Brief Report

Diagnosis of appendicitis by bedside ultrasound in the ED

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ARTICLE INFO

Article history:
Received 3 June 2014
Received in revised form 6 October 2014
Accepted 6 October 2014

ABSTRACT

Background: Computed tomography (CT) has largely become standard of care for diagnosing appendicitis at the expense of increased patient radiation exposure, cost, and time to surgical intervention. To date, there are very limited data on the accuracy of bedside ultrasound (BUS) for the diagnosis of appendicitis in adults.

Objective: The objective of this study is to evaluate test characteristics of BUS for diagnosis of acute appendicitis in the emergency department.

Methods: Data were prospectively collected on 97 cases of suspected appendicitis, which had BUS performed by trained residents with attending supervision between August 2011 and November 2013. All BUS interpretation and additional diagnostic imaging were left to the discretion of the physician or surgical consultants. A blinded ultrasound fellowship-trained physician reviewed all images after clinical treatment. Bedside ultrasound findings and patient outcomes were reported.

Results: A total of 97 adult cases underwent diagnostic ultrasound scans for suspected appendicitis. Of 97 cases, 34 had acute appendicitis by surgery/pathology report. Twenty-four BUS were positive for acute appendicitis and 11 were nondiagnostic. Of 24 positive ultrasounds, 23 had appendicitis on pathology report. There was 1 false-positive result, yielding a sensitivity of 67.65% (95% confidence limits, 49.5%-82.6%) and a specificity of 98.41% (95% confidence limits, 91.4%-99.7%). Of 23 positive BUS, 12 cases went to the Operating Room without an abdominal CT yielding a 12% reduction in CT utilization. If all positive BUS went to the OR without a CT scan, this would yield a 24% reduction in CT utilization.

Conclusions: Bedside ultrasound may be an appropriate initial test to evaluate patients with suspected acute appendicitis in the emergency department.

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1. Introduction

Appendicitis is the most common surgical abdominal emergency worldwide with more than 250 000 people diagnosed annually, and 7% of the population having the disease in their lifetimes [1]. Prompt diagnosis and treatment of acute appendicitis are important, as it is believed to reduce the risk of perforation, which is associated with greater morbidity and cost of care [2,3]. The clinical diagnosis of acute appendicitis can be complicated by an atypical presentation and a differential that can include gallbladder disease, urinary tract, and gynecologic pathologies [2,4]. Thus, imaging studies remain an essential part of the diagnostic process in a substantial proportion of cases of undifferentiated abdominal pain, where appendicitis is a concern.

Computed tomography (CT) is considered by many to be the criterion-standard in the diagnosis of acute appendicitis with sensitivities and specificities of 72% to 97% and 91% to 99%, respectively, and a positive predictive value (PPV) of 92% to 98% and negative predictive value of 95% to 100% [5,6]. One of the clear disadvantages of CT is the potential risk of increased malignancy rates associated with ionizing radiation exposure, particularly among children and young adults [7,8]. Currently, the estimated lifetime associated risk of radiation-induced malignancy from CT is 0.3%, and the cumulative effect of multiple CT examinations multiplies this risk [7,8]. It is estimated that between 0.7% to 2.0% of all cancers today are caused by CT radiation exposure [7,8].

Bedside ultrasound (BUS) is an evolving area of clinical imaging in which clinicians perform ultrasound examinations at the bedside and make interpretations in real time. By performing ultrasound examinations at the bedside, imaging can be completed faster and with less cost to the patient [9]. Bedside ultrasound for appendicitis can be typically performed in 5 minutes and has produced results...
similar to the traditional ultrasound examinations completed by a radiologist with sensitivities of 65% to 96.4%, specificities of 67.6% to 99%, and PPVs of 84% to 98% [10-12]. Because of its high specificity and high PPV, BUS is used by trained providers in many emergency departments (EDs), including the University of Utah, as an initial examination to evaluate for appendicitis. Typically, if the BUS is positive, the surgical service is consulted immediately; whereas, if it is negative, additional imaging is obtained, or surgical evaluation or a period of observation is undertaken. There is a lack of adult literature evaluating the accuracy and effectiveness of such an approach.

2. Methods

This study was approved by the Institutional Review Board at the University of Utah. We collected prospective data on all cases of suspected appendicitis in which a provider performed a BUS since August 2011, when we first started documenting appendiceal ultrasounds. Credentialed attending emergency physicians or residents with attending supervision perform all ultrasounds in the ED. The American College of Emergency Physicians 2009 Emergency Ultrasound guidelines are used to establish credentialing and privileging for BUS within the department. The residents have a variable amount of ultrasound training, depending on postgraduate level, and perform a dedicated ultrasound elective during their first and second years. Both attendings and residents received a 30-minute didactic lecture on appendicitis, and credentialed attendings have participated in bedside teaching on the diagnosis of appendicitis using ultrasound.

