, as the character and location of the patient's abdominal pain strongly influences the differential diagnosis and the choice of initial imaging test.

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# Trauma of the Abdomen and Pelvis

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## Introduction

Trauma is a major health problem in all age groups but it is especially true in the young, due to high-velocity transportation, altercations, including with weapons and resulting in penetrating injuries, as well as falls and sports-related injuries. In addition, both the elderly and pregnant women are vulnerable to trauma. Improvements in the management of trauma include more rapid rescue, better organization of trauma centers, and advances in treatment. Current trends include increased non-operative management of trauma-related injuries, accurate imaging-based diagnosis, and greater emphasis on the efficient but cost-effective use of imaging. One aspect of the trend to non-operative care is the desire to avoid non-therapeutic surgery; this is possible if imaging can identify those patients who require surgery. Another is the realization that non-operative care can result in better long-term outcome, such as splenic salvage.

## Computed Tomography vs. Ultrasound

Controversy exists about the appropriate use of computed tomography (CT) vs. ultrasound (US), although each modality has its advantages and disadvantages [1, 2]. In general, CT has the best statistical accuracy for detecting, characterizing, and excluding injuries. In modern high-volume trauma centers, the CT apparatus must be located in the trauma suite such that even unstable patients can be examined quickly without compromise. This allows for the efficient use of CT in rapid and accurate diagnostics and obviates the need for outmoded studies, such as diagnostic peritoneal lavage. CT is also more reliable at excluding injury, allowing the patient to be discharged home and avoiding the expense of observation in hospital.

However CT may be overused; indeed, in one study only three of 100 patients had alterations of clinical management due to follow-up CT [3]. US can detect significant injury which can then be appropriately treated; conversely, low-risk patients with normal sonograms may be observed and possibly avoid CT [2]. However, patients with abnormal US findings often require further evaluation with CT. In a large study, US had 86% sensitivity and 98% specificity but with 43 false-negative and 23 indeterminate studies, including six splenic, one liver, one renal, one pancreatic, and one bowel injury [2].

In traumatized pregnant women, US should be the first examination as it can evaluate the pregnancy, documenting fetal death or viability. US is nearly as accurate in detecting the abnormal presence of fluid in pregnant patient as in non-pregnant patients [4]. If US shows fluid or other injury, CT is justified for further evaluation (Fig. 1). The best outcome for the fetus is assured by best care of the mother. The radiation risk is reasonable if there is life-threatening injury, such that prompt diagnosis and treatment are paramount [5].

## Urinary Tract

The nearly universal use of CT has altered the assessment of urinary tract trauma. While significant hematuria has been shown to be the best indicator of urinary tract injury, presently the decision to perform CT has little to do with the presence or absence of hematuria. CT is a primary investigation, after standard radiographs, in those with significant mechanisms of injury or *any* signs or symptoms of significant injury. Intravenous urography has been replaced by CT (Fig. 2).

The ability of US to evaluate renal injury is limited [6] whereas CT has excellent negative predictive value for renal injury. CT also accurately indicates the presence and type of renal injury [7]. Renal contusion appears as an ill-defined region of diminished enhancement. Segmental renal infarction is identified as a wedge-shaped, well-defined area of non-enhancement. Renal artery occlusion can be accurately diagnosed by its complete lack of either contrast enhancement or excretion by the kidney, usually with little to no associated hematoma. Angiography is thus not needed, and conservative therapy is most often used today. Most renal injuries are lacerations, with simple lacerations limited to the cortex and deep lacerations extending into the collecting system, which may show extravasation. Delay scans of 2-10 min aid in demonstrating or excluding

