The Journal of Emergency Medicine, Vol. ■, No. ■, pp. 1–5, 2016

0736-4679/$ - see front matter

http://dx.doi.org/10.1016/j.jemermed.2015.10.007

Ultrasound in Emergency Medicine

DOES RIGHT LOWER QUADRANT ABDOMINAL ULTRASOUND ACCURATELY IDENTIFY PERFORATION IN PEDIATRIC ACUTE APPENDICITIS?

Peggy Tseng, MD,* Carl Berdahl, MD,* Y. Liza Kearl, MD,† Solomon Behar, MD,† John Cooper, DO,‡ Ryan Dollbaum, MS,† Madhu Hardasmalani, MD,† Kevin Hardiman, DO,* Emily Rose, MD,† Genevieve Santillanes, MD,† ChunNok Lam, MPH,† and Ilene Claudius, MD†

*Department of Emergency Medicine, Los Angeles County/University of Southern California Medical Center, Los Angeles, California, †Department of Emergency Medicine, Keck School of Medicine, University of Southern California, Los Angeles, California, and ‡Department of Pediatrics, Los Angeles County/University of Southern California Medical Center, Los Angeles, California

Corresponding Address: Peggy Tseng, MD, Department of Emergency Medicine, Los Angeles County/University of Southern California Medical Center, 1200 North State Street 1011, Los Angeles, CA 90033

☐ **Abstract—Background: Acute appendicitis is the most common cause of acute abdomen in pediatric emergency department (ED) visits, and right lower quadrant abdominal ultrasound (RLQUS) is a valuable diagnostic tool in the clinical approach. The utility of ultrasound in predicting perforation has not been well-defined. Objectives: We sought to determine the sensitivity of RLQUS to identify perforation in pediatric patients with appendicitis. Methods: A chart review of all patients 3 to 21 years of age who received a radiographic work-up and who were ultimately diagnosed with perforated appendicitis between 2010 and 2013 at a pediatric ED was conducted. The final read for ultrasonography was compared to either the operative diagnosis, surgical pathology diagnosis, or further imaging results (if the patient was managed nonoperatively). Test characteristics were calculated for the identification of appendicitis and identification of perforation. Results: Of the 539 patients evaluated for appendicitis, 144 (26.7%) patients had appendicitis, and 40 of these (27.8%) were perforated. Thirty-nine had RLQUS performed as part of their evaluation. Of these, 28 had positive findings for appendicitis, and 9 were read as definite or possible perforated appendicitis. The sensitivity of RLQUS for the diagnosis of appendicitis in the group with perforation was 77.1% (95% confidence interval [CI], 59.4–89%) and the sensitivity for diagnosing a perforation was 23.1% (95% CI, 11.1–39.3%). Conclusion: There was a low rate of detection of perforation by RLQUS in our pediatric population. If larger studies confirm this, additional imaging should be recommended in patients with a high suspicion of perforation and in whom a diagnosis of perforation would change management.**

☐ **Keywords—appendicitis; perforation; radiation; ultrasound**

INTRODUCTION

Appendicitis is the most common cause of acute surgical abdominal presentations in pediatric patients, but making the diagnosis of acute appendicitis in the emergency department (ED) may be difficult because of variable and nonspecific history and clinical findings (1). Up to 50% of patients do not present with the classic Murphy's description of migratory colicky right lower quadrant (RLQ) pain (1). These atypical presentations have been associated with delays in diagnosis that can ultimately lead to perforation and abscess formation (2).

Approximately one-third of pediatric patients diagnosed with acute appendicitis have perforation noted at

Reprints are not available from the authors.

Received: 26 May 2015; Final submission received: 11 September 2015;
Accepted: 5 October 2015

time of operation, and patients with perforation have increased potential morbidity (3,4). When perforation is diagnosed before surgical intervention, the management strategy can shift significantly. The use of nonoperative management for perforated appendicitis may alter complication rates (5,6). For this reason, surgeons may rely on the ED to not only diagnose appendicitis, but to differentiate between perforated and nonperforated appendicitis.

