ULTRASONOGRAPHY IN THE DIAGNOSIS OF ACUTE ABDOMINAL DISORDERS*

RADOŚLAWSZ PACH, PIOTR KULIG, PIOTR KOŁODZIEJCZYK, ANTONI SZCZEPANIK, MAREK SIERŻĘGA

1st Department of General Surgery, Jagiellonian University Collegium Medicum in Cracow
Kierownik: prof. dr hab. J. Kulig

The possibility of the rapid implementation of real-time imaging and small requirements concerning the positioning and preparation of the patient render the ultrasound examination an increasingly performed method in case of patients diagnosed during emergency service. The surgeon performing the examination obtains immediate information supplementing the physical examination and medical history, enabling differential diagnosis and the implementation of proper treatment. It has been shown that an ultrasound examination performed during emergency service in case of a patient with abdominal pain of unknown cause increases the diagnostic accuracy and reliability of the diagnosis (1, 2). The ultrasound examination increases the diagnostic accuracy in case of patients with acute abdominal right upper quadrant pain (3). Still no significance was established concerning the ultrasound diagnosis of appendicitis—the value of the ultrasound examination depends on the experience of the examining physician (4), although several publications reported the efficiency of the method (5, 6). The authors demonstrated that FAST (focused assessment with sonography in trauma) was most often performed (93% of departments), followed by ultrasound when accessing the central or peripheral vein (90% of centers), and abdominal aortic aneurysm ultrasonography (88% of centers). Less frequent indications were as follows: exclusion of pericardial tamponade, evaluation of pleural fluid presence, abscess drainage, assessment of the urinary bladder, and evaluation of the gallbladder and biliary ducts (9).

The abdominal ultrasound examination should be performed using 3.5 MHz convex probes, which adhere to the convex or concave surfaces of the body. The examination often requires a change in the positioning of the patient and imaging of the abdominal structures in many sections. The examination may be hindered by the lack of patient cooperation, pain, and intestinal bloating. The physician performing the examination should evaluate the intraabdominal organs, and peritoneal and

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pleural recesses. The most frequently observed symptom in patients diagnosed during emergency service is the presence of fluid in the peritoneal cavity. The ultrasound examination can detect approximately 200 ml of fluid, however, its differentiation only on the basis of ultrasonography is unreliable. Free fluid in the peritoneal cavity may be visualized in the following locations:
- Morrison’s hepatorenal recess,
- rectovesical pouch or rectouterine pouch (Douglas’ pouch),
- subhepatic space,
- perisplenic recesses,
- omental sac,
- perihepatic recesses,
- intra-mesenteric recesses.

The limited fluid cistern observed in the ultrasound examination might correspond to an abscess or cyst. Abdominal cavity symptoms occur in case of cystic rupture or hemorrhage. Considering patients after trauma it is necessary to assess the continuity of parenchymal organ contours. The presence of fluid in the vicinity of the damaged organ is evidence of peritoneal cavity bleeding and requires surgical treatment. In a randomized study published in 2009, the authors from the Karolinska Institute in Sweden demonstrated that the ultrasound examination performed by a surgeon in case of patients with acute abdominal disorders enables to limit the number of additional examinations, reduce the frequency of hospitalizations, and allows faster qualification for surgical intervention (7). In 2010, a total of 4800 ultrasound examinations were performed at the 1st Department of Surgery, Jagiellonian University, Collegium Medicum, including 572 examinations (12%) during emergency service. Table 1 presented the number of ultrasound examinations performed during each month of the year 2010.

