Ultrasonography by Emergency Physicians in Patients With Suspected Cholecystitis

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This article investigates the use of bedside abdominal ultrasonography (BAU) performed by emergency physicians (EPs) to screen patients for cholelithiasis and cholecystitis. In this prospective study EPs performed BAU on 116 patients. Agreement between BAU and formal abdominal ultrasound (FUS) performed in the radiology department for detecting cholelithiasis and cholecystitis was determined using Kappa statistics. Test characteristics of BAU for detecting cholelithiasis and acute cholecystitis were calculated. Agreement between BAU and FUS was 0.71 for cholelithiasis and 0.46 for acute cholecystitis. Test characteristics of BAU for cholelithiasis were sensitivity 92%, specificity 78%, positive predictive value (PPV) 86%, negative predictive value (NPV) 88%. Test characteristics of BAU for acute cholecystitis compared with clinical follow-up were sensitivity 91%, specificity 66%, PPV 70%, NPV 90%. BAU may be used to exclude cholelithiasis and is sensitive for cholecystitis. However, when EPs with limited experience identify cholecystitis a confirmatory test is warranted before cholecystectomy. (Am J Emerg Med 2001;19:32-36. Copyright © 2001 by W.B. Saunders Company)

Recently, ultrasound (US) has been performed by emergency physicians (EPs) with limited sonographic training to assist in the diagnosis of a wide variety of conditions including ectopic pregnancy, hemoperitoneum, pericardial effusion, and hemothorax.[1-5] The advantage of using bedside emergency US in patients with suspected biliary colic is that it can result in earlier diagnosis and allow for more rapid administration of pain medication. It may also obviate the need for further tests in certain patients. In a previous study of a small number of patients, bedside US performed by EPs has been shown to be accurate for the detection of cholelithiasis.[3] However, there are no studies investigating the use of emergency bedside US for detecting the secondary findings of cholecystitis such as the sonographic Murphy's sign and for predicting acute cholecystitis.

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The present study investigates the use of bedside abdominal US (BAU) performed by emergency physicians with limited sonographic training and experience for detecting cholelithiasis and acute cholecystitis shortly after the introduction of an US machine into the ED. There were 2 study objectives. The first was to evaluate the agreement between BAU and formal abdominal ultrasound (FUS) performed in the department of radiology and interpreted by a radiologist for detecting cholelithiasis and acute cholecystitis in patients with suspected biliary colic. The second objective was to determine the test characteristics of BAU and FUS for detecting acute cholecystitis.

MATERIALS AND METHODS

The study was performed at an urban university hospital in an ED with over 66,000 annual patient visits, 3 months after the introduction of an US machine into the ED. The emergency sonographers on duty in the ED were 15 full-time attending EPs in the Department of Emergency Medicine. To be able to enter patients into the study, the emergency sonographer first had to complete an orientation course. This course consisted of a 2-hour didactic session and three hours of hands-on, supervised training, that included basic ultrasound principles, technical use of the equipment, probe positioning, and identification of the gallbladder, gallstones, and a sonographic Murphy's sign.

The patient population was a convenience sample of patients ≥18 years old who presented to the ED between November 9, 1995 and October 12, 1997 with abdominal or epigastric pain and were suspected of having biliary colic. Patients were eligible if a formal abdominal US performed in the radiology suite and interpreted by a radiologist was ordered to determine the presence or absence of cholelithiasis and acute cholecystitis. The decision to order the FUS was based on the clinical history and physical examination. Entry into the study was determined by the emergency sonographer. All patients who underwent BAU during the study period were included in the study.

Once the patient was entered, the emergency sonographer performed an examination of the gallbladder using an Aloka Echo Camera SSD-500 or a Siemens Sonoline Prima US machine with a 3.5-MHz probe. The sonographer recorded the presence or absence of cholelithiasis and of a sonographic Murphy's sign before FUS was performed. The sonographic Murphy sign was considered positive (SM+) when the site of maximal tenderness corresponded to the location of the gallbladder determined by the US transducer and negative (SM−) when the maximal tenderness was diffuse or present at a site distant from the gallbladder.[6-10]

Patients then underwent FUS which was interpreted by a staff radiologist who was blinded to the results of the emergency US. Each patient had the following information recorded by the emergency sonographer: age, sex, and the results of the BAU. The BAU was considered positive for acute cholecystitis if gallstones and an SM were present, and the BAU was considered negative if both findings were absent. If only one sign was present (gallstone or SM), but not both, the BAU was considered indeterminate. The FUS was considered positive for acute cholecystitis if gallstones were present and if there was pericholecystic fluid, gallbladder wall thickening, common bile duct dilatation, or a positive sonographic Murphy's sign.

