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Clinical Ultrasound Is Safe and Highly Specific for Acute Appendicitis in Moderate to High Pre-test Probability Patients

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Introduction: Clinical ultrasound (CUS) is highly specific for the diagnosis of acute appendicitis but is operator-dependent. The goal of this study was to determine if a heterogeneous group of emergency physicians (EP) could diagnose acute appendicitis on CUS in patients with a moderate to high pre-test probability.

Methods: This was a prospective, observational study of a convenience sample of adult and pediatric patients with suspected appendicitis. Sonographers received a structured, 20-minute CUS training on appendicitis prior to patient enrollment. The presence of a dilated (>6 mm diameter), non-compressible, blind-ending tubular structure was considered a positive study. Non-visualization or indeterminate studies were considered negative. We collected pre-test probability of acute appendicitis based on a 10-point visual analog scale (moderate to high was defined as >3), and confidence in CUS interpretation. The primary objective was measured by comparing CUS findings to surgical pathology and one week follow-up.

Results: We enrolled 105 patients; 76 had moderate to high pre-test probability. Of these, 24 were children. The rate of appendicitis was 36.8% in those with moderate to high pre-test probability. CUS were recorded by 33 different EPs. The sensitivity, specificity, and positive and negative likelihood ratios of EP-performed CUS in patients with moderate to high pre-test probability were 42.8% (95% confidence interval [CI] [25-62.5%]), 97.9% (95% CI [87.5-99.8%]), 20.7 (95% CI [2.8-149.9]) and 0.58 (95% CI [0.42-0.8]), respectively. The 16 false negative scans were all interpreted as indeterminate. There was one false positive CUS diagnosis; however, the sonographer reported low confidence of 2/10.

Conclusion: A heterogeneous group of EP sonographers can safely identify acute appendicitis with high specificity in patients with moderate to high pre-test probability. This data adds support for surgical consultation without further imaging beyond CUS in the appropriate clinical setting. [West J Emerg Med. 2018;19(3):460–464.]

INTRODUCTION
Acute appendicitis is inflammation of the appendix that can lead to perforation, abscess, other serious infections and death. Over 280,000 appendectomies are performed in the United States annually. Although widespread availability of computed tomography (CT) has allowed more accurate diagnosis of acute appendicitis before reaching the operating room, this has come at the price of increased radiation exposure, increased cost and longer emergency department (ED) lengths of stay. Due to these risks, it is common to perform ultrasound examinations as the initial imaging modality in children to diagnose acute appendicitis. Nonetheless, ultrasonography for appendicitis is not available in many EDs, and in most departments the availability of diagnostic ultrasonography is
limited by the time of day.\(^5\)\(^7\) Even when available, the accuracy of formal radiology ultrasound may be much lower in community practice than in academic centers where it is commonly studied.\(^8\)

Previous studies have demonstrated excellent specificity of point-of-care or clinical ultrasound (CUS) for acute appendicitis among small cohorts of highly trained sonographers,\(^6\)\(^-\)\(^15\) and incorporation of clinical risk-stratification with sonography has been shown to safely enhance diagnostic accuracy in a variety of settings.\(^16\)\(^-\)\(^20\) However, the accuracy of ultrasound is highly dependent on the skills of the operator. This may be a barrier to implementation of CUS for appendicitis in new settings. The goal of this study was to determine if a heterogeneous group of emergency physicians (EP) could diagnose acute appendicitis on CUS. We hypothesized that EP sonographers could diagnose acute appendicitis with high specificity using a combination of clinical risk assessment, CUS, and self-assessment of image acquisition and interpretation.

METHODS

Study Design

This was a prospective observational study on a convenience sample of adult and pediatric patients presenting to the ED with signs and symptoms concerning for acute appendicitis. Patients were enrolled from three large urban academic EDs between July 2014 and September 2016. The study sites consisted of two adult centers with a combined annual census of approximately 205,000, and one pediatric center with an annual volume >40,000 patient visits. The study protocol was approved by the institutional review board.

Seven studies were excluded for missing data on the data collection form, including missing or incorrect patient medical record numbers, missing sonographer interpretation or pre-test probability. Of the remaining 105 patients, 76 (72%) had moderate or high pre-test probability of appendicitis after the index visit. We defined a missed case of acute appendicitis as a discharge diagnosis or surgical pathology diagnosis of acute appendicitis after the index visit.

