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Original Contributions

PERFORMANCE AND INTERPRETATION OF FOCUSED RIGHT UPPER QUADRANT ULTRASOUND BY EMERGENCY PHYSICIANS

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□ **Abstract**—The objectives of this study were to determine the accuracy of Emergency Physicians (EP) performing focused right upper quadrant (RUQ) ultrasound, to quantify how sonographic experience affects accuracy for gallbladder pathology, and to establish the time needed to complete a focused RUQ ultrasound. A convenience sample of patients with suspected gallbladder disease received a focused RUQ ultrasound by an EP. Sonographic findings, number of previous RUQ ultrasounds performed, and time for examination completion were recorded. Each patient then had a formal RUQ ultrasound by a sonographer blinded to the focused RUQ ultrasound results. Focused RUQ and formal ultrasound findings were compared, with the exception of the sonographic Murphy sign, which was compared to pathology reports. One hundred nine patients were enrolled. Fifty-one had gallstones. Forty-nine were detected by EPs, yielding a sensitivity of 96% [95% confidence interval (CI) .87-.99]. Of the 58 patients without gallstones, 51 were correctly diagnosed by EPs (specificity = 88%, 95% CI .77-.95). The sonographic Murphy sign was present during 54 emergency examinations, but in only 24 formal studies. When compared to pathology reports, the emergency sonographic Murphy sign had a sensitivity of 75% compared to the formal ultrasound sensitivity of 45% for acute cholecystitis. EPs were less accurate for other sonographic findings, and level of experience had little effect on sensitivity or specificity for detecting gallstones. Eighty-three percent of emergency studies were completed in less than 10 min. Gallstones are accurately detected by EPs in a timely fashion. Additionally, compared to the radiologist's interpretation, the EP-detected sonographic Murphy sign was more sensitive for diagnosing acute cholecystitis. © 2001 Elsevier Science Inc.

□ **Keywords**—emergency ultrasound; gallbladder; gallstones; sonographic Murphy sign; cholecystitis

INTRODUCTION

Approximately 20 million people in the United States have gallstones, with up to 1 million newly diagnosed each year (1). Diagnostic evaluation commonly involves a right upper quadrant (RUQ) ultrasound performed by a sonographer and interpreted by a radiologist. Although this is the usual evaluation process for patients presenting to the Emergency Department (ED) with RUQ pain, it can result in long delays and potential patient dissatisfaction. Consequently, it has been suggested that Emergency Physicians (EPs) should perform the initial RUQ ultrasound, but there are few data to support this view (2).

Two studies in the Emergency Medicine literature report the accuracy of EPs performing RUQ ultrasound (2,3). In one, EPs correctly identified biliary tract disease in 22 of 22 patients, but follow-up was not obtained for the remaining 24 "negative" studies. Additionally, the range of sonographic findings was limited to 21 patients

with gallstones and one patient with sludge (2). Schlagger et al. also studied sonography by EPs. They reported a diagnostic sensitivity and specificity of 86% and 97%, respectively, in 65 patients with cholelithiasis or cholecystitis. Unfortunately, they did not obtain formal imaging in all patients. As well, they compared the ED ultrasound to formal ultrasound for diagnoses of cholelithiasis or acute cholecystitis, but failed to mention how many patients had only gallstones or what sonographic criteria constituted the diagnosis of acute cholecystitis.

Conversely, in the radiology literature, diagnostic accuracy of ultrasound for biliary tract disease has been demonstrated by identifying individual sonographic findings. Hessler et al. demonstrated that ultrasound identified gallstones <3 mm in diameter 98% of the time (4). In a much larger study, Shea et al. performed a MEDLINE search to estimate the accuracy of various imaging modalities for cholelithiasis and cholecystitis (5). They reviewed 61 published articles and found ultrasound to be 97% sensitive and 95% specific for gallstones. Engel et al. determined that ultrasound measurement of wall thickness correlated with pathologic specimens within 1 mm in 92.5% of cases and 1.5 mm in 100% of cases (6). These studies provide evidence that ultrasound, in the hands of a radiologist, can accurately identify specific gallbladder pathology.

Absence of a similar study in the Emergency Medicine literature prompted us to evaluate EPs' sensitivity and specificity for detecting individual sonographic findings of gallbladder disease. Additionally, we wanted to test how level of experience affects accuracy and to determine the time needed to complete a limited RUQ ultrasound examination. By addressing these questions, we hope to better define the role of EPs in performing focused RUQ ultrasound.

