An evidence-based clinical protocol for diagnosis of acute appendicitis decreased the use of computed tomography in children

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Abstract

Purpose: The increased use of computed tomography (CT) to diagnose appendicitis in children has led to a concern for the possibility of increased CT-related cancer morbidity. We designed a clinical protocol for the diagnosis and treatment of appendicitis in children in an attempt to decrease the use of CT scans at our institution.

Methods: Patients who had surgical consultation for suspected appendicitis were placed on the clinical protocol. Data concerning diagnosis and treatment were collected prospectively. Retrospective data from patients admitted to our institution with acute appendicitis before the clinical protocol were collected as historical controls.

Results: One hundred twelve patients were diagnosed and treated by our protocol between June and November 2009. Of these, 100 patients underwent an appendectomy for acute appendicitis. They were compared with 146 patients from 2007. In-house CT use decreased from 71.2% to 51.7% (P = .01). Preoperative ultrasound use increased from 2.7% to 21% (P < .001). The negative appendectomy rate increased (6.8% vs 11%, P = .25).

Conclusions: Our findings suggest that the implementation of an evidence-based clinical protocol for the diagnosis and treatment of acute appendicitis in children may safely decrease the use of CT scans and increase the use of ultrasound.

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Key words:
Acute appendicitis; Clinical protocol; Computed tomography; Ultrasound

Acute appendicitis is a common pediatric intraabdominal pathology. Despite its frequent nature, diagnosis remains enigmatic [1]. In recent years, there has been a gradual rise in the use of computed tomography (CT) as a clinical tool for the diagnosis of appendicitis [2-8]. Because of its sensitivity and specificity greater than 90% [1,4,9-11], some regard it as the “criterion standard” [12]. Concurrently, ultrasound (US), once thought of as the primary imaging modality, has seen a decrease in utilization [2,3,8]. The increased use of CT in the pediatric population is not without risk. For a single abdominal CT in a 5-year-old child, the lifetime risk of radiation-induced cancer could be 26.1 per 100,000 in girls and 20.4 per 100,000 in boys [13]. The National Cancer Institute considers the growing use of CT and the potential for increased radiation exposure to children undergoing these procedures a concern. Thus, the development of evidence-based clinical protocols that can decrease the overuse of CT in children is imperative.
scans as a public health concern [7]. They have encouraged the use of “selective strategies” for pediatric imaging [7]. A strategy we have chosen at our institution was to design a protocol for the diagnosis of acute appendicitis in children that relies on the clinical assessment by the pediatric surgical staff, with US as the primary imaging modality. Using this protocol, we aimed to safely decrease the use of CT in our institution; and here, we report our results in comparison to a historical control.

1. Materials and methods

1.1. Protocol design

The clinical protocol was developed with input from the departments of emergency medicine and radiology. After critical review of the literature, we decided to use the Pediatric Appendicitis Score (PAS) [14] as the primary clinical diagnostic tool (Table 1) because it is straightforward [14] and has been validated [14-16]. Fig. 1 illustrates the protocol in greater detail. However, in general, a patient with a PAS of at least 6 was diagnosed with acute appendicitis. If duration of symptoms was less than 36 hours (decided upon via interdepartmental consensus), the patient was taken to the operating room for a laparoscopic appendectomy. If the duration of symptoms was greater than 36 hours, imaging was ordered to rule out the possibility of an abscess. If the PAS was less than 6, the patient would either undergo an imaging study or be admitted for observation, at the discretion of the pediatric surgical staff.

The protocol dictated that, although the resident (PGY 1-3) initially evaluated the patient and calculated the PAS, the pediatric surgery fellow made the final assessment and decision on admission and/or imaging. The primary imaging modality in our protocol was US, followed by CT if US was equivocal. When an in-house radiologist or technician was unavailable, the patient would be admitted and a US would be obtained the following day. Patients who arrived to our institution with imaging from another hospital had their studies read by our attending pediatric radiologists before operative intervention. Patients who were discharged from the emergency department were instructed to return to our clinic within 48 hours for follow-up evaluation.