### Acute pancreatitis

The examination of the pancreas is performed with the patient lying on his back, beginning with the visualization of the cross-section and sagittal cross-sections. The presence of gas in the stomach, duodenum or transverse colon significantly hinders the assessment of the entire organ. In such situations the visualization of the pancreas is possible during inspiration through the left hepatic lobe or in the sitting position. In order to assess the size of the pancreas the antero-posterior (AP) dimension is usually presented. The proper AP dimension of the head of the pancreas should not exceed 30 mm, that of the body 25 mm and tail 30 mm. It is sometimes possible to visualize Wirsung’s duct in the pancreatic parenchyma—if its diameter exceeds 3 mm one should search for a pathology causing difficulties in the outflow of the pancreatic juice. Proper echogenicity of the pancreas increases with patient age, due to the greater amount of adipose tissue. Inflammatory edema during the course of acute pancreatitis leads towards reduced pancreatic echogenicity, while fibrosis

<table>
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<th>Month</th>
<th>Number of ultrasound examinations</th>
<th>Number of ultrasound examinations performed during emergency service</th>
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<td>328</td>
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as a consequence of chronic inflammation results in increased echogenicity. The appearance of the organ during acute pancreatitis may be described on the basis of Becker’s three-staged classification:

- stage I: uniform enlargement of the whole organ with parenchymal echogenicity change, organ contours preserved, possibility of fluid in the omental sac (fig. 1),
- stage II: presence of diffuse hypo- and hyperchogenic areas within the pancreatic parenchyma, and surrounding fat tissue, with preserved organ contours,
- stage III: significantly enlarged pancreas, heterogeneous echogram and blurring of organ contours (features of necrosis – fig. 2 and 3). The efficiency of ultrasonography in the diagnosis of pancreatic necrosis is limited, therefore, in patients with severe acute pancreatitis contrast computer tomography is the method of choice, enabling the assessment of the severity of the inflammation on the basis of Balthazar’s 5-point scale.

Additionally, during the ultrasound examination of patients with acute pancreatitis one may visualize acute phase fluid cisterns, left pleural fluid presence (Clairmont’s sign), splenic vein thrombosis with secondary hypersplenism, pseudoaneurysms (most often in patients with acute pancreatitis one may observe splenic and gastroduodenal artery pseudoaneurysms). The differentiation of a cyst and pseudoaneurysm is possible by means of color-Doppler or power-Doppler (fig. 4).
The value of the ultrasound examination in patients with acute pancreatitis also stems from the possibility of confirming the cholecystic etiology of the disorder and need to perform aspiration fine-needle biopsy, in order to detect necrotic pancreatitis. The diagnosis of cholic acute pancreatitis is an indication to perform endoscopic retrograde cholangiopancreatography and endoscopic papillotomy during the initial 24 hours, since the onset of symptoms. On the other hand, the diagnosis of septic pancreatic necrosis is an indication for surgical intervention. Ultrasonography also plays an important role in the monitoring of the course of acute pancreatitis, enabling to detect such complications as cysts, abscesses (fig. 5), and splenic vein thrombosis. Post-inflammatory cysts are usually isolated, most often located outside the pancreatic parenchyma, the wall thickness usually does not exceed 1cm, and may be subject to spontaneous resorption in nearly 50% of cases. The fluid from the post-inflammatory cyst contains increased amylase activity, low CEA level, and presence of characteristic inflammatory reaction cells observed in the cytologic examination.

Acute diseases of the gall-bladder and biliary ducts

Clinical symptoms of cholecystolithiasis occur in only 20-40% of patients with gallstones. The evaluation of the gall-bladder in patients with acute abdominal pain includes the assessment of the wall and interior of the organ. Pain on palpation and increased muscular hypertonia in the upper right quadrant of the abdominal cavity does not preclude the ultrasound examination of the gall-bladder, as it can be well visualized from the intercostal approach. One should not forget about the other reasons of pain in the above-mentioned area, such as acute pancreatitis, alcoholic hepatitis, ascending cholangitis, liver abscess, peptic ulcer disease, renal colic, and pyelonephritis. During the course of acute cholecystitis the wall of the gall-bladder >3 mm, while pericholecystitis is visible as a hypoechoic area (fig. 6). Differential diagnosis of pericholecystitis includes focal liver steatosis-in case of hyposteatosis the area of reduced echogenicity may be of irregular shape and does not cover the area around the gall-bladder. Inside the gall-bladder one may observe the presence of concrements, and thickened hyperechogenic content, being evidence of biliary infection. A thickened gall-bladder wall might also be associated with the following diseases: gall-bladder cancer, adenomyomatosis, cirrhotic gall-bladder, ascites and malnutrition. The diagnostic accuracy of the ultrasound examination in the diagnosis of cholecystolithiasis exceeds 90%. During emergency ultrasound examinations one requires a thorough evaluation of the neck of the gall-bladder and cystic duct for the search of a stone, which might block the outflow of bile. In case of 5-15% of patients with cholecystitis no concrements are observed (acalculuscholecystitis)- this is particularly true of long-term hospitalized patients in intensive care departments, as well

