The Role of Sonography in Abdominal Trauma: The European Experience

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Abdominal trauma may be a life-threatening entity. Whereas computed tomography (CT) seems to be the major noninvasive diagnostic tool for evaluation of abdominal trauma in the United States, sonography is the modality of first choice in the majority of European hospitals. Sonography has replaced diagnostic peritoneal lavage for detecting or excluding intraperitoneal free blood. We advocate sonography for any polytrauma patient in the trauma emergency room (TER), because it is a quickly performed, repeatable, and inexpensive imaging modality, serving as a decision-maker in the TER and enabling the avoidance of unnecessary CT. We strongly believe that radiologists should make full use of the potential of ultrasound in the TER. Radiologists should have access to, and experience with, CT as well as sonography, allowing an unbiased decision as to which modality is adequate to answer the specific questions raised by different trauma patients. This article defines the role of sonography in the TER and compares it with CT.

Key Words

Ultrasonography; Emergency service, hospital; Abdominal injuries

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Abdominal trauma may be a life-threatening entity that requires immediate action by all physicians involved. The initial survey of a patient who has sustained blunt thoracoabdominal or abdominal trauma requires quick and comprehensive evaluation of the patient's situation; however, the clinical examination, in most cases, does not provide enough information regarding the extent of abdominal injury. The mortality of patients with blunt abdominal trauma was significantly reduced by the introduction of diagnostic peritoneal lavage (DPL) in 1965 by Root et al. (1). This invasive procedure has a false-positive rate between 5% and 10% and may be associated with complications. It also is contraindicated in patients with previous laparotomy.

In the United States, the diagnostic imaging modality of choice for the abdominal cavity and the retroperitoneum is computed tomography (CT). CT provides global evaluation of the abdomen; however, its availability in the trauma emergency room (TER) is limited. In most circumstances, the patient must be transported to a CT scanner, which often is not located close to the TER. The patient also has to be moved from the trauma stretcher onto the CT table. As transportation, repositioning, and examination may take approximately 25-55 minutes, the patient has to be hemodynamically stable (2, 3; Häuser H, unpublished data). With spiral CT scanning, the actual scan time may be reduced to less than 5 minutes.

Whereas CT seems to be the major noninvasive diagnostic imaging tool in the United States, ultrasonography (US) is undisputedly the modality of first choice to evaluate patients with blunt abdominal trauma in most European hospitals. US has even replaced DPL for detecting or excluding intraperitoneal free blood (4, 5). US is a quick and repeatable diagnostic modality allowing the examination of pleural spaces, the abdominal cavity, and the retroperitoneum at the same time. This article defines the role of sonography in the emergency room, compares sonographic and CT findings, and attempts to compare the role of these two imaging procedures in blunt abdominal trauma.

SONOGRAPHY IN THE EMERGENCY ROOM

Under optimal circumstances, a polytraumatized patient should be simultaneously evaluated and treated by three groups of medical staff: trauma surgeons, intensive care specialists, and radiologists. While hemodynamic stabilization is being carried out, diagnostic imaging must be initiated as well.

Plain film radiographs of the spine, chest, pelvis, and extremities are taken, and US is applied simultaneously or directly afterward. A small, mobile US unit with a 3.5-MHz scanner allows US examination without interfering with resuscitation and hemostabilization. In general, US should be applied to visualize or exclude free fluid collections, detect and evaluate parenchymal lesions, and exclude or detect retroperitoneal and soft tissue hematomas. If a small amount of free fluid is detected and the patient is kept in the TER for other reasons, a second US is carried out after a delay of approximately 15-30 minutes. An increase of detectable fluid should lead to immediate laparotomy. In our opinion, US should serve as the decision-maker for further action, which may include immediate laparotomy, CT, angiography, or a repeat US. In the case of negative US findings in the abdomen and retroperitoneum, the patient is transported to the intensive care unit if trauma to other organ systems does not force surgical intervention.

The questions to be answered during the initial evaluation include: Are there direct or indirect signs of abdominal injury? If so, what is the extent of the injury? With a standardized sonographic protocol, all abdominal organs, the pleural, pericardial, and peritoneal spaces, and the retroperitoneum can be observed (Fig. 1). Transverse and longitudinal scans of the bladder should be obtained before catheterization of the bladder is carried out, because the filled bladder serves as a sonographic window to examine the pouch of Douglas. During the entire examination, documentation (video printer, film) is mandatory to enable comparison of follow-up studies.