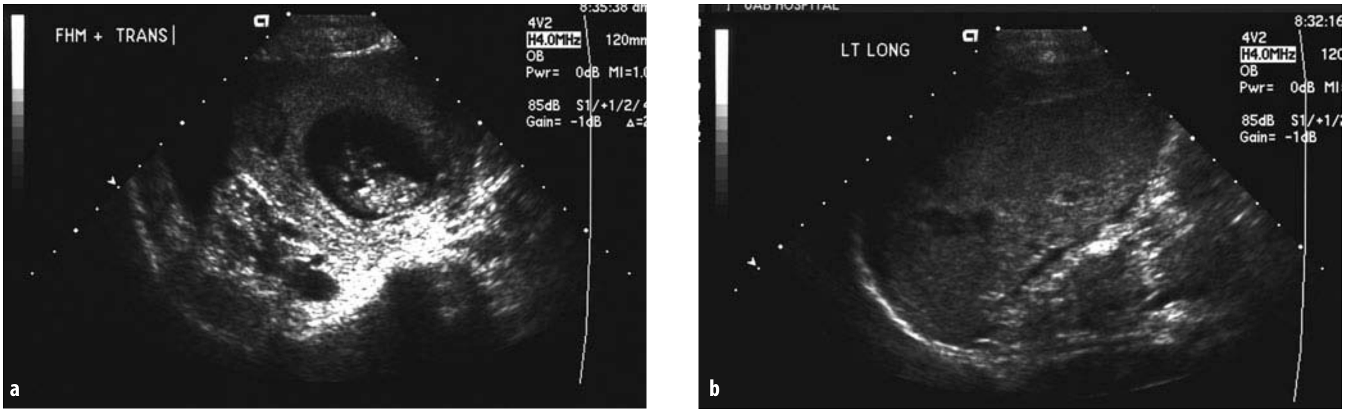



**Fig. 1 a-c.** A pregnant woman suffered a high-speed motor vehicle collision. **a** US demonstrates intrauterine fetus (heart motion documented) and free pelvic fluid. **b** US shows perisplenic fluid with hypoechoic defect. **c** CT confirms splenic laceration; note the higher density of the perisplenic hematoma compared to the rim of fluid about liver (sentinel clot sign)

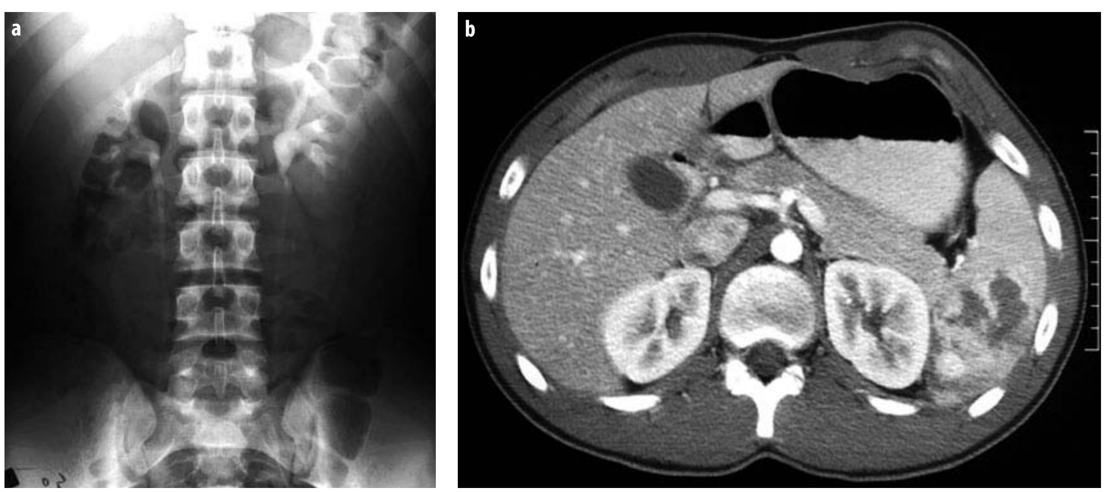


**Fig. 2 a, b.** Hematuria and left upper quadrant pain after a football-related injury. **a** Intravenous urogram shows no abnormality. **b** Subsequent CT for persistent pain showed free fluid in the pelvis and extensive splenic laceration with extensive "blush". Surgery confirmed a grade 4 splenic injury

