Title
Prospective evaluation of emergency physician performed bedside ultrasound to detect acute appendicitis

Journal
European Journal of Emergency Medicine, 15(2)

ISSN
0969-9546

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Publication Date
2008-04-01

DOI
10.1097/mej.0b013e328270361a

Peer reviewed

Prospective evaluation of emergency physician performed bedside ultrasound to detect acute appendicitis

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Objectives **To evaluate the accuracy of emergency physicians using bedside ultrasound to detect appendicitis (BUSA).**

Methods **Patients presenting to the emergency department with a clinical suspicion of appendicitis were prospectively enrolled and received a 5-min BUSA. Patients received routine work-up for acute appendicitis as deemed appropriate by the attending physician. Radiologists and consulting surgeons were blinded to BUSA results. The criterion standard for the presence or absence of acute appendicitis was the pathology report for patients who received appendectomies, and telephone follow-up for patients discharged home without surgical intervention.**

Results **A total of 132 patients were enrolled. In 44 cases BUSA was positive. Of these, 37 had surgical pathology reports consistent with acute appendicitis, whereas seven did not have appendicitis. In 82 cases, BUSA was negative. Of these, 62 were determined not to have appendicitis, whereas 20 had appendicitis by pathology. Sensitivity for BUSA was 65% [95% confidence interval (CI) 52–76], specificity was 90% (95% CI 81–95), positive predictive value was 84% (95% CI 71–92), and negative predictive value was 76% (95% CI 65–84). The likelihood ratio of a positive BUSA was 6.4 (95% CI 3.1–13.2). Five patients discharged home with a diagnosis other than appendicitis were unable to be reached by telephone, and were excluded from data analysis.**

Conclusion **Our study gives insufficient evidence to support the use of bedside ultrasound by emergency physicians to rule out appendicitis. The high specificity in our study, however, suggests that with further training, BUSA may be useful to rule-in appendicitis in some patients.** ***European Journal of Emergency Medicine*** **15:80–85 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

European Journal of Emergency Medicine 2008, **15**:80–85

Keywords: abdominal pain, appendicitis, diagnostic imaging, emergency ultrasound

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Received 27 October 2006 **Accepted** 9 April 2007

Introduction

Abdominal pain is one of the most common abdominal emergencies presenting to the emergency department (ED), with acute appendicitis being the most common abdominal surgical emergency [1–3]. Despite the prevalence of this disease, acute appendicitis remains a diagnostic challenge. Appendicitis is taught to be a 'clinical diagnosis', with classic presentations going directly to the operating room. Presentations of acute appendicitis, however, are often not typical, with female patients presenting an even more complicated diagnostic challenge [4–7]. Evidence of this is the negative appendectomy rate of 2–4% and appendiceal perforation rate of 9–35% [8–10]. Furthermore, clinical judgment has been shown to be suboptimal [11,12]. To aid in the diagnosis of acute appendicitis, a traditional ultrasound performed and interpreted by the department of radiology [radiology performed ultrasound (RUS)] and computerized tomography (CT) are utilized frequently [13–20]. It has been shown that preoperative imaging reduces both appendiceal perforation and negative appendectomy rate [21–23].

Although RUS and CT aid in the identification of appendicitis, there is a delay in the diagnosis because they are time consuming [24]. Early diagnosis of appendicitis is prudent because, among other things, time delay has been shown to be directly proportional to risk for appendiceal perforation [25–28]. In addition, CT has the inherent risks of radiation that becomes more of a factor in both pediatric and pregnant patients. The European Euratom Directive (EURATOM) and The Ionising Radiation (Medical Exposure) Regulations 2000 (IR-MER) have made it clear that the risks and benefits of radiation exposure should be carefully considered when ordering diagnostic imaging, especially with regard to pediatric and pregnant patients [29,30]. Avoiding CT or RUS in a proportion of patients could decrease length

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of stay in the ED, streamline transfer to the operative suite, and decrease radiation exposure. We evaluated the diagnostic accuracy of bedside ultrasound for appendicitis (BUSA) by emergency physicians.

Materials and methods

Study design

We performed a prospective cohort study using a convenience sample of patients with suspected acute appendicitis. The study team consisted of undergraduate research associates present each day between 8:00 and midnight who identified patients presenting to the ED with abdominal pain for which the attending physician initiated a diagnostic work-up to rule out appendicitis. Attending and resident physicians were eligible to perform a BUSA after attending a lecture given by the Director of Emergency Ultrasound at our institution. Our institution has a well-established emergency ultrasound program with an emergency ultrasound fellowship. Over 5000 bedside ultrasounds are carried out per year in our department. See Table 1 for characteristics of sonographers. Our primary outcome measure was the diagnostic accuracy of BUSA when compared with pathology report and telephone follow-up.