Clinical follow-up was used as the gold standard. This was determined as follows. Patient follow-up was performed which included a review of the computerized medical records for operative reports, surgical pathology, and other diagnostic procedures to determine if cholecystectomy was subsequently performed within 1 month of the initial ED visit, and if there was pathologic evidence of acute cholecystitis. Telephone follow-up was also performed at least 1 month after the ED visit in all study patients who did not undergo cholecystectomy to ensure that the diagnosis of acute cholecystitis was not missed. Any patient who underwent cholecystectomy within 1 month of the ED visit and had pathologic evidence of inflammation was considered to have acute cholecystitis. If surgery was not performed, any patient who did not have any further episodes of abdominal pain and did not present to an ED or physician's office with the diagnosis of acute cholecystitis within a month was considered to not have acute cholecystitis.

Kappa statistics were used to determine the agreement between BAU and FUS for the presence or absence of cholelithiasis and acute cholecystitis. The test characteristics (sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy) of BAU and FUS for detecting cholelithiasis and acute cholecystitis were calculated using clinical follow-up as the gold standard. The 95% confidence intervals were adjusted for clustering effect. McNemar's test was used to compare the accuracy of BAU and FUS for detecting acute cholecystitis.

The study was approved by the Institutional Review Board's Subcommittee on Human Studies. Verbal consent was obtained after the protocol was briefly explained to the patients and before the administration of analgesia.

RESULTS

Fifteen EPs were eligible to enter patients. Table 1 shows the characteristics of the emergency sonographers, and includes investigator status, prior training, the number of abdominal USs performed before the start of the study, and the number of examinations performed by each operator during the study. Prior additional training varied among emergency sonographers, some having taken courses such as the 2-day (21.25 hours) course developed by the Society for Academic Emergency Medicine's (SAEM) Ultrasound Task Force and the Medical College of Wisconsin (Course 1) or the Advanced Health Education Center's 3-day (27 hours) course (Course 2). Twelve of the attending physicians had experience with only 50 or fewer abdominal US examinations before the start of the study. Only 3 investigators had extensive previous experience with US (>100 examinations). We intentionally set the study in an ED where the emergency sonographers performing the exams had limited experience and were on duty when they entered patients, to best simulate the conditions experienced when implementing ultrasound in a busy ED.

TABLE 1. Operator Experience Before the Start of the Study

Operator	Prior Experience (No. of Abdominal Examinations Performed)	Prior Training	No. of Patients Entered in Study
1	7	None	5
2	8	None	3
3	9	None	10
4	10	None	1
5	12	None	5
6	20	None	1
7	22	None	5
8	35	None	5
9	45	None	3
10	50	None	9
11	50	None	3
12	50	Course 1	9
13*	110	Course 1	13
14*	175	Course 2	37
15*	450	Course 2	7

* Denotes investigator.

During the study period, 116 patients were entered into the study. Eighty-three patients (72%) were women. The mean age was 49. Sixty-nine patients (60%) had cholelithiasis by FUS, and 70 patients (64%) had cholelithiasis by BAU. Eighty-eight patients were examined with the Aloka SSD-500 machine and 28 with the Siemens Sonoline Prima. Six patients were excluded from further analysis because the gallbladder could not be visualized by BAU. Two of these patients had cholelithiasis and cholecystitis by FUS and clinical follow-up. The other four excluded patients had FUS and clinical follow-up that were negative for cholelithiasis and cholecystitis.

Table 2 shows the BAU results for cholelithiasis compared with FUS results. The degree of agreement, as measured by Kappa statistics, was 0.71 (95% CI 0.58 to 0.85) between BAU and FUS. All patients with cholelithiasis on FUS had this finding confirmed by clinical follow-up. Test characteristics of BAU for cholelithiasis were sensitivity 92% (95% CI 0.73 to 1.0), specificity 78% (95% CI 0.61 to 0.93), PPV 86% (95% CI 0.57 to 1.0), NPV 88% (95% CI 0.67 to 1.0), and accuracy 86% (95% CI 0.72 to 1.0). Table 3 shows the BAU results for acute cholecystitis compared with FUS results. Forty patients had only one sign present (gallstone or SM), but not both on BAU. In these patients the BAU was considered indeterminate, and these patients were excluded from this part of the analysis. Seventy-six patients had either gallstone present and SM+ or gallstone absent and SM− by BAU. The Kappa statistic for the agreement between BAU and FUS for acute cholecystitis in these patients was 0.46 (95% CI 0.29 to 0.62).