extravasation (Fig. 3), although in most cases small amounts of extravasation will resolve with conservative therapy. Subcapsular hematoma is delimited by the renal cortex and may deform the renal surface; perinephric hematoma extends from the renal surface to fill Gerota's space but does not deform the renal contour, although it may displace the kidney. CT is excellent at demonstrating the extent of hematoma and in evaluating enlargement on follow-up scans [7]. Renal fracture indicates a single complete fracture plane, often extending through the collecting system; multiple planes of disruption are seen in a shattered kidney. CT can also diagnose avulsion of the ureteropelvic junction (UPJ) or ureteral injury, demonstrating lack of opacification of the ureter, retroperitoneal water attenuation collections adjacent to the pelvis or ureter, and possibly extravasation of contrast on delay scans (Fig. 4) [7].

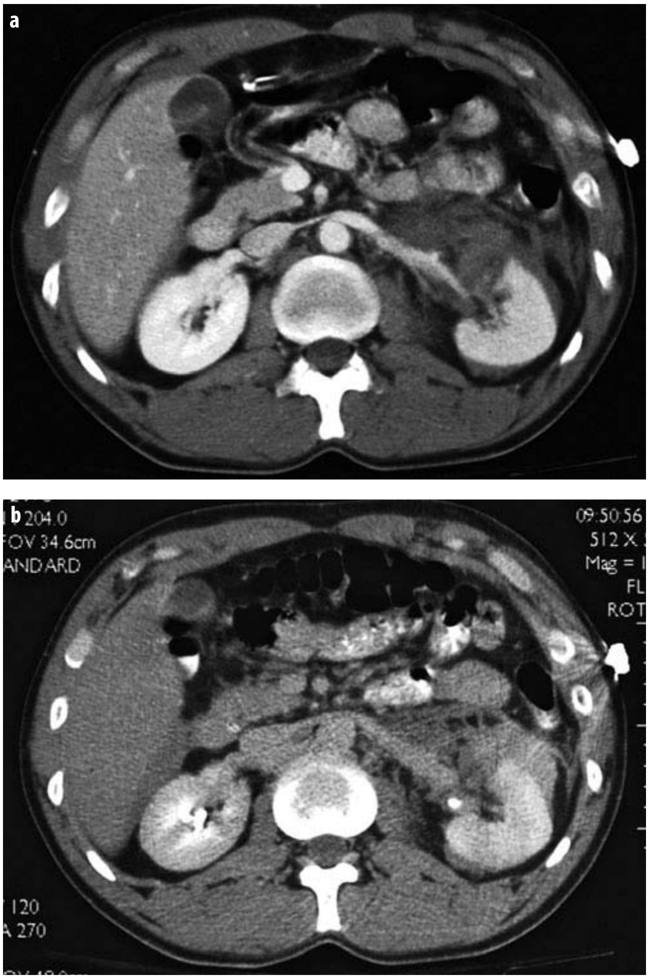


**Fig. 3 a, b.** Hematuria after fall from a power line. **a** Initial CT shows left renal laceration with perinephric hematoma. **b** Delay image shows no leak from the collecting system

