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A Prospective Evaluation of Emergency Department Bedside Ultrasonography for the Detection of Acute Cholecystitis

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Study objective: We assess the diagnostic accuracy of emergency physician–performed bedside ultrasonography and radiology ultrasonography for the detection of cholecystitis, as determined by surgical pathology.

Methods: We conducted a prospective, observational study on a convenience sample of emergency department (ED) patients presenting with suspected cholecystitis from May 2006 to February 2008. Bedside gallbladder ultrasonography was performed by emergency medicine residents and attending physicians at an academic institution. Emergency physicians assessed for gallstones, a sonographic Murphy's sign, gallbladder wall thickness, and pericholecystic fluid, and the findings were recorded before formal imaging. The test characteristics of bedside and radiology ultrasonography were determined by comparing their respective results to pathology reports and clinical follow-up at 2 weeks.

Results: Of the 193 patients enrolled, 189 were evaluated by bedside ultrasonography. Forty-three emergency physicians conducted the ultrasonography, and each physician performed a median of 2 tests. After the bedside ultrasonography, 125 patients received additional radiology ultrasonography. Twenty-six patients underwent cholecystectomy, 23 had pathology-confirmed cholecystitis, and 163 were discharged home to follow-up. Twenty-five were excluded (23 lost to follow-up and 2 unavailable pathology). The test characteristics of bedside ultrasonography were sensitivity 87% (95% confidence interval [CI] 66% to 97%), specificity 82% (95% CI 74% to 88%), positive likelihood ratio 4.7 (95% CI 3.2 to 6.9), negative likelihood ratio 0.16 (95% CI 0.06 to 0.46), positive predictive value 44% (95% CI 29% to 59%), and negative predictive value 97% (95% CI 93% to 99%). The test characteristics of radiology ultrasonography were sensitivity 83% (95% CI 61% to 95%), specificity 86% (95% CI 77% to 92%), positive likelihood ratio 5.7 (95% CI 3.3 to 9.8), negative likelihood ratio 0.20 (95% CI 0.08 to 0.50), positive predictive value 59% (95% CI 41% to 76%), and negative predictive value 95% (95% CI 88% to 99%).

Conclusion: The test characteristics of emergency physician–performed bedside ultrasonography for the detection of acute cholecystitis are similar to the test characteristics of radiology ultrasonography. Patients with a negative ED bedside ultrasonography result are unlikely to require cholecystectomy or admission for cholecystitis within 2 weeks of their initial presentation. [Ann Emerg Med. 2010;56:114-122.]

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INTRODUCTION

Background

In the United States, it is estimated that 20 million people have gallbladder disease, and the emergency physician is frequently confronted with patients with abdominal pain suspicious for acute cholecystitis.[1] Unfortunately, physical examination and laboratory evaluation are poorly sensitive and specific for this diagnosis.[2] Because clinical variables are often unreliable, radiology-performed ultrasonography is a common first step in emergency department (ED) patients presenting with a possibility of acute cholecystitis. However, this imaging modality is not always promptly available and requires transport outside of the ED. Also, radiologists may request a period of fasting for patients before ultrasonography, which is not always feasible in a busy ED. Because of these limitations, emergency physicians are increasingly exploring the utility of bedside gallbladder ultrasonography.[3-6] In a large retrospective study, patients who received bedside ultrasonography for suspected biliary colic had a significantly shorter length of stay than ED patients undergoing radiology ultrasonography, especially during off hours.[7] Furthermore, several studies comparing bedside ultrasonography to radiology ultrasonography as the criterion standard have shown that appropriately trained emergency physicians accurately detect gallstones.[8-15]

Importance

Because reader agreement studies comparing bedside ultrasonography to radiology ultrasonography test interobserver

Editor's Capsule Summary

What is already known on this topic
Radiology-performed biliary ultrasonography is frequently used to assess patients with suspected cholecystitis but is not always available and can increase length of stay. Bedside ultrasonography, performed by emergency physicians, avoids these problems as long as image quality and image interpretation equal that of the radiologists.

What question this study addressed
This 164-patient, 43-emergency-physician study examined whether the test characteristics of emergency physician–performed bedside ultrasonography equal those achieved by radiologists.

What this study adds to our knowledge
In this small, single-site study, emergency physicians' and radiologists' performance was similar.