Tables 4 and 5 show the results for BAU and FUS compared with clinical follow-up for acute cholecystitis for the 76 patients who had sonographic Murphy's sign and cholelithiasis both present or both absent. The test characteristics for the ability of BAU to detect acute cholecystitis

TABLE 2. BAU Results for Cholelithiasis Compared With FUS Interpreted by a Radiologist

	FUS		
BAU	Positive	Negative	Total
Positive	60	10	70
Negative	5	35	40
Gallbladder			
Not visualized	4	2	6
Total	69	47	116

with clinical follow-up as the gold standard were sensitivity 91% (95% CI 0.62 to 1.0), specificity 66% (95% CI 0.38 to 0.95), PPV 70% (95% CI 0.37 to 1.0), NPV 90% (95% CI 0.67 to 1.0), and accuracy 78% (95% CI 0.60 to 0.94). We also calculated the test characteristics of BAU for the entire study population (including the indeterminate BAU results) in two other ways. If the indeterminate BAU scans were considered as BAU negative then the test characteristics were: sensitivity 60%, specificity 78%, PPV 70%, NPV 70%, and accuracy 70%. If the indeterminate BAU scans were considered as BAU positive then the test characteristics were: sensitivity 94%, specificity 43%, PPV 58%, NPV 90%, and accuracy 66%. The test characteristics for the ability of FUS to detect acute cholecystitis with clinical follow-up as the gold standard for the 76 patients with definitive BAU results were sensitivity 69% (95% CI 0.51 to 0.83), specificity 95% (95% CI 0.83 to 0.99), PPV 92% (95% CI 0.75 to 0.99), NPV 78% (95% CI 0.64 to 0.88), and accuracy 83% (95% CI 0.73 to 0.91). The test characteristics of FUS for the entire study population were sensitivity 55%, specificity 97%, PPV 94%, NPV 72%, and accuracy 78%. The difference in terms of accuracy between the two tests was not statistically significant in all comparisons.

Thirty patients in the study had SM− and no cholelithiasis. If FUS was not ordered in these patients, this would have resulted in a 26% (95% CI 0.18 to 0.35) reduction in use of US ordered from the ED at a cost of missing one patient with acute cholecystitis that would have been detected by FUS.

DISCUSSION

Suspected biliary colic is an ideal clinical situation to incorporate emergency bedside US. There is a potential to facilitate early treatment with analgesia and decrease the length of stay in the ED. The results of this study suggest

TABLE 3. BAU Results for Acute Cholecystitis Compared With FUS Interpreted by a Radiologist

	FUS		
BAU	Positive	Negative	Total
SM+/GS+	25	21	46
SM+/GS−	0	10	10
SM+/GS not visualized	2	0	2
SM−/GS+	3	21	24
SM−/GS−	1	29	30
SM−/GS not visualized	0	4	4
Total	31	85	116

Abbreviations: SM, sonographic Murphy's sign; GS, gallstone.

TABLE 4. BAU Results for Acute Cholecystitis Compared With Clinical Follow-Up for Patients With Definitive BAU Results

	Follow-Up		
BAU	Positive	Negative	Total
Positive	32	14	46
Negative	3	27	30
Total	35	41	76

Abbreviations: SM, sonographic Murphy's sign; GS, gallstone.

that bedside US can be used to rapidly exclude the diagnosis of cholecystitis. In patients with a negative bedside US (SM− and no cholelithiasis), an alternate diagnosis can be entertained. Our data show that if US were relied on to screen patients there would have been a 26% decrease (30/116 patients) in the use of FUS ordered from the ED; and in only 1 of the 30 patients, the diagnosis of cholecystitis would have been missed by BAU but detected by FUS. Because it only takes a few minutes and can be performed along with the physical examination, the bedside US also saves precious time by obviating the need for an FUS that may require a technician and radiologist to come in from home. The other advantage to using bedside emergency US in patients with flank and abdominal pain is that if the gallbladder examination is negative, it can be used to evaluate for other life-threatening disorders such as abdominal aortic aneurysms.[11] Young, healthy patients with epigastric pain who have normal laboratory studies and a negative bedside US may be discharged without having to wait for formal radiologic tests. Although this is an ideal use of bedside emergency US, there is scant data in the emergency medicine literature on the accuracy of emergency US to detect cholelithiasis or cholecystitis. An initial report demonstrated a sensitivity of 86%, a specificity of 97%, a PPV of 97%, and an NPV of 85% when the emergency US diagnosis by EPs was compared with formal US and clinical follow-up as the gold standard.[3]