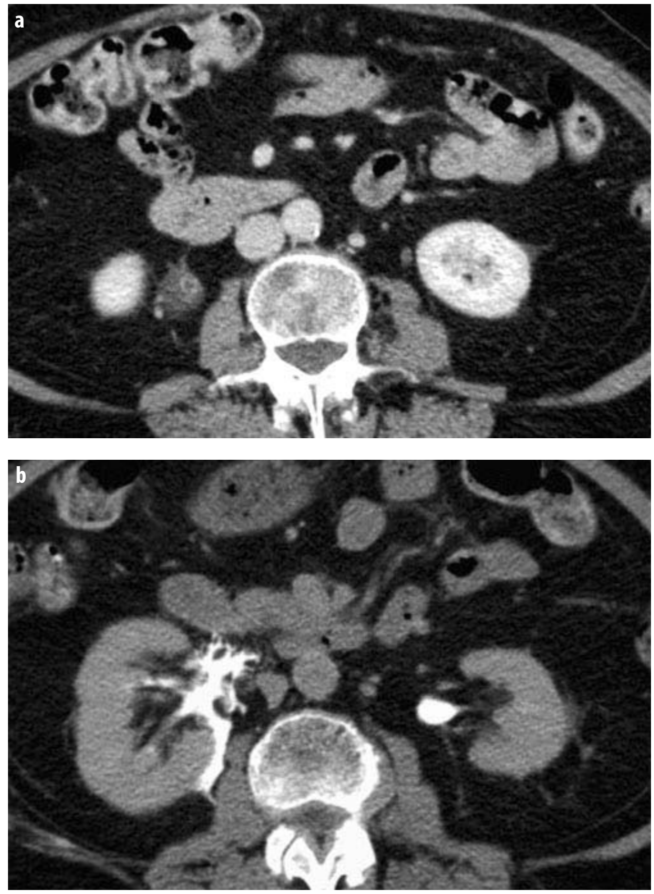


**Fig. 4 a, b.** Routine trauma CT image shows fluid and stranding about the right ureter. **a** Note that contrast filling of the ureter has not yet occurred. Delay image shows extravasation medial to the kidney typical, of UPJ avulsion. **b** Note the intact parenchyma

Ureteral injuries, including UPJ avulsion, are uncommon. They can occur either with penetrating trauma or high-velocity blunt trauma and have no specific signs or symptoms, but can be detected with CT. Routine CT scans show subtle suggestive signs, such as perinephric and peripelvic stranding or fluid, that indicate the need for delay scans, if not routinely done, to demonstrate extravasation. In a study based on over 4,000 trauma patients, CT enabled the correct identification of seven of eight UPJ avulsions [8].

The AAST Organ Injury severity scale for the kidney includes lesions with different appearances in each category (1: contusion, small subcapsular hematoma; 2: <1 cm laceration without extravasation; 3: >1 cm laceration without extravasation; 4: deep laceration with extravasation or main renal artery or vein injury; 5 shattered kidney or UPJ avulsion) and has been shown to correlate with need for surgery and outcome [9].

Urethral injuries are predominantly seen in males. Anterior urethral ruptures most commonly occur due to straddle injury. Posterior urethral ruptures most often are due to compressive force and resultant pubic bone fractures, although both anterior and posterior urethral injury can result from penetrating injury. Retrograde urethrography is the only accurate diagnostic imaging procedure. If a urethral injury is strongly suspected, a urethrogram should be performed before passage of a catheter (Fig. 5). However, in patients with moderate risk, a urethral catheter may be gently passed so that the patient may go on to CT. A pericatheter urethrogram may then be performed after any other injuries have been stabilized. Five types of urethral injuries are recognized. In type 1, the posterior urethra is stretched but intact; in type 2, there is a tear of the membranous urethra above the urogenital diaphragm; in type 3, the posterior urethral tear is above and below the urogenital diaphragm; type 4 is defined as a bladder-neck injury and type 5 as an anterior urethral injury [10].

Bladder injuries consist of contusions and ruptures; classically, they have been detected with standard radiographic cystography (Fig. 6). They may be extraperitoneal, most commonly, intraperitoneal, less commonly, or combined in about 5%. While CT with only intravenous contrast may fail to identify extravasation from

**Fig. 5.** Blunt trauma resulted in pubic rami fractures. Retrograde urethrogram reveals type 3 posterior urethral rupture