How this might change clinical practice
If validated in other settings, emergency physician–performed bedside ultrasonography could offer an alternative initial means of assessing emergency department patients with suspected acute cholecystitis.

reliability only and do not measure clinically useful outcome parameters, the test characteristics (sensitivity, specificity, predictive values, and likelihood ratios) of bedside ultrasonography for the diagnosis of acute cholecystitis remain uncertain. Without more data to support its use, emergency physicians may be hesitant to utilize bedside ultrasonography for medical decisionmaking and patient disposition.

Goals of This Investigation

The primary objective of this study was to determine the test characteristics of bedside ultrasonography, as well as radiology ultrasonography, for the detection of acute cholecystitis as defined by surgical pathology. The secondary objective was to determine the test characteristics of individual ultrasonographic findings to detect cholecystitis, including gallbladder wall thickening, pericholecystic fluid, and a sonographic Murphy's sign.

MATERIALS AND METHODS

Study Design

This was a single-setting, prospective, observational study designed to assess the diagnostic accuracy of ED bedside and radiology ultrasonography for the detection of cholecystitis as determined by surgical pathology. The study was approved by the institutional review board.

Setting

We conducted the study in an urban university hospital ED that supports a residency program, an emergency ultrasonography fellowship, and an annual patient census of 36,000. Ten of 21 faculty emergency physicians at this institution are registered diagnostic medical sonographers certified in ultrasonography of the abdomen, and the emergency medicine residents must complete 150 proctored gallbladder examinations before graduation.

Selection of Participants

We enrolled a convenience sample of adult patients between May 2006 and February 2008. Research assistants, on staff in the ED 7 days a week from 8 AM to 12 AM, selected all subjects for participation. Because of research assistant nonavailability during off hours, no patient was enrolled between midnight and 8 AM. There were 14 full-time attending physicians, 6 ultrasonography fellows, 1 disaster medicine fellow, and 36 residents eligible to perform bedside ultrasonography during the study period.

Inclusion criteria were patients aged 18 years and older, presenting to the ED with suspected cholecystitis. The research assistant monitored the ED electronic grease board for chief complaints consistent with acute cholecystitis, which included right upper quadrant abdominal pain, epigastric pain, vomiting, or fever. Once a potential study subject was identified on the grease board, the research assistant approached the treating emergency physicians (resident or attending) and asked whether they were concerned about possible cholecystitis. If the physician reported a possibility of cholecystitis after the clinical evaluation, the research assistant enrolled the patient. Patients were excluded from final data analysis if they were lost to follow-up or if there was no pathology report available.

Interventions

After informed consent was obtained, all patients underwent bedside gallbladder ultrasonography by the treating emergency physician. Residents, attending physicians, and fellows with various levels of training conducted the bedside ultrasonography according to their usual practice and did not receive additional training for study purposes. Occasionally, a senior physician assisted a junior resident with the bedside ultrasonography. If this occurred, the bedside ultrasonography was classified on the data sheet as being performed by the senior physician. The emergency physicians performed the study with their choice of the Sonosite Micromaxx (Bothell, WA) or Toshiba Xario (Tustin, CA). Patient positioning and probe selection were left to the discretion of the emergency physician. Although it was not mandated in the protocol, all bedside ultrasonography was performed with a low-frequency bandwidth transducer (phased array, large footprint curvilinear array, or microconvex array).

The emergency physician assessed for cholelithiasis, gallbladder wall thickening, pericholecystic fluid, and a sonographic Murphy's sign on the bedside ultrasonography (Figures 1 to 3). Before any radiology imaging, all findings were

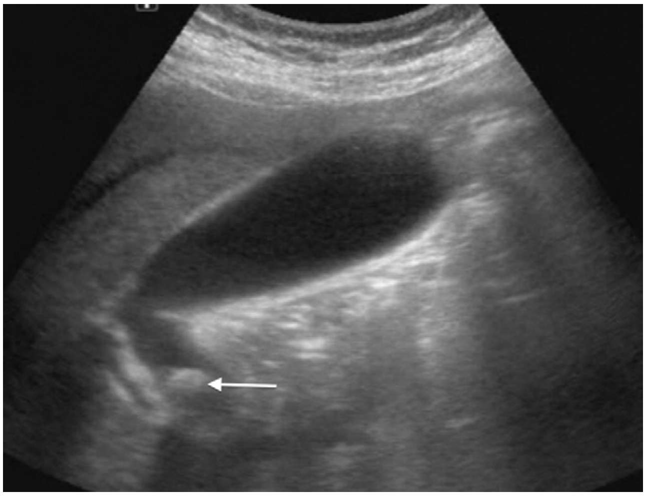

Figure 1. Long-axis view of the gallbladder demonstrates a large gallstone impacted in the neck (white arrow), without evidence of wall thickening or pericholecystic fluid. The patient had a sonographic Murphy's sign.