Fig. 5. Purulent recurring multilocular pancreatic cyst-visible fluid cistern inside the cyst

Fig. 6. Pericystitis – hypoechoic inflammatory infiltration of the hepatic tissue adhering to the thickened gall-bladder wall
as those after multi-organ injuries, burns, and immunological deficits. If the patient did not receive painkillers or relaxing agents before the examination, compression by means of the ultrasonographic probe leads towards pain (Murphy’s sonographic sign). Small abscesses might be visible inside the gall-bladder wall or hepatic tissue. Gall-bladder perforation might be indicative of the presence of fluid in the hepatorenal abscess and subhepatic space, as well as air in the biliary ducts (hyperechogenicity). Perforation is most often observed at the bottom of the gall-bladder, since alveolar artery branches are end arteries, thus, blood supplementation is delayed. The most common complication of perforation is the development of a pericystic abscess. Less commonly one may observe perforation to the peritoneal cavity, biliary peritonitis, or biliary-intestinal fistula development (10). In 2-30% of patients with acute cholecystitis one may observe gangrenous cholecystitis. It is more often observed in male, as compared to female patients. Ultrasonographic gangrenous cholecystitis signs are as follows: gall-bladder wall striation, fibrinous exudate, negative Murphy’s sign (due to the visceral necrosis of afferent fibers innervating the organ), and pericystitis (11). Emphysematous cholecystitis is diagnosed in 1% of patients with acute cholecystitis. It is more common in male patients, and 30-50% of patients are diagnosed with diabetes mellitus. The primary cause of this type of inflammation is thrombosis of the vesicular artery leading towards ischemic necrosis of the gall-bladder wall and bacteria colonization (Clostridium, Escherichia coli, anaerobic streptococci). The ultrasound examination can find hyperechogenic foci in the wall and lumen of the gall-bladder, corresponding to gas bubbles (12). The „ring down” artifact is characteristic as a result of the ultrasound wave reverberation hyperechogenic streaks develop. One can also observe the „comets tail” artifact (hyperechogenic streak with a lesion in the shape of letter V), although it is more characteristic of patients with adenomyomatosis, where one can observe cholesterol crystals in Rokitansky-Aschoff sinuses. Gas in the lumen of the gall-bladder, apart from inflammation might also be present in patients with enteroduodenal anastomoses, after endoscopic papillotomy, with biliary-intestinal fistulas, and Oddi’s sphincter failure.

Gall-bladder hydrocele is diagnosed when its transverse dimension is greater than 5 cm or its volume exceeds 200ml. During the first hours of hydrocele development the gall-bladder wall is subject to thickening, despite ongoing inflammation. Gall-bladder hydrocele should be distinguished from an enlarged and painless gall-bladder observed in patients diagnosed with hepatopancreatic ampulla tumors (Courvoisier’s sign). The image of an empyema gall-bladder includes a thickened, inflammatory infiltrated wall, pachychoelia, and hyperechogenic gas vesicles inside the organ (fig. 7). Considering patients subject to surgery due to cholecystolithiasis, 1-2% are diagnosed with Mirrizi’s syndrome associated with the compression of a stone wedged in the cystic duct on top of the common biliary duct (type I syndrome according to McSherry, and type II – presence of a biliary duct fistula). The ultrasound examination in case of patients with Mirrizi’s syndrome may show a normal sized common biliary duct, and enlarged intrahepatic bile ducts.

