Published in final edited form as:

Curr Probl Diagn Radiol. 2018 ; 47(1): 6–9. doi:10.1067/j.cpradiol.2016.12.002.

USE OF COMPUTED TOMOGRAPHY TO DETERMINE PERFORATION IN PATIENTS WITH ACUTE APPENDICITIS

Cameron E. Gaskill, MD, MPH^{a,b}, Vlad V. Simianu, MD, MPH^{a,b}, Jonathan Carnell, MD^c, Daniel S. Hippe, MS^c, Puneet Bhargava, MD^c, David R. Flum, MD, MPH^{a,b}, and Giana H. Davidson, MD, MPH^{a,b}

^aDepartment of Surgery, University of Washington, Seattle, WA

^bSurgical Outcomes Research Center, University of Washington, Seattle, WA

^cDepartment of Radiology, University of Washington, Seattle, WA

Abstract

Purpose—Urgent appendectomy has long been the standard of care for acute appendicitis. Six randomized trials have demonstrated that antibiotics can safely treat appendicitis, but approximately 1 in 4 of these patients eventually require appendectomy. Overall treatment success may be limited by complex disease including perforation. Patient success for antibiotic therapy may depend on preoperative identification of complex disease on imaging. However, the effectiveness of computed tomography (CT) in differentiating complex disease including perforated from non-perforated appendicitis remains to be determined. The purpose of this study was to assess the preoperative diagnostic accuracy of CT in determining appendiceal perforation in patients operated for acute appendicitis.

Methods—We performed a retrospective review of pathology and radiology reports from consecutive patients who presented to the emergency room with suspicion for acute appendicitis between January 2012 and May 2015. CT scans were re-reviewed by abdominal imaging fellowship trained radiologists using standardized criteria, and the radiologists were blinded to pathology and surgical findings. Radiologists specifically noted presence or absence of periappendiceal gas, abscess, appendicolith, fat stranding, and bowel wall thickening. The overall radiologic impression as well as these specific imaging findings were compared to results of pathology and operative reports. Pathology reports were considered the standard for diagnostic accuracy.

Results—Eighty-nine patients (65% male, average age of 34 years) presenting with right lower quadrant pain underwent CT imaging and prompt appendectomy. Final pathology reported perforation in 48% (n=43) of cases. Radiologic diagnosis of perforation was reported in 9% (n=8), correctly identifying perforation in 37.5% (n=3) and incorrectly reporting perforation in 62.5% of non-perforated cases per pathology. Radiology missed 93% (n=40) of perforations post-operatively diagnosed by pathology. There was no secondary finding (fat stranding, diameter >13mm, abscess, cecal wall thickening, periappendiceal gas, simple fluid collection,

appendicolith, phlegmon) with a clinically reliable sensitivity or specificity to predict perforated appendicitis. Surgeon report of perforation was consistent with the pathology report of perforation in only 28% of cases.

Conclusions—The usefulness of a CT for determining perforation in acute appendicitis is limited and methods to improve precision in identify patients with complicated appendicitis should be explored as this may help for improving risk prediction for failure of treatment with antibiotic therapy and help guide patients and providers in shared decision making for treatment options.

INTRODUCTION

Surgery has been the mainstay of treatment for appendicitis since the procedure's initial description by Lawson Tait in 1880.¹ Today, appendicitis has become the leading cause for acute abdominal surgery, with nearly 300,000 appendectomies performed annually in the United States alone.² Recently, evidence from six randomized trials^{3–8} comparing prompt appendectomy to treatment with antibiotics has challenged the treatment paradigm. These trials have shown antibiotics to be a safe alternative treatment to surgical appendectomy, but 18–36% of appendicitis cases initially treated with antibiotics require surgical therapy within 1 year follow up.^{3–6} Of the cases treated with antibiotics, 17–64% required operation within 30 days of presentation.^{3,4,6,7} Patients who were originally treated with antibiotics but subsequently underwent appendectomy had no increased rates of perioperative complications;^{3–8} however, more recent studies have reported longer lengths of stay in the hospital.^{3,4}