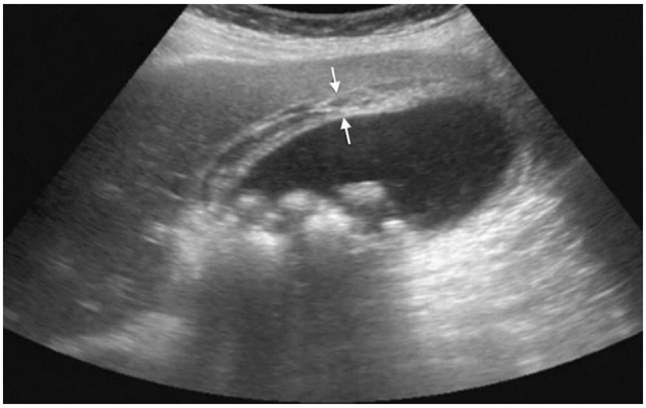

Figure 2. Long-axis view of a distended gallbladder reveals multiple gallstones with shadowing and significant gallbladder wall thickening. Note the appearance of the gallbladder wall with multiple alternating hyperechoic and hypoechoic layers (white arrows).

Figure 3. In the same patient as discussed in Figure 2, a transverse view near the fundus of the gallbladder is remarkable for a wedge of pericholecystic fluid (white arrow).

recorded by the research assistant on a structured data collection sheet. Serial bedside ultrasonography was not specifically prohibited, but only the results of the initial ultrasonography were used for final data analysis. Further patient management was determined by the attending emergency physician and included radiology ultrasonography (Philips/ATL 5500 SonoCT; Philips, Bothell, WA), surgical consultation and admission, or discharge home with outpatient follow-up. Radiology ultrasonography personnel were blinded to the bedside ultrasonography results. Bedside ultrasonography and radiology ultrasonography were compared to the criterion standard of surgical pathology reports and clinical follow-up.

For the clinical follow-up, patients discharged home from the ED were contacted once by telephone at 2 weeks to determine whether they had required cholecystectomy or admission to the hospital for cholecystitis since their initial visit. If patients could not be reached at 2 weeks, telephone calls continued monthly for up to 1 year. If patients were still unable to be contacted after 1 year, they were excluded from final data analysis. Research assistants examined the electronic medical records of all patients discharged from the ED. The research assistants specifically searched operative reports for evidence of cholecystectomy or for hospitalizations with an admitting diagnosis of cholecystitis. The death registry was also queried for all patients lost to follow-up.

Outcome Measures

The primary outcome measure was acute cholecystitis as determined by surgical pathology. An absence of cholecystitis was defined by a negative pathology report or an unremarkable clinical follow-up. The patient was considered to have an unremarkable clinical follow-up if he or she did not require cholecystectomy or admission to the hospital for cholecystitis within 2 weeks of the ED visit. If patients underwent a scheduled cholecystectomy more than 2 weeks after discharge, this was considered an elective surgery for biliary colic, and these cases were analyzed as negative results. If after operative intervention the pathologist reported an absence of gallstones, isolated choledocholithiasis, or "cholelithiasis without cholecystitis," these were also analyzed as negative results.

We defined bedside and radiology ultrasonography results as positive for acute cholecystitis if they demonstrated cholelithiasis plus any one of the following secondary findings: wall thickening greater than 3 mm, pericholecystic fluid, or a sonographic Murphy's sign. Although each secondary finding incrementally increases the diagnostic certainty, we required only the presence of one additional finding to define a positive test result because wall thickening, pericholecystic fluid, and a sonographic Murphy's sign may not be simultaneously present in cases of proven cholecystitis.[16] Review of the radiology literature shows that if the patient demonstrates both gallstones and a sonographic Murphy's sign on ultrasonography, the positive predictive value for acute cholecystitis is 92.2%. If that same patient also has gallbladder wall thickening, the positive predictive value only marginally increases, to 93.8%, at the expense of sensitivity.[16] Because we value potential increases in sensitivity, rather than decreases in specificity, we chose gallstones plus the addition of any other secondary finding as a positive ultrasonographic result. We did not intend to specifically capture cases of acalculous cholecystitis.