The present study is the first to describe the use of bedside US performed by EPs for the sole purpose of detecting cholelithiasis or acute cholecystitis. The study began 3 months after a new US machine was introduced into the ED. However, it shows that there is good agreement between bedside emergency US and formal US interpreted by a radiologist for the detection of cholelithiasis (Kappa = 0.71). The gallbladder is a technically easy area to image with US attributable to the acoustic window provided by the liver. Furthermore, gallstones are usually readily apparent because they are echogenic and cast an acoustic shadow. Imaging for gallstones is less subjective and technically easier than detecting the secondary characteristics of cho-

TABLE 5. FUS Interpreted by a Radiologist Results for Acute Cholecystitis Compared With Clinical Follow-Up for Patients With Definitive BAU Results

	Follow-Up		
FUS	Positive	Negative	Total
Positive	24	2	26
Negative	11	39	50
Total	35	41	76

lecystitis, such as gallbladder wall size or common bile duct size. The test characteristics of FUS for detecting cholelithiasis are well reported in the radiology literature. The sensitivity ranges from 84% to 98% and the specificity ranges from 90% to 99%.[12-23]

The sonographic Murphy's sign was chosen to be the focus of the BAU examination for acute cholecystitis because it is one of the most sensitive indicators of acute cholecystitis and is technically simple to elicit. The definition of the sonographic Murphy's (positive when the site of maximal tenderness corresponded to the location of the gallbladder determined by the US transducer) we used has been described in the radiologic literature.[6-10] This is different from the strict definition of the clinical Murphy's sign that is used during the physical examination of the gallbladder (inhibition of inspiration on palpation of the gallbladder). We found that the sonographic Murphy's sign was easy for the EPs to learn and perform as part of the sonographic examination of the gallbladder.

The agreement between BAU and FUS for the diagnosis of acute cholecystitis was fair (Kappa = 0.46). There are several potential reasons for the lack of agreement between the two diagnostic modalities for acute cholecystitis. The emergency sonographers had less experience with US than the radiologists, and used less expensive equipment with lower resolution. The radiologists may have been more cautious with their interpretations and may have committed less frequently to the diagnosis of cholecystitis because they are less influenced by the clinical presentation than the emergency sonographers. The emergency sonographers may have a higher sensitivity because they are at the bedside and are aware of the clinical history and physical examination. Because the EP was aware of the clinical presentation, in a patient with a clinical presentation very suggestive of acute cholecystitis, the EP may have overcalled acute cholecystitis if there was a gallstone but no sonographic Murphy's sign. Furthermore, there was a subgroup of patients in whom the initial BAU was positive for gallstones and sonographic Murphy's sign who went on to have an FUS that was positive for gallstones but negative for acute cholecystitis. This may have resulted from the administration of pain medications or the fact that the patient did not fit the stricter radiologic criteria for acute cholecystitis (gallbladder wall thickening, common bile duct dilatation, pericholecystic fluid). Many of these patients had pathologic evidence of cholecystitis after cholecystectomy. The apparent lower specificity of BAU for acute cholecystitis was probably caused by the fact that the FUS definition of acute cholecystitis included four secondary findings that were relatively objective (gallbladder wall thickening, common bile duct dilatation, pericholecystic fluid, and the sonographic Murphy's sign) versus the one finding of the sonographic Murphy's sign used by the EPs. The more findings that were required to make the test positive yielded a lower sensitivity, but higher specificity of FUS.

Although the agreement between BAU and FUS for acute cholecystitis was fair, we were unable to detect a difference in sensitivity. Bedside abdominal US performed by an EP was useful in decreasing the likelihood of cholecystitis when it showed the absence of cholelithiasis and a sonographic Murphy's sign (NPV of 90%). Considering the relatively high prevalence of cholecystitis (46%) in the study population, the NPV may even be higher in a different population with a lower pretest probability of cholecystitis. This suggests that for some patients a negative BAU may obviate the need for a formal US in the radiology suite at the time of the ED evaluation.