In both Vons³ and Salminen⁴ studies, computed topography (CT) was used to exclude patients with “complicated appendicitis” including radiographic impression of perforation. Despite attempted exclusion, Vons reported that of patients initially treated with antibiotics who required surgical appendectomy within 1 year, 27% had complicated appendicitis. Furthermore, Salminen reported that 33% of antibiotic treatment failures within their index hospitalization had perforated appendicitis, compared to 15% in the surgery control group. The failure to exclude these patients as planned in the protocol where CT imaging was used raises the question of the utility of imaging to accurately identify perforated appendicitis.

CT is well established as the gold standard for the diagnosis of acute appendicitis;⁹ however, its use in differentiating perforated appendicitis has yet to be demonstrated.^{10,11} As the paradigm of appendicitis treatment changes, it is critical that research focuses on ways to improve precision of recommendations for treatment and prediction of treatment failure. In the prior research on use of antibiotics in appendicitis, cases of perforation were missed by CT and had a higher rate of treatment failure. The objective of this study is to determine the diagnostic accuracy of CT in differentiating non-perforated from perforated appendicitis in a cohort of surgical patients with acute appendicitis, with the hypothesis that specific CT findings and reported imaging diagnosis would not be accurate in predicting perforation on final pathologic specimen.

METHODS

Study population

Using the imaging database for the University of Washington and Harborview Medical Centers, a retrospective cohort of patients who received CT imaging for clinical suspicion of appendicitis was assembled. All patients with CT scans performed between 1/2012 – 5/2015 for the indications of “right lower quadrant (RLQ) pain”, “rule out (r/o) appendicitis”, “r/o appy”, or “r/o appi” were considered eligible for inclusion. Patients were excluded if they had previous clinical and/or radiologic evidence of appendectomy or trauma as indication for imaging. Chart review revealed that 89 patients had undergone appendectomy within 24 hours following imaging with available pathology and surgery reports.

Medical record review

Patient medical records were reviewed to ascertain basic demographics. Original CT reports were created by CT body fellowship-trained radiology attending faculty members. CT studies were completed with use of intravenous contrast. All CT images were multiplanar and reviewed on Centricity PACS machines. These reports were retrospectively reviewed to determine findings of appendiceal perforation for patients operated for acute appendicitis. Reports were classified as positive for perforation if they contained affirmative phrases with the term “perforation”. Reports without mention of perforation or containing negating phrases regarding perforation (e.g. no evidence of perforation) were classified as negative for appendiceal perforation. Surgical reports were retrospectively reviewed to ascertain intraoperative diagnosis of perforation. Similarly, pathology reports were reviewed to determine pathology diagnosis of perforation.

Imaging review

CT scans were independently reviewed by 14 body fellowship-trained radiologists to ascertain specific presence of findings including peri-appendiceal gas, fluid collections, fat stranding, bowel wall thickening, abscess, phlegmon, and location of fluid. All reading sessions were facilitated in a uniform and standardized fashion. Both the facilitator and the reader were blinded to the original radiology reports, surgical reports, and pathology results.

Statistical analysis

Groups were stratified based on diagnosis of perforation on pathology. Cohort descriptions included demographic characteristics and presence of specific CT findings. CT findings were reported as counts and summarized as percentages. Proportions of each positive CT findings were compared between perforated and non-perforated groups using Fisher’s exact test. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each finding. Radiology diagnosis concordance with pathology and intraoperative diagnosis were determined in similar manner, using Fisher’s exact and chi-squared tests.