Data Analysis

The expected rate of appendicitis was 35%.\(^11\)\(^-\)\(^13\) We expected specificity to be 85%, based on prior studies demonstrating a specificity ranging from 71 to 91%.\(^17\) A sample size of 75 patients with moderate to high pre-test probability of appendicitis was planned to demonstrate specificity within 10% of the expected value. This calculation assumes a power of 0.80 and alpha of 0.05. We calculated sensitivity, specificity, and positive and negative likelihood ratios with 95% confidence intervals (CI). Twenty percent of studies were randomly selected for blinded review by a fellowship-trained expert to calculate observed agreement and inter-rater reliability between EP sonographers’ interpretations using Cohen’s unweighted kappa. The expert reviewer was blinded to sonographer identity, sonographer interpretations, and clinical data.

RESULTS

During the study period 122 patients underwent CUS. Seventeen studies were excluded for missing data on the data collection form, including missing or incorrect patient medical record numbers, missing sonographer interpretation or pre-test probability. Of the remaining 105 patients, 76 (72%) had moderate or high pre-test probability (see Figure). Of these 76 patients, 28 (36.8%) had acute appendicitis (Table 1).
The sensitivity and specificity of EP-performed CUS in patients with moderate to high pre-test probability were 42.8% (95% CI [25-62.5%]) and 97.9% (95% CI [87.5-99.8%]) (Table 2). The positive and negative likelihood ratios were 20.6 (95% CI [2.8-149.9]) and 0.58 (95% CI [0.42-0.8]). In 31 studies sonographers reported high confidence in image acquisition and interpretation (6 or higher on a 1-10 VAS). Of these studies, the sensitivity and specificity improved to 80% and 100%, respectively. The 16 false negative scans all were interpreted as indeterminate; for all 16, appendicitis was confirmed by CT at the index visit. There was one false positive ultrasound. For this study the sonographer reported low confidence in image interpretation (2 out of 10). This patient had a CT that demonstrated an obstructing ureteral stone at the right ureterovesical junction. Two patients proceeded directly to the operating room for appendectomy based on a positive CUS with no further imaging.

Thirty-three different sonographers performed CUS with a range of 1-13 scans per sonographer. Residents performed 40 (52.6%) of the CUS and identified five (41.7%) of the true positives. Inter-rater reliability was high, with 100% agreement and kappa = 1 (95% CI [1-1]).

**DISCUSSION**

Our study demonstrates that a heterogeneous group of EPs can diagnose acute appendicitis by CUS with high specificity in the appropriate clinical context. In our study, most sonographers had performed an average of 100 prior CUS examinations. Pre-enrollment training was limited to 20 minutes of didactics and hands-on training with a healthy model.
of image quality and interpretation may improve diagnostic accuracy. Surgical consultation without further imaging beyond CUS may be supported in the appropriate clinical setting. This data does not support the use of CUS to rule out appendicitis when there is persistent clinical concern.

LIMITATIONS


REFERENCES


Recent research has shown diagnostic accuracy can be improved by combining clinical assessment with sonography. Therefore, we identified patients with moderate to high pre-test probability. Since ultrasound accuracy is highly dependent on the skill of the sonographer, we also collected data on sonographer confidence. Higher confidence in the ultrasound diagnosis yielded improved sensitivity and specificity of the results. This suggests that confidence in image acquisition and interpretation is an important predictor of diagnostic accuracy for CUS. These results are consistent with prior studies demonstrating high specificity and moderate sensitivity of EP-performed CUS for acute appendicitis. In a meta-analysis of 21 studies, Fields et al. showed high specificity of 92% and relatively high sensitivity of 80% for CUS by EPs. Our sensitivity is lower than that reported by Fields et al. because the authors excluded non-diagnostic studies from analysis. These results further support the use of CUS as a first-line imaging modality in patients with suspected appendicitis. CUS has potential advantages as compared to CT with reduced time to diagnosis, reduced costs, reduced radiation and contrast dye exposure, and shorter ED stays.

### Table 2. Sensitivity and specificity by level of training.

<table>
<thead>
<tr>
<th></th>
<th>Faculty</th>
<th>Fellow</th>
<th>Resident</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>25</td>
<td>11</td>
<td>40</td>
<td>76</td>
</tr>
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<td>Sensitivity</td>
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<td>75%</td>
<td>31%</td>
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<tr>
<td>Specificity</td>
<td>100%</td>
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<td>96%</td>
<td>98%</td>
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CONCLUSION

A heterogeneous group of EPs can safely identify acute appendicitis on CUS with high specificity and a positive likelihood ratio of 20. Clinical risk stratification and appraisal