Diagnostic Imaging and Negative Appendectomy Rates in Children: Effects of Age and Gender

WHAT’S KNOWN ON THIS SUBJECT: Cross-sectional imaging can reduce the negative appendectomy rate (NAR) in children being evaluated for suspected appendicitis; however, the ability of diagnostic imaging to decrease NAR may vary by age and gender.

WHAT THIS STUDY ADDS: Cross-sectional imaging leads to a significant reduction in NAR for children younger than 5 years and girls older than 10 years. For boys older than 5 years being evaluated for uncomplicated appendicitis, advanced imaging appears to have limited value.

abstract

BACKGROUND AND OBJECTIVES: Diagnostic imaging is often used in the evaluation of children with possible appendicitis. The utility of imaging may vary according to a patient’s age and gender. The objectives of this study were (1) to examine the use of computed tomography (CT) and ultrasound for age and gender subgroups of children undergoing an appendectomy; and (2) to study the association between imaging and negative appendectomy rates (NARs) among these subgroups.

METHODS: Retrospective review of children presenting to 40 US pediatric emergency departments from 2005 to 2009 (Pediatric Health Information Systems database). Children undergoing an appendectomy were stratified by age and gender for measuring the association between ultrasound and CT use and the outcome of negative appendectomy.

RESULTS: A total of 8,959,155 visits at 40 pediatric emergency departments were investigated; 55,227 children had appendicitis. The NAR was 3.6%. NARs were highest for children younger than 5 years (boys 16.8%, girls 14.6%) and girls older than 10 years (4.8%). At the institutional level, increased rates of diagnostic imaging (ultrasound and/or CT) were associated with lower NARs for all age and gender subgroups other than children younger than 5 years, The NAR was 1.2% for boys older than 5 years without any diagnostic imaging.

CONCLUSIONS: The impact of diagnostic imaging on negative appendectomy rate varies by age and gender. Diagnostic imaging for boys older than 5 years with suspected appendicitis has no meaningful impact on NAR. Diagnostic strategies for possible appendicitis should incorporate the risk of negative appendectomy by age and gender.

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Address correspondence to Richard Bachur, MD, Division of Emergency Medicine, Children’s Hospital, 300 Longwood Ave, Boston, MA 02115. E-mail: richard.bachur@childrens.harvard.edu
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AUTHORS: Richard G. Bachur, MD, Kara Hennelly, MD, Michael J. Callahan, MD, Catherine Chen, MD, MPH, and Michael C. Monuteaux, ScD

Division of Emergency Medicine, Departments of Radiology and Surgery, and Clinical Research Program, Children’s Hospital and Harvard Medical School, Boston, Massachusetts

KEY WORDS appendicitis, computed tomography, ultrasound, radiation, pediatric, diagnostic studies, abdominal pain, health services research, male, adolescent

ABBREVIATIONS CT—computed tomography
ED—emergency department
ICD—International Classification of Diseases
NAR—negative appendectomy rate
PHIS—Pediatric Health Information System

Dr Bachur was responsible for conception and design, analysis and interpretation of the data, drafting and critical revision of the manuscript, and final approval of the submitted manuscript; Dr Hennelly was responsible for drafting and critical revision of the manuscript, and final approval of the submitted manuscript; Dr Callahan was responsible for analysis and interpretation of the data, drafting and critical revision of the manuscript, and final approval of submitted manuscript; Dr Chen was responsible for drafting, critical revision, and final approval of the manuscript; Dr Monuteaux was responsible for conception and design, acquisition of the data, analysis and interpretation of the data, drafting and critical revision of the manuscript, and final approval of submitted manuscript; and Dr Monuteaux had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Cross-sectional imaging with computed tomography (CT) and ultrasound are frequently used in the diagnostic evaluation of appendicitis in children. Both CT and ultrasound have been reported to improve outcomes related to pediatric appendicitis.1–10 As initially investigated, the optimal application of advanced diagnostic imaging was focused on cases with equivocal clinical findings. Over time, however, advanced imaging for suspected appendicitis has expanded to include many children with more typical presentations and those with abdominal pain and a low likelihood of appendicitis. Although there is considerable variation and debate over the best application of advanced imaging,7,11–23 one key driver for this broader application of imaging appears to be minimizing negative appendectomies rather than outcomes related to perforation rates or costs of hospital admission for serial examinations. The negative appendectomy rate (NAR; surgical removal of a normal appendix) decreased dramatically with the introduction of diagnostic imaging for possible appendicitis, whereas perforation rates have not changed.5,14,16,21,24–50

