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Original Contribution

Intravenous contrast alone vs intravenous and oral contrast computed tomography for the diagnosis of appendicitis in adult ED patients☆,☆☆,★

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Abstract

Objective: When the diagnosis of appendicitis is uncertain, computerized tomography (CT) scans are frequently ordered. Oral contrast is often used but is time consuming and of questionable benefit. This study compared CT with intravenous contrast alone (IV) to CT with IV and oral contrast (IVO) in adult patients with suspected appendicitis.

Methods: This is a prospective, randomized study conducted in a community teaching emergency department (ED). Patients with suspected appendicitis were randomized to IV or IVO CT. Scans were read independently by 2 designated study radiologists blinded to the clinical outcome. Surgical pathology was used to confirm appendicitis in patients who went to the operating room (OR). Discharged patients were followed up via telephone. The primary outcome measure was the diagnosis of appendicitis. Secondary measures included time from triage to ED disposition and triage to OR.

Results: Both IV (n = 114) and IVO (n = 113) scans had 100% sensitivity (95% confidence interval [CI], 89.3-100 and 87.4-100, respectively) and negative predictive value (95% CI, 93.7-100 and 93.9-100, respectively) for appendicitis. Specificity of IV and IVO scans was 98.6 and 94.9 (95% CI, 91.6-99.9 and 86.9-98.4, respectively), respectively, with positive predictive values of 97.6 and 89.5 (95% CI, 85.9-99.9 and 74.2-96.6). Median times to ED disposition and OR were 1 hour and 31 minutes ($P < .0001$) and 1 hour and 10 minutes ($P = .089$) faster for the IV group, respectively. Patients with negative IV scans were discharged nearly 2 hours faster ($P = .001$).

Conclusions: Computerized tomography scans with intravenous contrast alone have comparable diagnostic performance to IVO scans for appendicitis in adults. Patients receiving IV scans are discharged from the ED faster than those receiving IVO scans.

1. Introduction

1.1. Background and importance

In 2006, there were over 8 million emergency department (ED) visits for "stomach and abdominal pain, cramps and spasms [1]." Several million more patients with abdominal pain sought care from their primary care

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physicians. Acute appendicitis is frequently on the differential diagnosis and is a common cause of acute abdominal pain with an incidence of 250 000 cases annually in the United States [2]. Definitive diagnosis of acute appendicitis based on history and physical and laboratory data alone remains challenging, and some form of imaging is often needed to establish the diagnosis. Early diagnosis of acute appendicitis is important because delayed diagnosis can result in perforation, which is known to increase morbidity and mortality including the incidence of reoperation, intraabdominal sepsis, and tubal infertility [3,4].

Computed axial tomography (CT) is the imaging modality of choice for the diagnosis of appendicitis, having 95% sensitivity and 95% to 100% specificity [5]. Standard abdominal CT calls for administration of both oral and intravenous (IV) contrast. This method is based on routine body imaging techniques that were adopted in the earliest days of abdominal CT [6]. Multiple variations of contrast administration have been described in the literature, including focused scanning with rectal contrast only, oral contrast only, IV contrast only, oral and IV contrast, "triple" contrast (IV, oral, and rectal), and completely unenhanced [7-10]. The American College of Radiology's Appropriateness Criteria for CT of the abdomen and pelvis in patients with right lower quadrant pain and suspected appendicitis makes no formal recommendation on the optimal contrast technique, stating that "use of oral or rectal contrast depends on institutional preference." The lack of consensus on optimal contrast regimen has led to a wide variation in clinical practice.

Oral contrast administration has several drawbacks. One to 2 hours is required for the contrast to traverse the intestinal tract. This results in prolonged stays in EDs and could delay diagnosis. It may also delay operative intervention, which could potentially increase the chance of rupture [11]. Patients with appendicitis are frequently nauseated and might have difficulty drinking a liter of liquid.

Several recent studies have suggested that IV contrast alone is equally sensitive and specific for the diagnosis of appendicitis [7-9,12,13]. Lane et al [11] reported a sensitivity and specificity of 96% and 99%, respectively, using completely unenhanced scans for appendicitis. In a recent prospective study comparing unenhanced, IV-enhanced–only, and IV- and oral-enhanced CT for acute appendicitis, Keyzer et al [7] concluded that "diagnostic correctness is much more influenced by the reader than by the use of contrast medium (oral, IV, or both)..." Use of IV contrast does offer some advantages over unenhanced scans, including better solid organ visualization.