INDIRECT SIGNS OF ABDOMINAL INJURY

Free fluid collections are indirect signs of abdominal injury. Free fluid is typically found in certain peritoneal recesses such as the Morison pouch (Fig. 2, left), Koller pouch, and Douglas pouch (Fig. 2, right). The sensitivity of US in detecting free abdominal fluid is nearly 100%. Under optimal circumstances, such as in thin patients and children, the minimal amount of free fluid that can be detected in the Douglas pouch is around 50 ml. An accurate quantification of fluid is hardly possible. A prospective, blinded study by Branney et al. (6), using DPL for quantification of fluid, revealed that 619 ml was the mean volume of free fluid necessary for enabling its detection in the Morrison pouch. Klotter et al. (2) estimate that a 5-mm layer of fluid corresponds to approximately 500 ml free fluid. In comparison, CT requires at least 500 ml of free fluid for

Figure 1

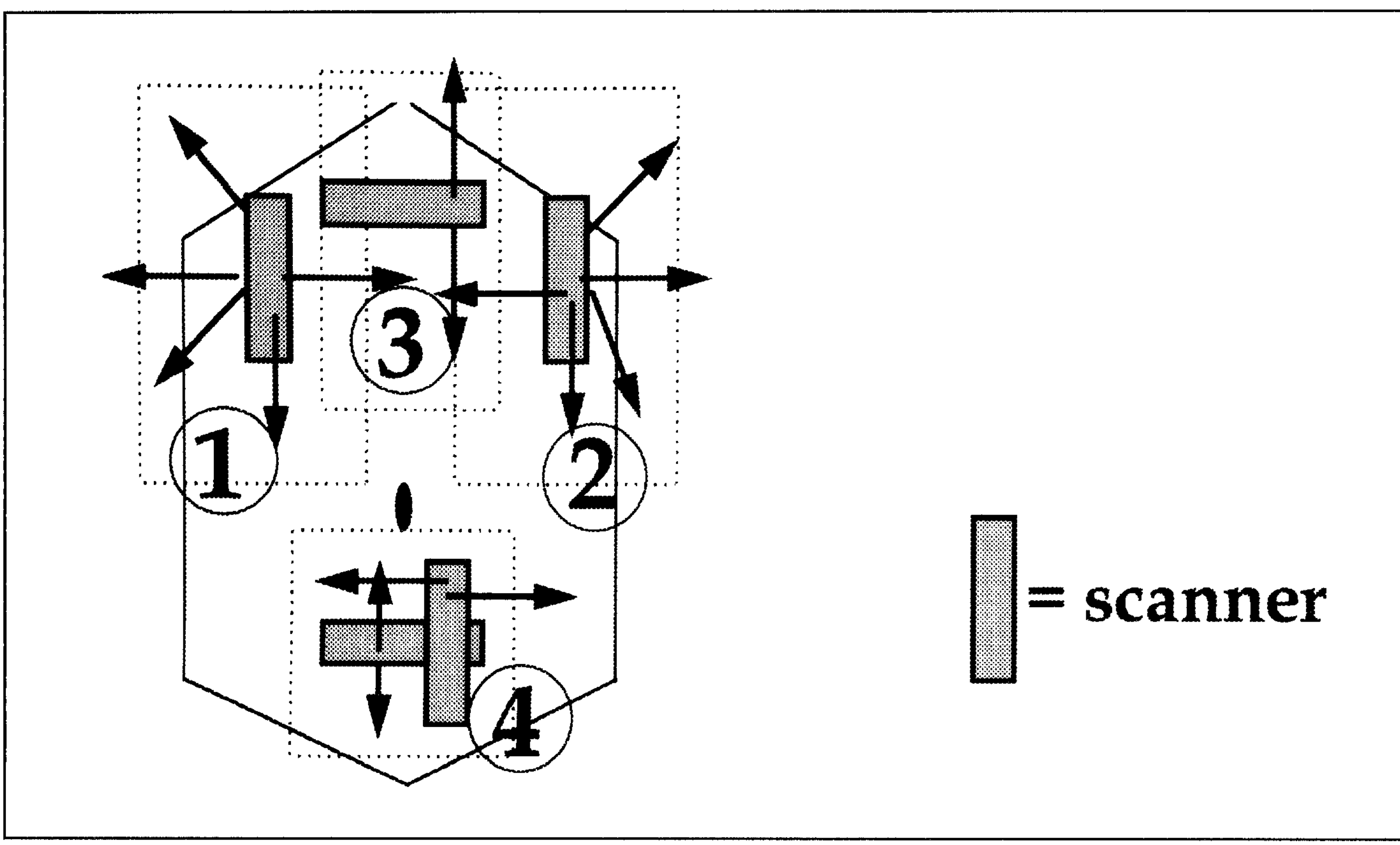

Figure 1. Minimal sonographic program in the TER. Numbers 1–4 indicate scanner positions during the US examination, with the performance of transverse and longitudinal scans while moving the scanner as shown by the arrows. 1 = pleural space, liver, Morison pouch, kidney; 2 = pleural space, spleen, Koller pouch, kidney; 3 = pericardial space, liver, pancreas, great vessels; 4 = bladder, Douglas pouch.

Figure 2

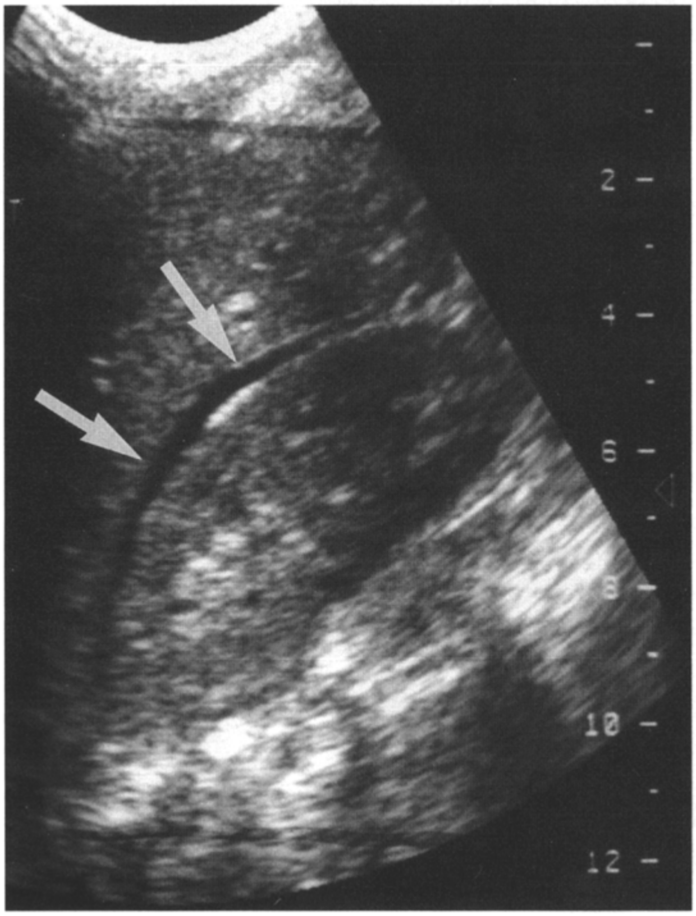
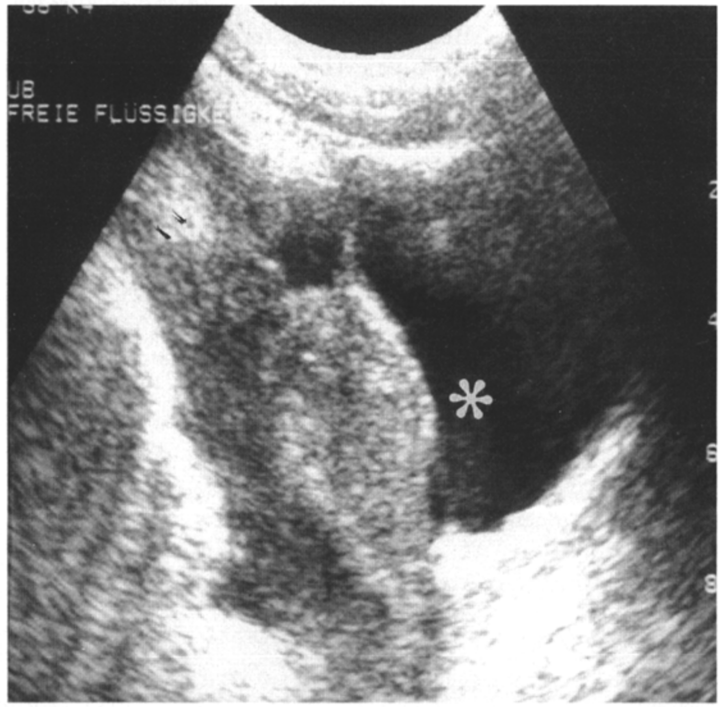