In case of 40% of patients with choledocholithiasis one may visualize biliary duct concrements (fig. 8). The limited diagnostic accuracy of ultrasonography in the diagnosis of the above-mentioned pathology is associated with difficulties in visualizing the distal segment of the common biliary duct, which may be obscured by duodenal gas. The proper diameter of the common biliary duct should

![Fig. 7. Empyema of the gall-bladder – double thickened wall, condensed bile and presence of a concrement in its lumen](image-url)
not exceed 8 mm, while in case of patients after cholecystectomy-10 mm. In case of patients with cholecystitis one may observe biliary duct dilatation and intensified wall echo. The “snow flake” sign consists in hyperecho-genic scattered echos in the hepatic parenchyma associated with cholangitis.

Vessels

The ultrasound examination of abdominal vessels should visualize the course and blood flow through the aorta, iliac, renal and visceral vessels. The evaluation of the venous system includes the inferior caval vein, portal, hepatic, renal, and iliac veins. Abdominal cavity vascular injuries constitute less than 0.5% of all injuries. After rupture of the muscular type vessel the vascular stumps constrict and the inner membrane folds into the lumen, which favors spontaneous hemostasis. However, the interruption of elastic arteries (aorta and iliac arteries) usually leads towards life-threatening hemorrhage. Injuries leading towards non-continuity disruption are responsible for local vascular wall thickening. Thrombus development is also possible in the lumen of the vessel- fresh thrombotic material might be anechoic or hypoechogenic, which hinders the diagnosis in the B presentation. Thanks to power and cortex-Doppler it is possible to evaluate the size of the thrombus. In patients with acute abdominal symptoms one should consider the possibility of the following intra-abdominal vascular pathologies:
- dissecting aortic aneurysm,
- ruptured aortic aneurysm,
- mesenteric artery thrombosis or embolism,
- mesenteric venous thrombosis.

Aortic dissection usually begins in the thoracic, followed by the abdominal part of the aorta. The characteristic ultrasound image of aortic dissection consists in the reinforcement of its lumen and dual channel blood flow, as well as waving of the intima. In case thrombosis develops between the dissected intima and aortic wall the ultrasound image is hard to distinguish between an aortic aneurysm and parietal thrombus. Additionally, as in case of a parietal thrombus in an aneurysm, one may observe blood flow between the thrombus and vascular wall.

Abdominal aortic aneurysms usually rupture to the retroperitoneal space, which enables the implementation of surgical treatment. The ultrasound evaluation of the aortic aneurysm should consist in the determination of ruptured aneurysmal signs, the distance between the aneurysm and renal artery branching (when the renal arteries cannot be visualized one may assume that they branch off the aorta 1.5 cm below the superior mesenteric artery) and aortic bifurcation. Aneurysmal rupture is demonstrated by the blurred shape of the aortic wall with the presence of a hematoma in the retroperitoneal space. The above-mentioned should be differentiated from aneurysmal aortitis (5% of all abdominal aortic aneurysms), where one may distinguish a hypoechogenic inflammatory infiltration located from the anterolateral side of the vessel.

In patients suspected of superior mesenteric artery obstruction it is required to visualize the artery and evaluate blood flow by means of the Doppler examination. The visualization of the inferior mesenteric artery by means of the abdominal examination is much more difficult, as compared to the superior mesenteric artery. However, the superior mesenteric artery can usually be traced from the branching point from the aorta on the distance of several centimeters. Proper flow spectrum of the superior mesenteric artery observed by means of the Doppler duplex examination (B presentation + spectral Doppler) is highly resistant.
during fasting, and low resistant after nutrition (13). The diagnosis of mesenteric venous thrombosis by means of ultrasonography is only possible when the lesions include the main mesenteric venous trunk- in such cases one may observe vascular dilatation, lack of flow, and presence of a thrombus in the lumen of the vessel (the thrombus may be anechoic, its visualization being possible after selecting color-Doppler).

