Ultrasound versus CT for Diagnosing Acute Appendicitis and Appendicitis Treatment Altering Conditions

Christopher Borowy, MS-IV[1]*, Luke Rond, D.O[2], John Ashurst, D.O[2], and Stefan Merrill, M.D[2]

[1]Arizona College of Osteopathic Medicine, Midwestern University, Glendale, AZ, USA
[2]Department of Emergency Medicine, Kingman Regional Medical Center, Kingman, AZ, USA

*Corresponding Author: Christopher Borowy; cborowy29@midwestern.edu

Introduction: *Acute appendicitis is the most common cause of atraumatic abdominal pain in children over 1 year of age. Even though diagnostic imaging modalities have evolved over the past 20 years, accurate diagnosis of acute appendicitis still presents as a challenge. Computed tomography (CT) is currently the most commonly used radiographic test for acute appendicitis. Unlike CT, ultrasound (US) does not require ionizing radiation which is harmful to the patient. Even though the specificity of US has been well studied in acute appendicitis, CT is still commonly requested after a positive US. Till date, there has been no published research evaluating the utility of US in changing management in appendicitis.*

Purpose: *The purpose of the study is to compare the ability of US and CT to diagnose pathology proven acute appendicitis and to predict Appendicitis Treatment Altering Conditions (ATAC).*

Methods: *This is a retrospective cohort study that compares the positive predictive value (PPV) and the ATAC rate of US and CT when diagnosing acute appendicitis.*

Results: *There were 432 appendicitis cases reported between 1 October 2012 and 30 June 2017. Of those cases, 409 were diagnosed by CT and 23 were diagnosed by US. The PPV of both modalities was above 90% (CT = 97%, US = 95%), and the ATAC rates were statistically similar (CT = 14%, US = 22%, P = 0.21).*

Conclusion: *The study supports that a positive US for appendicitis is as diagnostic as a positive CT. Therefore, adding on a CT scan after a positive US does not help recognize other sources of intra-abdominal pathology that would negate doing a laparoscopy.*

Keywords: *US, ultrasound, CT, CAT, ATAC, appendicitis, sensitivity, positive predictive value, PPV*

INTRODUCTION

Acute appendicitis is the most common cause of atraumatic abdominal pain in children over 1 year of age, and it has a lifetime risk of 12% in males and 25% in females in the United States.[1] Even though technology has progressed in the past 20 years, with several inflammatory lab markers and diagnostic imaging modalities, accurate diagnosis of acute appendicitis still presents a challenge.[1,2] 'Negative appendectomies' and missed appendicitis still occur and can cause significant morbidity and mortality.[1] Clinical diagnosis alone is unreliable as it has an accuracy of 80% and has a negative appendectomy rate of 20%.[3] Similarly, laboratory values are unreliable and cannot be used in isolation to include or exclude the diagnosis of acute appendicitis,[4] signifying the need for imaging. Computed tomography (CT) is currently the most commonly used radiographic diagnostic test for acute appendicitis but causes ionizing radiation to the patient.[5] The use of ultrasound (US) to diagnose appendicitis can save the USA $24.9 million per year and can prevent 180 excess cancer deaths, which would be another $339.5 million toward those lives lost.[6]

There has been extensive research evaluating the reliability of US to diagnose acute appendicitis, showing a sensitivity of 29–94% and a specificity of 83–100%.[3,7–26] Even though there is an exceptional specificity of US for acute appendicitis, CT scans are still commonly requested after a positive US. It has been documented that 48% of patients with a positive US still get an abdominal CT scan.[12] While the study did not indicate the reason for the supplemental CT scans, in practice this is often a standard protocol. In fact, a CT scan is often ordered to help assist in planning an operation, to help identify a periappendiceal abscess that may delay immediate appendectomy, and to help recognize other sources of intra-abdominal pathology.[27] When an inflamed appendix develops microperforations, a periappendiceal abscess can develop.[2] These abscesses are commonly treated with antibiotics with or without percutaneous drainage with an elective appendectomy 6 weeks later.[2] This approach is associated with lower rates of complications, such as abscess formation, bowel obstructions, and reoperation when compared to early appendectomy.[2] While these concerns are understandable, there has been no published research evaluating the utility of US in predicting such Appendicitis Treatment Altering Conditions (ATAC).