Figure 2. 21-year-old woman with splenic rupture resulting from a traffic accident. Left, longitudinal scan shows small anechoic fluid collection in Morison pouch (arrows). **Right,** longitudinal scan in the same patient showing hypoechoic blood within Douglas pouch behind the uterus. Asterisk indicates the bladder.

hemoperitoneum to be detected (7). An advantage of CT over US is the ability of CT to differentiate between blood and water (e.g., urine and bile).

DIRECT EVIDENCE OF ABDOMINAL TRAUMA

Sonography of the injured spleen

The spleen is the organ most commonly injured in abdominal trauma (7). The current trend in therapy is a nonoperative or at least spleen-saving surgical approach whenever possible (8). Different types of splenic injury to be distinguished include: (a) intrasplenic hematoma, (b) subcapsular hematoma, (c) small laceration with capsular involvement, (d) splenic fracture, and (e) injury of the splenic artery and/or vein.

Rupture of the spleen after an asymptomatic period has been defined as "delayed rupture." The true incidence and validity of delayed rupture have been questioned. Taking into account that hemodynamic stabilization after treatment of shock may provoke increased bleeding, delayed rupture may represent the failed diagnosis of a splenic capsular disruption at the primary investigation owing to a small amount of blood loss (9). This fact emphasizes the need for an easily repeatable examination tool, such as US. Sonographic features of the injured spleen include: change of the normal intrasplenic homogeneous echo pattern, including hyperechoic areas (Fig. 3); perisplenic anechoic or hypoechoic unclotted blood; and intraperitoneal blood appearing as anechoic or hypoechoic fluid.

The role of sonography is to define the existence of intra- or perisplenic change of normal echo pattern; provide direct visualization of the subcategories of splenic injury; monitor patients with splenic injury treated conservatively; and monitor patients with suspected splenic injury and initially negative US findings.

CT versus US

CT grading of splenic injury based on morphologic signs was proposed in the 1980s to decide which patients required emergency surgery. The clinical value of those scoring systems, however, remains controversial (7). Becker et al. (10) emphasize that the decision for laparotomy in cases of splenic injury should be based on clinical, not CT, findings, because the latter do not determine the need for surgery. It has to be stressed that CT has pitfalls due to motion artifacts and inhomogeneous enhancement in fast dynamic or spiral scanning. Sonography has its pitfalls as well (e.g., a lobulated spleen may be confused with a capsular rupture).