Although CT has repeatedly been shown to have higher diagnostic performance than ultrasound for appendicitis,31 there has been an effort to decrease CT use because of concerns for ionizing radiation exposure and consequent increased lifetime cancer risk, particularly in children.22–24 Several recent studies have discussed an ultrasound-only approach11,25,35,36 or a staged approach with ultrasound first and then a CT if needed.15,37

Herein, we report the use of CT and ultrasound for age and gender subgroups to examine the impact of diagnostic imaging on NARs.

METHODS

Data Source and Design

This was a retrospective study using an administrative database, Pediatric Health Information System (PHIS), managed by the Children’s Hospital Corporation of America (Shawnee Mission, KS), a business alliance of freestanding pediatric hospitals. Data quality and reliability were ensured through a joint effort between the Child Health Corporation of America and participating hospitals. The data warehouse function for the PHIS database is managed by Thomson Reuters (Ann Arbor, MI). For the purposes of external benchmarking, participating hospitals provide discharge/encounter data, including demographics, diagnoses, and procedures. Forty of these hospitals also submit resource utilization data (eg, pharmaceuticals, imaging, and laboratory) into PHIS. Data are de-identified at the time of data submission, and data are subject to a number of reliability and validity checks before being included in the database. No patient-level clinical data exist in the database.

Study Patients

We investigated all children younger than 19 years who were evaluated in the emergency department (ED) from 2005 to 2009, inclusive, and had an appendectomy performed during the course of their clinical encounter. All patients undergoing an appendectomy are referenced as having suspected appendicitis. Given the administrative nature of the database, those patients with a final diagnosis of appendicitis (International Classification of Diseases, Ninth Revision [ICD-9] codes 540.0, 540.1, 540.9, 541.0, and 542.0) are considered to have appendicitis even though clinical (surgical or histopathology) information was not available in the database. Those patients undergoing an appendectomy without a final diagnosis of appendicitis were considered to have a negative appendectomy. This methodology for defining negative appendectomy has been previously applied.58 To account for the possibility of an appendectomy being performed during another primary surgical procedure (“incidental appendectomy”), cases with other emergent surgical procedures were excluded (ICD-9 codes of 46.80, intra-abdominal manipulation of intestine, such as intussusception, volvulus, torsion of intestine; 65.95, release of torsion of ovary; 53.X, hernia repair; 41.X, splenectomy). For this study, we also assumed that any diagnostic imaging ordered in the ED was performed for the purpose of evaluating acute abdominal pain. Data integrity was evaluated by testing 2 assumptions: patients with a final diagnosis of appendicitis without abscess (ICD-9 code of 540.9) should have an appendectomy (98.3%) and patients with perforated appendicitis (ICD-9 codes of 540 and 540.1) required admission (99.4%) and parenteral antibiotics (97.0%).

Analytic Plan

Age and Gender Subgroups

The use of diagnostic studies for study patients was analyzed by gender and age subgroups. Considering the variation of clinical presentation of abdominal pain by age,39,40 we categorized age subgroups of <5 years of age, 5 to 10 years, and >10 years. We additionally stratified cases by gender to account for the differing diagnostic considerations of postpubertal girls.

NARs

The NAR was determined by dividing the number of ED patients who had an appendectomy (primary surgical procedure) without a final diagnosis of appendicitis by the total number of ED patients who underwent an appendectomy.

Hospital-Level Analysis

The association between advanced diagnostic imaging and the clinical outcome of negative appendectomy was examined by using linear regression models, with the hospital-level NAR as the dependent variable and the hospital-level imaging rate as the independent variable, weighted by the
number of appendectomies performed at each hospital. The analysis was performed for age and gender subgroups (as above) and adjusted for the patient volume at each institution.