MATERIALS AND METHODS

Patients were eligible for study entry if they had an RUQ ultrasound ordered during an ED visit to an urban teaching hospital from March 1996 to October 1997. The ED has approximately 55,000 yearly patient visits and an Emergency Medicine residency (PG 2–4) is based here. From 10 AM to 10 PM, patients who presented with abdominal pain and stable vital signs were triaged from the ED to the walk-in clinic (WIC) and were not seen by an EP. These patients were not included in this study. Patients with ascites and those who were human immunodeficiency virus positive were also excluded.

A convenience sample of patients receiving a formal ultrasound for the indications of RUQ abdominal pain, epigastric pain, or jaundice first had a focused RUQ ultrasound performed by an EP. Emergency ultrasound

findings were limited to the presence or absence of a sonographic Murphy sign, gallstones, thickened gallbladder wall, sludge, dilated common bile duct, pericholecystic fluid, or air in the gallbladder wall. EPs recorded their findings on a data sheet. Additional data points included estimated number of previous RUQ ultrasounds performed by the examiner, estimated total examination time, type of ultrasound machine used, time from patient's last meal, gender of the patient, and examination indications. Level of experience was listed in increments of 0–10, 11–25, 26–50, 51–75, 76–100, and more than 100 previous RUQ examinations performed. EPs recorded total examination times in 5-min increments (0–5, 6–10, 11–15, 16–20). Emergency ultrasound examinations were performed by using either a Toshiba Capasee (Toshiba America, Tustin, CA) or Toshiba SSH-140A. The examiner made the choice of which machine to use. The Capasee is an entry-level machine, whereas the 140A was the type used in the Department of Radiology at the time. A curvilinear 3.75 MHz abdominal transducer was used to obtain images on both machines. Images were printed with a Sony (Sony Corporation, Japan) video graphic printer on Sony high-density thermal printer paper and were stored with the data sheet.

After the ED ultrasound, a formal ultrasound was performed by a certified ultrasonographer, radiology resident, or attending radiologist. Sonographers performing the formal ultrasound were blinded to the ED ultrasound results, but were given indications for ordering the study. Formal studies were interpreted by a radiologist, with specific attention given to the same six sonographic findings of: gallstones, Murphy sign, wall thickness, sludge, pericholecystic fluid, dilated common bile duct, or air in the gallbladder wall.

The ED ultrasound results were compared against the gold standard formal ultrasound by using 2 × 2 tables to determine the sensitivity, specificity, and predictive values for each focused RUQ ultrasound sonographic finding. The sonographic Murphy sign was the only exception. It was compared against pathology reports. Individual sonographic findings, rather than final diagnosis of cholelithiasis or cholecystitis, were used as a means of comparing the two ultrasounds. This was done for two reasons. First, multiple sonographic findings constitute the diagnosis of acute cholecystitis. Therefore, if ultrasounds were compared for this diagnosis it would be difficult to determine the EP's accuracy for detecting specific sonographic findings. Second, by evaluating for several individual sonographic findings, we hoped to differentiate between findings that EPs can and cannot accurately detect.

All EPs attended at least one session of an existing emergency ultrasound curriculum before commencing the study. It involved a 2-h lecture on physics, instru-

Table 1. Indications for Ordering the RUQ Ultrasound

Indication	Number	Percent of Total
RUQ pain	86	78.9
Epigastric pain	58	53.2
History of stones	6	5.5
Jaundice	5	4.6

More than one indication was present in some patients.

mentation, and technique; 4 h of lecture for echocardiography and trauma ultrasound; 3 h of lecture pertaining to abdominal ultrasound for nontraumatic indications; and a 2-h lecture on pelvic ultrasound. Additionally, there were three ultrasound laboratories that comprised 10 h of hands-on training. Forty-seven physicians were eligible to enroll patients, including eight full-time Emergency Medicine trained faculty and 39 Emergency Medicine residents (PG 2–4). This study was approved by the Colorado Multi-Institutional Review Board prior to enrolling patients. Statistical analysis was performed by using SPSS, version 8.0 (SPSS, Chicago, IL). Confidence intervals were calculated by using Graph Pad Statmate, version 1.01i (GraphPad Software, San Diego, CA).