Many centers, including ours, have shifted to use of RLQ ultrasound (RLQUS) as the primary radiographic modality by which to evaluate appendicitis. The primary objective of this study was to assess the sensitivity of US to identify perforated appendicitis in a pediatric ED population. Secondarily, other test characteristics were also calculated.

METHODS

Setting/Patients

Pediatric patients 3 to 21 years of age presenting to an urban, tertiary pediatric ED and receiving a radiographic work-up for appendicitis were retrospectively identified from 2010 to 2013. Search strategies included: vomiting, abdominal pain, RLQ pain, US of the abdomen, US of the pelvis, computed tomography (CT) scan of the abdomen, CT scan of the pelvis, magnetic resonance imaging (MRI) scan of the abdomen, MRI of the pelvis, and MRI of an undefined area. This is a subgroup analysis of this larger data set including only patients in whom appendicitis with perforation was identified at time of surgery or on surgical pathology.

Procedures

Data were retrospectively collected. All data collection was performed by pediatric emergency medicine attending physicians, pediatric or emergency medicine residents, or medical students. All received training instructions from one of the study coordinators. For all patients, the final read for radiographic studies was ascertained, as was the operative diagnosis and surgical pathology. The US report was assessed for a reading of perforation or potential signs of perforation, such as loculated fluid collection, absence of echogenic submucosal layer, or free air (7,8). If a patient was noted to have perforated appendicitis on the operative report or the pathology report revealed perforation, the patient was considered to be perforated for the purposes of this study. If a patient was managed nonoperatively because of perforation, the results of a CT or MRI scan documenting the perforation was used a surrogate for surgical pathology. US reports were assessed for both patients ultimately shown to have a perforation and those whose final diagnosis was nonperforated appendicitis. Data on laboratories and physical examinations were obtained similarly from patient chart review.

Radiographic Studies

RLQUSs are performed with a 14- or 18-MHz linear transducer with the use of Doppler. Point-of-care USs were not reviewed; only those performed and read in the radiology suite were used for this study.

Statistical Analysis

Only descriptive statistics are reported. Because of the small number of patients, further statistical analysis was not attempted.

This study was approved by the institutional review board.

RESULTS

Five hundred ninety patients received a radiographic evaluation for appendicitis during the study period, of whom 144 patients had appendicitis. Forty of these were perforated by our definition: 34 were noted to be perforated at time of surgery, 3 were not noted to be perforated in the operative report but were diagnosed with perforation on pathology, and 3 were managed nonoperatively based on perforation noted radiographically on CT or MRI scans. The rate of perforation was 27.8% of the total 144 patients with appendicitis. In the patients with a perforation, the mean documented maximum temperature was 100.9°F (range, 97.9–104.8°F) and the mean white blood cell count was $18.4 \times 10^5/\mu L$ (range, 6.1–$25.7 \times 10^5/\mu L$). Three of the 38 patients for whom the physical examination findings were documented had peritoneal findings and 5 of 27 patients had rebound tenderness.

Of 40 patients with perforated appendicitis, 39 of the patients had a RLQUS performed as part of their evaluation for appendicitis. One patient was lost to follow-up after transfer to an outside hospital for treatment; however, a MRI scan that revealed a perforation was performed before the transfer, and this patient was included. Twenty-three (57.5%) were female and the median age was 13.3 years. No patient had free air limiting interpretation, nor were any studies deemed inadequate because of movement. Of these, 27 had positive findings for appendicitis (23 demonstrated appendicitis and 4 did not visualize the appendix but noted findings such as periappendiceal inflammation suspicious for appendicitis). Four were read as equivocal, and 8 were thought not to have findings indicative of appendicitis, although no

appendix was seen. Sensitivity for appendicitis in the patients with perforation was 77.1% (95% confidence interval [CI], 59.4–89%). Of the 27 positive studies, 9 (33.3%) found possible or definite evidence of perforation (8 were read as perforated on RLQUS and 1 was read as a possible perforation). Therefore, the sensitivity of diagnosing perforated appendicitis with RLQUS was 23.1% (95% CI, 11.1–39.3%). Specificity was 100% (95% CI, 96.5–100%), the positive predictive value was 100% (95% CI, 66.4–100%), and the negative predictive value was 77.4% (95% CI, 69.4–84.2%). Indirect findings associated with perforation are summarized in Table 1. The time from US to surgery was available in 33 patients, and the average time was 732 min (range, 65–3098 min).