Study setting and population

We performed the study in a 35-bed American College of Surgeons-verified Level I trauma center ED, with a census of 46 000, supporting a postgraduate year 1–3 emergency medicine residency. The patient population consists of a mixture of low-income, minority, immigrant, and middle class patients. All participants with abdominal pain requiring work-up for acute appendicitis as determined by the attending emergency physician were eligible for this study. Patients were excluded if pregnant or unable to consent. Before any participant enrollment, the study was granted expedited approval by our Human Subjects Institutional Review Board. One hundred and thirty-two patients were prospectively enrolled between February 2004 and November 2004. See Table 2 for characteristics of enrolled patients.

Study protocol

The treating physician obtained a routine history, physical exam, blood draws and ordered diagnostic imaging or surgical consultation as deemed appropriate for the clinical situation. After initiation of the diagnostic work-up, patients were approached by the study team for enrollment. Patients of any age were eligible for enrollment. In patients aged 7–17 years, informed consent was given by the parent or legal guardian in addition to an age-appropriate assent form signed by the minor. Patients aged less than 7 years were not required to complete an assent form.

Table 1 Characteristics of sonographers at the beginning of study period

Level of training	Patients enrolled in study	Average number of ultrasounds performed
PGY-1	12	57
PGY-2	62	329
PGY-3	47	516
Faculty	11	607

Average number of bedside ultrasounds done by sonographers at the beginning of study period.
PGY, postgraduate year.

Table 2 Patient characteristics

Variable	% (Number)
Sex	
Male	50.8 (67)
Female	49.2 (65)
Age (years)	
Age <6	1.5 (2)
Age 6–12	21 (28)
Age 13–18	14 (18)
Age 19–45	52 (69)
Age 46–65	7.5 (10)
Age >65	3.8 (5)
Symptoms	
History of RLQ pain	93.2 (123)
History of nausea	54.5 (72)
History of vomiting	41.7 (55)
History of fever	31.1 (41)
History of anorexia	40.9 (54)
History of periumbilical pain	33.3 (44)
Signs	
Temperature >38°C	14.4 (19)
McBurney's point tenderness	72 (95)
WBC 0–9.9	39.4 (52)
WBC 10–14.9	30.3 (40)
WBC >15.0	25 (33)

RLQ, right lower quadrant of abdomen; WBC, white blood cell count, 1000/ml.

Analgesia for abdominal pain in our institution generally involves the administration of short acting narcotic at the discretion of the treating physician. Immediately after analgesia, the patient underwent a single BUSA, which was performed with either a B-K Hawk 2102 with 5.5 MHz linear transducer (Copenhagan, Denmark) or a Sonosite Titan with 5.0 MHz linear transducer (Bothell, Washington, DC, USA). BUSA entailed placing the linear transducer over the right lower quadrant of the abdomen in the location of the appendix for no longer than 5 min. We utilized grayscale ultrasound to attempt visualization of the appendix and determine if all three of the following criteria were present: internal diameter of greater than 6 mm, noncompressibility in the transverse plane, and a lack of peristalsis. The presence of all three findings was required for a positive study. Conversely, the absence of any of these findings or inability to visualize the appendix was considered negative for appendicitis [31–33]. This was a limited ultrasound and no attempt was made to identify other abdominal pathology.

All patients received at least one of the following: RUS, CT, surgical consultation (with or without confirmatory imaging), laparoscopy, or open surgical exploration. Although the physician performing the BUSA was not blinded to the patient's clinical presentation, the decision of a particular diagnostic approach was made before performing the BUSA. Furthermore, to ensure that the BUSA did not affect the standard of care or introduce bias, the surgeon(s) and radiologist(s) were blinded to the results of the BUSA. In concordance with our accepted IRB protocol ensuring current standard of care, no decision to operate or choice of imaging modality was made based on the BUSA. Only the physician performing the ultrasound and the study team were aware of the results of the BUSA.