1.2. Goals of this investigation

The purpose of this study was to compare IV contrast–only (IV) vs IV and oral contrast (IVO) CT in adult ED patients with suspected appendicitis. The primary outcome measure was the diagnosis of acute appendicitis. Secondary measures included time from triage to operating room (OR), time from triage to ED disposition (home, inpatient bed, or OR), whether oral contrast reached the cecum, and body mass index (BMI). Alternative diagnoses (CT diagnoses other than appendicitis) were also recorded and analyzed.

2. Methods

2.1. Study design and setting

This was an institutional review board–approved, prospective, randomized study conducted in a community teaching ED with approximately 75 000 visits annually. The study was approved by the departments of emergency medicine, surgery, and radiology. Enrolled patients were randomized to CT of the abdomen and pelvis with IV or IVO contrast (Fig. 1). Patients assigned to the IVO group were given 50 mL of iohexol (Omnipaque) in 1 L of liquid to consume orally. Patients in the IVO group were taken to CT 90 to 120 minutes after they began drinking oral contrast, which is our protocol for CT of the abdomen and pelvis with oral contrast. All patients received 80 mL of iohexol (Omnipaque 350) intravenously as IV contrast. Intravenous contrast was administered per protocol, with injection beginning approximately 1 minute before the start of the scan. All scans were done in the supine position on a Siemens Somatom Sensation 16 slice scanner (Siemens Medical Solutions USA, Inc., Malvern, PA, USA) with a slice thickness of 3 mm. Patients were given pain medication, IV fluids, and antiemetics at the discretion of the treating emergency physician (EP).

Computed tomographic scans were read contemporaneously by an attending radiologist. Clinical decision making and patient disposition were based on the contemporaneous read. Two designated study radiologists, board certified by the American Board of Radiology in diagnostic radiology (R. K., 27 years experience; B. G.,18 years experience), subsequently read all study scans independently. The study radiologists' reads were used for analysis. The study radiologists were blinded to the contemporaneous read and the clinical outcome of the patient visit. The study radiologists documented their findings on a standardized data collection sheet. The diagnosis of appendicitis was based on a combination of the following CT findings: presence of an appendicolith, localized fluid collection or abscess, presence of periappendiceal stranding, hyperenhancement of the appendiceal mucosa, outer wall to outer wall diameter of 6 mm or more, and wall thickness of 3 mm or more. After evaluating the scan, the radiologists had the options of "yes," "no," and "possible" for the diagnosis of appendicitis. The radiologists also documented any alternative diagnoses or significant incidental findings on the data collection form. For data analysis, all "possible" reads were treated as "yes" because we felt that this is how it would be handled in