**Patient-Level Analysis**

We tested the association between negative appendectomy and each modality of diagnostic imaging within each age and gender subgroup. We estimated a logistic regression model with the negative appendectomy indicator as the dependent variable and imaging indicator as the independent variable. Given that our data were taken from several hospitals, the assumption of independent observations may not hold (ie, a patient from hospital A is more likely to correlate with another patient from hospital A compared with a patient from hospital B). To accommodate these data, we used clustered sandwich SE estimates, which allow for intra-hospital correlation, relaxing the assumption that observations from the same hospital are independent.

**General Considerations**

Hospitals that provided fewer than 2 years of data or had a low patient volume (defined as total volume less than 1.5 SDs below the mean annual ED volume) were excluded from inferential analyses. All statistical tests were performed by using the software package Stata 12.0 (Stata Corp, College Station, TX). All statistical tests were 2-tailed and α was set at 0.05.

The study was approved by the institutional review board and the administrators of the PHIS database. In accordance with PHIS policies, the identity of the institutions was not reported.

**RESULTS**

**Study Population**

A total of 8 959 155 ED visits at 40 pediatric institutions were studied. After excluding patients meeting our criteria for “incidental appendectomy,” 55 227 children had a final diagnosis of appendicitis: 35 335 (64.0%) had uncomplicated appendicitis, 13 166 (23.8%) had appendicitis with perforation, and 6726 (12.2%) had appendicitis with perforation and abscess formation. A total of 52 290 patients underwent an appendectomy and constitute the study population; of these, 96.4% had a final diagnosis of appendicitis for an overall NAR of 3.6%. The patient-level NARs among boys stratified by age were 16.9% (age <5 years), 1.3% (5–10 years), and 1.1% (>10 years). Among girls, the rates were 13.3% (age <5 years), 1.8% (5–10 years), 5.5% (>10 years).

**Hospital-Level Analysis: Association Between Use of Advanced Diagnostic Studies and NARs**

The use of CT and ultrasound among the hospitals across the age and gender subgroups and the corresponding NARs are summarized in Table 1. CT rates exceeded ultrasound rates for each age and gender subgroup. Overall, girls had more imaging than boys for each subgroup. For both boys and girls, those younger than 5 years are most likely to have both ultrasound and CT before appendectomy.

Figure 1 shows the association of hospital-level CT, ultrasound, and either CT or ultrasound use rates with the hospital-level NARs. Children younger than 5 years and girls older than 10 had the highest NARs. The rate of either CT and/or ultrasound use by individual institutions was significantly associated with NAR among all subgroups except children younger than 5 years; however, the rate of CT alone was not associated with the institutional NAR among any subgroup. Boys older than 5 years had the lowest rates of negative appendectomy regardless of imaging.

**Patient-Level Analysis: Association Between Use of Diagnostic Imaging and NARs**

A patient-level analysis is seen in Table 2 (by subgroups) and in Figs 2 (boys) and 3 (girls). Similar to hospital-level analysis, boys older than 5 years have lower NARs compared with boys younger than 5 years. The use of CT before appendectomy was significantly associated with lower NARs only among boys younger than 5. For boys younger than 5 years, use of ultrasound was associated with a higher NAR. Among girls, those younger than 5 years had significantly lower NARs if CT was obtained, but no difference in NAR was found if ultrasound was used. Girls

| TABLE 1 Hospital-Level Rates of Cross-sectional Imaging Among Age- and Gender-Stratified Pediatric Patients Undergoing an Appendectomy After Presenting to the ED Across a Sample of 40 Pediatric Hospitals in the United States, 2005–2009 |
|-----------------|-----------------|----------------|-----------------|-----------------|
|                | CT Ultrasound    | Both CT and Ultrasound | Either CT or Ultrasound | Negative Appendectomy |
| **Boys**       |                 |                        |                            |                             |
| <5 y           | 35.4 [8.5, 47.0] | 17.7 [2.4, 34.7]       | 2.1 [0.5, 5.2]             | 52.8 [39.8, 65.4]          | 16.8 [12.3, 26.8] |
| 5–10 y         | 29.7 [12.1, 44.5] | 5.1 [1.2, 24.2]        | 1.4 [0.3, 2.9]             | 44.9 [30.6, 55.4]          | 1.1 [0.4, 2.2]     |
| >10 y          | 33.2 [16.2, 44.9] | 4.4 [1.0, 20.1]        | 0.8 [0.3, 3.3]             | 43.5 [35.2, 53.0]          | 0.8 [0.2, 1.7]     |
| **Girls**      |                 |                        |                            |                             |
| <5 y           | 40.3 [16.2, 49.6] | 15.0 [6.4, 35.7]       | 3.0 [0.0, 6.6]             | 59.7 [44.7, 68.4]          | 14.8 [9.6, 18.9]   |
| 5–10 y         | 38.2 [16.1, 47.3] | 6.2 [2.0, 26.3]        | 0.9 [0.0, 3.9]             | 49.4 [40.8, 57.3]          | 1.5 [0.5, 3.3]     |

