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Hepatobiliary ultrasound

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The use of ultrasound technology in the emergency department (ED) is a recent and fast-growing phenomenon. One of the most valuable uses of ultrasound in the ED is to image the hepatobiliary system—specifically, the gallbladder (GB). Ultrasound is an extremely valuable tool for the evaluation of GB disease in the ED for several reasons: this disease is a common medical problem, cholecystitis can present in different ways clinically, the nature of the GB allows it to be well visualized by ultrasound, and ultrasound has many benefits and few complications associated with its use.

It is estimated that gallstones are present in approximately 10% to 15% of Americans and that more than 20% of women and 8% of men over 40 years of age have gallstones [1–5]. Among patients with gallstones, it is estimated that new biliary pain will occur in 10% at 5 years, 15% at 10 years, and 18% at 15 to 20 years [4]. There are 500,000 cholecystectomies performed each year and approximately 6000 to 10,000 deaths associated with GB disease annually in the United States [3,5,6].

GB disease (ie, biliary colic, cholecystitis) can present to the ED in a variety of ways: right upper quadrant pain, epigastric pain, abdominal pain, right flank pain, right shoulder pain, nausea/vomiting, and sepsis without a source. The emergency physician (EP) must be able to narrow a large differential diagnosis to make a diagnosis and disposition quickly and efficiently. Real-time ultrasound allows the EP to assess the GB to determine whether the best first diagnostic test should be formal ultrasound or abdominal CT and,

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potentially, to provide earlier consultation, earlier pain medication, earlier antibiotics, and earlier definitive diagnosis or disposition [7–10].

The GB is ideal for ultrasound detection and disease diagnosis. It located fairly superficially in the body under the liver, which is an excellent acoustic window, meaning that it enhances resolution of ultrasound waves. The GB itself is a cystic structure that is filled only with echo-free substance (bile) in the normal state. Gallstones, the most common sign of GB disease, are identified easily because they are echogenic and cast an acoustic shadow. With real-time ultrasound, the movement of stones can be appreciated with changes in position of the patient; gallstones should settle in dependent areas. Ultrasound is the test of choice to diagnose acute cholelithiasis, with an accuracy of 90% to 95% [11–13].

The benefits of bedside ultrasound in the ED are safety (no contrast material or radiation is required), speed (no significant preparation is required, such as oral contrast load or transport to another location in the hospital), cost (other than the initial purchase and minimal maintenance costs of an ultrasound machine, there is no additional cost to the physician or patient), and accuracy, especially to rule out disease.

Limited, goal-directed emergency ultrasound

The field of emergency medicine has promoted the use of ultrasound with a specific, unique philosophy: limited, goal-directed ultrasonography. The EP is not expected to identify subtle abnormalities in the hepatobiliary system. The goal is to answer specific binary (yes or no) questions to help determine the presence or absence of disease (eg, Are there gallstones present? and Is there a sonographic Murphy's sign?). If the pretest probability for GB disease is increased significantly, then the EP not only can order a formal ultrasound but also initiate subsequent steps that normally would be delayed until after a formal ultrasound, such as surgical consultation, antibiotics, and pain medication. If the pretest probability is reduced significantly, then the first diagnostic test may be abdominal CT scan instead of formal ultrasound. In indeterminate cases (GB not visualized or tender GB without stones), there is only a small loss of time to perform the bedside ultrasound; in general, the time investment is worth the potential benefit of ultrasound.

The accuracy of EP ultrasonography of the hepatobiliary system has been investigated. This article reviews the focused examination of the GB, with specific attention to test characteristics (sensitivity, specificity, positive predictive value, and negative predictive value) when performed by EPs in the ED.

Technical ultrasound considerations

Although the GB can be assessed well with ultrasound, it is one of the more difficult structures to locate; therefore, a methodological approach is

recommended. Using a 3.5- 5.0-MHz ultrasound probe, the right upper quadrant of the abdomen is scanned in the longitudinal plane under the costal margin, initially using the liver as an acoustic window to identify the GB. If there is difficulty, the patient can be asked to take a slow deep breath because the GB moves significantly with respiration. Changing the position of the patient also can be helpful. To avoid bowel gas and rib shadows, the probe can be positioned in the intercostal space.