All statistical calculations were conducted with statistical computing language R (version 4.1–9; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 238 patients had undergone CT for appendicitis, of which 56 were excluded for previous clinical and/or radiologic evidence of appendectomy, 82 were excluded as they had not undergone appendectomy, and 11 were excluded for undergoing appendectomy outside of 24 hours from presentation. This left 89 patients (65% male, average age of 34 years $\pm$ 13) who underwent appendectomy for acute appendicitis. The incidence of perforated appendicitis according to pathology report was 48% (n= 43). There was no statistically significant difference in gender, age, or white blood cell count among those found to have appendiceal perforation compared to those with non-perforated appendicitis (table 1).

Frequency of specific CT findings in each group are tabulated in table 2. No statistically significant differences were seen for any CT finding between groups. Fat stranding had the highest sensitivity for perforated appendicitis at 95%; however, specificity was low at only 9% (table 3). An appendiceal diameter of over 13mm predicted perforation with the second highest sensitivity at 63% and a specificity of 78%. The remaining findings, including abscess, cecal wall thickening, periappendiceal gas, simple fluid collection, appendicolith, and phlegmon had sensitivities for perforation of equal to or less than 50%. Appendiceal diameter over 13mm, fat stranding, and appendicolith had the best negative predictive for an outcome of pathologic perforation with values at 70%, 67%, and 67%, respectively. Absence of the remaining CT findings, including periappendiceal gas, abscess, phlegmon, and cecal wall thickening on CT was correlated to the unperforated appendicitis in 52%, 53%, 52%, and 50% of cases, respectively.

The radiology reports had a sensitivity and specificity for identifying perforated appendicitis of 7% and 89%, respectively. Positive and negative predictive values for radiology reports identifying perforated appendicitis were 33% and 51%, respectively. Radiology diagnosed perforation in only 9% (n=8) of cases, correctly identifying perforation in 37.5% (n=3). Surgeon intraoperative diagnosis had a sensitivity and specificity of 28% and 87%, respectively. Intraoperative diagnosis identified perforation in 67% (n=12) of cases (table 4) noted to be perforated on final pathology. Sensitivity and specificity of intraoperative diagnosis to radiology report was 11% and 89%, respectively.

DISCUSSION

The use of CT in the diagnosis of appendicitis is well established and credited with a significant reduction of negative appendectomies.⁹ New use of antibiotics could reduce the need for appendectomy; however, success may be limited by proper patient selection.¹² Recent studies investigating use of antibiotics in acute appendicitis intended to exclude patients with perforated appendicitis based on CT imaging. Despite this, undetected cases of perforated appendicitis were mistakenly included, and the prevalence of these perforations were higher in patients who failed antibiotic treatment. Therefore, there may be an opportunity for clinicians to better understand which patients are more likely to fail antibiotic treatment by improving preoperative precision for identifying the “right patients for the right treatment”. This would guide shared decision making conversations between clinicians and patients.

Our study evaluated the diagnostic accuracy of CT in identifying appendiceal perforation. Specifically, we attempted to prove CT as a pragmatic tool for clinicians to differentiate perforated appendicitis to identify patients that may have a higher likelihood to be successful with antibiotic treatment for appendicitis. Furthermore, we attempted to identify specific findings on CT that may be of highest utility in making this differentiation. Our results suggest that no individual CT finding demonstrated a suitable sensitivity or specificity to aid identification or exclusion of perforation in our analysis. Additionally, poor concordance was found between reported radiologic diagnosis of appendiceal perforation and both pathology and intraoperative reported diagnoses.