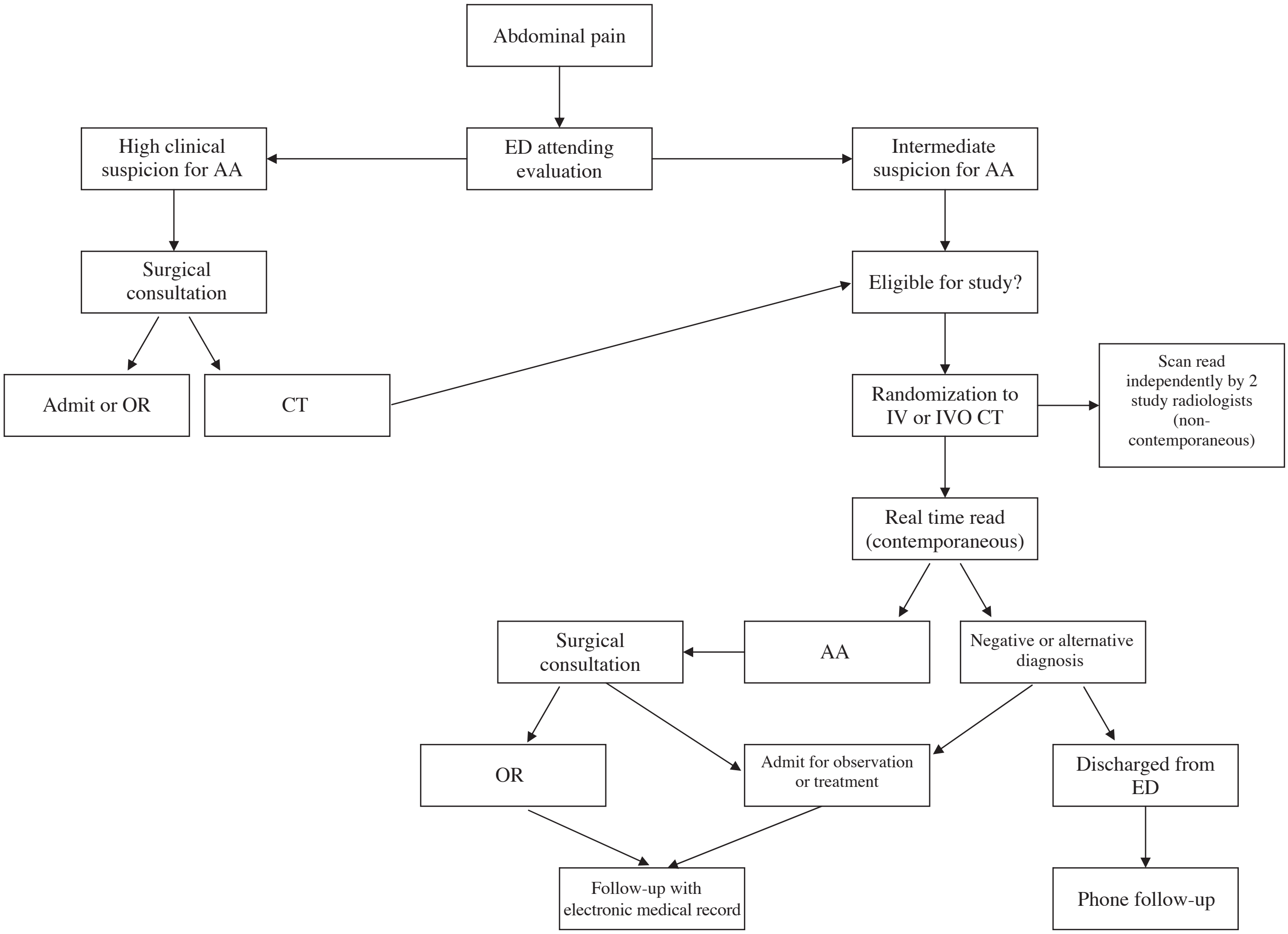

Fig. 1 Enrollment process and flow of study.

clinical practice. In the event of a discrepancy between the study radiologists, the contemporaneous read was used as the tie breaker.

If the contemporaneous read was appendicitis, a surgical consultation was obtained. If the contemporaneous read was negative or revealed an alternative diagnosis, appropriate disposition was made by the attending EP. Patients who were admitted or had appendicitis were followed up via the electronic medical record (EMR). Discharged patients were followed up by telephone (Fig. 1).

Patients who were followed up by telephone were contacted by one of the authors, either A. K. or J. B. First contact was attempted within a week of the study visit and continued for 1 month. If the patient could not be reached after a month, a certified letter was sent requesting that the patient call the ED research office or fill out a questionnaire and return it in a self-addressed stamped envelope. Attempts at telephone follow-up continued for a total of 3 months. If the patient could not be reached after this time, they were considered lost to follow-up.

A standardized questionnaire was completed by A. K. or J. B. at the time of telephone follow-up. The questionnaire included questions such as, “Has your pain resolved?”, “Have you followed up with another physician (either family physician or specialist)?”, and “Have you been treated at another ED since your visit and if so, what was the outcome?” All completed follow-up forms were reviewed by both A. K. and J. B., as well as a third physician in the ED research department who was not involved with the study, to reach consensus that a patient could be adjudicated as negative. The authors reviewed the contemporaneous read and the study reads before telephone contact so that any significant incidental findings could be discussed with the patient.

If a patient in the IV group was rescanned with oral contrast at the discretion of the admitting physician, they were not charged for the scan. Patients were informed of the possibility of repeat exposure to radiation in this situation during the consent process.

2.2. Selection of participants

Patients 18 years and older with signs and symptoms suggestive of appendicitis were eligible for enrollment. All patients were evaluated by an attending EP before enrollment. If the attending EP felt certain of the diagnosis based on presentation and examination, a surgical consultation was obtained immediately. Patients receiving immediate surgical consultation were also eligible for enrollment if the consulting surgeon requested a CT scan. Exclusion criteria included patients younger than 18 years old, confirmed pregnancy as determined by serum β human chorionic gonadotropin, allergy to IV or oral contrast, creatinine level of 1.5 or greater, current incarceration, inability to give consent, and patients in whom appendicitis was not the primary concern of the attending EP. Eligible patients were offered enrollment, and written consent was obtained.