RESULTS

Between March 1996 and October 1997, 112 patients were enrolled in this study. Three were excluded: one patient was human immunodeficiency virus positive and two did not have a formal ultrasound during the ED visit. Therefore, 109 patients were included in the final analysis. There were 23 men and 86 women. Mean age was 39 years, with a range of 16–88 years. Indications for ordering the RUQ ultrasound are listed in Table 1. Thirty ED ultrasounds were performed with the Toshiba Capasee and 79 with the Toshiba 140A. Thirty-two of the 109 ED ultrasounds were performed in less than 5 min, 59 in 6–10 min, 12 in 11–15 min, and 6 in 16–20 min (Figure 1). Level of previous RUQ ultrasound experience for EPs entering patients is listed in Figure 2. In general, EPs entering patients had limited experience because 52% had done fewer than 25 previous limited RUQ ultrasounds.

Fifty-one patients had gallstones diagnosed by formal ultrasound. Overall, 49 were detected by EPs, resulting in a sensitivity of 96% [95% confidence interval (CI) .87-.99; (Table 2). Of the 58 patients without gallstones, 51 were correctly diagnosed by EPs, with a resulting specificity of 88% (95% CI .77-.95). The sonographic Murphy sign was present during 54 ED ultrasounds, but in only 24 formal studies. When compared to pathology reports, the ED sonographic Murphy sign had a sensitivity of 75% compared to the formal ultrasound sensitivity of 45% for the diagnosis of acute cholecystitis (Table 3A). If patients had a sonographic Murphy sign by itself or with gallstones, ED ultrasound sensitivity improved to 82%, whereas formal ultrasound sensitivity remained at
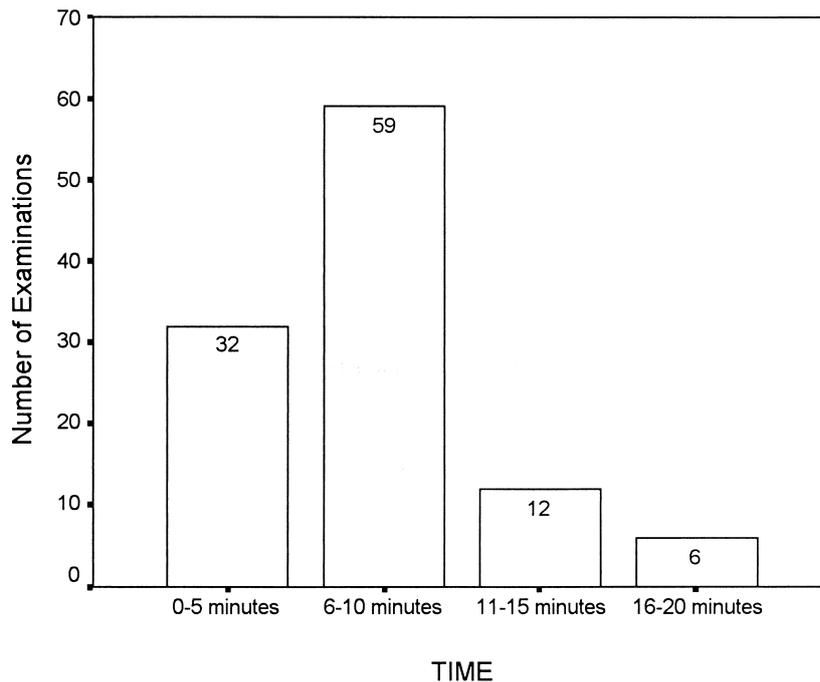
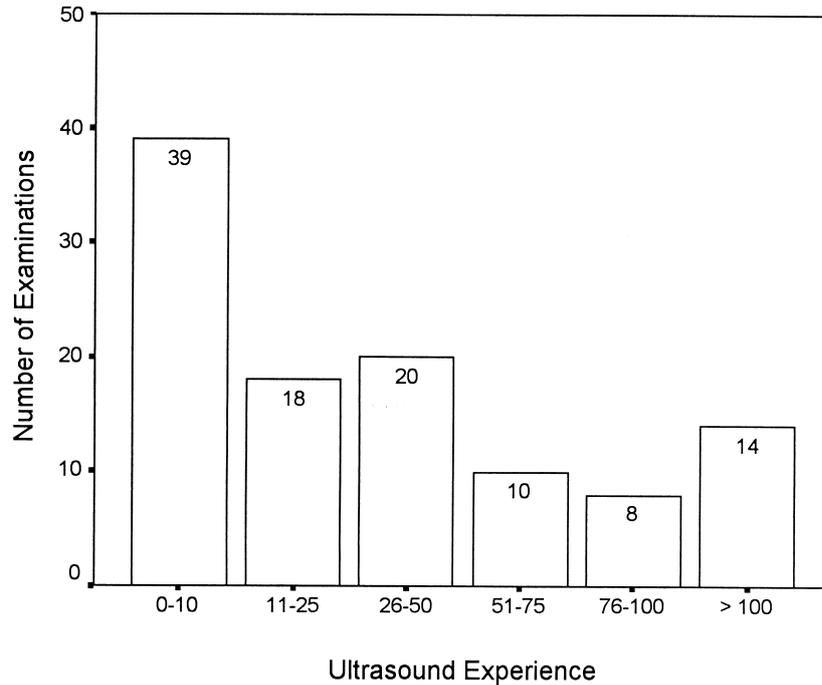**Figure 1. Time for completion of ED ultrasounds.**