Whenever an ultrasound is performed at the bedside in our institution, the ED provider produces a clinical note documenting their interpretation of the images in the electronic medical record. A trained clerk identifies all ultrasounds performed in the ED through a query of our Picture Archiving and Communication System (PACS) and cross-references them with the patient’s electronic medical record to obtain the ultrasound reports. A single author (JS) reviewed the quality assurance (QA) lists generated through this process and identified all Right Lower Quadrant ultrasound interpretations. Additional authors, PO and MM, who were not blinded to the objectives of the study, reviewed the results of subsequent formal radiology service ultrasounds, CTs, and operative reports to determine agreement between these measures and the diagnosis of appendicitis.

Appendicitis was defined as a surgical and pathologic diagnosis of the same. Patients were considered negative for appendicitis if they underwent subsequent negative radiology service imaging and/or were discharged after a period of observation without surgical intervention. We also performed chart surveillance for those who were discharged without additional imaging for any evidence of return to our hospital for treatment of appendicitis in the 5 months after ED discharge. For purposes of this study, a BUS was considered positive for appendicitis, when providers documented that (1) the appendix was visualized and (2) noncompressible with an external diameter more than 7 mm. The presence of periappendiceal fluid or the presence of an appendicolith was thought to be suggestive but nondiagnostic findings. A negative study was so classified, when the appendix was positively identified but did not meet the above listed appendicitis criteria. When the appendix was not visualized, we defined this as a nondiagnostic BUS for acute appendicitis.

A Mindray M7 Portable Ultrasound Machine (manufactured in Shenzhen, China; domestic headquarters located in Mahwah, NJ) was used for all didactic and training sessions as well as for all clinical ultrasound examinations related to the study. This machine incorporated a C5-2 s 2.0 to 5.0 MHz (50-mm footprint) Convex-Wide transducer and/or 7L4s 4 to 10 MHz (38-mm footprint) Linear Transducer for all examinations.

Sensitivity and specificity and positive and negative likelihood ratios are reported as proportions with exact 95% confidence limits (CI) and were computed using STATA statistical software (STAT/IC 12.1 for Mac; StataCorp, College Station, TX). Because this was an observational study, which does not test a hypothesis, no formal power calculation was performed. The precision obtained with the available sample size is reflected in the width of the corresponding confidence intervals for sensitivity, specificity, and likelihood ratios.

3. Results

A total of 97 adult cases underwent diagnostic ultrasound scans for suspected appendicitis. The self-identified race/ethnicity of the enrolled patients was as follows: 77 White, 12 Hispanic/Latino, 3 Asian, 3 Black/African American, 1 Pacific Islander, and 1 Arabic. The average patient age was 28 years (range, 10-51 years), and average body mass index (BMI) was 25.05 kg/m² (SD, 6.10; range, 17.57-44.25 kg/m²).

During the study period, the diagnosis of acute appendicitis was made in the ED 193 times, which means that ultrasound was performed as the initial examination in 13.5% of cases. Diagnostic results from the performed ultrasonography are shown in the Table. Of 97 cases, 34 had acute appendicitis by surgery/pathology report. Twenty-four BUS were positive for acute appendicitis and 11 were nondiagnostic. Of 24 positive ultrasounds, 23 had appendicitis on pathology report, with 1 false-positive result. This yielded a sensitivity of 67.7% (95% CI, 49.5%-82.6%) and a specificity of 98.4% (95% CI, 91.4%-99.7%) for the diagnosis of appendicitis. Positive predictive value was found to be 95.8% (95% CI, 78.8%-99.3%) and negative predictive value, 84.9% (95% CI, 74.6%-92.2%). Positive and negative likelihood ratios were 42.6 (95% CI, 6.0-302.0) and 0.3 (95% CI, 0.2-0.5), respectively.

Of the 24 positive BUS cases, 12 went to the Operating Room without an abdominal CT, yielding in a 12% reduction in CT utilization. In 3 cases of confirmed appendicitis, the BUS was positive for appendicitis, and the CT was falsely normal. One of these patients also had a nondiagnostic radiology ultrasound, in addition to a falsely normal CT and positive BUS. There was 1 false-positive result in which the BUS and CT were positive, and the patient was taken to the OR and found to have mucinous cystadenoma with no evidence of appendicitis. Eleven BUS were nondiagnostic but were confirmed to have appendicitis on surgery/pathology; of these 11 cases, 10 patients had a positive CT before the OR, whereas 1 patient was taken to the OR on a clinical basis without CT.

Of the 97 cases, 62 had nondiagnostic BUS studies and were found to be negative upon chart review 5 weeks after the ED visit. Of these cases, 26 had negative CTs, and 13 had negative formal ultrasounds performed by radiology. One patient had a negative BUS but equivocal CT and so was taken to the OR and found to have no evidence of appendicitis on pathology. Thirty-three patients (34%) with negative BUS and no additional imaging were given final ED discharge diagnoses of abdominal pain, urinary tract infection, vomiting, gastroenteritis, and/or ovarian cyst. Among those patients without additional imaging, none was found to have evidence of appendicitis on subsequent chart review 5 months after initial presentation.

4. Limitations

Study results are limited to the experience of 1 academic ED, which may affect the generalizability of the study. Emergency departments may differ among their patient demographics and protocols regarding suspected appendicitis.