Measurements

Outcome measures

The primary outcome measurement was the accuracy of BUSA. After BUSA was performed, the study team followed the participants to obtain results of diagnostic imaging, surgical consultation, and/or operative intervention. Results of pathological specimens were obtained for all participants who had appendectomies. All participants discharged home from the ED with a negative work-up for appendicitis had telephone follow-up. Only participants who had appendectomies with pathology confirming acute appendicitis were considered to have acute appendicitis as their discharge diagnosis for data analysis. Participants were considered negative for acute appendicitis only if discharged from the hospital with a diagnosis other than acute appendicitis and asymptomatic at telephone follow-up. These calls took place at least 2 weeks, but no later than 3 months after discharge.

Data analysis

Analysis of the data included sensitivities, specificities, positive predictive values (PPVs), and negative predictive values (NPVs). The results for these proportions were reported with 95% confidence intervals (CIs). Data were entered using EpiInfo (Centers for Disease Control and Prevention, Atlanta, Georgia, USA) and analyzed using SPSS 11.0 (SPSS Inc., Chicago, Illinois, USA). CIs were calculated using VassarStats (*http://faculty.vassar.edu/lowry/VassarStats.html*) using the efficient-score method without continuity correction.

Results

We enrolled 132 patients, of which 36% were pediatric (see Table 2). Forty-four patients were BUSA-positive, and of these 37 agreed with the surgical pathology report (true positives), whereas seven were found to be negative by other means (false positives, see Table 3). Additionally, one BUSA-positive patient had a positive CT and a negative RUS and was subsequently admitted and treated nonoperatively with antibiotics. After a 3-day hospital course treating the patient nonoperatively, the patient was discharged with a diagnosis of perforated appendicitis. This patient was followed up in general surgery clinic after discharge and opted not to undergo an interval appendectomy after discussing risks, benefits and alternatives with the general surgeon. The patient was healthy and without abdominal pain 3 months after the hospitalization. Despite having acute appendicitis as a discharge diagnosis, there was no pathologic specimen for confirmation and the participant was excluded from data analysis.

Table 3 Results of imaging, pathology findings, and follow-up outcomes for BUSA-positive patients

Imaging modality	No. of patients	Imaging result	Patient outcome
CT	19	14 positive	14 to OR with positive pathology
		5 negative	5 asymptomatic at follow-up
RUS	6	3 positive	3 to OR with positive pathology
		3 negative	1 to OR with positive pathology 1 to OR with negative pathology 1 asymptomatic at Follow-up
RUS and CT	1	1 positive CT/negative RUS	1 to OR with positive pathology
No imaging	18	Not applicable	18 to OR with positive pathology

BUSA, bedside ultrasound for appendicitis; CT, computerized tomography; OR, operating room; RUS, radiology performed ultrasound.

Table 4 Results of imaging, pathology findings, and follow-up outcomes for BUSA-negative patients

Imaging modality	No. of patients	Imaging result	Patient outcome
CT	48	36 negative	33 asymptomatic at follow-up 2 to OR with negative pathology 1 to OR with positive pathology
		12 positive	8 to OR with positive pathology 3 to OR with negative pathology 1 no OR and asymptomatic
RUS	14	12 negative	12 asymptomatic at follow-up
		2 positive	2 to OR with positive pathology
RUS and CT	4	3 negative (both)	3 asymptomatic at follow-up
		1 positive CT/negative RUS	1 to OR with positive pathology
No imaging	16	Not applicable	8 to OR with positive pathology 8 asymptomatic at follow-up

BUSA, bedside ultrasound for appendicitis; CT, computerized tomography; OR, operating room; RUS, radiology performed ultrasound.

In 82 cases BUSA was negative. Of these, 62 were determined not to have appendicitis (true negatives), whereas 20 received appendectomies and had positive pathology (false negatives, see Table 4). In addition, five patients were discharged home with a diagnosis other than appendicitis but could not be reached for follow-up. All five of these patients had a negative BUSA; four had a negative CT and one was sent home on clinical grounds with a surgical consult without further imaging. Without telephone follow-up these patients were excluded from final data analysis.

Sensitivity for BUSA was 65% (95% CI: 52–76), specificity was 90% (95% CI: 81–95), PPV was 84% (95% CI: 71–92), and NPV was 76% (95% CI: 65–84). The likelihood ratio of a positive BUSA was 6.4 (95% CI: 3.1–13.2, see Table 5). The diagnostic accuracy of BUSA did not differ by age (Table 6) or by ultrasound machine (Table 7).