2.3. Methods of measurement

The primary outcome measure was the diagnosis of appendicitis. Surgical pathology was used as confirmation of appendicitis in patients who went to the OR. For patients with a positive CT for appendicitis who did not go to the OR, the presence or absence of appendicitis was determined by the admitting physician's discharge diagnosis and course of follow-up.

Secondary outcome measures included time from triage to ED disposition, time from triage to OR, whether oral contrast had reached the cecum, and BMI. For time-related data, the time of triage was taken from the EMR and was used as the start of the patient visit. Disposition time was also taken from the EMR as the time the patient left the ED, whether it was for discharge, transfer to the inpatient unit, or transfer to the OR. The OR "in room time" was obtained from the EMR and was used as the time to OR. A standardized study radiologist data collection sheet was used to collect data on whether the oral contrast had reached the cecum and also to collect data on alternative diagnoses.

2.4. Statistical analysis

Mann-WhitneyU test- Non parametric t-test

Patient age and BMI data are expressed as medians and interquartile ranges and compared using nonparametric Mann-Whitney *U* tests. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the diagnosis of appendicitis were calculated for the IV and IVO groups. Data for these analyses are presented as percentages with 95% confidence intervals (CIs). Categorical variables between subgroups were compared using χ^2 tests. Time data were skewed and are presented as medians and interquartile ranges in hours:minutes format. Comparisons of time between groups were assessed using independent-samples Mann-Whitney *U* tests. All hypothesis tests were 2 sided, and a *P* value of less than .05 was considered to indicate statistical significance. Statistical analysis was carried out using SPSS Statistics Software Version 19.0 (SPSS Inc, Chicago, IL). Post-hoc sample size calc?

A post hoc sample size calculation was performed based on the results of a prior study [13]. Using an α of .05, a β of .80, and a noninferiority limit (Δ) of 5%, a total of 230 patients (115 per group) would be needed. This was performed using SPSS Sample Power 3.0.1 software.

3. Results

Between February 2007 and January 2010, we enrolled 244 patients. There were 14 exclusions and 3 patients lost to follow-up (Table 1), leaving 227 patients for analysis. There were 114 patients in the IV group and 113 in the IVO group. Baseline characteristics were similar (Table 2).

3.1. Primary outcomes

There were 80 (35.2%) patients with positive CT scans for appendicitis. Of these patients, 42 were IV and 38 were IVO (P = .612). Diagnostic performance results are summarized in Table 3.

In addition, we also calculated diagnostic performance assuming a "worst case scenario" (ie, assume that the incorrect study radiologist had read all yes/no discrepancies). This would result in a sensitivity of 97.6% (95% CI, 85.6-99.9) and NPV of 98.6% (95% CI, 91.6-99.9) for IV scans. There would be no impact on the 100% sensitivity and NPV of IVO scans. Recalculating in this manner would yield a specificity of 93.7% (95% CI, 85.5-97.6) and a PPV of 87.2% (95% CI, 71.8-95.2) for IVO scans. There would be no impact on the specificity and PPV of IV scans.

Of the 80 patients with a CT diagnosis of appendicitis, 73 went to the OR. All had surgical pathology that confirmed appendicitis.

There were 7 patients (5 IVO and 2 IV) with appendicitis on CT who did not go to the OR. Four of these patients (3 IVO and 1 IV) were false positives, and 3 (2 IVO and 1 IV) were true positives. Two of the false positives were diagnosed with inflammatory bowel disease, and 2 were diagnosed with abdominal pain of uncertain etiology.

The first true-positive patient who did not go to the OR was admitted for 2 days on antibiotics, clinically improved, and was discharged with a plan to discuss interval

Table 1 Exclusions (n = 17)

Patient inadvertently given oral contrast when randomized to IV only group (4)
Lost to follow-up (3)
Patient eloped before getting scan (2)
Consenting physician did not have required institutional review board training
Indeterminate pregnancy test
Patient was a prisoner
Patient refused IV contrast at time of scan
Consulted physician took patient for unenhanced scan without notifying emergency physician
Patients pregnancy test was positive
Contemporaneous radiologist refused to read IV only scan
IV contrast allergy was discovered by CT technologist

Chi-square- observed vs. expected frequencies

How do you calculate sensitivity vs. specificity?