After the GB is identified, confirmation is needed that the structure is indeed the GB. Associated structures must be identified because the GB easily can be mistaken for a vessel (eg, inferior vena cava), duct in the liver, or loop of intestine on cross-section. Helpful associated structures include (1) gallstones within the lumen of the GB that are echogenic with echolucent shadows; (2) the main lobar fissure of the liver (linear echogenic structure) in sagittal section points toward the GB neck and also connects the portal vein; (3) the common bile duct (CBD) usually runs between the GB and the portal vein and usually is seen when the probe is parallel to the subcostal margin (transverse or slightly oblique view); and occasionally (4) the hepatic artery visible anteromedial to the portal vein in addition to the CBD visible anterolateral to the portal vein, forming the ''Mickey Mouse'' sign (Fig. 1). Identifying these structures is essential to prove that the image is the GB and useful when taking pictures to convince consultants and colleagues that the structure is the GB.

It is important always to visualize the GB in various planes (eg, longitudinal and transverse) to see the entire extent of the structure.

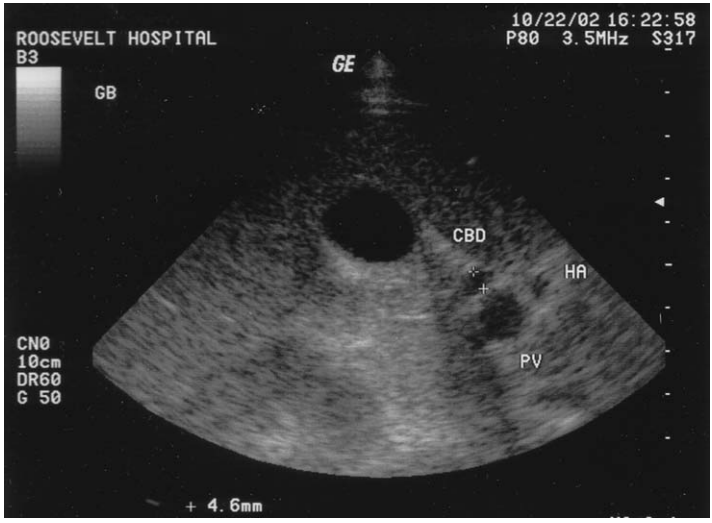

Fig. 1. The ''Mickey Mouse'' sign is comprised of the portal vein (PV), common bile duct (CBD), and hepatic artery (HA) as labeled on the ultrasound scan.

Gallstones or polyps occasionally can be seen in only certain views. Also, small stones impacted in the cystic duct can be overlooked.

When gallstones are suspected, the position of the patient should be changed from lying flat to left lateral recumbent to see the stones shift position. Gallstones should settle in dependent regions. If the stones do not move and there is no acoustic shadow, then they may not be stones at all.

Rarely, the GB can be scarred down on a large gallstone, resulting in an atypical appearance of the GB. There will be no standard "pear-shaped" GB and no lumen. There may be only a hyperechoic area with distal shadowing.

Focus emergency medicine examination

As discussed previously, the goal of the EP is to identify the presence or absence of specific findings to raise the suspicion of cholecystitis. The following is a review of the most common findings and signs that should be sought during an ultrasound of the right upper quadrant.

Gallstones/cholelithiasis

The presence or absence of gallstones is critical because it is the primary sonographic criteria for the diagnosis of acute cholecystitis [12,14]. Most patients (approximately 95%–99%) who have cholecystitis have gallstones [14,15]. It should be noted that stones also can be present in the setting of biliary colic or found incidentally (asymptomatic gallstones); however, in the ED ultrasound evaluation to rule out cholecystitis, every effort should be made to identify gallstones.

As mentioned earlier, there are three important characteristics of gallstones: they appear as an echogenic focus within the GB, they may cast an acoustic shadow, and they exhibit gravitational dependency. Note that very small stones (usually less than 3 mm) may not cast a shadow due to the nature of ultrasound waves, especially with low-frequency transducers (Fig. 2) [12].