Primary Data Analysis

The data were entered in an Excel spreadsheet (Microsoft, Redmond, WA) and analyzed with Stata (version 10.1; StataCorp, College Station, TX). For the primary and secondary objectives, the bedside and radiology ultrasonography was compared with the criterion standard with conventional diagnostic test statistics. Exact binomial confidence intervals (CIs) were calculated for sensitivity, specificity, predictive values, and likelihood ratios.

We considered that this study might be prone to the unit of analysis error (that the correct unit of analysis is the physician performing the ultrasonography, not the patient on whom the ultrasonography was performed), because ultrasonographic tests performed and evaluated by an individual physician may not be independent of one another.[17-19] To evaluate for significant clustering at the physician level, we calculated the intraclass correlation coefficient among the physicians who examined patients both with and without cholecystitis, using a random-effects analysis of variance procedure that limits the intraclass correlation coefficient to the range 0 to 1. In addition, we conducted an analysis with the provider as the unit of analysis, restricted to physicians who examined patients both with and without cholecystitis. We report sensitivity and specificity obtained from standard fixed-effects logistic regression to that obtained from random-effects logistic regression, controlling for clustering by physician.[20]

We also performed a sensitivity analysis to address potential biases in our study. To evaluate the possibility that patients lost to follow-up may have presented with cholecystitis to another hospital, we made the assumption that we missed several cases of disease in this group. Because of the low overall prevalence of cholecystitis in our study, we believe that analyzing all patients lost to follow-up as false-negative patients would be unnecessarily conservative. Instead, we assumed that the lost to follow-up group had the same prevalence of cholecystitis as the overall study population, and we recalculated the test characteristics of bedside ultrasonography accordingly. Finally, to address the possibility that advanced operator experience may have affected our results, we planned to exclude all scans performed by registered diagnostic medical sonographer–certified physicians and evaluate the performance of the junior residents as a group.

Table 1. Descriptive statistics of the study population (n=164).

Characteristics	No. (%)
Female	119 (73)
Hispanic	97 (59)
White	47 (29)
Asian	17 (10)
Black	3 (2)
Age, y, median	36
Interquartile range, y	26–46
Range, y	18–87

RESULTS

The research assistants identified and approached 196 potential study subjects during their duty hours. Three patients chose not to participate, leaving 193 enrolled. Of the 193 enrolled, 2 patients did not receive bedside ultrasonography for unclear reasons and were excluded. Two patients were also excluded because an off-service medical student performed the bedside ultrasonography without the supervision of the emergency physician. The remaining 189 patients underwent bedside ultrasonography by the treating emergency physician, and 125 of these received additional radiology ultrasonography. Twenty-five (13%) patients were excluded after the bedside ultrasonography (23 lost to follow-up and 2 unavailable pathology reports), leaving 164 for final data analysis. Descriptive statistics of the study population are reported in Table 1. Forty-three emergency physicians conducted the bedside ultrasonography, and each physician performed a median of 2 tests (Figure 4).

Twenty-six patients went to the operating room for emergency cholecystectomy. All 26 patients had radiology ultrasonography before intervention, and in this group there were 23 cases of pathology-confirmed acute cholecystitis (overall prevalence 14%). Of the remaining 3 cases, 1 pathology report revealed "cholelithiasis without evidence of cholecystitis," and in the other 2, the pathology findings were unavailable. In both cases of lost pathology reports, the bedside ultrasonography and radiology ultrasonography demonstrated concordant findings. In the first case of a lost pathology report, bedside and radiology ultrasonography demonstrated isolated gallstones without secondary findings. For insurance reasons, the patient was transferred to an outside institution, and the hospital records were not available for review. However, we were able to contact the patient at 2 weeks, and he reported that he underwent cholecystectomy during his hospital stay, without complications. In the second case of a lost pathology report, the bedside and radiology ultrasonography and a computed tomography scan were positive for acute cholecystitis, but the findings from the pathologist were not documented in the electronic record, for unclear reasons. The surgeons, however,

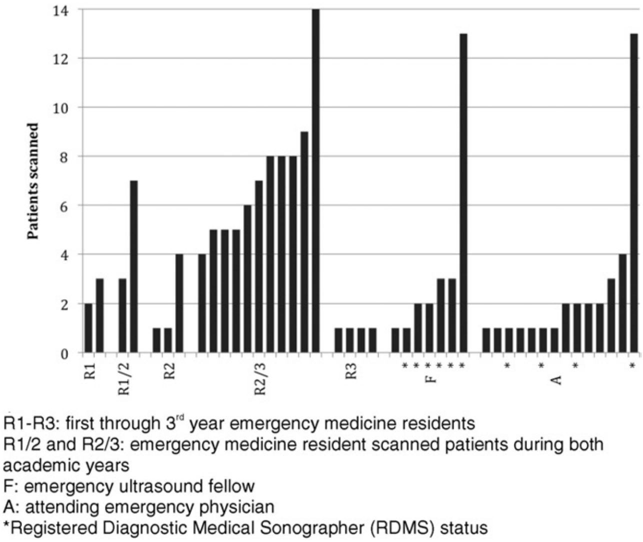

Figure 4. Number of patients scanned per physician, by experience level and registered diagnostic medical sonographer status.