Figure 3

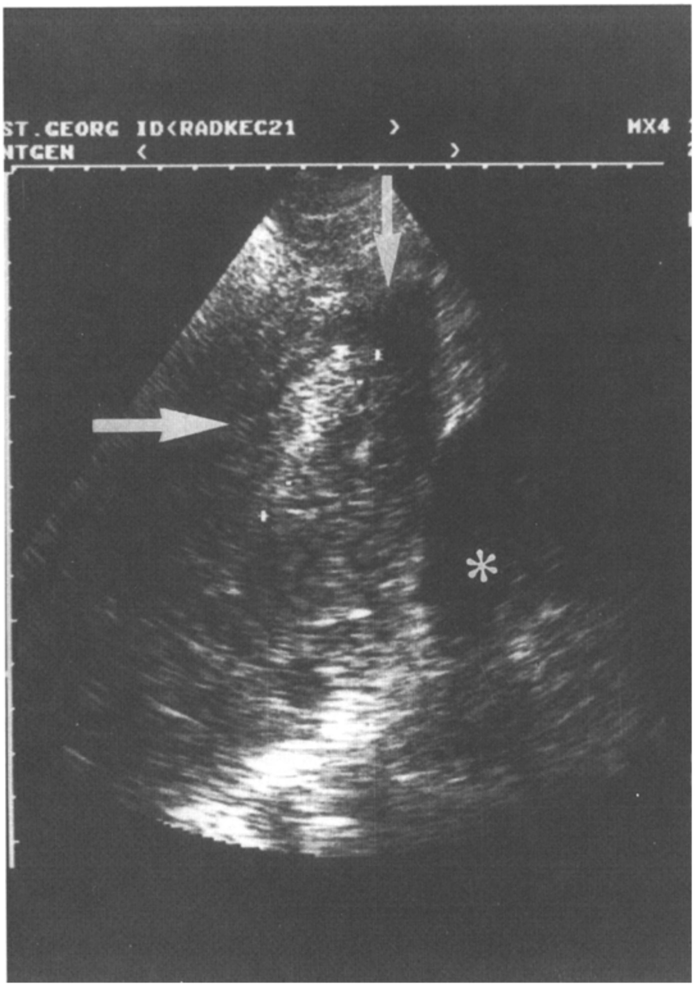

Figure 3. Abdominal trauma with consequent splenic injury. The intrasplenic hematoma (arrows) shows a mixed pattern, with hypo-, iso-, and hyperechoic areas. The upper part of the left kidney (asterisk) is also documented on longitudinal scan.

Sonography of the injured liver, gallbladder, and biliary tree

The liver is involved in 13-20% of polytraumatized patients with blunt abdominal trauma (5). Isolated periportal bleeding, hematoma (intraparenchymal or subcapsular), laceration, and lobar fractures can be differentiated by US. Injuries to the intrahepatic biliary tree are secondary to hepatic parenchymal lacerations. Clinically, in many cases, the findings are insignificant. Bile leakage and biloma formation may be the sequelae. Isolated trauma to the gallbladder is rare. Complete avulsion, perforation of the wall, or intramural hematoma of the gallbladder may occur.

Sonographic features of liver injuries may include: subcapsular hematoma appearing as a sharply marginated mass of low echogenicity; intraparenchymal hematoma, which may be either hypoechoic and/or hyperechoic with irregular borders (Fig. 4, left); capsular disruption; hematoperitoneum; and widening of the distance between the liver and the abdominal wall.

Sonographic features of injuries to the gallbladder and bile ducts include: biloma appearing as an anechoic, sharply marginated structure with distal acoustic enhancement and pericholecystic fluid collection and layering of the gallbladder wall in cases of perforation. A wall defect can be detected only in rare cases (11).

The role of sonography is to define the existence of any hepatic parenchymal and/or capsular injury and assess the presence and amount of associated hemoperitoneum. Sonography should not be used to classify various subcategories of liver injury. Small subcapsular or intraparenchymal injuries may be missed by sonography. Liberal use of sonographic follow-up is mandatory in instances of conservative management. The detection of fluid-filled spaces in or around the liver that may be due to bilomas cannot be reliably differentiated from abscesses, hematomas, or hepatic cysts. US-guided needle aspiration with laboratory assessment of the aspirate is the definitive way to differentiate among these fluid collections.

CT versus US

Patient selection for further imaging studies or immediate surgery is based on hemodynamic stability. Lobar fractures or large lacerations of the liver can only rarely undergo further imaging, because the clinical condition of the patient requires immediate surgical intervention in most cases. There is evidence, however, that patients with even large amounts of hemoperitoneum (>500 ml) can be successfully managed conservatively (12). This ability gives sonography an additional role as a quick and effective tool for follow-up examinations when conservative management is elected. There is no doubt that CT scans produce more information about the extent of liver injury when compared with US. But, as with the spleen, the CT classification of hepatic trauma based on the morphologic extent of the injury is not an accurate indicator of patient outcome (7). In addition, US is the primary modality to evaluate important complications of hepatic trauma, such as abscesses and bilomas.

Sonography of the retroperitoneum

Evaluation of the retroperitoneum is seriously impaired in the presence of large amounts of intestinal gas. An empty urinary bladder further diminishes US visualization of the retroperitoneum. Even large hematomas may be missed if the bladder is not filled and in the presence of intestinal gas (13).