In an early prospective study by Jehle et al [16] in 1989, EPs moderately trained in sonography successfully identified all 21 patients with gallstones among 48 suspected of biliary tract disease. Subsequent studies also have found high rates of gallstone identification by EPs: Kendall and Shimp [8] reported successful identification of 49 of 51 patients with gallstones, yielding a sensitivity of 96%, and Rosen et al [9] reported successful identification of 60 of 65 patients with gallstones, yielding a sensitivity of 92%. The specificity in both studies was slightly lower: 88% and 78%, respectively.

It is now generally accepted that moderately trained EPs can identify gallstones by ultrasonography with reasonable accuracy.

Sonographic Murphy's sign

A sonographic Murphy's sign is positive when maximal tenderness exists where pressure is applied with the ultrasound probe directly over the

Fig. 2. Echogenic gallstones casting an acoustic shadow are clearly visible.

sonographically visualized GB. It is, theoretically, more specific than the standard Murphy's sign because tenderness is elicited from the GB specifically and not just the right upper quadrant. It is important to test for sonographic Murphy's sign because a positive sign in addition to the presence of gallstones has a positive predictive value greater than 90% for cholecystitis [12,14].

In one formal radiology study, sonographic Murphy's sign was found to be 86% sensitive for acute cholecystitis [17]. In a study of 109 limited right upper quadrant ultrasounds performed by EPs, 54 patients had a sonographic Murphy's sign that correlated with a 75% sensitivity for a pathologic diagnosis of acute cholecystitis; interestingly, the sensitivity was only 45% when elicited by formal ultrasound technicians [8]. In another study, combining the presence of gallstones and a positive sonographic Murphy's sign yielded a sensitivity of 91% in the hands of EPs [9].

A sonographic Murphy's sign is a valuable test to diagnose cholecystitis and can be elicited reliably by EPs.

Gallbladder wall thickening

GB wall thickening is a secondary sign of acute cholecystitis [18,19]. In general, however, it is a nonspecific finding because it may appear thickened in conditions other than GB disease. Other common medical problems that increase GB wall thickness are congestive heart failure, renal disease, hepatitis, ascites, and alcoholic liver disease (for a more complete list, see Box 1). Even in an otherwise healthy person, the GB wall may appear thickened when the GB is contracted, particularly after a large, fatty meal (Fig. 3).

To avoid measuring artifact, the anterior wall always should be measured perpendicular to the ultrasound beam. The normal, noncontracted GB wall

Box 1. Differential diagnosis of thickened gallbladder wall

Adenomyomatosis
Alcoholic liver disease
Ascites
Cholecystitis
Congestive heart failure
Gallbladder tumors
Hepatitis
Hypoalbuminemia
Hypoproteinemia
Multiple myeloma
Pericholecystic abscess
Renal disease
Systemic venous hypertension

Adapted from Simon B, Snoey E. Ultrasound in emergency and ambulatory medicine. St. Louis (MO): Mosby; 1997; with permission.

usually measures less than 3 mm; the mean GB wall thickness in acute cholecystitis is 9 mm [12,20]. For purposes of ED ultrasonography, a GB wall greater than 3 mm is considered abnormal. Ultrasound measurements correlate within 1 mm to pathology specimen findings after surgery in greater than 90% of cases and within 1.5 mm in 100% of cases [18].

Clinical correlation is critical when using GB wall thickness to diagnose cholecystitis. In the appropriate clinical setting, a thickened GB wall in addition to gallstones can raise the positive predictive value greater than 90% [12,14]. Data on the correlation of EP measurement of GB wall thickness compared with formal ultrasonography measurements or pathology specimen measurements is sparse.

A thick-walled, tender GB without gallstones should not be disregarded. Among 31 cases identified by a radiology department in Sweden, 14 were found to have stones and cholecystitis on further study, 7 had another etiology (concomitant disease) for the thickened GB wall, 7 had acalculous cholecystitis, and 3 did not have further evaluation [21]; clearly, stones can be elusive even to highly trained sonographers, and secondary findings of cholecystitis in the right clinical setting are clues to the rare diagnosis of acalculous cholecystitis.