Review of the literature has revealed mixed results in the use of CT to diagnose perforated appendicitis. Siddiqui et al.¹³ evaluated radiologist reported diagnosis, finding CT to be 72% sensitive and 97% specific for identifying appendiceal perforated. However, this study's findings have yet to be repeated, and our study found a significantly lower sensitivity and specificity of radiology reported perforation, at 7% and 89%, respectively. Early studies^{14–16} evaluating use of specific CT findings to diagnose perforated appendicitis showed the presence of either abscess, phlegmon, or extraluminal gas carried a sensitivity and specificity of 92% and 88%, respectively.¹⁴ Interestingly, these findings were not concordant with later studies^{11,17,18} that found the same CT findings to have low sensitivities for perforation, ranging 12–76% for any one specific CT finding. These authors' criticisms of the prior studies focused on the low numbers of included patients (n = 59, 75, 94) and patient sample bias towards higher rates of perforation. More recently, Kim¹⁹ and Verma²⁰ confirmed poor sensitivity of specific CT findings in detecting appendiceal perforation, with sensitivities ranging 11–71%. Our findings are consistent with recent literature, with none of the specific CT findings we examined able to identify cases of perforation, nor the absence of these findings suitable to rule out perforation as diagnosed by pathology specimens.

The reported prevalence of appendiceal perforation in the radiographic studies ranged from 41–79%,^{11,14–20} much higher than the reported rates in epidemiologic studies of 18–30%.^{2,21,22} Our study had a prevalence of appendiceal perforation of nearly 50%. Despite a higher than expected rate of perforation, calculated positive predictive values of specific CT findings remained poor. For example, within our study's cohort, if a radiology report was interpreted as having a perforation, the appendix was twice as likely to not be perforated on final pathology.

The large discordance in perforation rates seen across studies is in part due to the lack of a clear definition of perforated appendicitis. Studies may report true perforation based on a diagnosis from either pathology reports or surgical findings, with gold standard having been established. Diagnostic criteria also differ within sources, as large and small (micro) perforations may be categorized inconsistently. Furthermore, the presence of tissue necrosis or suppurate remains ambiguous as they relate to the presence of perforation. The lack of a standardized definition brings into question the current use of the term “perforation” in radiology reports examining the appendix. Finally, the methods utilized in this study, specifically use of imaging indication to identify potential subjects, may bias the cohort towards those with more advanced disease as it would not capture patients imaged for vague or centralized abdominal pain typical of early appendicitis.

Comparing intraoperative diagnosis to pathology diagnosis had a sensitivity and specificity of 28% and 87%, respectively. In distinction from radiology reports, this discrepancy may be due to consistency in surgeon reporting rather than intraoperative misdiagnosis given that perforation should be clearly visible in surgery. These discrepancies highlight the issue with using pathology as the gold standard for diagnosis. Pathology may over call micro-perforation that are otherwise clinically irrelevant or under call perforations that were not included in the portion of specimen sectioned. However, correlation of intraoperative diagnosis to radiology report was also poor, with a sensitivity and specificity of 11% and 89%, respectively.

This study has several limitations. The largest limitation is the small number of patients. This is due to our method of using CT indication as means of identifying cases of appendicitis that surgical patients were selected from. This limited the final analysis in combining variables to improve diagnostic accuracy for or against perforation. Furthermore, the retrospective methodology and secondary analysis of previously collected data limited the availability of variables and inhibited forming results that could be directly compared to previous studies. Additionally, while CT findings were reported in a standardized way, pathology, radiology, and intraoperative diagnosis were not, thus leaving the results vulnerable to underreporting of perforation diagnosis in pathologic and surgical reports.

CONCLUSIONS

The diagnostic accuracy of CT in differentiating appendiceal perforation from uncomplicated appendicitis is poor. Specific CT findings and radiology report do not correlate well with pathology or intraoperative diagnosis. Future efforts should be aimed at a multicenter experience with increased case numbers and standardized radiology, pathology, and intraoperative reporting to improve the precision in identifying patients that have the best chance of success for antibiotic therapy and moving directly to surgery for those with a high likelihood of requiring an operation for appendicitis. As the field continues to explore the use of antibiotics for treating appendicitis, caution should be exercised in relying on CT for ruling out perforation.