dictated in the operative report that the gallbladder appeared grossly inflamed. Because pathology reports could not be located in these instances, both of these cases were excluded from data analysis.

One hundred sixty-three patients were discharged home without surgery. Twenty-three of these patients were unable to be contacted by telephone and were excluded. Review of the electronic medical record revealed that no patient lost to follow-up had a cholecystectomy or hospital admission documented within 2 weeks of the ED visit. Of the 140 patients available for telephone follow-up, only 1 reported cholecystectomy after discharge from the ED. Because this patient reported undergoing elective surgery for biliary colic 10 months after his initial presentation, his case was analyzed as negative for acute cholecystitis. His pathology report was annotated "cholelithiasis without evidence of cholecystitis."

The test characteristics for bedside and radiology ultrasonography to detect cholecystitis as determined by surgical pathology are reported in Table 2. For bedside ultrasonography, results included 20 true positives, 115 true negatives, 26 false positives, and 3 false negatives compared with the criterion standard. For radiology ultrasonography, results included 19 true positives, 77 true negatives, 13 false positives, and 4 false negatives. The sensitivity and specificity of bedside ultrasonography were 87% (95% CI 66% to 97%) and 82% (95% CI 74% to 88%), respectively. Radiology ultrasonography was slightly less sensitive, at 83% (95% CI 61% to 95%) but more specific, at 86% (95% CI 77% to 92%).

The sensitivity and specificity for the 12 physicians who examined both patients with and without cholecystitis are shown in Table 3. The intraclass correlation coefficient for physician clustering in the diagnosis of cholecystitis by bedside ultrasonography was 0.00 (95% CI 0.00 to 0.13). Because there was no clustering, the CIs were nearly identical in the fixed-effect logistic regression and the random-effects logistic regression controlling for clustering.

Table 2. Test characteristics of bedside ultrasonography and radiology ultrasonography for the detection of acute cholecystitis compared with the criterion standard.

Test Characteristics	Bedside Ultrasonography (95% CI)	Radiology Ultrasonography (95% CI)
Sensitivity, %	87 (66–97)	83 (61–95)
Specificity, %	82 (74–88)	86 (77–92)
LR+	4.7 (3.2–6.9)	5.7 (3.3–9.8)
LR-	0.16 (0.06–0.46)	0.20 (0.08–0.5)
Positive predictive value, %	44 (29–59)	59 (41–76)
Negative predictive value, %	97 (93–99)	95 (88–99)

LR, Likelihood ratio.

Table 3. Percentage of positive bedside ultrasonographic results, sensitivity and specificity by physician for 12 physicians who examined patients both with and without cholecystitis (n=87).

Level	No.	Positive, %	Sensitivity (%)	Specificity (%)
Resident	14	50	3/3 (100)	7/11 (64)
Attending*	13	38	1/1 (100)	8/12 (67)
Fellow*	13	31	2/2 (100)	9/11 (82)
Resident	8	25	1/2 (50)	5/6 (83)
Resident	8	38	2/2 (100)	4/4 (100)
Resident	7	29	1/2 (50)	4/5 (80)
Resident	6	33	2/2 (100)	4/4 (100)
Resident	5	20	2/2 (100)	3/3 (100)
Resident	5	20	1/1 (100)	4/4 (100)
Fellow*	3	33	1/1 (100)	2/2 (100)
Resident	3	50	1/1 (100)	2/2 (100)
Attending*	2	50	1/1 (100)	1/1 (100)
Total	87	36	19/20 (90)	54/67 (81)

*Registered diagnostic medical sonographer.

For the secondary objective, the presence of a sonographic Murphy's sign, gallbladder wall thickening, and pericholecystic fluid on bedside and radiology ultrasonography was also compared individually to our criterion standard (Table 4). No individual secondary sonographic finding was sufficiently sensitive to exclude cholecystitis on either bedside or radiology ultrasonography. Bedside sonographic Murphy's sign was more sensitive than the radiology sonographic Murphy's, but much less specific. Wall thickening and pericholecystic fluid were both poorly sensitive for the detection of acute cholecystitis. Pericholecystic fluid was the least sensitive finding on bedside ultrasonography, at 26% (95% CI 10% to 48%); however, it was also the most specific, at 94% (95% CI 89% to 98%).