Pericholecystic fluid

Pericholecystic fluid is a sign of GB inflammation and appears as fluid (echolucent) within or around the GB wall. Identifying the presence of

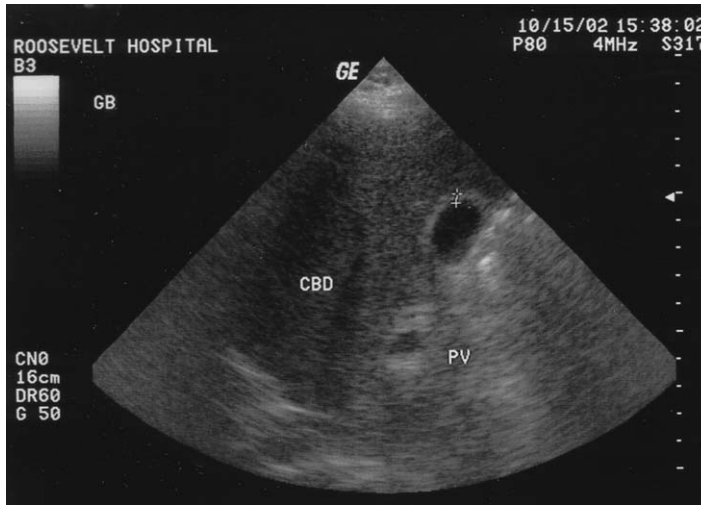

Fig. 3. A contracted gallbladder can appear to have a thickened gallbladder wall. Also visible in this scan are the portal vein (PV) and, vaguely, the common bile duct (CBD) between the portal vein and the gallbladder.

pericholecystic fluid is useful because it is highly specific for GB disease (either acute cholecystitis, GB perforation, or pericholecystic abscess) but seen only occasionally [14,20].

When there is enough inflammation to produce pericholecystic fluid around the entire GB, a ''halo'' or echolucent space develops around the external wall of the GB [22]. In one retrospective review, this halo sign was seen in 26% of patients with acute cholecystitis [23]. This sign is believed to be very specific in a noncontracted GB.

Common bile duct dilatation

Measurement of the CBD is recommended as part of the right upper quadrant ultrasound because a dilated CBD suggests obstruction most commonly due to choledocholithiasis (a stone in the biliary ducts). Depending on the location of the lodged stone, there can be inflammation of the GB or pancreas. In cases of acute biliary pancreatitis, ultrasound is the initial test of choice because a gallstone is identified in 60% to 80% of cases [24,25].

Dilatation of the CBD greater than 6 mm is considered abnormal, but the CBD usually is less than one tenth of the patient's age [22]. Data from ultrasound and autopsy studies clearly demonstrate that the size of the CBD increases with age [26–28]. When scanning an elderly patient, the common rule of thumb is to add 1 mm the standard 6 mm for each decade over 60 years to determine the upper limit of normal; however, a large prospective study of elderly patients found that 98% had a CBD less than 6 mm and 99% had a CBD less than 7 mm.

Ultrasound is sensitive for the detection of CBD dilatation; however, even in the hands of formal ultrasonographers, detection of the underlying problem (choledocholithiasis, pancreatic mass, stricture, and so forth) is inaccurate [22]. The EP should attempt to identify and measure the CBD in every patient being evaluated for hepatobiliary disease but is not expected to determine the underlying cause based on ultrasonography.

Other signs

Gallbladder size

In general, the GB size is not important or helpful. In an otherwise normal person, the size of the GB correlates best with the time and quality of the last meal. ''Normal'' GBs can be as large as 11 to 13 cm [10]. On the other hand, approximately 87% of infected GBs (cholecystitis) are larger than 4 to 5 cm in transverse diameter [20]; size may be somewhat sensitive but certainly not specific for acute cholecystitis.