Table 2 Characteristics of the study participants

Characteristic	IV group (n = 114)	IV and oral group (n = 113)	*P*
Age (y)			.483
Median	32	32	
Interquartile range	22-40	25-43	
Male, n (%)	47 (41.2)	51 (45.1)	.553
BMI			.407
Median	29	27	
Interquartile range	23-33	24-32	

appendectomy at follow-up. The second patient was admitted and had CT-guided drainage of an abscess due to perforated appendicitis. This patient had an interval appendectomy 3 months later. The third patient had an IV scan with a contemporaneous read of "nonspecific inflammation in lower mid abdomen, appendix not seen." The patient was admitted to surgery, had a gynecology consult, improved on antibiotics, and was discharged 2 days later with a diagnosis of pelvic inflammatory disease. Both study radiologists read the CT as positive for appendicitis, feeling confident that the appendix was clearly seen following a course across the abdomen with an inflamed tip located just inferior to the umbilicus. This was reviewed with the admitting surgeon who subsequently agreed that the patient had appendicitis. At telephone follow-up several days after discharge, the symptoms had completely resolved. The patient was to follow-up with the surgeon to discuss interval appendectomy.

Table 3 Diagnostic Performance Analysis

Characteristic	IV group (n = 114)	IV and oral group (n = 113)	*P*
Appendicitis			
Positive, n (%)	42 (36.8)	38 (33.6)	.612
Sensitivity, % (95% CI)	100 (89.3-100)	100 (87.4-100)	
Specificity, % (95% CI)	98.6 (91.6-99.9)	94.9 (86.9-98.4)	
NPV, % (95% CI)	100 (93.7-100)	100 (93.9-100)	
PPV, % (95% CI)	97.6 (85.9-99.9)	89.5 (74.2-96.6)	
Alternative diagnosis			
Overall, n (%)	21 (18.4)	31 (27.4)	.106
GI, n	12	15	
Gyn, n	3	10	
GU, n	5	5	
Other, n	1	1	
Negative, n (%)	51 (44.7)	44 (38.9)	.377
Cecum opacified, n (%)	N/A	82 (72.6)	
Repeat CT within 24 hours, n (%)	3 (2.6)	0	

Abbreviations. GI, Gastrointestinal; Gyn, Gynecologic; GU, Genitourinary.

Twelve patients (5.3%) had discrepant reads (study radiologists disagreed). A summary of the discrepant reads can be seen in Table 4. There were 6 discrepancies in each group. In 10 of these cases, one of the radiologists read the scan as "possible." There were 2 cases of "yes/no" discrepancy, 1 in each group (patients 69 and 146).

Three patients (2.6%) in the IV group were rescanned with oral contrast. The first patient had a contemporaneous read of "mild appendicitis." Both study radiologists read this scan as positive for appendicitis. The patient was admitted to surgery and had a repeat scan with oral contrast 6 hours later, which was read as follows: "Appendix has enlarged since previous study and has increased stranding." The patient was taken to the OR and had surgical pathology of appendicitis. The second patient's scan was read as negative by the study radiologists. This patient was admitted and had a repeat scan with oral contrast performed the following day, which was also negative. The patient had persistent pain and was taken to the OR for laparoscopy at which time an incidental appendectomy was performed. Surgical pathology was normal appendix. The third patient had a negative IV scan and was admitted. A repeat scan with oral contrast was done 48 hours later because of persistent pain. This scan was also read as negative. The patient was taken to the OR for laparoscopy and had an incidental appendectomy performed. Surgical pathology was normal appendix.

3.2. Secondary outcomes

Alternative diagnoses were found in 52 patients (22.9%). There were 31 patients (27.4%) in the IVO group and 21 patients (18.4%) in the IV group (P = .106). The alternative diagnoses are summarized in Table 5. Most of the alternative diagnoses were other gastrointestinal processes (n = 27), followed by gynecologic (n = 13) and genitourinary pathology (n = 10).

Time data are presented as median times with interquartile ranges in Table 6. The median time from triage to ED disposition for all patients was 1 hour and 31 minutes faster in the IV group ($P < .0001$). The median time from triage to ED disposition for patients with a negative CT for appendicitis was 1 hour and 57 minutes faster in the IV group (P = .001). The median time from triage to OR for patients with a positive CT for appendicitis was 1 hour and 10 minutes faster in the IV group; however, this was not statistically significant (P = .089).

Oral contrast reached the cecum 72.6% of the time. There was no statistically significant difference in BMI between the groups.