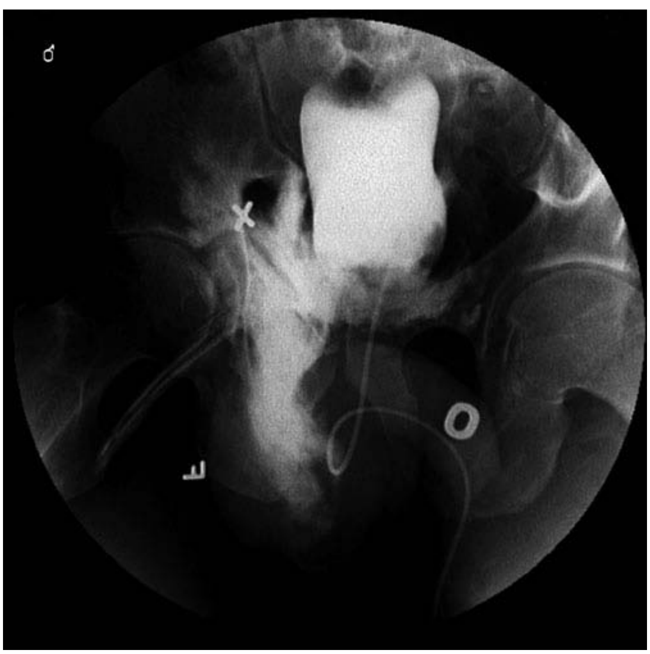


**Fig. 6.** Gross hematuria after gunshot wound to the pelvis. Standard cystogram shows extraperitoneal rupture (*X* marks entry site, *O* exit)

a ruptured bladder, several studies have shown very high accuracy for CT-cystography (Fig. 7), which is now the standard in our institutions. In patients with suspected bladder rupture (primarily those with gross hematuria, over 25 RBC/hpf, with pelvic fractures or unexplained pelvic fluid), a standard CT with the


**Fig. 7 a, b.** Gross hematuria following motor-vehicle collision resulting in extensive pelvic fractures. **a** Standard CT shows pelvic fluid but no extravasation. **b** CT cystogram documents extraperitoneal bladder rupture (note the clot in the bladder)

bladder catheter clamped is performed. If there is no extravasation, the bladder is drained and then re-filled with 300-500 mL of dilute contrast and the pelvis rescanned. Bladder ruptures are virtually always associated with fluid or hematoma in the pelvis, but such blood or fluid may be due to splenic or other injuries or to pelvic fracture. Extravasation confined to the lower pelvis and not outlining bowel loops (and which may extend up the retroperitoneum) indicates extraperitoneal rupture, which most often is managed conservatively. Extravasation high near the dome and outlining bowel loops or extending to the gutters or higher indicates intraperitoneal rupture, which is more often managed surgically [11]. In a study of 495 patients with potential pelvic injuries, CT-cystography detected 98% of the bladder injuries while standard cystography detected 95%. Of the patients with bladder injury (65% extraperitoneal, 35% intraperitoneal, 5 combined), 89% had gross hematuria and pelvic fracture, 9% had gross hematuria with no pelvic fracture, and one patient had microscopic hematuria and pelvic fracture [12]. CT-cystography carried out with multidetector CT allows for reformatting, which can more clearly demonstrate the point of leakage and allows more accurate characterization of the type of injury [13].