Biliary sludge

On occasion, gallstones are not identified; however, low-amplitude echoes in the dependent portion of the GB that do not produce significant acoustic shadowing (''sludge'') are present. Can this sludge block the cystic duct or be the nidus for acute cholecystitis? This question has been the source of some debate. It is believed that biliary sludge is echogenic bile that develops due to stasis [10]. The clinical significance of this finding is unclear because biliary sludge is present in 50% of patients with cholecystitis and commonly present in nursing home patients and those who are fasting or have poor nutrition [10]. Eberle and Rettenmaier [29] found no biliary tract symptoms in a study of 82 patients with sludge, whereas Allen et al [30] reported 2 cases of gangrenous cholecystitis in a study of 97 patients with sludge. Over the course of 6 years, one institution identified 87 patients with biliary sludge without gallstones and 11 were diagnosed with GB disease; interestingly, 5 of the 11 patients had gallstones found after cholecystectomy [31]. In a prospective longitudinal study of 96 patients with sludge, 14 (14.5%) developed gallstones and 6 required cholecystectomy in the subsequent 3 years [32].

Clearly, the finding of biliary sludge alone is not diagnostic; however, it may be a useful secondary finding, especially in the right clinical setting.

Intramural/intraluminal gas

Although rare, identification of intramural/intraluminal gas in the GB is important because it reflects the presence of gas-forming organisms that lead to relatively high mortality due to gangrene of the GB called *acute emphysematous cholecystitis*. The literature contains many case reports of successful identification of gas in the GB by radiology departments. It is not a necessary part of the ED bedside ultrasound but, given the associated increased mortality, it is worth mentioning and remembering.

Intramural gas is seen as an area of high reflectivity in the GB wall, with distal reverberations that change position with movement of the patient; intraluminal gas is seen as a dense band of hyper-reflective echoes, causing reverberation and shadowing that often obscures the posterior wall of the GB [33–36]. These ultrasonographic findings are a result of the behavior of sound waves against focal areas of gas.

"Wall, echo, and shadow" sign

It is difficult to assess a contracted GB for signs of cholecystitis because the GB wall measurements often are falsely high, stones are not as clearly visible, and occasionally, it is difficult to find the GB at all. There is, however, a finding called the WES sign (WES is an acronym for *wall*, *echo*, and *shadow*) that is a specific sonographic sign of gallstones in a contracted GB. When ultrasonography demonstrates only the anterior GB wall, the echogenicity of the stone, and a shadow, it can be fairly certain that a contracted GB containing a stone has been identified [37,38].

Incidental findings: phrygian cap, septa, Heister's valves

It is useful to know about a few incidental findings that may be encountered so as not to confuse them with true pathology. The distal segment of the GB will be found to fold over on itself in approximately 4% of the population; this is called a *phrygian cap* (Fig. 4) and has no clinical significance [22]. On occasion, there are benign junctional folds called *septa* that extend from the GB wall and can be seen to traverse the entire GB (complete septa) or only partially (incomplete septa) [22]. It also is important to know about the

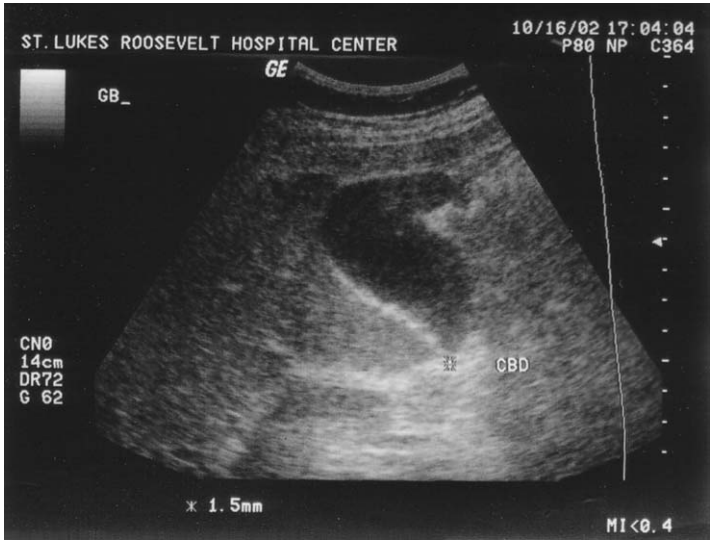

Fig. 4. A pharygian cap is a normal variant of gallbladder wall appearance on ultrasonography.

existence of Heister's valves because they can be mistaken for an impacted stone at the neck of the GB [22].

Clinical correlation

The most important question remains: Can EP-performed ultrasound diagnose cholecystitis? It has been well demonstrated in multiple studies that ED bedside ultrasound aids in ruling in and ruling out the diagnosis of acute cholecystitis.