4. Discussion

In this study, CT scans with IV contrast alone had comparable diagnostic performance to scans with IV and oral contrast for the diagnosis of appendicitis in adult ED

Table 4 Discrepancies between study radiologists

Patient ID	Study rad 1	Study rad 2	Contemporaneous read	Final interpretation	Outcome/diagnosis *
IV (n = 6)					
21	Poss	No	Poss	+	FP, Admit, colonoscopy, dx IBD
23	Yes	Poss	Yes	+	TP by surgical pathology
35	Poss	No	Poss	+	FP, discharge from ED, dx ovarian cyst
69	Yes	No	Yes	+	TP by surgical pathology
155	Poss	Yes	Yes	+	TP by surgical pathology
245	No	Poss	No	−	TN, abd pain unknown etiology
IVO (n = 6)					
43	Yes	Poss	Yes	+	TP by surgical pathology
146	Yes	No	No	−	TN, admitted, dx abd pain unknown etiology
187	No	Poss	No	−	TN, to OR for perforated cecal mass
196	Poss	No	No	−	TN, inflamed terminal ileum, IBD
203	Poss	No	Poss	+	FP, admitted 48 h, dx IBD
212	Poss	No	Poss	+	FP, admit x 24 h, dx abd pain unknown etiology

Abbreviations. rad, Radiologist; Poss, Possible; dx, diagnosis.
* FP, false positive; FN, false negative; TP, true positive; TN, true negative; IBD, inflammatory bowel disease.

Table 5 Alternative diagnoses

Category	IV group (n = 21)	IV and oral group (n = 31)
GI (n = 27)	Mesenteric adenitis (3)	Diverticulitis (3)
	Small bowel obstruction (3)	Terminal ileitis (3)
	Colitis (2)	Colitis (2)
	Terminal ileitis (1)	Mesenteric adenitis (2)
	Diverticulitis (1)	Thickened small bowel (1)
	Fluid in large bowel, diarrhea (1)	Small bowel obstruction (1)
	Pancreatic mass (1)	Diverticular abscess with perforation (1)
	n = 12	Duodenal perforation (1)
		Large bowel obstruction with perforation (1)
		n = 15
Gyn (n = 13)	Ruptured ectopic (1)	Right ovarian pathology (8)
	Tubo-ovarian abscess (1)	Pelvic mass with inflammation (2)
	R ov pathology (1)	n = 10
	n = 3	
GU (n = 10)	R uvj calc (3)	R pyelo (3)
	R pyelo (2)	R uvj calc (2)
	n = 5	n = 5
Other (n = 2)	R middle lobe pneumonia (n = 1)	VP shunt inflamation/ infxn (n = 1)

Abbreviations. R ov, right ovarian; Ruvj, right ureterovesical junction; R pyelo, right pyelonephritis; VP, ventriculo-peritoneal; infxn, infection.

patients, with each boasting 100% sensitivity and NPV. This seemingly perfect sensitivity and NPV for IV scans was due in part to the method we chose for data analysis (ie, using the contemporaneous read as the tie breaker when the study radiologists disagreed). When we recalculated the data in a "worst case scenario" format, the result was a slight decrease in the sensitivity and NPV of IV scans (from 100% to 97.6% and 98.6%, respectively) and a slight decrease in the specificity and PPV of IVO scans (from 94.9% to 93.7% and 89.5% to 87.2%, respectively). Even in this "worst case scenario," it seems fair to say that the 2 contrast regimens exhibit comparable diagnostic performance. Although IVO scans may be slightly more sensitive, they also appear to be

Table 6 Time analysis (h:min)

Triage to	IV group	IV and oral group	Δt	P
ED disposition for all patients				
Median	6:41	8:12	1:31	<.0001
Interquartile range	5:03-8:49	6:40-9:44		
n	114	113		
ED disposition for patients with a negative CT for appendicitis				
Median	6:10	8:07	1:57	.001
Interquartile range	4:58-8:11	6:44-9:26		
n	72	75		
OR for appendicitis patients *				
Median	7:05	8:15	1:10	.089
Interquartile range	5:16-9:07	6:23-10:02		
n	40	33		

* There were 7 patients with CT positive appendicitis that did not go to the OR.

slightly less specific and could potentially lead to more false positives. This lower specificity and PPV with oral contrast was also noted by Anderson B et al [9]. False positives also carry potential risks, including unnecessary surgery, consultations, and hospital observation. Any small difference in these statistical values must also be weighed against the potential time savings that IV contrast alone offers for patients and the EDs in which they are being treated.