Figure 2. ED ultrasounds performed according to the EP's level of experience (previous RUQ ultrasounds performed).

45% (Table 3B). Results for the remaining sonographic findings are listed in Table 2.

Sensitivity and specificity varied depending on the ultrasound machine used. For the detection of gallstones, the Toshiba Capasee had a sensitivity of 92% and a specificity of 78%. Sensitivity and specificity were 97% and 93%, respectively, with the Toshiba 140A. The remaining sonographic findings were present too infrequently to yield meaningful comparisons between the two machines.

EP's level of experience was compared to accuracy for detecting individual sonographic findings (Table 4).

Gallstones were the only finding present in enough examinations to yield meaningful comparisons.

DISCUSSION

This prospective study found that EPs could accurately detect gallstones in a timely fashion. Our sensitivity of 96% and specificity of 88% for the detection of gallstones is comparable to that in the radiology literature (4). This is especially true when examinations using the Toshiba 140A are considered (sensitivity 97%, specific-

Table 2. Results of ED Ultrasound Compared to Formal Ultrasound for Six Sonographic Findings

	Gallstones	Sludge	Thick Wall	Dilated CBD	Pericholecystic Fluid	Air GB Wall
True positive	49	8	3	0	1	0
False positive	7	15	8	3	1	0
True negative	51	78	95	104	107	109
False negative	2	8	3	2	0	0
Sensitivity	96%	50%	50%	NA	100%	NA
	(95% CI	(95% CI	(95% CI		(95% CI	
	0.87–0.99)	0.25–0.75)	0.12–0.88)		0.03–1.00)	
Specificity	88%	84%	92%	97%	99%	NA
	(95% CI	(95% CI	(95% CI	95% CI	(95% CI	
	0.77–0.95)	0.75–0.90)	(0.85–0.97)	0.92–0.99)	0.94–0.99)	
PPV	88%	34%	27%	NA	50%	NA
NPV	96%	91%	97%	98%	100%	100%

CBD, common bile duct; GB, gallbladder; PPV, positive predictive value; NPV, negative predictive value.

Table 3A. Comparison of the Sonographic Murphy Sign to Pathology Report Diagnosis of Acute Cholecystitis

	ED Ultrasound	Formal Ultrasound
True positive	9	5
False positive	44	19
True negative	53	79
False negative	3	6

Table 3B. Comparison of the Sonographic Murphy Sign Alone or With the Presence of Gallstones for the Pathology Report Diagnosis of Acute Cholecystitis

	ED Ultrasound	Formal Ultrasound
True positive	9	5
False positive	45	19
True negative	53	79
False negative	2	6

ity 93%). These results are also similar to those found by Schlagger et al. (sensitivity 86%, specificity 97%; Reference 3). Despite this, Schlagger et al.'s study is hard to compare to ours because they grouped cholelithiasis and cholecystitis together as criteria for comparison to formal studies. Demonstrating that EPs can accurately detect gallstones is significant because they are the primary sonographic criteria for the diagnosis of acute cholecystitis (7). In one study, 99% of patients diagnosed with acute cholecystitis had gallstones (7). Despite this, gallstones may also be an isolated finding in patients with RUQ pain secondary to another cause. Consequently, additional sonographic findings are incorporated to es-