During a 1-year proctoring period of EPs by the medical imaging department at one institution, the accuracy of ED GB ultrasound yielded a sensitivity of 86%, a specificity of 97%, and a positive predictive value of 97% [39].

Rosen et al [9] studied the accuracy of EPs who made the diagnosis of cholecystitis based on the presence of gallstones and a positive sonographic Murphy's sign in the first 3 months after the introduction of an ultrasound machine into the ED; the sensitivity was high (91%), but the specificity was relatively low (66%), leading the investigators to conclude that EPs with limited ultrasound experience should order a confirmatory test before cholecystectomy.

Residents also can perform ultrasound of the GB successfully. A prospective study at an inner-city emergency medicine residency program over the course of 2.5 years yielded a sensitivity of 90% and a specificity of 85% in diagnosing acute cholecystitis by ultrasound in the ED [40].

The sensitivities and specificities generated by EP-performed ultrasound to diagnose cholecystitis are comparable to those of formal ultrasound test characteristics found in the radiology literature; sensitivity ranges from 84% to 98% and specificity ranges from 90% to 99% [11,41–44].

Making the diagnosis of cholecystitis requires more than simply identifying gallstones. Gallstones alone (or any ultrasonographic sign alone) cannot make the diagnosis of an infected GB. Rosen et al [9] postulated that the low specificity of bedside ultrasound by EPs likely was due to not using secondary findings. Although EPs have the advantage of knowing the history and having the ability to do a physical examination, it is critical to look for secondary signs of cholecystitis in addition to gallstones and a sonographic Murphy's sign. Fig. 5 shows the recommended approach to bedside ultrasound of the GB.

Machine matters

Although many EDs are obtaining ultrasound machines for use by EPs, the quality of the machines generally is inferior to those used by the radiology department. The reasons for this discrepancy often involve cost and portability/size. Many practices use the Sonosite (Sonosite, Inc., Bothell, Washington) machines that allow quick and easy mobility from

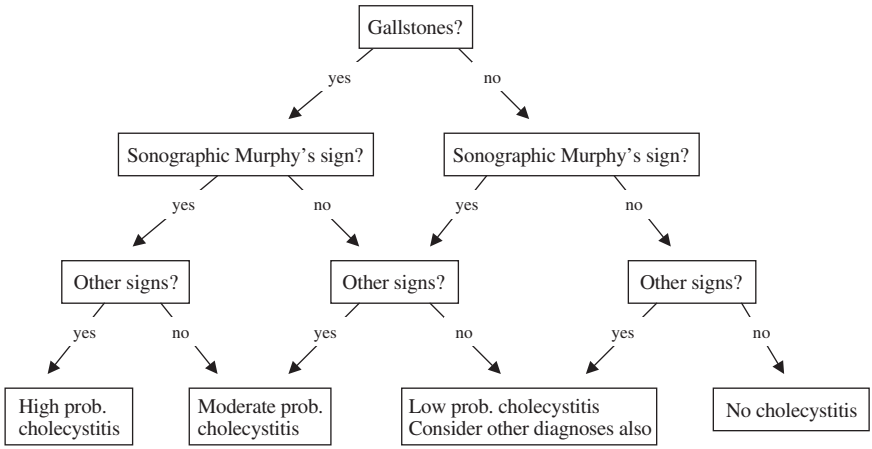

Fig. 5. A suggested approach to using bedside ultrasound to evaluate the gallbladder for possible cholecystitis.

room to room at the expense of image quality. Few studies have compared operator accuracy between two different-quality machines. Kendall and Shimp [8] found that sensitivity and specificity for detection of gallstones were higher with the Toshiba (Toshiba America, Inc., New York, New York) 140A (97% and 93%, respectively) ultrasound machine compared with the Toshiba Capasee (92% and 78%, respectively) in their study containing 51 patients with gallstones.