Values in table represent median [interquartile range].
older than 10 had significantly higher NARs than boys (5.5% vs. 1.1%, respectively) independent of diagnostic imaging (adjusted odds ratio [95% confidence interval] = 5.2 [4.4, 6.1]).

**DISCUSSION**

Appendicitis is the most common surgical emergency in children. Delays in diagnosis can lead to significant morbidity from appendiceal rupture, possibly leading to abscess formation and, more rarely, peritonitis and septic shock. History and physical examination alone are often insufficient for making a diagnosis in many pediatric patients, especially in young children or those presenting early in the disease process. Advanced imaging with CT and ultrasound has become routine in many children undergoing diagnostic evaluation for pediatric appendicitis because of the relatively limited performance of clinical intuition and clinical decision rules.\textsuperscript{41–43} CT has been consistently shown to have superior diagnostic performance as compared with ultrasound but exposes the patient to ionizing radiation. A 2006 meta-analysis by Doria et al.\textsuperscript{31} provided estimates of test performance sensitivity.
TABLE 2 Rates of Imaging Among Pediatric Patients Undergoing an Appendectomy After Presenting to the ED (n = 52,290) Across a Sample of 40 Pediatric Hospitals in the United States, 2005–2009

<table>
<thead>
<tr>
<th>Age Group</th>
<th>CT</th>
<th>Ultrasound</th>
<th>Both CT and Ultrasound</th>
<th>Either CT or Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>31.7</td>
<td>28.0</td>
<td>26.7</td>
<td>29.3</td>
</tr>
<tr>
<td>&lt;5 y</td>
<td>31.7</td>
<td>30.5</td>
<td>28.3</td>
<td>30.3</td>
</tr>
<tr>
<td>5–10 y</td>
<td>31.7</td>
<td>27.0</td>
<td>21.8</td>
<td>29.3</td>
</tr>
<tr>
<td>&gt;10 y</td>
<td>31.7</td>
<td>28.2</td>
<td>18.9</td>
<td>37.1</td>
</tr>
<tr>
<td>Girls</td>
<td>20.5</td>
<td>32.5</td>
<td>24.7</td>
<td>29.4</td>
</tr>
<tr>
<td>&lt;5 y</td>
<td>20.5</td>
<td>33.1</td>
<td>25.9</td>
<td>37.1</td>
</tr>
<tr>
<td>5–10 y</td>
<td>20.5</td>
<td>30.9</td>
<td>21.6</td>
<td>39.7</td>
</tr>
<tr>
<td>&lt;10 y</td>
<td>20.5</td>
<td>33.3</td>
<td>22.2</td>
<td>41.0</td>
</tr>
<tr>
<td>Total &lt;5 y</td>
<td>20.5</td>
<td>31.6</td>
<td>26.4</td>
<td>43.7</td>
</tr>
<tr>
<td>Total 5–10 y</td>
<td>20.5</td>
<td>28.5</td>
<td>21.1</td>
<td>47.1</td>
</tr>
<tr>
<td>Total &gt;10 y</td>
<td>20.5</td>
<td>30.2</td>
<td>20.2</td>
<td>47.1</td>
</tr>
</tbody>
</table>

**FIGURE 2** Association between negative appendectomy and diagnostic imaging at patient level among boys by age subgroups.

and specificity of CT and ultrasound (sensitivity: CT 94% [95% confidence interval 92%, 97%] and ultrasound 88% [86%, 90%]; specificity: CT 95% [94%, 97%] and ultrasound 94% [92%, 95%]). Despite the better test characteristics, the most current recommendations are to either consider an ultrasound-only approach or an approach of ultrasound first followed by CT if the ultrasound is inconclusive and suspicion for appendicitis remains.11,15,25,31,34–37,44–52