There have been several recent studies evaluating the optimal CT contrast regimen for diagnosing appendicitis in adults. In 2005, Anderson B et al [9] performed a meta-analysis of 23 studies comparing various contrast regimens for CT diagnosis of appendicitis and concluded that "noncontrast CT techniques to diagnose appendicitis showed equivalent or better diagnostic performance compared with CT scanning with oral contrast." In 2009, Anderson S et al [13] evaluated 64-multi-detector computerized tomography with and without oral contrast and included patients with suspected appendicitis as well as diverticulitis and small bowel obstruction. They reported 100% sensitivity for both regimens and concluded that there was no statistically significant difference in specificity for diagnosing appendicitis between IV contrast alone and IV and oral contrast. Keyzer et al [7], also in 2009, concluded that "diagnostic correctness is much more influenced by the reader than by the use of contrast medium (oral, IV, or both)…" Our study adds to the growing body of evidence that oral contrast may not be necessary for the diagnosis of appendicitis in adults. Our study is also the first to evaluate the impact of oral contrast on ED length of stay.

Patients in the IV group who had a negative scan for appendicitis had a median time from triage to disposition that was nearly 2 hours (1 hour and 57 minutes) faster than the IVO group. Patients in the IV group overall (those with negative scans and those with scans that were positive for either appendicitis or alternative pathology) had a median triage to ED disposition time that was 1 hour and 31 minutes faster than the IVO group. The faster disposition time for the negative scan group is explained by patients with positive scans taking up ED bed time while waiting for consultation, for an inpatient bed, or to go to the OR. Both of these time differences are not only statistically significant but also clinically significant. Emergency department crowding is a national health care problem. If the IVO patients in our study had IV studies instead, we could have had an additional 10 283 minutes (171 hours) of available bed time for other patients.

Patients with appendicitis who were randomized to IV scans had a median time to OR that was 1 hour and 10 minutes faster than their IVO counterparts. This was not statistically significant, suggesting that faster time to diagnosis does not necessarily lead to faster time to OR. A contributing factor to this smaller time difference is that although the diagnosis is made more quickly, patients are often boarded in the ED or sent to the inpatient unit to wait until the surgeon or OR is available. This gap between diagnosis and OR can be several hours on occasion. Many factors contribute to this, including time of day and hospital census. Theoretically, you may reduce the chance of perforation by getting to the OR sooner and therefore reduce the morbidity and mortality associated with perforation [3,14]. Practically speaking, it seems that this would involve a very small number of patients.

There were 80 patients (35.2%) with CT scans that were positive for appendicitis. Seven of these patients (5 IVO and 2 IV) did not go to the OR. Four of these patients had false-positive scans, 2 of which were diagnosed with inflammatory bowel disease and 2 of which were diagnosed with abdominal pain of uncertain etiology. Three patients had true-positive scans. One of these patients had CT-guided drainage of a periappendiceal abscess and subsequent interval appendectomy. Two of these patients were treated with antibiotics alone with planned follow-up to discuss interval appendectomy. Although a discussion of antibiotic therapy alone vs surgery for the treatment of appendicitis is not appropriate in this context, it is a well-described strategy, as discussed in a recent meta-analysis by Varadhan et al [15]. In our series, 2 patients with appendicitis were successfully managed with antibiotics alone, at least in the short term.

Several alternative diagnoses were found by both IV and IVO scans (Table 5). These included other gastrointestinal, gynecologic, and urologic pathologies. There was 1 case of pneumonia diagnosed with an IV study and 1 case of a ventriculoperitoneal shunt infection diagnosed with an IVO study. There were more alternative diagnoses found with IVO scans (31 vs 21), particularly gynecologic pathology (10 vs 3), but this did not reach statistical significance. Whether this occurred by chance or because of the oral contrast is uncertain. The possibility does remain that IVO scans may be better at finding alternative diagnoses than IV scans.

There were 12 (5.3%) read discrepancies between the study radiologists (Table 4). There were 6 discrepancies in the IV group and 6 in the IVO group. In each group, 5 of the 6 discrepancies involved a "possible" read. This suggests that IV contrast alone does not result in an increased number of "possible" reads compared with IV and oral contrast.

There were 2 cases of "yes/no" discrepancies, 1 in each group. In the IV group, the contemporaneous read was "yes," so for data analysis, this case was counted as a "yes." The patient went to the OR and had surgical pathology that confirmed acute appendicitis. Despite this case being statistically true positive, it did reveal a false-negative read in the IV group by one of the study radiologists. In the IVO group, one of the study radiologists read the scan as positive for appendicitis based on what they felt was some periappendiceal stranding. The contemporaneous radiologist read the scan as negative. In this case, the patient was observed overnight by the surgical team and discharged the next day without antibiotics with a diagnosis of musculoskeletal abdominal pain. At follow-up in the surgical clinic, the patient's pain had resolved without further treatment.