Sensitivity Analyses

There were 23 patients lost to follow-up in the bedside ultrasonography group. For bedside ultrasonography, if we make the assumption that the prevalence of cholecystitis was the same in patients lost to follow-up as in the study population

Table 4. Test characteristics of individual sonographic findings for the detection of acute cholecystitis compared with the criterion standard (n=164).

	Sono Murphy's Sign (95% CI)		Gallbladder Wall Thickening ≥3 mm (95% CI)		Pericholecystic Fluid (95% CI)	
Test Characteristics	**Bedside**	**Radiology**	**Bedside**	**Radiology**	**Bedside**	**Radiology**
Sensitivity, %	65 (43–84)	48 (26–70)	65 (43–84)	59 (36–79)	26 (10–48)	39 (20–62)
Specificity, %	82 (74–88)	96 (89–99)	91 (85–95)	88 (79–94)	94 (89–98)	94 (88–98)
LR+	3.5 (2.2–5.6)	10.5 (3.6–30)	7.2 (3.9–13)	5.0 (2.5–10)	4.6 (1.8–12)	7.0 (2.6–19)
LR-	0.43 (0.24–0.75)	0.55 (0.36–0.83)	0.38 (0.22–0.67)	0.46 (0.28–0.77)	0.78 (0.61–1)	0.65 (0.46–0.90)
Positive predictive value, %	37 (22–53)	71 (42–92)	56 (36–75)	59 (36–79)	43 (18–71)	64 (35–87)
Negative predictive value, %	94 (88–97)	88 (80–94)	94 (88–97)	88 (79–94)	89 (83–93)	86 (20–62)

(14%), bedside ultrasonography would have missed 3.2 additional cases. Rounding up to 4 missed cases, the test characteristics of bedside ultrasonography would be the following: sensitivity 74% (95% CI 58% to 86%), specificity 84% (95% CI 81% to 86%), positive predictive value 44% (95% CI 34% to 51%), and negative predictive value 95% (95% CI 92% to 97%). Likewise, there were 10 patients lost to follow-up in the radiology ultrasonography group. With the same assumptions as above, radiology ultrasonography would have missed 1.4 cases of cholecystitis. To provide the most conservative sensitivity analysis, we rounded down to 1 missed case, resulting in the following test characteristics of radiology ultrasonography: sensitivity 86% (95% CI 70% to 95%), specificity 86% (95% CI 82% to 88%), positive predictive value 59% (95% CI 48% to 65%), and negative predictive value 96% (95% CI 92% to 99%).

Forty-one bedside ultrasonographic tests were performed by registered diagnostic medical sonographer–certified fellows and attending physicians (25%). For the 123 bedside ultrasonographic tests performed by physicians without registered diagnostic medical sonographer certification, our test characteristics were as follows: sensitivity 82% (95% CI 57% to 96%), specificity 85% (95% CI 77% to 91%), positive predictive value 47% (95% CI 28% to 66%), and negative predictive value 97% (91% to 99%). We also compared the 50 bedside ultrasonographic tests (30%) performed solely by junior residents (first- and second-year emergency medicine residents) against the criterion standard, and we found that the results were comparable to those of the more senior residents and faculty. The test characteristics of bedside ultrasonography in this group (n=50) were sensitivity 77% (95% CI 40% to 97%), specificity 90% (95% CI 77% to 97%), positive predictive value 64% (95% CI 31% to 89%), and negative predictive value 95% (95% CI 83% to 99%). No senior physician was present to assist the junior physician during the bedside ultrasonography in these cases.

In the main analysis, 64 patients were discharged home without radiology ultrasonography, and none of the patients available for follow-up in this group (n=51) had a cholecystectomy or admission for cholecystitis within the 2-week follow-up period. Of the 13 lost to follow-up in this group, no patient was reported in the death registry or had a cholecystectomy documented in the record. Although the various reasons behind the emergency physician's decision to forgo radiology ultrasonography were not documented, it is conceivable that for these patients the bedside ultrasonography was technically easy to perform and clearly yielded a negative result. Including these true-negative cases in the main analysis may have led to a falsely increased specificity and negative predictive value for bedside ultrasonography. Thus, we excluded the 64 patients who received bedside ultrasonography only and recalculated the test characteristics with only those patients who received both studies. In this cohort, the sensitivity of bedside ultrasonography was unchanged, at 87% (95% CI 66% to 97%), and the specificity and negative predictive value were decreased from 82% to 78% (95% CI 68% to 86%) and 97% to 96% (95% CI 88% to 99%), respectively.