References

1. Seal A Appendicitis: a historical review. *Can J Surg J Can Chir.* 1981;24(4):427–433.
2. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. *Am J Epidemiol.* 1990;132(5):910–925. [PubMed: 2239906]
3. Vons C, Barry C, Maitre S, et al. Amoxicillin plus clavulanic acid versus appendicectomy for treatment of acute uncomplicated appendicitis: an open-label, non-inferiority, randomised controlled trial. *The Lancet.* 2011;377(9777):1573–1579.
4. Salminen P, Paajanen H, Rautio T, et al. Antibiotic Therapy vs Appendectomy for Treatment of Uncomplicated Acute Appendicitis: The APPAC Randomized Clinical Trial. *JAMA.* 2015;313(23):2340. doi:10.1001/jama.2015.6154. [PubMed: 26080338]
5. Turhan AN, Kapan S, Küçükçü E, Yi itba H, Hatipo lu S, Aygün E. Comparison of operative and non operative management of acute appendicitis. *Ulus Travma Acil Cerrahi Derg.* 2009;15(5):459–62. [PubMed: 19779986]
6. Styrd J, Eriksson S, Nilsson I, et al. Appendectomy versus Antibiotic Treatment in Acute Appendicitis. A Prospective Multicenter Randomized Controlled Trial. *World J Surg.* 2006;30(6):1033–1037. doi:10.1007/s00268-005-0304-6. [PubMed: 16736333]

7. Hansson J, Körner U, Khorram-Manesh A, Solberg A, Lundholm K. Randomized clinical trial of antibiotic therapy versus appendicectomy as primary treatment of acute appendicitis in unselected patients. *Br J Surg.* 2009;96(5):473–481. doi:10.1002/bjs.6482. [PubMed: 19358184]
8. Eriksson S, Granström L. Randomized controlled trial of appendicectomy versus antibiotic therapy for acute appendicitis. *Br J Surg.* 1995;82(2):166–169. [PubMed: 7749676]
9. Krajewski S, Brown J, Phang PT, Raval M, Brown CJ. Impact of computed tomography of the abdomen on clinical outcomes in patients with acute right lower quadrant pain: a meta-analysis. *Can J Surg J Can Chir.* 2011;54(1):43–53.
10. Solomon CG, Flum DR. Acute Appendicitis — Appendectomy or the “Antibiotics First” Strategy. *N Engl J Med.* 2015;372(20):1937–1943. doi:10.1056/NEJMcp1215006. [PubMed: 25970051]
11. Bixby SD, Lucey BC, Soto JA, Theysohn JM, Ozonoff A, Varghese JC. Perforated versus Nonperforated Acute Appendicitis: Accuracy of Multidetector CT Detection 1. *Radiology.* 2006;241(3):780–786. [PubMed: 17114626]
12. Ehlers AP, Talan DA, Moran GJ, Flum DR, Davidson GH. Evidence for an Antibiotics-First Strategy for Uncomplicated Appendicitis in Adults: A Systematic Review and Gap Analysis. *J Am Coll Surg.* 2016;222(3):309–314. doi:10.1016/j.jamcollsurg.2015.11.009. [PubMed: 26712246]
13. Siddiqui AH, Afzal S. Perforated appendicitis: accuracy of ct diagnosis and correlation of ct findings with the length of hospital stay. *J Coll Physicians Surg--Pak JCPSP.* 2007;17(12):721–725. doi:12.2007/JCPSP.721725. [PubMed: 18182135]
14. Oliak D, Sinow R, French S, Udani VM, Stamos MJ. Computed tomography scanning for the diagnosis of perforated appendicitis. *Am Surg.* 1999;65(10):959–964. [PubMed: 10515543]
15. Horrow MM, White DS, Horrow JC. Differentiation of Perforated from Nonperforated Appendicitis at CT1. *Radiology.* 2003;227(1):46–51. doi:10.1148/radiol.2272020223. [PubMed: 12615997]
16. Yeung K-W, Chang M-S, Hsiao C-P. Evaluation of perforated and nonperforated appendicitis with CT. *Clin Imaging.* 2004;28(6):422–427. doi:10.1016/S0899-7071(03)00286-9. [PubMed: 15531143]
17. Lin C-J, Chen J-D, Tiu C-M, et al. Can ruptured appendicitis be detected preoperatively in the ED? *Am J Emerg Med.* 2005;23(1):60–66. doi:10.1016/j.ajem.2004.09.021. [PubMed: 15672340]
18. Foley TA, Earnest F, Nathan MA, Hough DM, Schiller HJ, Hoskin TL. Differentiation of Nonperforated from Perforated Appendicitis: Accuracy of CT Diagnosis and Relationship of CT Findings to Length of Hospital Stay1. *Radiology.* 2005;235(1):89–96. doi:10.1148/radiol.2351040310. [PubMed: 15749978]
19. Kim MS, Park HW, Park JY, et al. Differentiation of early perforated from nonperforated appendicitis: MDCT findings, MDCT diagnostic performance, and clinical outcome. *Abdom Imaging.* 2014;39(3):459–466. doi:10.1007/s00261-014-0117-x. [PubMed: 24633221]
20. Verma R, Grechushkin V, Carter D, Barish M, Pryor A, Telem D. Use and accuracy of computed tomography scan in diagnosing perforated appendicitis. *Am Surg.* 2015;81(4):404–407. [PubMed: 25831188]
21. Livingston EH, Woodward WA, Sarosi GA, Haley RW. Disconnect Between Incidence of Nonperforated and Perforated Appendicitis: Implications for Pathophysiology and Management. *Ann Surg.* 2007;245(6):886–892. doi:10.1097/01.sla.0000256391.05233.aa. [PubMed: 17522514]
22. Barrett ML, Hines AL, Andrews RM. Trends in rates of Perforated Appendix, 2001–2010. *Agency Healthc Res Qual.* 2013 <http://www.ncbi.nlm.nih.gov/books/NBK169006>.