Sonography of the pancreas

Pancreatic injuries are rare, occurring in approximately 1% of patients with blunt abdominal trauma. In most instances, pancreatic injury is associated with other abdominal or spine injuries (7). Sonographic features of pancreatic trauma include enlargement of the pancreas with a variable echo pattern dependent upon the degree of intrapancreatic hemorrhage. Pancreatic injury may lead to pseudocysts, which are usually anechoic. The role of

Figure 4

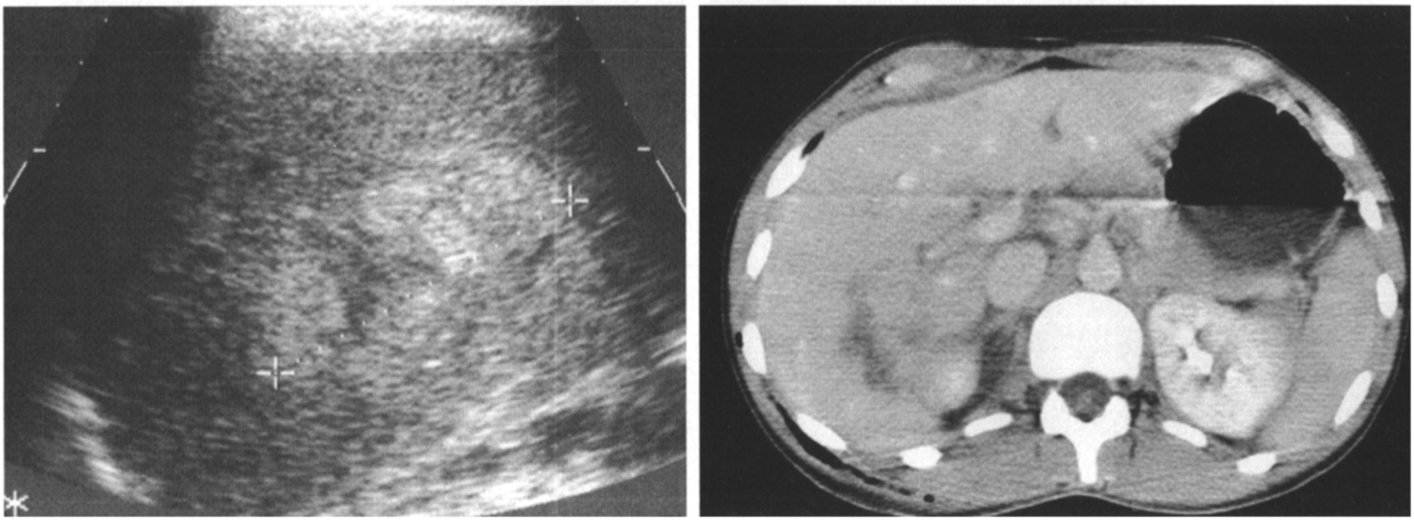

Figure 4. 24-year-old woman injured in a motor vehicle accident. Left, transverse US scan of the right lobe of the liver shows an ill-defined intraparenchymal lesion with hyper- and hypoechoic parts, characteristic of a hematoma of the right lobe of the liver. **Right,** enhanced abdominal CT, performed approximately 30 minutes later, confirms this hematoma as a hypodense lesion of the right lobe of the liver.