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Inclusion into the study was at the discretion of the treating ED physician. As such, there may have been an inherent selection bias, as an overtly positive or negative study may have been more likely to be included than an indeterminate study. However, this may not be a limitation, given that the study was partly observational in nature, in an attempt to better understand clinical practice patterns in addition to sensitivities and specificities of BUS for acute appendicitis.

Potentially, it would have been useful to have the physicians commit on a diagnosis as well, preferable before BUS. However, it is difficult to obtain these data given the prospective, observational nature of the study. Most physicians would not commit on a diagnosis before the BUS, as they would only have the history and physical examination at that point and would be lacking any other laboratories, diagnostic imaging, consultant opinion, etc. As well, in many cases of suspected appendicitis, the diagnosis was not fully ruled in or out, until the surgical pathology report returned. Furthermore, the cause of abdominal pain in the ED is frequently not determined, and patients are sent home with discharge diagnoses of “abdominal pain and uncertain etiology” and given return precautions if the pain changes or worsens. Thus, in many cases, physicians did not know the final diagnosis before or after the diagnostic work-up and so were reluctant to commit to one. As such, these data could not be accurately obtained.

5. Discussion

Pediatric literature has supported the use of an ultrasound-first approach in the diagnosis of appendicitis. This concept is feasible given that the most powerful aspect of appendiceal ultrasound is the PPV. In the adult literature, the PPV has been described as 85% to 94% [6]. Pediatric literature has suggested that the PPV is 95%, when an ultrasound-first approach is used followed by CT in equivocal cases. This method has been shown to safely reduce the proportion of patients receiving CT scans by 49% [13], Ramarajan et al [13] further showed that ultrasound alone had an acceptable negative appendectomy rate of 7%. Despite these encouraging data from the pediatric literature, to our knowledge, there is no adult study that has tried to duplicate these findings.

In congruence with the pediatric literature, our data suggest that BUS is an acceptable initial test for the diagnosis of appendicitis among adult patients presenting to the ED, although numbers are too small at this time to make firm recommendations. Of 24 patients diagnosed with acute appendicitis by BUS in our study, 23 had positive surgical pathology reports, providing a PPV of 95.8% (95% CI, 78.8–99.3%). It should be noted that the only false-positive was found to be a mucocele by surgery/pathology, which could have findings similar to an acute appendicitis on ultrasound and CT, and so, this brings into question if BUS specificity and PPV in our study were actually closer to 100%. As well, given that all patients in our study with a positive BUS had some form of surgical pathology, this brings into question the necessity for CT or formal ultrasound in radiology after a positive BUS. Computed tomography traditionally carries a specificity of 91% to 99% and a PPV of 92% to 98% [5,6]. Our study results fell within this range, with a specificity of 98.4% (95% CI, 91.4–99.7%) and a PPV of 95.8% (95% CI, 78.8–99.3%). As such, this lends further support to an ultrasound-first protocol and the theory that confirmatory imaging may not be needed in the event of a positive BUS. Of 24 cases with positive BUS, 12 went to the OR without any additional imaging, resulting in a 12% reduction in the utilization of CT. If all cases with a positive BUS went to the OR without additional imaging, this could potentially result in a 24% reduction in CT utilization.

Fox et al [12] described a modest PPV for BUS of 84% and a specificity of 90% in a prospective evaluation of 144 patients presenting to the ED with suspected appendicitis. These data were obtained after performing a 5-minute BUS and produced a + LR of 6.4, which is most helpful in those patients with a higher pretest probability. Our data report a higher specificity, PPV, and + LR, which may be secondary to inherent selection bias by ED providers in performing ultrasounds in patients with a more desirable body habitus (average body mass index in our study was 25.05 kg/m²; SD, 6.10) and in those with a higher pretest probability. Likewise, there may be additional reporting bias, where providers were more likely to save their images if there were significant findings. Furthermore, the data of Dr Fox et al [12] were collected 8 years ago; and in that time, ultrasound technology and the capabilities of emergency physicians performing BUS may have improved significantly. Regardless, the discrepancy suggests that the sensitivity and specificity may be improved by more rigorous selection criteria for BUS. Aside from consideration of technical difficulties to be anticipated due to body habitus, a clinical prediction score such as the Alvarado score may be helpful in defining a pretest probability to facilitate use of the BUS in formal Bayesian reasoning [14].

This study is limited by the inherent selection bias and small numbers. Our study is likely to significantly underrepresent the proportion of nondiagnostic ultrasounds of the appendix obtained, as clinicians are probably less likely to take the time to document nondiagnostic findings, thus excluding them from the quality assurance process. Those confident in their findings were probably more likely to record either positive or negative findings.

Bedside ultrasound may be an appropriate initial test to evaluate patients with suspected acute appendicitis in the ED; yet in our chart review, most of these cases still required confirmatory imaging, possibly due to surgical or emergency physician uncertainty regarding the predictive value of ultrasound findings. A large prospective study of an ultrasound-first approach is needed to further evaluate the accuracy and safety of an ultrasound-first protocol in adult patients.

References