The purpose of this study is to compare the ability of US and CT to diagnose pathology proven acute appendicitis and to predict ATAC. If US has a similar positive predictive value (PPV) and ATAC rate as CT, then a CT scan is not warranted after a positive US examination.

METHODS

This is a retrospective cohort study meant to calculate and compare the PPV and the ATAC rates of US and CT when diagnosing acute appendicitis. This research was performed at Kingman Regional Medical Center (KRMC), a rural 235-bed hospital with residency training programs in emergency and family medicine.[28] This project was approved by the Institution Review Board at KRMC. The data were initially obtained by collecting all of the appendectomy pathology reports performed at KRMC from 1 October 2012 to 30 June 2017, the time when KRMC increased their use of US to diagnose acute appendicitis. For each patient, we collected their pathology diagnosis, demographics (age, gender, and race), date of procedure, medical record number, postoperative diagnoses, imaging modality type and date, interpretation of that modality, and the inflammatory indicators (temperature, heart rate, and white cell count) in a de-identified manner. The inflammatory indicators recorded was the highest value recorded while in the emergency department (ED), in the scenario that an ED note was not created (i.e., direct admit), the earliest documented note for the appendicitis visit was used. Patients were then excluded if their diagnostic modality was not a CT or US identifying the appendix, appendectomy was incidental (i.e., right hemicolectomy for colon cancer), or the patient developed appendicitis while in the hospital for another condition. An ATAC was then identified when the pathology diagnosis and/or postoperative diagnosis was perforated appendix or appendicitis with abscess, the pathology diagnosis was negative for acute appendicitis, or there was no pathology report documented. Appendiceal masses on the pathology report were included as that diagnosis still warrants an appendectomy. To help reduce selection bias, these inclusion/exclusion criteria and ATAC definitions have been clearly defined. It was then recorded whether this ATAC was predicted by the imaging modality. There were scenarios where US found the appendix and CT was not recommended, but a subsequent CT was still performed. In this scenario, the patient was included twice, first for the US modality and the second for the CT. Microsoft Excel 2016 was then used to calculate the PPV of each modality and their ATAC rate (defined as the number of ATACs missed by that modality divided by the total number of cases for that modality).

RESULTS

Within the 5 years queried there were 462 appendectomy pathology reports, 40 of which were excluded and 10 were duplicated. The excluded patients involved 32 incidental appendectomies (right hemicolectomies, small bowel obstructions, obstetrics or gynecologic cases such as pelvic inflammatory disease (PID) or cesarean sections, hernia repair, and one found on imaging during a chest pain workup), seven occurred in the hospital, two were diagnosed with magnetic resonance imaging (MRI), one was diagnosed by the clinical examination, and two did not have a documented pathology report. This left 432 patients, of which 409 were diagnosed by CT and 23 were diagnosed by US (Figure 1).

The ethnic demographics of the population have a chi-squared value of 0.009 (Table 1). Comparatively, the US group was significantly younger (14 vs. 40 years, $P < 0.001$), had a higher heart rate (107 vs. 95, $P < 0.001$), and a higher white blood cell (WBC) (16 vs. 14, $P = 0.03$), but had similar temperatures (98.8 vs. 98.5, $P = 0.25$) (Table 2). The PPV of both modalities was above 90% (CT = 97%, US = 95%), and the ATAC rates were statistically similar (CT = 14%, US = 22%, $P = 0.21$) (Table 3).

DISCUSSION

This retrospective study supports that a positive US for appendicitis is as diagnostic as a positive CT, as both of their PPVs are above 90% and the ATAC rates are similar. Therefore, if an US is positive for acute appendicitis adding a CT scan does not help recognize other sources of intra-abdominal pathology or identify a periappendiceal abscess that would negate doing a laparoscopy. The ATAC rate of 15% could be because of the time between the imaging modality being obtained and the operating room, which would further support not getting a CT when the US is positive. To illustrate this point, there was a case where the emergency physician communicated an US finding consistent with appendicitis on a 16-year-old female and the general surgeon requested a CT, which delayed care by 2 h and 3 min by which time the CT showed evidence of perforation. This young patient could have avoided the harm of ionizing radiation, delayed antibiotics, and perforated viscous if the US findings had been trusted. This was included as an ATAC for the US as it is possible that US missed the appendicitis; however, US still showed statistically similar ATAC rates to CT. In addition, the CT did not change management as the patient was taken for an immediate appendectomy anyways, further supporting no added benefit of CT compared to a positive US.

