



## Diagnostic Imaging Strategies in Pediatric Appendicitis at Tertiary and Referring Hospitals

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### Abstract

**Background:** The diagnosis of pediatric appendicitis has evolved from a clinical evaluation, to one relying heavily on imaging. Increasing awareness of the danger of ionizing radiation with Computed Tomography (CT) has led to more frequent use of Ultrasound (US). The study aim was to assess imaging techniques and their accuracy at Children's Medical Center Dallas (CMC) and its Referring Hospitals (RH) in patients with a limited differential diagnosis of appendicitis.

**Methods:** Upon IRB approval, we reviewed the medical records of all boys, who underwent appendectomy at CMC in one year.

**Results:** 385 boys, aged 8 to 14 years, underwent appendectomy during the study, 238 (61.8%) patients initially presented to CMC, 86% had an US, with 80% accuracy, 147 (38.2%) were transferred from RHs, 96 (65%) patients had a CT before transfer. The ratio of US: CT as the initial imaging test was 69%:6% at CMC, and at RHs 7%:66% ( $p < 0.0001$ ), 40 patients were transferred without an imaging study. After transfer, 22 patients (55%) had an US, 3 (8%) a CT, and 6 (16%) had both US and CT. Only 23 patients underwent appendectomy without imaging. There was no significant difference in rate of appendicitis, perforation, or negative appendectomy between the two groups.

**Conclusions:** This study shows a great disparity in imaging modalities at different hospitals, and US has a high accuracy in most patients. US as the initial study, with CT in cases where diagnosis remains uncertain, both reduces diagnostic uncertainty and radiation risk.

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### Introduction

The diagnosis of acute appendicitis has evolved from a purely clinical evaluation, based on history, physical examination, and laboratory findings, to one that relies heavily on imaging, including Computed Tomography (CT) and Ultrasonography (US). Several studies have demonstrated a trend toward increased use of CT for the evaluation of pediatric abdominal pain [1-3]. However, due to radiation exposure and the cost associated with CT, a number of pediatric institutions have shifted to US as the initial diagnostic imaging modality of choice for appendicitis, with CT reserved for cases in which US findings are equivocal [4,5]. Other authors have reported that, for patients between the ages of 1 and 18 years, the use of diagnostic imaging for the diagnosis of pediatric appendicitis depends significantly on the type of hospital in which evaluation takes place [6].

Even in a highly selected population of children in whom alternative diagnoses are less likely, very few patients undergo appendectomy at a tertiary children's medical center without pre-operative imaging. We hypothesized that, because of institutional expertise and around-the-clock availability of US, the radiographic evaluation of these children is determined by the type of hospital to which they initially present. The aim of this study was to identify the imaging modalities at a Children's Hospital (CH) vs. Referring Hospitals (RH), the ratio of CT:US, and the diagnostic accuracy of those studies.

### Methods

We undertook an IRB approved retrospective review of all boys aged 8-14 years who underwent appendectomy at Children's Medical Center Dallas (CMC) between April 2010 and March 2011. Subjects were identified by query of our operating room database, and data were gathered from the CMC electronic medical record. We chose to include only boys in this study as, in this limited

population, the diagnosis of appendicitis should be fairly straightforward given the lack of potential confounding gynecologic diagnoses. Patients who had interval appendectomies were excluded from the study.

Data included information prior to transfer and at CMC, including use of imaging, which modality, US or CT, and operative findings and histological findings. A Pediatric Appendicitis Score (PAS) was calculated for all subjects using laboratory data and findings as documented in the surgical history and physical examination [7]. Statistically significant differences were evaluated using Student's t-test, the Wilcoxon signed rank test, and Fisher's exact test as appropriate. All analyses were performed using GraphPad InStat v. 3.06.

## Results

During the study period of one year, 1,005 appendectomies were performed at our institution, of which 385 met inclusion criteria. 238 (62%) boys initially presented to CMC, and the remaining 147 (38%) were transferred from RH. There was no difference in the age ( $11.3 \pm 2.0$  years vs.  $11.2 \pm 1.9$  years,  $p = 0.68$ ) or PAS ( $6 \pm 3$  vs.  $6 \pm 2$ ,  $p = 0.19$ ) of subjects evaluated initially at CMC versus RH. In the study, 115 children (30%) underwent CT and 198 (51%) had an US as the only study prior to appendectomy. Forty-six children (12%) had both CT and US, and 26 (7%) had no imaging in their evaluation.

### Initial evaluation

221 children (93%) initially evaluated at CMC had imaging prior to appendectomy. US was performed in 205 patients (86%), and had an 80% diagnostic accuracy. The remaining 41 patients with a non-diagnostic US underwent CT evaluation. CT was used as the first imaging modality in an additional 16 children (7%). In total, 57 children (24%) had a CT as part of their evaluation if they initially presented to CMC. 17 (7%) other children had no imaging prior to appendectomy.

Among the 147 children transferred from an RH, 107 children (73%) had imaging prior to transfer. 96 (90%) children had a CT, and 11 (10%) had an US study, with no child having both a CT and US study. Children who presented to a RH were significantly more likely to have a CT as part of their initial evaluation than at CMC (65% vs. 24%, RR 2.8, 95% CI 2.4-3.6). Forty children were transferred to CMC with no imaging performed at the RH. Patients were more likely to undergo imaging if they initially presented to CMC vs. RH (93% vs. 73%, RR 1.3, 95% CI 1.1-1.4). These data are summarized in Table 1.