LIMITATIONS

The largest limitation of our study is convenience sampling. We did not have the resources to consecutively capture all patients who presented to our ED with suspected cholecystitis. To minimize selection bias, research assistants were counseled weekly on the proper conduct of clinical trials and the importance of systematically capturing all potential study subjects. Although the research assistants were not available to enroll patients between midnight and 8 AM, it is unlikely that those who presented to the ED at night were significantly different from those who presented during the day. However, perhaps because our research assistants were not clinicians, they may have missed potential study subjects during their duty hours, especially those with atypical presentations of cholecystitis. We do not know how this may have altered the parameter estimates.

The emergency physician was not blinded to historical data, physical examination findings, or laboratory testing before bedside ultrasonography. Using clinical data in addition to bedside ultrasonography could have resulted in confirmation bias. We attempted to minimize this by relying on specific, objective ultrasonographic findings to diagnose cholecystitis, rather than the physician's clinical impression. In fact, we did not ask the physicians whether the patient had cholecystitis at all; rather, we only asked them to report the individual ultrasonographic findings: cholelithiasis, wall thickness greater than or equal to 3 mm, pericholecystic fluid, or a sonographic Murphy's sign. Furthermore, the radiologists in our study were frequently privy to clinical and laboratory information when interpreting radiology ultrasonography.

Because emergency physicians in our study tended to be highly experienced in bedside ultrasonography, our results may not be applicable to the general community or reproducible at centers without ultrasonographic training programs. However, in our sensitivity analysis the results did not vary dramatically according to level of training. Future studies are warranted on the performance of bedside ultrasonography in community hospitals or at academic centers without ultrasonographic fellowships.

DISCUSSION

Biliary disease is a common entity in the ED, and radiology ultrasonography has traditionally been the imaging modality of choice in patients with acute right upper quadrant pain. Radiology ultrasonography has been shown to be accurate to diagnose cholelithiasis and acute cholecystitis in patients referred from the ED,[16,21-31] but it is limited by its routine availability and portability. To facilitate throughput, rapidly narrow the differential diagnosis, and institute early treatment, emergency physicians are increasingly using bedside ultrasonography in the initial evaluation of patients with suspected cholecystitis.[7-13] Unfortunately, much of the data available on the performance of bedside gallbladder ultrasonography have been determined through comparison to radiology as the criterion standard, rather than clinically significant outcome measures.

To our knowledge, only 1 other study has evaluated the test characteristics of bedside ultrasonography to detect cholecystitis through comparison to pathology reports.[8] In this study, the emergency physician assessed for gallstones and a sonographic Murphy's sign in 116 patients with suspected biliary disease. Patients with a positive screening test result, which was defined as gallstones plus a sonographic Murphy's sign, were sent to radiology for a confirmatory study. Patients with a negative screening test result, which was defined as absent gallstones and sonographic Murphy's sign, were followed up clinically. The test characteristics of bedside ultrasonography for acute cholecystitis in this study were as follows: sensitivity 91%, specificity 66%, positive predictive value 70%, and negative predictive value 90%. Because 26% of patients had a negative screening test result and only 1 of these patients had cholecystitis, the authors concluded that bedside ultrasonography has the potential to safely reduce the number of radiology ultrasonographic tests ordered from the ED.

Although the results were promising, this study was limited by the fact that patients with discordant results on bedside ultrasonography, such as positive gallstone results and a negative sonographic Murphy's sign result or vice versa, were excluded. Unfortunately, this occurred for 40 of 116 patients (34%), perhaps because of the older-generation ultrasonography technology used when this study was conducted in 1995. With newer-generation machines available, and the resultant ability to detect more subtle findings such as wall thickening and pericholecystic fluid, we did not have to exclude patients for indeterminate scan results.

At our institution, bedside ultrasonography had test characteristics similar to those of radiology ultrasonography for the detection of acute cholecystitis. To achieve comparable results, emergency physicians should be competent to detect gallstones, gallbladder wall thickening, pericholecystic fluid, and a sonographic Murphy's sign. The presence of gallstones and any other secondary finding should be considered a positive test result and prompt further evaluation. On the other hand, patients with a negative bedside ultrasonographic result, including those with gallstones but no secondary findings, frequently forgo further testing at our center.