Pitfalls of this article include the different patient demographics and disproportionate population sizes. The US population was younger and had a higher WBC and heart rate. The younger age is likely because of the body habitus restrictions on US, which could also explain the higher heart rate as younger ages tend to have higher heart rates, but does not explain the higher WBC. The implication of the higher WBC and heart rate is that the US population was sicker. If so, this would make US even more trustworthy as it could have the same ATAC rate in a sicker population, many of whom are more likely to have complications such as perforation or abscesses. Another asymmetry involves the population sizes as there were a total of 409 who got a CT and 23 who got an US, even after duplicating the 10 patients who got both. However, this was also a handicap for the US modality as those 10 patients who had an added delay for the CT scan had an increased chance of perforation between the US and the CT, worsening the ATAC rate for US and not for CT. Even with these handicaps, US still had a statistically similar ATAC rate.

Overall, these results support that US and CT have statistically similar PPV and the ATAC rates. However, given the relatively low sample size these data need to be replicated in a larger sample population before being applied to the general population.

CONFLICTS OF INTEREST AND FUNDING

There were no conflicts of interest, and no need for funding of this research as was a retrospective chart review.

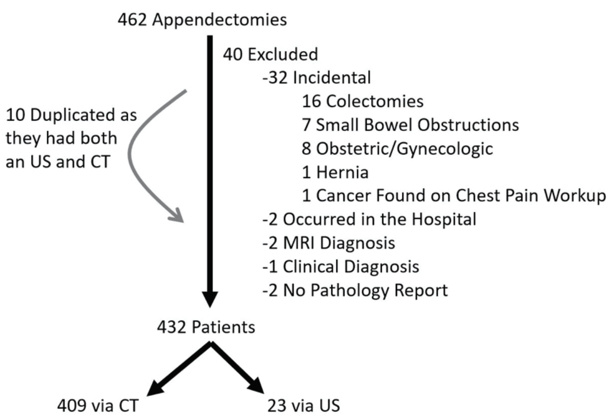

Figure 1. Population diagram showing those excluded and duplicated.

Table 2. Average age and inflammatory indicators for CT and US, with standard deviations and two-tailed homoscedastic *P*-values between the two modalities.

	CT	US	*p*-value
Age(years)	40.0±21.4	14.2+6.9	<0.001
T emperature(F)	98.5±1.2	98.8±1.4	0.25
Heart Rate (bpm)	94.8±17.8	107.2±18.9	<0.001
WBC(K/p.L)	14.0+4.9	16.0±6.2	0.03

similar (CT = 14%, US = 22%, *P* = 0.21) (Table 3).

Table 3. Statistical analysis. The calculated PPV and ATAC rate.

	TP	FP	Neg	PPV	#missed ATAC	Total	ATAC rate
CT	393	11	5	**0.973**	58	409	**14.2%***
US	18	1	4	**0.947**	5	23	**21.7%***

**P* = 0.21 (1-tailed, paired).

Table 1. Population demographics. Chi-squared value between the two modalities is 0.009.

	African American	American Indian	Asian & Oriental	Hispanic	Middle Eastern Indian	White	Other
CT	3(0.7%)	21(5%)	1(0.2%)	34(8%)	2(0.5%)	344(84%)	4(1%)
US	0(0%)	1(5%)	0(0%)	4(21%)	0(0%)	18(95%)	0(0%)

REFERENCES

1. Tintinalli MD, Judith E, et al., editors. Tintinalli's emergency medicine: a comprehensive study guide. 8th ed. New York, NY: McGraw Hill; 2016; 532–36.

2. Doherty MD, Gerard M, et al., eds. Current diagnosis and treatment: surgery. 14th ed. New York: McGraw Hill; 2015.

3. Toorenvliet BR, et al. Routine ultrasound and limited computed tomography for the diagnosis of acute appendicitis. World J Surg. 2010; 34(10): 2278–85.