tablish the diagnosis of acute cholecystitis. One such finding is the sonographic Murphy sign. It is elicited by identifying the gallbladder sonographically and then applying pressure. If pain occurs with this maneuver, a sonographic Murphy sign is present. Studies in the radiology literature suggest that it is one of the most sensitive findings for acute cholecystitis (7–9). In one study it was 86% sensitive for this diagnosis (9). In our study, it was present in 54 of the 109 limited RUQ ultrasounds, with a sensitivity of 75% for the pathologic diagnosis of acute cholecystitis. If it was present with or without gallstones, the sensitivity for acute cholecystitis improved to 82%. Of concern is that it was present in only 24 formal studies, with a sensitivity of 45% for the diagnosis of acute cholecystitis. Sensitivity was unchanged when the Murphy sign was an isolated finding or was present with gallstones. One possible explanation for this disparity between the ED and formal ultrasound is that the radiologist typically reads the printed version of the ultrasound rather than actually performing the ultrasound. Consequently, if the ultrasound technician fails to comment on this finding, it will go unnoticed by the radiologist. Our results suggest that not only can gallstones be accurately detected by EPs, but also that when compared to that of a radiologist, the ED sonographic Murphy sign improves sensitivity for the diagnosis of acute cholecystitis.

Other findings were inconsistently detected by EPs (Table 2). There are a number of explanations for the different accuracy with these findings compared to gallstones or the sonographic Murphy sign. First, they are less common than primary findings (gallstones,

Table 4. Sensitivity and Specificity for Detecting Gallstones by Level of Experience

	0–10	11–25	26–50	51–75	76–100	>100
Sensitivity	88% (15/17) (95% CI 0.64–0.99	100% (9/9) (95% CI 0.66–1.0)	100% (9/9) (95% CI 0.66–1.0)	100% (7/7) *	100% (3/3) *	100% (6/6) (95% CI 0.54–1.0)
Specificity	100% (22/22) (95% CI 0.85–1.0)	63% (5/8) (95% CI 0.24–0.91)	82% (9/11) (95% CI 0.48–0.98)	67% (2/3) *	100% (5/5) *	88% (7/8) (95% CI 0.47–0.99)
Toshiba 140A Only						
Sensitivity	91% (10/11) (95% CI 0.59–1.0)	100% (9/9) (95% CI 0.66–1.0)	100% (5/5) (95% CI 0.48–1.0)	100% (6/6) *	100% (2/2) *	100% (6/6) (95% CI 0.54–1.0)
Specificity	100% (19/19) (95% CI 0.82–1.0)	67% (2/3) (95% CI 0.09–0.99)	88% (7/8) (95% CI 0.47–0.99)	100% (2/2) *	100% (1/1) *	86% (6/7) (95% CI 0.42–0.99)

Top portion includes all patients and bottom reports those done using the Toshiba 140A.
* Confidence intervals were not calculated because more than one cell contained no entries.

Table 5. Patients with "False Positive" ED Ultrasounds

Patient #	Formal US	Emerg. Dept. US	Abnormal Labs	Admit	Surgery	Comments
50	Normal	Sludge, wall thickness	Alkaline phosphatase-508, bilirubin (total)-5.7	Yes	Yes	Pathologic report: chronic cholecystitis
55	Gallstones	Gallstones, wall thickness	WBC-13.7	Yes	Yes	Patient admitted for persistent abdominal pain. Pathologic report: chronic cholecystitis, wall thickness = 0.4 cm
91	Gallstones	Gallstones, dilated common bile duct	Amylase (total)-1167, Amylase (pancreatic)-1142	Yes	Yes	Pathologic report: chronic cholecystitis. Impacted stone in cystic duct

sonographic Murphy sign), so it is possible EPs were not as familiar with their sonographic appearance. Additionally, they are more difficult findings to identify, so they may have been beyond the scope of the training of the majority of physicians entering patients into this study. Unfortunately, EPs with more experience did not enter enough patients with secondary findings to determine if accuracy improved as experience increased.