Time and money

EP use of bedside GB ultrasound has been shown to decrease patient length of stay in the ED. In comparing discharged patients who had bedside ultrasounds with those who did not, Blaivas et al [7] demonstrated a decrease in length of stay of 10% (30 minutes); similarly, those who presented to the ED "after hours" had a length of stay shortened by 15% (58 minutes) when they were scanned by an EP. For patients suspected of GB disease, the use of ultrasound likely improves patient flow.

Given that formal ultrasound is not available 24 hours per day at most institutions, it has been suggested that ultrasonography in the hands of EP is accurate enough to rule out acute cholecystitis [9,16]. In fact, Durston et al [45] demonstrated that ED ultrasound not only is reasonably accurate but also improves quality of care and decreases cost of care (the cost of having and maintaining an ED ultrasound was offset by the cost of calling in a formal ultrasound technician in the middle of the night).

The amount of time required of the EP to perform a biliary ultrasound also is a critical issue. One study demonstrated that most (83%) focused

right upper quadrant ultrasounds performed by EPs were completed in a reasonable amount of time (less than 10 minutes), and no scans took longer than 20 minutes [8].

Summary

Ultrasound is an extremely valuable tool for the evaluation of GB disease in the ED.

References

[1] Traverso LW. Clinical manifestations and impact of gallstone disease. Am J Surg 1993; 165(4):405–9.
[2] Warwick DJ, Thompson MH. Six hundred patients with gallstones. Ann R Coll Surg Engl 1992;74(3):218–21.
[3] Cucchiaro G, Watters CR, Rossitch JC, Meyers WC. Deaths from gallstones. Incidence and associated clinical factors. Ann Surg 1989;209(2):149–51.
[4] Gracie WA, Ransohoff DF. The natural history of silent gallstones: the innocent gallstone is not a myth. N Engl J Med 1982;307(13):798–800.
[5] Vitetta L, et al. Gallstones at autopsy and cholecystectomy: a comparative study. Aust N Z J Surg 1988;58(7):561–8.
[6] Hopper KD, et al. The prevalence of asymptomatic gallstones in the general population. Invest Radiol 1991;26(11):939–45.
[7] Blaivas M, Harwood RA, Lambert MJ. Decreasing length of stay with emergency ultrasound examination of the gallbladder. Acad Emerg Med 1999;6(10):1020–3.
[8] Kendall JL, Shimp RJ. Performance and interpretation of focused right upper quadrant ultrasound by emergency physicians. J Emerg Med 2001;21(1):7–13.
[9] Rosen CL, et al. Ultrasonography by emergency physicians in patients with suspected cholecystitis. Am J Emerg Med 2001;19(1):32–6.
[10] Heller M, Jehle D. Ultrasound in emergency medicine. Philadelphia: W.B. Saunders; 1995.
[11] Marton KI, Doubilet P. How to image the gallbladder in suspected cholecystitis. Ann Intern Med 1988;109(9):722–9.
[12] Cooperberg PL, Gibney RG. Imaging of the gallbladder 1997. Radiology 1987;163(3): 605–13.
[13] Walker J, Chalmers RT, Allan PL. An audit of ultrasound diagnosis of gallbladder calculi. Br J Radiol 1992;65(775):581–4.
[14] Ralls PW, et al. Real-time sonography in suspected acute cholecystitis. Prospective evaluation of primary and secondary signs. Radiology 1985;155(3):767–71.
[15] Babb RR. Acute acalculous cholecystitis. A review. J Clin Gastroenterol 1992;15(3):238–41.
[16] Jehle D, et al. Emergency department sonography by emergency physicians. Am J Emerg Med 1989;7(6):605–11.
[17] Bree RL. Further observations on the usefulness of the sonographic Murphy sign in the evaluation of suspected acute cholecystitis. J Clin Ultrasound 1995;23(3):169–72.
[18] Engel JM, Deitch EA, Sikkema W. Gallbladder wall thickness: sonographic accuracy and relation to disease. AJR Am J Roentgenol 1980;134(5):907–9.
[19] Sanders RC. The significance of sonographic gallbladder wall thickening. J Clin Ultrasound 1980;8(2):143–6.
[20] Simon B, Snoey E. Ultrasound in emergency and ambulatory medicine. St. Louis (MO): Mosby; 1997.