4. Wesson, David E, MD. Acute appendicitis in children: clinical manifestation and diagnosis. Up To Date. 2014 [cited 06 Aug 6], Available from: http://www.uptodate.com

5. Klingensmith MD, Mary E, et al., editors. The Washington manual of surgery. 6th ed. Philadelphia, PA: Lipincott Williams and Wilkins; 2012.

6. Parker L, et al. Cost and radiation savings of partial substitution of ultrasound for CT in appendicitis evaluation: a national projection. AJR; 2014; 202(1): 124–35.

7. Mittal MK, et al. Performance of ultrasound in the diagnosis of appendicitis in children in a multicenter cohort. Acad Emerg Med. 2013; 20(7): 697–702.

8. Kearl YL, et al. Accuracy of magnetic resonance imaging and ultrasound for appendicitis in diagnostic and nondiagnostic studies. Acad Emerg Med. 2016; 23(2): 179–85.

9. Doniger SJ, Kornblith A. Point-of-care ultrasound integrated into a staged diagnostic algorithm for pediatric appendicitis. Pediatr Emerg Care. 2016; 34(2):109–115.

10. Lourenco P, et al. The current utility of ultrasound in the diagnosis of acute appendicitis. Clin Imag. 2016; 40(5):944–8.

11. Pare JR, et al. Revival of the use of ultrasound in screening for appendicitis in young adult men. J Clin Ultrasound. 2016; 44(1): p3–11.

12. Mallin M, et al. Diagnosis of appendicitis by bedside ultrasound in the ED. Am J Emerg Med. 2015; 33(3): 430–2.

13. Carroll PJ, et al. Surgeon-performed ultrasound at the bedside for the detection of appendicitis and gallstones: systematic review and meta-analysis. Am J Surg. 2013; 205(1): 102–8.

14. Al-Ajerami Y. Sensitivity and specificity of ultrasound in the diagnosis of acute appendicitis. EMHJ. 2012; 18(1): 66–9.

15. Reich B, et al. An international evaluation of ultrasound vs. computed tomography in the diagnosis of appendicitis. Int J Emerg Med. 2011; 4: 68.

16. Fox JC, et al. Prospective evaluation of emergency physician performed bedside ultrasound to detect acute appendicitis. Eur J Emerg Med. 2008; 15(2): 80–5.

17. Gracey D, McClure MJ. The impact of ultrasound in suspected acute appendicitis. Clin Radiol. 2007; 62(6): 573–8.

18. Johansson EP, Rydh A, Riklund KA. Ultrasound, computed tomography, and laboratory findings in the diagnosis of appendicitis. Acta Radiol. 2007; 48(3): 267–73.

19. West WM, et al. Ultrasound and white blood cell counts in suspected acute appendicitis. W Indian Med J. 2006; 55(2):100–2.

20. Dilley A, et al. The impact of ultrasound examinations on the management of children with suspected appendicitis: a 3-year analysis. J Pediatr Surg. 2001; 47: 299–328.

21. Karakas SP, et al. Acute appendicitis in children: comparison of clinical diagnosis with ultrasound and CT imaging. Pediatr Radiol. 2000; 30(2): 94–8.

22. Gutierrez CJ, et al. Doppler ultrasound accurately screens patients with appendicitis. Am J Surg. 1999; 65(11): 1015–7.

23. Wade DS, et al. Accuracy of ultrasound in the diagnosis of acute appendicitis compared with the surgeon's clinical impression. Arch Surg. 1993; 128(9): 1039–44.

24. Sim KT, et al. Ultrasound with graded compression in the evaluation of acute appendicitis. J Natl Med Assoc. 1989; 81(9): 954–7.

25. Thirumoorthi AS, et al. Managing radiation exposure in children – reexamining the role of ultrasound in the diagnosis of appendicitis. J Pediatr Surgery. 2012; 47(12): 2268–72.

26. Fathi M, et al. Diagnostic accuracy of emergency physician performing compression ultrasound study in acute appendicitis: a prospective study. J Ultrasound. 2014; 18(1): 57–62.

27. Souba MD, Wiley W, et al., eds. ACS surgery: principles and practice. 6th ed. New York: WebMD; 2007.

28. About KRMC. Kingman Regional Medical Center; 2018. Available from: www.azkrmc.com.