We did not determine the nothing-by-mouth status of study subjects, nor did we require any fasting before bedside ultrasonography; however, this is unlikely to influence our results because the radiologists in our study had the same potential disadvantage of performing ultrasonography on nonfasting patients as the emergency physicians. Furthermore, waiting for a prolonged period of fasting before the study would slow ED throughput and negate one of the main advantages of bedside ultrasonography. We believe that a recent meal is unlikely to negatively affect the sensitivity of bedside ultrasonography because the gallbladder can still be visualized in postprandial patients (especially with cystic duct obstruction and gallbladder distention). In a recent study of emergency medicine residents performing bedside ultrasonography on healthy volunteers 30 minutes after a fatty meal, the gallbladder was still identified in 100% of cases.[32] However, because nonfasting individuals may have a contracted gallbladder, the specificity of bedside ultrasonography may be decreased because of false-positive wall thickening (Figure 5).

Only 7.8% of all study subjects were older than 65 years (Table 1). Many elderly patients may have escaped enrollment because of atypical chief complaints, severity of illness, or consent issues. Therefore, until further data are available, bedside ultrasonography should be interpreted with caution as the sole diagnostic test for elderly patients with suspected cholecystitis. Although the elderly were relatively underrepresented, there was still a broad spectrum of serious disease detected across our study population. In addition to the 23 cases of acute cholecystitis, some alternative diagnoses documented in the medical record after the ED evaluation included symptomatic cholelithiasis, choledocholithiasis, pancreatitis, pyelonephritis, liver cirrhosis, polycystic kidney disease, bowel obstruction, appendicitis, and ectopic pregnancy.

One diagnosis absent from the 125 formal radiology reports was acalculous cholecystitis. Because 90% to 95% of cases of cholecystitis involve the presence of gallstones and

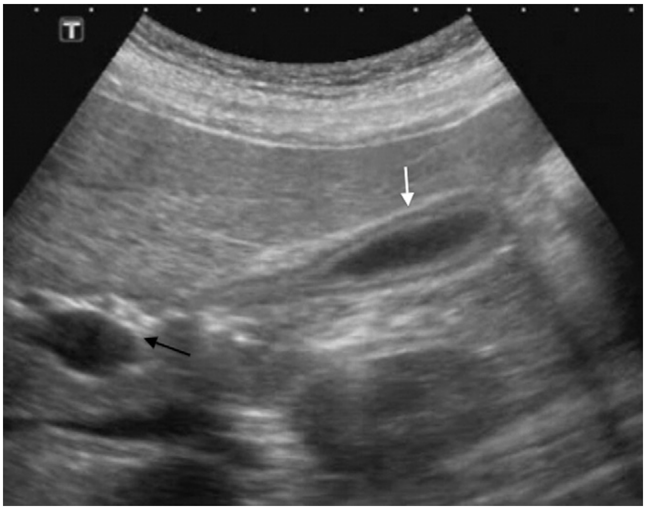

Figure 5. Long-axis view of the right upper quadrant in a postprandial patient demonstrates the classic appearance of a contracted gallbladder with narrow lumen and slightly thickened wall (white arrow). The gallbladder was readily identified by its proximity to the portal triad (black arrow). The patient had no gallstones and a negative sonographic Murphy's sign.

because acalculous cholecystitis is usually associated with some definable risk factor such as multisystem trauma, burns, chronic debilitation, total parenteral feeding, or immunosuppression, we did not design our study to specifically detect these cases.[1,33] Thus, we do not know the performance of bedside ultrasonography in patients with potential acalculous cholecystitis, and supplemental imaging should be considered for patients with clinical concern or risk factors.

In conclusion, the test characteristics of bedside ultrasonography for the detection of acute cholecystitis are similar to those of radiology ultrasonography compared with the criterion standard of pathology reports and clinical follow-up. As portable ultrasonography machines achieve resolutions comparable to those used in radiology, there is potential to further improve on our test characteristics. At our center, bedside ultrasonography was a sensitive diagnostic test for acute cholecystitis, and patients with a negative bedside ultrasonographic result were unlikely to require cholecystectomy or admission for cholecystitis within 2 weeks of their initial presentation. If the results are validated in a large multicenter study, bedside ultrasonography has the potential to become the initial test of choice for ED patients with suspected cholecystitis, rather than a useful adjunct to radiology ultrasonography.

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