Table 5 Accuracy of BUSA

	BUSA (n = 126)
Sensitivity (95% CI)	65% (52–76)
Specificity (95% CI)	90% (81–95)
PPV (95% CI)	84% (71–92)
NPV (95% CI)	76% (65–84)
+Likelihood ratio (95% CI)	6.4 (3.1–13.2)

BUSA, bedside ultrasound for appendicitis; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Table 6 Accuracy of BUSA by age group in years

	Age 2–17 (n = 42)	Age 18–81 (n = 83)
Sensitivity (95% CI)	74% (53–87)	59% (42–74)
Specificity (95% CI)	85% (64–95)	92% (81–97)
PPV (95% CI)	85% (64–95)	83% (64–93)
NPV (95% CI)	74% (53–87)	76% (64–85)
+Likelihood ratio (95% CI)	4.9 (1.7–14.4)	7.2 (2.7–19.2)

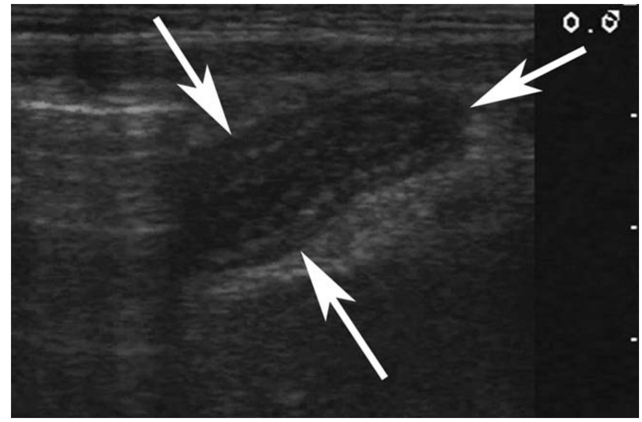
No significant difference between age groups based on the Breslow–Day test for homogeneity (P = 0.999).
BUSA, bedside ultrasound for appendicitis; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Table 7 Accuracy of BUSA by ultrasound machine

	B and K Hawk 2102 (n = 91)	Sonosite Titan (n = 35)
Sensitivity (95% CI)	64% (49–77)	67% (42–85)
Specificity (95% CI)	86% (73–93)	100% (84–100)
PPV (95% CI)	70% (63–90)	100% (72–100)
NPV (95% CI)	74% (61–83)	80% (61–91)
+Likelihood ratio (95% CI)	4.5 (2.2–9.3)	Undefined

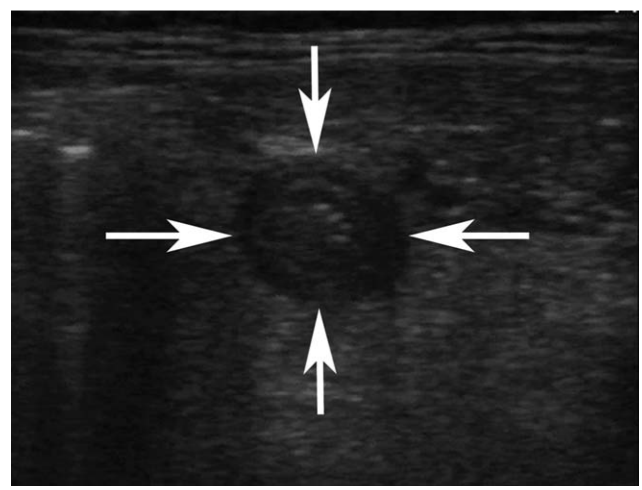
No significant different between machine type based on the Breslow–Day test for homogeneity (P = 0.09).
BUSA, bedside ultrasound for appendicitis; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Fig. 1



Long axis of blind-ended appendix. Arrows outline the outer wall of the appendix.

Fig. 2



Cross-section of 11 mm noncompressible, nonperistalsing appendix diagnostic of appendicitis. Arrows outline the outer wall of the appendix.

Discussion

The work-up of patients who present to the ED with right lower quadrant pain often involves the combined consultative efforts of radiology and surgery. Although it has been shown in the radiology literature that use of RUS and CT have decreased the negative appendectomy rate, these study modalities are time consuming, delay the diagnosis and final disposition, and in the case of CT exposes the patient to ionizing radiation [8,9,34–36].