Of the 114 patients in the IV group, 3 (2.6%) were rescanned with oral contrast at the discretion of the admitting physician. None of these patients had a change in management based on the results of the subsequent IVO scan. The possibility remains, however, that some patients receiving IV scans will be subjected to subsequent IVO scans and additional radiation exposure.

Of the 113 IVO patients, oral contrast was determined to have reached the cecum 72.6% of the time. This suggests that, in over a quarter of the patients given oral contrast, it is not getting far enough in the gut to localize the cecum and appendix or to see if the appendix fills with contrast. It is possible that the patients with cecal opacification waited longer between contrast administration and CT, but we did not collect this data. It is also possible that the presence of contrast anywhere in the gut may be of some assistance to the radiologist.

5. Limitations

First, our study radiologists knew that they were looking specifically for appendicitis on all study scans. This could have caused them to be more critical of the right lower quadrant than they would have been had they just known “abdominal pain.”

A second limitation of this study could be that the study radiologists were better than average at reading CT scans without oral contrast. This could have caused our IV studies to have a higher sensitivity than would be found elsewhere. The study radiologists had no specialized training in reading scans without oral contrast and neither had a strong preference for any particular contrast regimen.

The next limitation is that we only used the contemporaneous read in the event of a discrepancy between the study radiologists (a total of 12 times). The reason for this is that we use an off-site radiology service for night and weekend reads, and it was not possible to ensure that all of the reading radiologists were trained to participate in research. Including these reads could affect the results.

The next limitation is that 7 patients with positive scans for appendicitis were managed nonoperatively and, therefore, did not have surgical pathology to confirm the diagnosis. Two of these patients were clearly false positives with endoscopy proven inflammatory bowel disease and one was clearly true positive with perforated appendicitis treated with CT guided drainage and delayed appendectomy. The remaining 4 patients were adjudicated as true positive or false positive based on the clinical impression of the attending physician. Incorrect diagnosis would impact diagnostic performance data.

Another important limitation to our study is that an a priori power analysis was not calculated. A post hoc sample size of 230 patients (115 per group) was calculated based on the results of Anderson S et al [13]; however, post hoc analyses are not always reliable and should be viewed with due skepticism. The chance remains that our study may be underpowered.

Our time data were taken from the EMR. Times entered into the EMR are not always accurate in reflecting the time an event actually occurred. This may have impacted our time data.

The final limitation is that we used a 16-slice scanner with 3-mm slice thickness. Higher resolution scanners (32 and 64 slice) are widely available and might affect the diagnostic performance of IV, IVO, and unenhanced scans [12].

6. Conclusions

In summary, our results suggest that CT scans with IV contrast alone have comparable diagnostic performance to scans with IV and oral contrast for the diagnosis of appendicitis in adults. Oral contrast is not required to diagnose appendicitis in adult ED patients. Oral contrast may be beneficial for the diagnosis of alternative pathology, but further study is needed to definitively answer this question. Oral contrast may also result in lower specificity and PPV compared with IV contrast alone, leading to an increase in false-positive CT scans for appendicitis. Patients receiving IV scans are dispositioned from the ED approximately 90 minutes faster than those receiving IVO scans, whereas patients with a negative IV scan are discharged nearly 2 hours faster. Eliminating oral contrast does not necessarily get patients to the OR faster.

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Sensitivity:
If a person has a disease, how often will the test be positive (true positive rate)?
Put another way, if the test is highly sensitive and the test result is negative you can be nearly certain that they don’t have disease.
A Sensitive test helps rule out disease (when the result is negative). Sensitivity rule out or "Snout"
Sensitivity= true positives/(true positive + false negative)

Specificity:
If a person does not have the disease how often will the test be negative (true negative rate)?
In other terms, if the test result for a highly specific test is positive you can be nearly certain that they actually have the disease.
A very specific test rules in disease with a high degree of confidence Specificity rule in or "Spin".
Specificity=true negatives/(true negative + false positives)

Predictive value for a positive result (PV+):
PV+ asks " If the test result is positive what is the probability that the patient actually has the disease?"
PV+= true positive/(true positive + false positive)

Predictive value for a negative result (PV-):
PV- aks " If f the test result is negative what is the probability that the patient does not have disease?"
PV-= true negatives/(true negatives +false negatives)