### Imaging after transfer

Upon arrival, 22 patients (55%) underwent an US, 3 (8%) had a CT, and 6 (15%) had both US and CT at CMC prior to appendectomy. Only 9 children (23% of children with no imaging prior to transfer and 6% of total transferred subjects) were taken to the operating room without imaging either before or after transfer. Six children with imaging at a RH, four children with CT and two with US, had additional imaging at CMC. In all six cases, US was the only additional imaging used at CMC. In total, 359 (93%) of the 385 boys underwent an imaging study before appendectomy.

### Accuracy of diagnosis

Histological diagnosis was consistent with appendicitis in 381 cases (99%). The rates of perforated appendicitis did not differ between those who presented at CMC versus an RH (21% vs. 27%,  $P = 0.17$ ). Of the four negative appendectomies (1%), all patients were

**Table 1:** Diagnostic imaging in the initial evaluation of appendicitis. Referring Hospital (RH); Children's Medical Center (CMC). Fisher's Exact Test for significance.

	Initial Evaluation		
	CMC (N=238)	RH (N=147)	
US	165 (69%)	11 (7%)	$p < 0.001$
CT	16 (6%)	96 (66%)	$p < 0.001$
US&CT	40 (17%)	0 (0%)	$p < 0.001$
None	17 (7%)	40 (27%)	$p < 0.001$

initially evaluated at CMC and had imaging prior to appendectomy, including one patient with an US, one patient with a CT, and two patients with both US and CT. There were no statistically significant correlations between incidence of negative appendectomy and either place of initial presentation or pre-operative imaging modality.

## Discussion

Acute appendicitis is the most common indication for urgent operation in children, and this prevalence is reflected in our experience at CMC, a large metropolitan pediatric tertiary referral center where 1,005 appendectomies were performed over the course of the study period. The diagnostic evaluation of pediatric appendicitis has changed dramatically since the 1990s when US and CT were first applied as adjuncts to a thorough history and physical examination. Although physicians increasingly depend on these imaging modalities, some authors have suggested an experienced pediatric surgeon should be able to make a diagnosis of appendicitis without imaging in the majority of cases [2,3,8]. While most clinicians and families now demand a high degree of diagnostic certainty which can be achieved only with some form of imaging, we observed that our institutional practice pattern was vastly different from that of local facilities that refer patients to us for management. We chose to study a subset of patients-boys between the ages of 8 and 14 years for whom the differential diagnosis of right-lower quadrant pain is narrow. We found that, even in this select group, only a small number of patients underwent an appendectomy at our institution without pre-operative imaging. RHs were significantly more likely than CMC to diagnose appendicitis without imaging, with over one quarter of transferred patients arriving at CMC without a study. This is likely for several reasons. There may have been a strong suspicion of the diagnosis which obviated the need for imaging, and, our Emergency Department (ED) has advised that the RHs defer imaging prior to transfer for probable appendicitis.

There was a striking difference in the radiographic strategies at CMC when compared with RHs. The ratio of US: CT as the first imaging study was nearly 10:1 at CMC; the exact opposite was true for patients who underwent imaging at RHs, where 90% of patients had a CT scan. Similar findings have been reported in recent single- and multi-institutional reviews. A decade ago, even at children's hospitals, CT was used more frequently than US. Bachur reviewed over 50,000 admissions and found that the median use of US for the diagnosis of appendicitis at 40 participating pediatric hospitals was 6%, whereas the median utilization of CT was 34% [9].

The addition of CT to the routine evaluation of pediatric abdominal pain can reduce the misdiagnosis of appendicitis, with diagnostic sensitivity and specificity of 94% and 95%, respectively [10-13]. For this reason, some authors have advocated the liberal use of CT as a means of both reducing the incidence of negative appendectomy

and decreasing unnecessary hospitalizations for observation and serial examination of children with suspected appendicitis [14]. For children, however, US has distinct advantages including avoidance of ionizing radiation and reduced cost. In our diagnostic algorithm US is the imaging study of choice, followed by CT in cases where the diagnosis remains uncertain. With this approach, we were able to achieve a negative appendectomy rate of only 1%.

For most clinicians, concerns about the additional cost and radiation exposure associated with CT outweigh the benefits of a confirmed diagnosis. Therefore, in pediatric ED, the use of CT has begun to decline. Over the last five years, our institution has introduced a diagnostic algorithm beginning with the use of the Pediatric Appendicitis Score (PAS) [4,15]. With this staged approach, only 20% of patients evaluated by US had equivocal findings that required CT for confirmation of the diagnosis. The applicability of US-based protocols for community hospitals has been thought to be limited by the experience of the radiology staff, and inconsistent availability and accuracy of US [16,17]. This is a hurdle which may not be difficult to resolve. Our study found a high diagnostic accuracy in the limited number of RH patients who had an US. The CMC radiologist confirmed the US diagnosis of appendicitis in nine of these patients. In the other two cases an imaging study was ordered, and corroborated the RH diagnosis of appendicitis. There is a clear educational opportunity to move to 24 hour 7 day a week US availability for diagnosis of pediatric appendicitis. This study was limited to boys alone. With broadening the patient population to all children with right lower quadrant abdominal pain, the differential diagnosis is larger due to possible gynecologic pathology. This differential includes ovarian cysts, torsion, and abscess. The US study has significant diagnostic accuracy in evaluating this pathology along with the suspected appendicitis. In our limited study population of boys alone with suspected appendicitis, 93% of patients had some imaging study. The reasons for the high imaging rate include a study ordered by the ED staff before a surgeon is even consulted, medical/legal concerns in regard to an incorrect diagnosis, and the pendulum has swung to a point that physicians often need to have some imaging study to corroborate their clinical diagnosis. This study shows that a liberal US-based imaging strategy minimizes the need for CT scans, decreasing radiation exposure, and is associated with a very low rate of negative appendectomy. CT should be reserved for patients where a diagnosis could not be made by clinical presentation and US findings.

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