Abdominal cavity injuries

The ultrasound examination in patients after trauma has many advantages. The method is non-invasive, possible to perform anywhere, repeatable, allowing to diagnose the presence of fluid in the peritoneal and pleural cavity, and pericardial sac. The main limitations of the examination arise from the fact that it has a low sensitivity in the diagnosis of small parenchymal organ damage, does not allow to differentiate the character of the peritoneal fluid (blood/bile/urine/intestinal content/serous fluid), and depends on the experience of the physician performing the examination. Apart from the evaluation of the presence of peritoneal cavity fluid in patients after abdominal cavity injuries, it is also possible to determine the extent of parenchymal organ trauma, the size of the posttraumatic hematoma, and monitoring of patients subject to conservative treatment. In case of a subcapsular hematoma the dual contour image is a characteristic sign, due to the presence of fluid between the capsule and organ parenchyma. The interstitial hematoma is usually irregular, initially hypoechoic (contains blood). As a result of blood clotting hyperechoic structures develop within the hematoma. Hematoma organization leads towards the development of a hyper- or iso-echogenic area. The liquefying hematoma contains hypoechoic areas. The presence of a fissure in the organ parenchyma and continuity rupture of the capsule, as well as free peritoneal cavity fluid is evidence of parenchymal organ rupture. It is most difficult to determine damage to the pancreas and small bowel by means of emergency ultrasonography, which is associated with the presence of air in the stomach, intestinal loop bloating, and integument damage in posttraumatic patients.

Focused assessment sonography for trauma (FAST) plays a significant role in case of patients after abdominal cavity injuries. FAST consists in the application of the ultrasonographic probe in 4 points: under the right costal arch, under the left costal arch, under the xiphoid process, and in the hypogastrium in the midline. The above-mentioned allows to determine the presence of fluid in the pleural and peritoneal cavity, as well as pericardial sac (at least 200 ml) (fig. 9). The examination can be performed by an ER physician. The presence of fluid in the peritoneal cavity raises suspicion of bleeding. If the patient is hemodynamically unstable he may be transferred to the OR and qualified for emergency laparotomy. In case of patients that are hemodynamically stable computer tomography should be additionally performed, in order to determine the source of bleeding and extent of damage, which will enable the implementation of proper treatment. The introduction of the FAST method into clinical practice enabled to reduce the number of diagnostic peritoneal cavity lavage, however, did not show the lower incidence of laparotomies (14). A false positive FAST examination might result from the presence of ascites before the injury, minor pelvis organ inflammation, or presence of fluid in Douglas’s sinus in female reproductive patients. Thus far, no influence of FAST on the reduction of mortality has been demonstrated, considering patients after blunt abdominal injuries. According to the recommendations of The Society of Polish Surgeons published in the pages of Practical Medicine (number 5/2010) the FAST ultrasound examination is included in the algorithm of management in
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In case of patients after injuries. The examination is recommended in patients after injuries who are in shock, suspected of cardiac tamponade, internal bleeding, and penetrating wounds. In case of abdominal injuries FAST is recommended in hemodynamically stable patients without peritoneal symptoms, as well hemodynamically unstable patients, although not in critical condition (> 3 points according to the Revised Trauma Score scale).

Intestinal obstruction

Peritonitis is the cause of intestinal obstruction in 80% of patients, while mechanical ileus is diagnosed in only 20% of cases. Mechanical ileus mostly concerns the small bowel (82%), followed by colon obstruction (18%). The ultrasound examination in patients with intestinal obstruction enables to visualize intestinal loop bloating containing fluid or gas content, and evaluate intestinal peristalsis (fig. 10). On the basis of the number and shape of the intestinal loops one might determine the level of obstruction. In case of intestinal intussusception one may visualize the hypoechogenic tumor with several concentric hyperechogenic layers (the bull’s eye sign, buffalo eye). Paralytic ileus should be differentiated from intestinal ischemia, due to mesenteric artery embolism. If possible blood flow through the mesenteric vessels should be visualized.