Figure 5

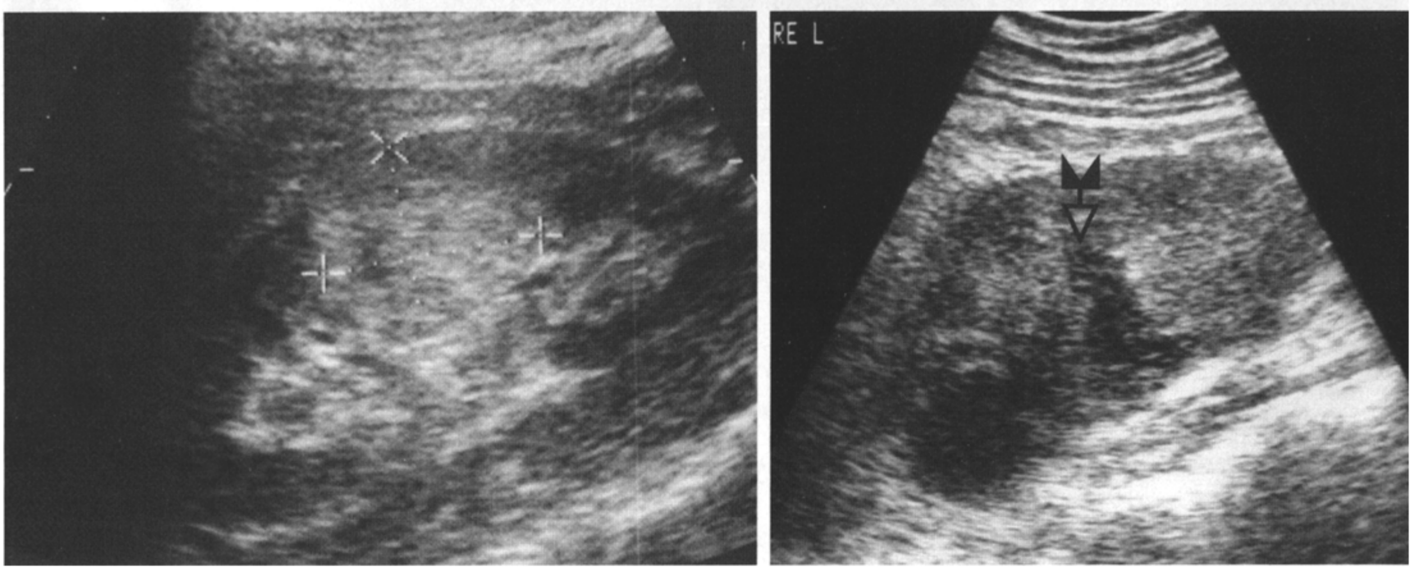

Figure 5. Left, longitudinal scan showing renal injury with change of intraparenchymal echo pattern. Hyperechoic lesion of the right kidney represents a parenchymal hematoma. The renal contour is well defined. **Right,** longitudinal scan showing laceration of the left kidney, indicated by a hypoechoic tear through the parenchyma (arrow). A pararenal hematoma is seen in the upper part of the left kidney.

sonography in blunt pancreatic trauma is extremely limited in the emergency setting.

Sonography of the injured kidney

Hematuria and spinal trauma always draw attention to the kidneys. As with all other parenchymal organs, the change in echogenicity will lead to the diagnosis of renal trauma. Morphologically, US can differentiate between a subcapsular hematoma, intraparenchymal hematoma, and laceration. Sonographic features of renal trauma include: perirenal anechoic or hypoechoic blood, change of intrarenal echo pattern (Fig. 5, left), and laceration with a hypoechoic tear through the parenchyma (Fig. 5, right).

CT versus US

Although sonography of the kidneys may not reveal renal injury, clinical and laboratory findings may make the diagnosis of renal trauma likely; contrast studies must then be performed, provided that the clinical condition of the patient permits them. There is no doubt that CT shows much more detail regarding retroperitoneal structures than US (14).

CONCLUSIONS

In many institutions in Europe, diagnostic peritoneal lavage has long been abandoned, in favor of US. In our institutions, US in the TER is performed by radiologists who have at least 6 months of sonographic experience and who have performed more than 3000 US examinations of the body. Sonography is the diagnostic modality of choice to exclude free intraperitoneal fluid. This is emphasized by an increasing number of reports, even in the American literature (15-19). US shows a sensitivity of 81-89%, a specificity of 93-100%, and an accuracy of 90-97% in these studies. These figures reflect our own clinical experience.

The direct visualization of organ injuries is less valid, however. Rothlin et al. (20) report a sensitivity of 41%. The liver and spleen are better evaluated with US than the pancreas, the bile ducts, or the gallbladder. US is not reliable in patients with intestinal perforation, in whom the amount of detectable fluid may be small. Nevertheless, in cases of polytrauma with or without obvious abdominal injury, US is an integral part of the primary survey. The importance of the concurrent examination of the pleural spaces must be stressed. In a prospective study of 120 consecutive polytrauma patients in our department, a mean time of 6 min was necessary for the US examination (Häuser H, unpublished data). We agree with Bode et al. (21) and Glaser et al. (13) that, in hemodynamically unstable patients, sonographic evidence of free fluid in the abdominal cavity requires immediate laparotomy. There is no time, no indication, and no need for further imaging in nearly all of these cases. Many unnecessary CT examinations of the abdomen can be avoided by appropriate application of US. Nevertheless, we advocate further imaging in hemodynamically stable patients with inconclusive US findings or detectable organ injury. CT and, in rare cases, angiography will further define the existence, the nature, and the extent of intraperitoneal and/or retroperitoneal organ injuries. In addition, other structures, such as the pelvis, can be evaluated easily with CT at the same time. In clinically stable patients with negative US findings, sonographic follow-up should be conducted, even when the patient's clinical condition shows improvement.

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