Appendicitis is diagnosed using ultrasound by demonstrating lack of compressibility of a nonperistalsing tubular structure found in the right lower quadrant that measures greater than 6 mm in diameter (see Figs 1 and 2). Depending on the patient's body habitus, it may be necessary to use constant pressure in the right lower quadrant with the transducer to compress subcutaneous fat and displace loops of bowel. To achieve this adequate compression, it is imperative to provide the patient with sufficient analgesia. Similar to other applications of bedside ultrasound, this is a focused examination that should take no longer than 5 min. Although the linear transducers for both systems were capable of scanning in the 8–10 MHz range, we chose to use the lower frequency settings of 5–5.5 MHz. This setting enabled us to take advantage of the superior image quality and lateral resolution provided by a linear probe while balancing this with a lower frequency setting sufficient to penetrate to the depth of interest. An alternative approach could include the use of a curvilinear probe set to the 'high'-frequency setting of 5 MHz.

Only one other study has evaluated bedside ultrasound for appendicitis by emergency physicians [37]. Chen *et al.* showed a sensitivity of 96.4%, specificity of 67.6%, PPV of 74.6% and NPV of 55.6%. Their much higher sensitivity could be explained by the fact that their sonologists had a 5-day intensive training course in abdominal ultrasound. Although they demonstrated a much higher sensitivity than our study, their low PPV resulted in a high negative laparotomy rate. We believe that for BUSA to be useful clinically, the PPV of this modality must be optimized so as to not erroneously send false-positive patients to the operating room to undergo negative appendectomies.

In addition to visualization of the appendix, pain is often produced by the ultrasound transducer. Soda *et al.* [12], showed a sensitivity of 86.7%, specificity of 89.7%, PPV of 94.5%, and NPV of 76.5% by using tenderness in conjunction with ultrasound to diagnose appendicitis. Although we did not use this method in our study, this technique might be useful in combination with our criteria. This dual role of the clinician/imager (sonologist) has been emerging with a variety of applications in bedside ultrasound, including the sonographic Murphy's sign [38].

Although we only achieved a sensitivity of 65%, the 90% specificity was similar to that seen in the most recent radiology literature [39]. With this low sensitivity, BUSA would not be useful as a screening test to rule out appendicitis. Given the difficulty of detecting the normal appendix and low sensitivity of ultrasound, a high clinical suspicion for appendicitis in light of a negative ultrasound should prompt the emergency physician to rule out the diagnosis by other means, such as with CT, surgical consultation, or further observation. Given our high specificity, however, there may be a utility of this bedside application to rule in a number of patients and avoid timely and costly radiology studies. The department of radiology has traditionally performed ultrasound for the detection of appendicitis; however, there are many hospitals where a radiology-performed ultrasound is not available 24 : 00 h a day. It is partially for this reason that many bedside ultrasound applications by emergency physicians have emerged, such as in the evaluation of early pregnancy to rule out ectopic pregnancy [40]. As emergency physicians become more adept at bedside ultrasound, and hence take on roles traditionally performed by radiologists, it is imperative that they uphold the recommendations of the EURATOM and IRMER and limit radiation exposure if clinical feasible. An emergency physician with sufficient training in bedside ultrasound, which is familiar and proficient with BUSA, could potentially reduce the number of CT scans performed and hence decrease the radiation burden in the ED.

Limitations

Several limitations to this study exist. First, the sonographers were not blinded to the clinical presentation. This could heighten the suspicion of appendicitis in a proportion of patients and artificially increase our accuracy. The real-time integration, however, of bedside ultrasound into the clinical picture more appropriately models the situation in which an emergency physician would use BUSA. This is not different than the incorporation of historical and physical findings that refine an emergency physician's pretest suspicion of disease while interpreting other imaging, such as plain radiographs of the chest or skeleton. Furthermore, as our sample size is low, larger studies are warranted. Additionally, the percentage of participants going directly to the operative suite without confirmatory imaging (43%) may suggest a selection bias toward patients with more obvious presentations of acute appendicitis. A review of the literature, however, reveals that a similar proportion of patients presenting with right lower quadrant pain go directly to the operating room based on clinical presentation alone [21,34,41–48]. A future area of study could tailor BUSA to patients with equivocal presentations.

No attempt was made to take into account the widely held notion that larger body habitus is more difficult to insonate [49]. This may be more of a concern in emergency ultrasound because of our use of entry-level machines. Finally, with increased training, including a hands-on component, we expect expertise with BUSA to follow the other modalities of emergency ultrasound.

Conclusion

Our study gives insufficient evidence to support the use of bedside ultrasound by emergency physicians to rule out appendicitis based on the sensitivity achieved. The high specificity in our study, however, suggests that BUSA may be useful to rule in appendicitis in some patients. With further study and training, BUSA may be a useful adjunct in the early management of acute appendicitis to facilitate early surgical intervention and limit radiation exposure by avoidance of CT.

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