## Bowel and Mesenteric Injuries

Bowel and mesenteric injuries are found in about 5% of patients undergoing surgery for trauma and are seen in 0.7% of all traumatized patients [1, 14]. The mechanism of injury is direct compressive force, including from seatbelts, although deceleration may play a role. Morbidity and mortality can occur, with peritonitis and abscess resulting if the injury is missed. Clinical signs and symptoms are non-specific. Although diagnosis by CT is not as straightforward as is the case for other abdominal organ injuries, CT is the most accurate diagnostic modality, with >90% sensitivity and specificity reported [14, 15]. The use of orally administered contrast is now somewhat controversial; while extravasation of oral contrast can be a very specific sign of bowel injury, it is rarely seen. Contrast administration delays performance of the scan, and most bowel injuries will be evident based on other signs. There is no one CT sign that is both sensitive and specific for bowel or mesenteric injury. Focal bowel wall thickening, mesenteric stranding, interloop fluid, and hematoma are common but less specific, particularly for surgically important injuries (Fig. 8). Active bleeding, vessel beading, abrupt termination of mesenteric vessels, and bowel wall defect are more specific but less sensitive signs [16]. Active bleeding is seen as a focal extraluminal collection with attenuation similar to that of the aorta at the same level and different from the adjacent organs. Free air is considered a good sign of perforated bowel, but in fact it has limited value. It is infrequently seen in those with bowel injury and may represent air tracking into the peritoneum from thoracic injuries. In a study reported in 2008, free air had a sensitivity of 24% albeit a specificity of 95%. There were three false-positives with intraperitoneal air instead resulting from supradiaphragmatic or bladder injuries [16]. If a single finding is noted, the likelihood of injury is low; a combination of findings, particularly free fluid without obvious source in combination with focal bowel wall thickening and/or mesenteric stranding, is very suggestive of bowel injury and such patients should be explored or followed very carefully [14-16]. In our practice, we have found that performing a repeat abdominal-pelvic CT 4-6 h after the admission scan can be helpful in patients with suspicious but non-diagnostic findings for full-thickness bowel injury, by demonstrating injury progression such as the development of free air, increasing intraperitoneal fluid, or stability of findings. Of course, management decisions are made in conjunction with any evolution of the clinical findings.


**Fig. 8.** Motor-vehicle collision. Focal hematoma and thickening of cecum; at surgery, cecal laceration found

## Splenic Injuries

The spleen is the most frequently injured abdominal organ in blunt trauma. There may be signs of blood loss or left upper quadrant pain, but the diagnosis largely rests on imaging or surgical exploration. A trend to non-operative management is supported by evidence that long-term health is better in those who have had splenic function preserved. This necessitates accurate non-invasive diagnosis and is aided by signs predictive of the success or failure of conservative management.

Splenic injuries can cause free fluid, perisplenic or elsewhere, which can readily be detected by sonography. Splenic injury may alter echo-texture: lacerations may be anechoic if there is rapid bleeding, but more commonly are more echogenic than normal spleen [2]. With such findings on sonography, the decision whether to further evaluate with CT or to proceed to surgery can be made on clinical grounds. Splenic injuries may be missed by sonography, particularly if they are not associated with free fluid. In one large study, there were 43 false-negative sonograms, including six splenic ruptures that required surgery [2].

CT is quite sensitive in the detection of splenic injuries [17]. Subcapsular hematoma is seen as a crescentic, low-attenuation, peripheral rim; intraparenchymal hematoma as a rounded area within the spleen with low attenuation and no enhancement. Lacerations are common, appearing as linear or branching low-attenuation lesions that often extend to the surface; if so, they are often associated with perisplenic or free fluid. Hemoperitoneum tends to be of higher attenuation close to the source of bleeding; thus, when the spleen is the source, the collection adjacent to the spleen may be higher in attenuation than elsewhere, a finding referred to as the *sentinel clot sign*. Lacerations may involve the vasculature. There can be devascularization of the spleen by hilar injury, or active extravasation into the peritoneal cavity, or a confined area of extravasation (pseudoaneurysm) (Fig. 9). Both types of extravasation indicate that non-operative management may not succeed, although angiographic embolization may control the bleeding and allow splenic salvage [18].