1.2. Data collection

After Institutional Board Review approval of the protocol and study, all patients evaluated by the surgical staff at the Children’s Hospital of Alabama were entered into a database designed using Access software (Microsoft, Redmond, WA). Informed consent was waived because diagnosis via the protocol was evidence based and not considered experimental. Patients with inflammatory bowel disease or a gynecologic pathology were excluded from the study. Data collected included age, sex, PAS, white blood cell count, C-reactive protein, imaging modality and source (in-house or outside hospital), disposition (admit or discharge), management (operative, nonoperative, or observation), final imaging results, and operative findings (confirmed by pathology). All imaging was read by an attending pediatric radiologist. Patients were entered consecutively into the database. Patients who required abscess drainage and an interval appendectomy were not included in the final analyses.

For the historical controls, charts of patients who underwent an appendectomy at our institution between January and December 2007 were reviewed (after Institutional Board Review approval). Data collected included age, sex, imaging modality and source (in-house or outside hospital), final imaging results, management (operative or nonoperative), and pathology findings. Acute appendicitis was divided into 2 groups according to pathologic diagnosis: simple appendicitis included those that were inflamed, whereas complex appendicitis included those that were perforated, gangrenous, or suppurative.

1.3. Statistical analysis

Statistical analysis was performed using PASW Statistics (formerly SPSS Statistics) Version 17 (Chicago, IL). The Student t test was used to compare continuous data, whereas the Pearson $\chi^2$ test was used to compare group proportions. Significance was determined by a $P$ value < .05.

2. Results

One hundred sixty-five patients were evaluated under our protocol between June 8 and November 30, 2009. No patient was lost to follow-up. Of these, 100 (60.9%) underwent an appendectomy at our institution. These were compared with 146 appendectomies performed in 2007. The mean age and sex proportions were similar between the 2 groups. In 2007, 118 patients (80.8%) underwent a preoperative CT; 4 patients (2.7%) received a preoperative US. Of the 100 patients who underwent an appendectomy in 2009, 60 (60%)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Pediatric Appendicitis Score [14]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic indicator</td>
<td>Score</td>
</tr>
<tr>
<td>Cough/percussion/heel tapping tenderness in RLQ</td>
<td>2</td>
</tr>
<tr>
<td>Anorexia</td>
<td>1</td>
</tr>
<tr>
<td>Low-grade fever (99°F-101°F)</td>
<td>1</td>
</tr>
<tr>
<td>Nausea/emesis</td>
<td>1</td>
</tr>
<tr>
<td>RLQ tenderness upon light palpation</td>
<td>2</td>
</tr>
<tr>
<td>Leukocytosis</td>
<td>1</td>
</tr>
<tr>
<td>Left shift</td>
<td>1</td>
</tr>
<tr>
<td>Migration of pain to RLQ</td>
<td>1</td>
</tr>
</tbody>
</table>

RLQ indicates right lower quadrant.
underwent a preoperative CT; and 21 preoperative USs were performed (21%) \((P = .01\) and \(P < .001\), respectively). All USs were done in-house. Three patients received both CT and US in 2007 as well as in 2009. Twenty-five patients (17.1%) and 22 patients (22%) did not receive any imaging in 2007 and 2009, respectively; the difference was not statistically significant (Table 2).

In 2007, 27 patients (18.8%) had complex appendectomies; and 10 (6.8%) had negative appendectomies. Using the protocol, 25 patients (25%) were found to have complex appendicitis; and 11 operations (11%) resulted in negative appendectomies \((P = .16\) and \(P = .25\), respectively) (Table 2).

### 3. Discussion

The exposure to radiation from CT use in the pediatric population poses an increased risk of cancer [17,18]. Indeed, one abdominal CT is equal in radiation to 500 chest radiographs [17]. It is estimated that approximately 500 children younger than 15 years will ultimately die from a cancer attributable to the radiation from CT [18]. Aware of these risks and in adherence to the doctrine *primum nil nocere* (first do no harm) [19], we sought a safer, yet equally effective, primary imaging modality for the diagnosis of acute appendicitis.