[21] Ekberg O, Weiber S. The clinical importance of a thick-walled, tender gall-bladder without stones on ultrasonography. Clin Radiol 1991;44(1):38–41.
[22] Roy S. Hepatobiliary. In: Ma OJ, Mateer JR, editors. Emergency ultrasound. New York: McGraw-Hill Professionals; 2002.
[23] Elyaderani MK, Gabriele OF. Cholecystosonography in detection of acute cholecystitis: the halo sign—a significant sonographic finding. South Med J 1983;76(2):174–80.
[24] Pezzilli R, et al. Ultrasonographic evaluation of the common bile duct in biliary acute pancreatitis patients: comparison with endoscopic retrograde cholangiopancreatography. J Ultrasound Med 1999;18(6):391–4.
[25] Neoptolemos JP, et al. The urgent diagnosis of gallstones in acute pancreatitis: a prospective study of three methods. Br J Surg 1984;71(3):230–3.
[26] Perret RS, Sloop GD, Borne JA. Common bile duct measurements in an elderly population. J Ultrasound Med 2000;19(11):727–30 [quiz: 731].
[27] Kaude JV. The width of the common bile duct in relation to age and stone disease. An ultrasonographic study. Eur J Radiol 1983;3(2):115–7.
[28] Wu CC, Ho YH, Chen CY. Effect of aging on common bile duct diameter: a real-time ultrasonographic study. J Clin Ultrasound 1984;12(8):473–8.
[29] Eberle F, Rettenmaier G. [Gallbladder sludge: a sonographically recognizable stage of lithogenesis]. Z Gastroenterol 1984;22(2):82–7.
[30] Allen B, et al. Sludge is calcium bilirubinate associated with bile stasis. Am J Surg 1981; 141(1):51–6.
[31] Ohara N, Schaefer J. Clinical significance of biliary sludge. J Clin Gastroenterol 1990; 12(3):291–4.
[32] Lee SP, Maher K, Nicholls JF. Origin and fate of biliary sludge. Gastroenterology 1988; 94(1):170–6.
[33] Bloom RA, et al. The ultrasound spectrum of emphysematous cholecystitis. J Clin Ultrasound 1989;17(4):251–6.
[34] Bloom RA, et al. Shifting intramural gas—a new ultrasound sign of emphysematous cholecystitis. J Clin Ultrasound 1984;12(1):40–2.
[35] Blaquiere RM, Dewbury KC. The ultrasound diagnosis of emphysematous cholecystitis. Br J Radiol 1982;55(650):114–6.
[36] Nemcek AA Jr, et al. The effervescent gallbladder: a sonographic sign of emphysematous cholecystitis. AJR Am J Roentgenol 1988;150(3):575–7.
[37] Rybicki FJ. The WES sign. Radiology 2000;214(3):881–2.
[38] MacDonald FR, Cooperberg PL, Cohen MM. The WES triad—a specific sonographic sign of gallstones in the contracted gallbladder. Gastrointest Radiol 1981;6(1):39–41.
[39] Schlager D, et al. A prospective study of ultrasonography in the ED by emergency physicians. Am J Emerg Med 1994;12(2):185–9.
[40] Lanoix R, et al. A preliminary evaluation of emergency ultrasound in the setting of an emergency medicine training program. Am J Emerg Med 2000;18(1):41–5.
[41] Berk RN, et al. The radiological diagnosis of gallbladder disease. An imaging symposium. Radiology 1981;141(1):49–56.
[42] Detwiler RP, Kim DS, Longerbeam JK. Ultrasonography and oral cholecystography: a comparison of their use in the diagnosis of gallbladder disease. Arch Surg 1980;115(9): 1096–8.
[43] McAvoy JM, et al. Role of ultrasonography in the primary diagnosis of cholelithiasis: an analysis of fifty cases. Am J Surg 1978;136(3):309–12.
[44] McKay AJ, et al. A prospective study of the clinical value and accuracy of grey scale ultrasound in detecting gallstones. Br J Surg 1978;65(5):330–3.
[45] Durston W, et al. Comparison of quality and cost-effectiveness in the evaluation of symptomatic cholelithiasis with different approaches to ultrasound availability in the ED. Am J Emerg Med 2001;19(4):260–9.