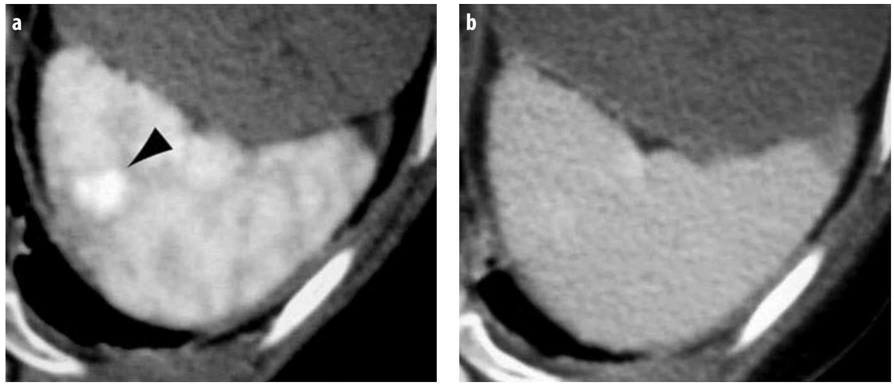


**Fig. 9 a, b.** Blunt trauma. **a** Routine trauma CT image shows area of hyperdensity (*arrowhead*). **b** Delay image shows that the hyperintensity is no longer visible; the lesion has become isodense with blood pooling, indicating confined pseudoaneurysm rather than free active bleeding

A number of schemes have been devised to grade splenic injury on CT in an attempt to predict outcome, with variable correlation with the need for surgery [1]. One of the commonest is the AAST scoring system. In a large study, failure of non-operative management correlated with splenic injury grade: the failure rate was <10% with grades 1 or 2, while one-third of the grade 4 injuries and three-fourths of the grade 5 injuries required surgery [19]. Nevertheless, in occasional cases of low-grade injury, the patient suffered delayed rupture, while some high-grade injuries have been successfully managed conservatively. Attempts have been made to develop CT-based criteria that may be more predictive: one referred to three key features: devascularization, laceration of >50% of the parenchyma; contrast blush >1 cm; or large hemoperitoneum; however, further study showed that this approach also had limited predictive value with poor sensitivity although fair specificity [20]. The additional finding of traumatic pseudoaneurysm or active extravasation (which does not confer a specific stage in the AAST scoring system) increased the likelihood of failure of non-operative management, regardless of grade [21]. Delayed images can help distinguish between active bleeding, which persists as a hyperdense area, and confined vascular injury (pseudoaneurysm), which washes out [22]. Patients with active bleeding are more likely to require surgery or other forms of intervention.

## Hepatic Injuries

The liver is the second most frequently injured abdominal organ, accounting for about 20% of abdominal injuries [1, 17]. The right lobe is more often affected than the left, with the posterior right lobe the most commonly injured segment. Hepatic injuries may be associated with intraperitoneal hemorrhage, but injury may be confined to the liver, or hemorrhage may be limited by an intact capsule. Lacerations involving the bare area may be associated with retroperitoneal hematoma. US may show liver lacerations, which appear similar to splenic injuries but this modality has limited sensitivity (67%, compared to 93% for CT) [23]. This is in part due to the large size of the liver and the difficulty in clearly imaging all portions of the organ ultrasonographically.

Injuries to the liver include contusion, seen on CT as an ill-defined area of low attenuation; subcapsular hematoma, a crescentic collection limited by the capsule; and intraparenchymal hematoma, a collection of blood within a liver laceration. Laceration is commonest, seen as linear or branching low-attenuation regions, sometimes with jagged margins, that can extend to the hepatic surface or to vessels. Superficial lacerations are <3 cm in size. Periportal low attenuation is usually edema, a distended inferior vena cava and renal veins, and subserosal edema of the gallbladder wall, but on occasion may represent blood tracking along the portal veins (Fig. 10). It is rare that periportal low attenuation is the only sign of liver injury, and patients with only this finding should be managed conservatively [24].

Liver injuries may require surgery but most can be managed non-operatively. The liver, with its dual blood supply, is relatively resistant to infarction and has considerable functional reserve. Grading systems

**Fig. 10.** Blunt trauma, shock, and aggressive resuscitation followed by trauma CT. Note the periportal low attenuation tracking throughout the liver with intact parenchyma and no perihepatic hematoma