One concern about EPs performing RUQ ultrasound is that significant pathology, such as wall thickness, pericholecystic fluid, air in the gallbladder wall, or ductal dilation, might be missed. In this study, three patients with wall thickness and two patients with common bile duct dilation went undetected by EPs. Review of these cases demonstrated that each had another sonographic finding, laboratory value, or persistent pain or vomiting that prompted admission to the hospital. There were also three patients whose ED ultrasound was labeled "falsely positive" because a particular finding was not identified during the formal ultrasound. These false-positives included two patients with a thickened gallbladder wall and one patient with a dilated common bile duct (Table 5). They also had abnormal laboratory values or persistent pain that prompted admission to the hospital. Each underwent surgery, and pathology reports confirmed the interpretation of the ED ultrasound. In part, these cases illustrate the limitations of using the formal ultrasound as a gold standard. They also demonstrate that misinterpretation of isolated sonographic findings, in these patients, resulted in no deleterious effects.

In addition to accuracy, time for ultrasound completion is an important issue for EPs. If an ultrasound examination takes too long to complete, EPs will be less inclined to incorporate it into their clinical practice. Schlager et al. demonstrated ED stay times to be shorter in patients evaluated by emergency ultrasound compared to a formal study (3). Patients evaluated in the ED had an average length of stay of 180 min compared to 223 min if they had an ultrasound from the Department of Radiology. In another study, length of stay was significantly decreased for patients receiving a RUQ ultrasound by an

EP compared to one from the Department of Radiology (10). Overall, length of stay was decreased by 6%. Patients discharged home had a 10% decrease in length of stay, and if their ultrasound was completed after hours, total ED time was decreased by 21%. Our data also show that focused RUQ ultrasound can be completed in a timely fashion. Eighty-three percent of the studies were completed in less than 10 min, and none took more than 20 min (Figure 1). We chose not to measure length of stay because each patient received both an ED and formal ultrasound. Despite this, our study demonstrates that focused RUQ ultrasound can be done quickly while also decreasing length of stay.

Another important issue for EPs is the impact training and experience have on performance. The model curriculum drafted by Matteer et al. suggests that completing 150 ultrasound examinations constitutes training in emergency ultrasound (11). On the other hand, the American Institute of Ultrasound in Medicine has developed guidelines for those without formal radiology training that include 100 h of continuing medical education and 500 examinations performed under the supervision of a qualified physician. No studies in the Emergency Medicine literature have specifically addressed the issue of training as it relates to accuracy for RUQ ultrasound. Schlagger et al. inferred that accuracy improves with greater experience, but no data were presented supporting this statement (3). In our study, training was standardized by requiring EPs to complete the curriculum offered through the Department of Emergency Medicine before entering patients. Level of experience of examiners at the time they enrolled patients was documented. Although sensitivity and specificity for detecting gallstones varied for physicians with experience of less than 25 previous examinations, sensitivity was 100% when experience was greater than this (Table 4). Specificity varied throughout the spectrum of experience, but when ultrasounds from the Toshiba 140A are considered, specificity was fairly consistent above a level of experience of 25 previous ultrasounds. Despite this, from our data it is not possible to conclusively establish a level of experience that cor-

relates with proficiency. Future studies will need to address this issue specifically.

There are several limitations to this study. First, non-consecutive patients were enrolled. Some patients were triaged to the WIC, whereas others received a formal ultrasound from the ED but were not enrolled in this study. We were not able to determine how many patients fell into each of these categories. Second, EPs chose which machine to use. From our data it appears that one machine was more accurate than the other for detecting gallstones, but this may have been a function of less experienced sonographers using the Capasee or because too few patients were studied with the use of this machine. Third, EPs were responsible for reporting results. This prevented us from verifying the number of previous examinations done by an EP or the exact time to complete an examination. We were also unable to determine how many patients each EP enrolled or whether accuracy improved with greater experience. Lastly, we relied on the formal ultrasound as our gold standard. It can be argued that the only way to confirm ultrasound findings is by pathology reports. For our patients this was not possible. Many were not admitted to the hospital and subsequently the minority had a cholecystectomy.

Ultrasound is a diagnostic modality in growing use by EPs. Our data demonstrate that EPs can accurately diagnose gallstones in a timely fashion. Furthermore, a positive sonographic Murphy sign during a focused ultrasound examination is more sensitive than that from the Department of Radiology for the diagnosis of acute cholecystitis. Future studies should examine how these findings can be applied to the evaluation of and clinical decisions about patients with suspected gallbladder disease presenting to the ED.

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