The predictive values of the BAU findings of cholelithiasis and a sonographic Murphy's sign for acute cholecystitis are similar to those reported in the radiology literature. In the hands of the radiologists, a sonographic Murphy's sign has been reported to have an accuracy of 65% to 85%, specificity of 40%, and a sensitivity of 84% for predicting acute cholecystitis.[6-10,24] Combining the sonographic Murphy's sign with the presence of gallstones yields a PPV of 92% and a NPV of 95% for diagnosing cholecystitis.[7,8] In the radiology literature, FUS has a sensitivity of 88% to 94% and a specificity of 78% to 80% for detecting cholecystitis based on the secondary findings of common bile duct dilatation, pericholecystic fluid, gallbladder wall thickening, and the sonographic Murphy's sign.[12]

There are several limitations to our study. We used a convenience sample because the emergency sonographers were on duty and could not enter all patients meeting the inclusion criteria. This raises the possibility of selection bias. The emergency sonographers may have avoided entering patients in whom they felt the gallbladder would be difficult to visualize. However, we felt that this best represented the actual use of an emergency US in a busy ED. BAU performed by an EP is a screening examination, and we wanted to measure the test characteristics in as realistic a setting as possible where the EP would select patients most likely to benefit from the procedure. The purpose was not to compete with or replace formal US but to determine if BAU could be used effectively. Patients were entered even when the gallbladder could not be visualized; and the rate of gallbladder nonvisualization was low (5% of patients).

The BAU findings that were the basis for the diagnosis of acute cholecystitis were different than the findings on FUS that defined acute cholecystitis. This is justified, as BAU is a different study than FUS, and the limited examination is easily taught and can be performed in less than 5 minutes. We felt that the sonographic Murphy's sign is simple and technically easy to detect, and therefore would be appropriate for EPs with limited sonographic experience and training to use as a secondary finding of acute cholecystitis. Other findings such as gallbladder wall thickening and common bile duct dilatation require more training and expertise. Future studies are needed to evaluate the accuracy of these other findings in the hands of emergency sonographers.

We performed the analysis of the test characteristics of BAU for detecting acute cholecystitis in several ways. In the first calculation, patients with either gallstone present and sonographic Murphy's absent, or gallstone absent and sonographic Murphy's present were excluded. We performed the analysis in this fashion, as BAU is a screening study directed at decreasing the use of FUS, not replacing the study. The clinician needs to know how this technique can be used to evaluate patients with suspected biliary colic. An indeterminate result requires further study, as does the case in which gallstone and sonographic Murphy's sign are present. Because of the low specificity, a confirmatory test is re-

quired before cholecystectomy, at least with levels of experience comparable to our emergency sonographers. In a small percentage of patients, the gallbladder could not be visualized. For these patients, FUS is also recommended. We also performed the analysis including the indeterminate BAU scans as positive and as negative to show the true range of the test characteristics.

Another limitation is that the gold standard (clinical follow-up and operative findings) may not have been 100% accurate. In certain patients cholecystectomy was not performed until days or even weeks after the initial presentation. We chose the gold standard of cholecystectomy within a month with pathologic evidence of cholecystitis and clinical follow-up as the gold standard because this is the clinically important information needed to manage and refer these patients. The importance of making the diagnosis of acute cholecystitis lies in detecting patients who need treatment and referral to a surgeon for cholecystectomy. Unfortunately, there is no perfect gold standard and it is not feasible to obtain immediate surgical pathology on all patients. In consideration of this, the records of all study patients were reviewed and telephone follow-up was performed to determine if a patient returned to our ED or another hospital with continued symptoms and underwent another diagnostic test that revealed cholelithiasis or acute cholecystitis. Because of the limitations of the gold standard, we used Kappa statistics to report the agreement between BAU and FUS, which is currently the initial diagnostic modality for patients with suspected biliary colic in most centers.

Another limitation is that the emergency sonographers had varying degrees of experience at the start of the study. Twelve of the emergency sonographers had minimal experience ($\leq$50 examinations) before they started entering patients. Only three emergency sonographers had previous experience performing greater than 100 examinations. This distribution reflects the US experience of a group of EPs starting to use US in the ED. This study examines the early phase of US in the ED and cannot predict changes in physician accuracy with increased use and experience. We anticipate that the accuracy will be significantly higher with increased experience. Learning curves documenting how many emergency US examinations should be performed before the operator achieves a reasonable accuracy have yet to be determined.

Future studies are needed to assess the consequences of incorporating emergency US into a clinical pathway for patients with suspected biliary colic. This may lead to a reduction in the cost of care by a decrease in the use of formal imaging studies and a decrease in the total time spent in the ED. Emergency abdominal US may also improve the quality of care and patient satisfaction by decreasing the ED length of stay and the time to administration of analgesia.

In conclusion, this study shows that BAU performed by EPs may be an effective method of excluding the diagnosis of cholelithiasis and may be a sensitive tool for detecting acute cholecystitis in patients with abdominal pain. However, when EPs with limited experience identify cholecystitis (using gallstones and a sonographic Murphy's sign as criteria) a confirmatory test should be performed before cholecystectomy.

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