DISCUSSION

In children, CT scans have the highest sensitivity for diagnostic imaging of acute appendicitis, but US and its role in the diagnosis of appendicitis are gaining interest (9). The use of US has been shown to decrease rates of CT scan utilization, decrease radiation exposure, and decrease health care costs (9–11). A recent study on US for appendicitis revealed high accuracy in diagnosing acute appendicitis and reduced rate of negative appendectomies with a sensitivity of 88% and a specificity of 92% (12).

Recent investigations into US and its role in identifying perforated appendicitis have yielded limited data in the pediatric population. In a prospective study of children and adults, Puylaert et al. reported the sensitivity of US for diagnosing acute appendicitis in patients with perforation at 28.5% compared to 80.5% in acute nonperforated appendicitis (13). In a different study, Borushok et al. looked at adult and pediatric abdominal US and found that when multiple radiologic findings were combined, the sensitivity of US in detecting perforated appendicitis improved to 86%, and the specificity was 60% (14). While visualizing the appendix in pediatric patients with perforation has been estimated to occur in only 38% of cases, the sensitivity of corroborative findings, such as loss of the echogenic submucosal layer, is questionable, particularly in older children (7,8). In our study, few of those findings outside of appendicolith were noted. Appendicolith was more common in the patients with perforation (38.5% vs. 13.5%), but the clinical significance of this difference is questionable.

Table 1. Ultrasonographic Features of Appendicitis

Feature	Perforated Appendicitis (n = 40)	Nonperforated Appendicitis (n = 104)
Evidence of appendicitis on US	29/39	78/104
Evidence of perforation on US	12/39	0
Appendicolith	15/39	14/104
Loculated fluid collection	3/39	0
Free air	0	0
Loss of echogenicity	1/39	0

US = Ultrasound.

Certainly, the poor sensitivity of US to determine perforation demonstrated in this study creates a conundrum for physicians at institutions that manage perforated appendicitis in nonsurgical or delayed surgical fashions. To follow all US with a CT or MRI scan negates the utility of US as an inexpensive and radiation-reducing diagnostic tool. In this study, 16 patients underwent a subsequent MRI scan and 3 patients a subsequent CT scan, and management changes occurred in 3 patients. Clearly, white blood cell counts, temperature, and peritoneal signs increase the suspicion of perforation, and may help supplant the US somewhat. Still, while it is recognized that US is a poor test for perforation, additional imaging should depend not only on suspicion, but also on the likelihood of management change.

LIMITATIONS

Our rate of perforation of the total 144 appendicitis cases included in our study was lower than the expected perforation rate of about a third of all pediatric acute appendicitis (3). This may have been related to having an older pediatric patient population in the study (median age, 12.33 years), because younger pediatric patients are more likely to be perforated at the time of presentation (7,8). It is difficult to claim with certainty that the sensitivity of RLQUS for the diagnosis of perforation is comparable across the pediatric age range. While our group ranged in age from 1.2 to 21.7 years, only 4 of the patients were <8 years of age. An inherent weakness of our retrospective study is the possibility of missing some patients with perforated appendicitis. We used a follow-up attempt for all of the patients with negative US studies, and we achieved a follow-up rate of 88.6%. None of the patients that were contacted as follow-ups were later diagnosed with missed acute appendicitis, yet it is still possible that a patient we were unable to reach was discharged home with a perforation. Another limitation of this project was the factor of time. While all patients were treated urgently, the exact time lapse between when the US was performed to when the perforated appendicitis was diagnosed (either by surgery, pathology, or other diagnostic imaging) was just over 12 hours. Delay in treatment or intervention has been found to be highly associated with perforation in acute appendicitis (15). Although delays of >12 hours are associated with perforation risk, it may be possible that some of our patients had acute nonperforated appendicitis at the time of US and perforated while awaiting surgery (16). Finally, while the diagnostic quality of US

can be operator-dependent, we did not test interobserver reliability of the various different sonographers and radiologists who participated in our patients' care.