Table 1:

Demographics

	Perforated (n=43)	Non-Perforated (n=46)	p value
Age	37±14	31±11	0.322
Sex (% male)	29 (67%)	(28) 61%	0.518
White Blood Cell Count	12,600	12,100	0.522

Table 2:

Frequency of CT finding in perforated and non-perforated appendicitis

Finding on CT	Perforated (n=43)	Non-perforated (n=46)	p value
Abscess	2 (4.7%)	0 (0.0%)	0.231
Appendicolith	9 (20.9%)	14 (30.4%)	0.336
Cecal Wall Thickening	22 (51.2%)	25 (54.3%)	0.833
Fat Stranding	41 (95.3%)	42 (91.3%)	0.678
Peri-appendiceal Gas	1 (2.3%)	0 (0.0%)	0.483
Phlegmon	2 (4.7%)	1 (2.2%)	0.608
Simple Fluid Collection	0 (0.0%)	4 (8.7%)	0.117

* p value by fisher exact test

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value for CT findings in perforated appendicitis

Table 3:

Finding on CT	Sensitivity	Specificity	PPV	NPV
Abscess	4.7%	100.0%	100.0%	53.0%
Appendicolith	20.9%	68.9%	49.0%	67.0%
Cecal Wall Thickening	51.2%	45.7%	47.0%	50.0%
Fat Stranding	95.3%	8.7%	49.0%	67.0%
Peri-appendiceal Gas	2.3%	100.0%	100.0%	52.0%
Phlegmon	4.7%	97.8%	66.7%	52.3%
Simple Fluid Collection	0.0%	91.3%	0.0%	49.0%

Accuracy of Radiology reported diagnosis and Surgeon Intraoperative diagnosis compared to pathology gold standard

Table 4:

Reported Diagnosis	Perforated (n=43)	Non-perforated (n=46)	Sensitivity	Specificity
Radiologist Report	7.0%	10.9%	7.0%	89.1%
Surgeon Report	27.9%	13.0%	27.9%	87.0%