The use of US for the diagnosis of acute appendicitis has a sensitivity of 44% to 87.3% and a specificity greater than 90% [9,20,21]. The onus upon the operator has been the major drawback in using the US. This, along with the ease and rapidity of the helical CT, has caused a drop in the use of US as an imaging modality for acute appendicitis [2,3,20,22]. We and others [19] believe that if US is performed by experienced radiologists and radiology technicians, it may achieve a diagnostic accuracy equal to that of the CT. We have demonstrated that through implementation of a diagnostic protocol for acute appendicitis that relies on clinical assessment and decision making by the surgeon, we can safely decrease the use of CT while increasing the use of US. Although not statistically significant, we were also able to decrease the proportion of patients not obtaining any imaging. Others [1,10,23,24] have shown that a protocol designed with the

### Table 2 Demographics and results

<table>
<thead>
<tr>
<th>Age (mean ± SD) [range]</th>
<th>2007; n (%)</th>
<th>2009; n (%)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD) [range]</td>
<td>11 ± 3.8 [2-21]</td>
<td>10.9 ± 4.1 [1-18]</td>
<td>.9</td>
</tr>
<tr>
<td>Male</td>
<td>76 (59.6)</td>
<td>64 (64)</td>
<td>.49</td>
</tr>
<tr>
<td>Preop CT</td>
<td>118 (80.8)</td>
<td>60 (60)</td>
<td>.01</td>
</tr>
<tr>
<td>In-house CT</td>
<td>84 (71.2)</td>
<td>31 (51.7)</td>
<td>.01</td>
</tr>
<tr>
<td>Outside CT</td>
<td>34 (28.8)</td>
<td>29 (48.3)</td>
<td>.01</td>
</tr>
<tr>
<td>US use</td>
<td>4 (2.7)</td>
<td>21 (21)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No imaging</td>
<td>25 (17.1)</td>
<td>22 (22)</td>
<td>.34</td>
</tr>
<tr>
<td>Complex appendicitis</td>
<td>27 (18.5)</td>
<td>25 (25)</td>
<td>.16</td>
</tr>
<tr>
<td>Negative appendectomy</td>
<td>10 (6.8)</td>
<td>11 (11)</td>
<td>.25</td>
</tr>
</tbody>
</table>

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**Fig. 1** Algorithm for protocol.
surgeon at the fulcrum of the algorithm is both safe and cost-effective.

Martin and colleagues [2] suggested that the ideal rate of the preoperative CT should fall between 29% and 57% because the benefit of a decreased negative appendectomy rate levels off once CT use surpasses 30%. Our study has demonstrated this hypothesis. However, although we may be able to influence change at our own hospital, we noticed a rise in the CT rate at outside hospitals (Table 2). Further educating our referring pediatricians would be necessary to appreciate a substantial decrease in the use of CT for diagnosing acute appendicitis. We were surprised to see an increase in both the complex appendicitis rate and the negative appendectomy rate with the protocol compared with the historical control, although the difference was not statistically insignificant. Our negative appendectomy rate from the protocol is similar to that found by others [6,25]. Furthermore, because our definition of complex appendicitis encompasses perforated, gangrenous, and suppurative appendices, our reported rate may be an overestimation of our actual perforation rate. In the study by Kosloske et al [1], rates for both advanced and perforated appendicitis were reported from their clinical protocol, totaling 33%.

A closer look into our negative appendectomies prompted us to investigate if a positive CT led to the decision of an operation. We found that 9 of the 11 patients with negative appendectomies received a preoperative CT. Seven of the 9 scans were read as positive for appendicitis (Table 3). Although not the focus of this study, the accuracy of the imaging modalities derived from our prospective data was 82.3% for CT and 88.3% for US. We recognize that accuracy of the US is operator dependent. A children’s hospital, where technicians and radiologist are accustomed to performing US on children for various medical issues, is the ideal institution for this particular protocol. This may explain the low incidence of US equivocal readings. We recognize that our protocol may be impractical in institutions with limited exposure to the pediatric population.

Based on this study, we believe that a diagnostic protocol for acute appendicitis can safely decrease the number of preoperative CT scans performed at a children’s hospital. We and others [13,22] suggest that US should be the primary diagnostic modality when clinical assessment is equivocal, with CT reserved for an equivocal US.

**References**