CONCLUSION

Ultrasonography is a useful tool to diagnose pediatric acute appendicitis, but we found an unacceptably low rate of detection of perforated appendicitis by RLQUS in our pediatric patients with final diagnosis of perforation. For emergency providers, it is invaluable to quickly distinguish a perforated appendix from the classic noncomplicated appendicitis because of the change in management and difference in morbidity. If larger studies confirm this center's experience, additional imaging should be recommended in patients with a high suspicion of perforation and in whom a diagnosis of perforation would change management.

REFERENCES

1. Humes DJ, Simpson J. Acute appendicitis. BMJ 2006;333:530–4.
2. Rothrock SG, Skeoch G, Rush JJ, Johnson NE. Clinical features of misdiagnosed appendicitis in children. Ann Emerg Med 1991;20:45–50.
3. Lund DP, Murphy EU. Management of perforated appendicitis in children: a decade of aggressive treatment. J Pediatr Surg 1994;29:1130–4.
4. Chen C, Botelho C, Cooper A, Hibberd P, Parsons SK. Current practice patterns in the treatment of perforated appendicitis in children. J Am Coll Surg 2003;196:212–21.
5. Fishman SJ, Pelosi L, Klavon SL, O'Rourke EJ. Perforated appendicitis: Prospective outcome analysis for 150 children. J Ped Surg 2000;35:923–6.
6. Perović Z. Drainage of the abdominal cavity and complications in perforating appendicitis in children. Med Pregl 2000;53:193–6. [in Croatian].
7. Quillin SP, Siegel MJ, Coffin CM. Acute appendicitis in children: value of sonography in detecting perforation. AJR Am J Roentgenol 1992;159:1265–8.
8. Blumfield E, Nayak G, Srinivasan R, et al. Ultrasound for differentiation between perforated and nonperforated appendicitis in pediatric patients. AJR Am J Roentgenol 2013;200:957–62.
9. Doria AS, Moineddin R, Kellenberger CJ, et al. US or CT for diagnosis of appendicitis in children and adults? A meta-analysis. Radiology 2006;241:83–94.
10. Pastore V, Cocomazzi R, Basile A, Pastore M, Bartoli F. Limits and advantages of abdominal ultrasonography in children with acute appendicitis syndrome. Afr J Paediatr Surg 2014;11:293–6.
11. Wan MJ, Krahn M, Ungar WJ, et al. Acute appendicitis in young children: cost-effectiveness of US versus CT in diagnosis—a Markov decision analytic model. Radiology 2009;250:378–86.
12. Hussain S, Rahman A, Abbasi T, Aziz T. Diagnostic accuracy of ultrasonography in acute appendicitis. J Ayub Med Coll Abbottabad 2014;26:12–7.
13. Puylaert JB, Rutgers PH, Lalisang RI, et al. A prospective study of ultrasonography in the diagnosis of appendicitis. N Engl J Med 1987;317:666–9.
14. Borushok KF, Jeffery RB Jr, Laing FC, Townsend RR. Sonographic diagnosis of perforation in patients with acute appendicitis. AJR Am J Roentgenol 1990;154:275–8.
15. Brender JD, Marcuse EK, Koepsell TD, Hatch EI. Childhood appendicitis: factors associated with perforation. Pediatrics 1985;76:301–6.
16. Chang Y, Chao HC, Kong MS, Hsai SH, Yan DC. Misdiagnosed acute appendicitis in children in the emergency department. Chun Gung Med J 2010;33:551–6.

ARTICLE SUMMARY

1. Why is this topic important?

Evaluation for acute appendicitis is a common reason for obtaining radiographs in the emergency department. As ultrasound gains popularity as a diagnostic tool, so should the understanding of its limitations.

2. What does this study attempt to show?

This study attempts to evaluate the sensitivity of ultrasound in identifying patients with perforated appendicitis.

3. What are the key findings?

In our pediatric patients with perforated appendicitis, ultrasound correctly identified the appendicitis with a sensitivity of 73.7% and identified the perforation with a sensitivity of 23.7%.

4. How is patient care impacted?

In centers where perforated appendicitis in children is managed with an alternative approach, consideration should be given to further imaging in patients with a presentation concerning for perforation.