Diverticulitis

The diverticuli are mostly located in the left part of the colon. The ultrasound examination in case of patients with sigmoid diverticulitis might not reveal any pathological lesions. The following lesions are most often observed: intestinal wall thickening, hyperechogenic infiltration at the site of the diverticulitis, intra-abdominal abscess resulting from diverticulum perforation (fig. 11). Computer tomography has greater diagnostic accuracy than the ultrasound examination in the diagnosis of diverticuli perforation, and intra-abdominal abscesses.

Acute appendicitis

The diagnosis of acute appendicitis in adult patients on the basis of ultrasonography is difficult, thus, the above-mentioned serves mainly to exclude other intra-abdominal pathologies. The infiltrated appendix is usually at least 6 mm in size, being oval on transverse section (fig. 12). In contrast to the intestinal loop it does not collapse during compression by means of the ultrasound probe (fig. 13). In case of periappendicular infiltration the ultrasound examination enables to diagnosis and monitor its complications (fig. 14). It is also possible to diagnose a periappendicular abscess (initially a heterogenous echogenic area, then a hypoechogenic fluid cistern located above the right iliac fossa- the change in the appearance of the abscess is associated with the development of colliquative necrosis inside the lesion) (fig. 15).

Fig. 10. Small bowel ileus

Fig. 11. Simoid diverticulum perforation – thickened intestinal wall, next to the sigmoid visible free, heterogenous fluid
Fig. 12. Acute appendicitis, visible hypoechochogenic area above the right iliac fossa (> 6 mm in size) without a change in shape after compression by means of the ultrasound probe

Fig. 13. Acute appendicitis, hypoechochogenic area above the right iliac fossa without a change in shape after compression by means of the ultrasound probe

Fig. 14. Periappendicular infiltration-heterogenous fluid collection, physical examination-palpable resistance above the right iliac fossa

Fig. 15. Periappendicular abscess, fluid cistern above the right iliac fossa

Intraabdominal abscesses

The visualization and diagnosis of an intraabdominal abscess by means of ultrasound requires experience and careful examination. Most often the abscess is a fluid cistern of decreased echogenicity, with a marked capsule and internal echos (derived from necrotic tissue and fibrin) (fig. 16). Less often can we visualize the fluid level, which develops as a consequence of the sedimentation of a thick purulent serous fluid. The differentiation of an abscess and intestinal loop is possible by changing the positioning of the probe, in order to visualize the intestinal longitudinal section and presence of peristalsis. Abscesses located in the pelvis are more visible in the endosonographic examination (15). Intraperitoneal abscesses are mostly located in the subphrenic and intraloop areas, as well as in the minor pelvis. Untreated abscesses usually increase in size, which might lead towards their rupture and infiltration of surrounding structures.

Amongst intraabdominal abscesses, hepatic (fig. 17) and pancreatic lesions are most often observed (2 weeks after pancreatitis) (fig. 18). Splenic abscesses are less commonly observed (hemorrhagic). Liver abscesses are usually a complication of acute abdominal diseases or previous surgical procedures. Most abscesses (80%) are located in the right hepato-
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Acute diseases of the reproductive system

The most common diseases of the reproductive system associated with acute abdominal symptoms are as follows: adnexitis, ovarian cyst torsion, and ruptured extrauterine pregnancy. Transvaginal USG (TVUSG) is the basic method in gynecology considering ultrasonographic diagnostics. Adnexitis usually occurs during menstruation or in the following days. The ultrasound examination might show enlarged adnexa and free fluid in Douglas’s cavity. Untreated adnexitis might lead towards hydrocele or empyema development followed by abscess formation. Ovarian cyst torsion requires emergency surgery. The ultrasound image shows an ovarian cyst with a thickened wall and areas of hyperechogenicity. Additionally, one may observe the presence of peritoneal cavity fluid. The ruptured extrauterine pregnancy is manifested by the presence of hyperechogenic fluid in the rectouterine pouch, endometrium hypertrophy, and an enlarged uterine, which may be displaced by the tumor.

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Address correspondence: 31-501 Kraków, ul. Kopernika 40