When CT was introduced as a diagnostic tool for pediatric appendicitis, the diagnostic sensitivity reduced the need for routine admission of patients with equivocal findings for serial examinations.4,53 In addition, CT was expected to identify early appendicitis and thereby reduce perforation rates; this improvement in perforation rates has been variable.6,18,21,22,26,54 The current data continue to support the inverse association between diagnostic imaging and NARs that likely led to the surge of diagnostic imaging among children with abdominal pain.5,6,18,21,22,26,28

The current study’s findings extends to the clinical management by suggesting that age and gender must be incorporated into any evaluation algorithms. The most striking finding is the low NARs among boys older than 5 years; the value of diagnostic imaging for this subgroup appears to be limited with regard to this particular outcome. Of note, the paradoxically higher NAR for boys younger than 5 years who had an ultrasound (compared with those who did not have an ultrasound) might reflect an attempt to rely on ultrasound over CT when the diagnosis is especially difficult in this age group. For girls, advanced diagnostic imaging for those younger than 5 years reduces the NAR; the higher NAR for those girls older than 10 years likely stems from the presence of gynecologic conditions where secondary findings noted by imaging may mimic appendicitis.55 Despite this relatively high rate of negative
appendectomy, the use of imaging among postpubertal girls is associated with the greatest absolute reduction in negative appendectomies as previously recognized.\textsuperscript{14,56} The current investigation is limited by the use of administrative data to infer clinical management and clinical outcomes. As noted earlier, we relied on basic assumptions that diagnostic coding has an accurate clinical correlate. Despite reliance on these assumptions, the NARs are comparable to previous clinical studies.\textsuperscript{6,14,16,17,19,22,26,28,56} The lack of actual clinical data for each patient is counterbalanced by the large dataset that facilitates analysis for NARs across institutions and varying populations; however the database does not allow analysis of cases that were evaluated for appendicitis but did not undergo an appendectomy. Therefore, the value of imaging in ruling out appendicitis could not be studied. In addition, because these institutions serve as referral centers, imaging obtained before transfer to a center cannot be studied. The patient demographics likely differ among hospitals and basic considerations, such as access to care or access to advanced imaging, might influence the timing of presentation and approach to making the diagnosis. Finally, the investigation of any association between imaging and NARs is confounded by the fact that patients represent a heterogeneous population where imaging is theoretically biased toward those with equivocal clinical findings or concern for complications of appendicitis.

**CONCLUSIONS**

NARs are highest for children younger than 5 years and girls older than 10 years and are reduced through the use of advanced diagnostic imaging. The routine use of CT and ultrasound should be limited in boys older than 5 years with suspected appendicitis (and no other clinical concerns), given the relatively low NARs independent of cross-sectional imaging.

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HANDS OR NO HANDS: The other night, I took my son out to dinner at a local restaurant that serves Ethiopian food. I was excited because he had not eaten Ethiopian before and I had recently spent a month in Ethiopia and had enjoyed the cuisine. After ordering, I explained to him how the food would arrive on a large communal metal serving platter and how to use injera, the bread made from tif, to transfer food from the platter into one's mouth. I was stunned when we were served individually on typical dinner plates and each given a knife, spoon, and fork with which to eat. While in much of the Middle East, Africa, and parts of Asia, eating with hands is common, I had forgotten the usual American antipathy to eating with one's hands except when at a barbecue. According to an article in The New York Times (Dining: January 17, 2012), some of the barriers to using hands to eat food in American restaurants may finally be starting to fall. Many upscale restaurants, and not just restaurants catering to African or Middle Eastern foods, are encouraging diners to dig in with their fingers. The idea is that eating with hands decreases the formality of eating, increases the likelihood that dining will be a social event, and heightens the diner's connection to the food. While the restaurants still provide utensils, servers generally recommend the food is best eaten with hands and that no rules apply. Interestingly, in many cultures where utensils are not used for eating, strict rules of etiquette, something American restaurants are trying to avoid, guide dining. A no-utensil approach to eating has made it all the way to the White House, if only barely. A state dinner for the Indian prime minister included a bread course consisting of naan, flat leavened bread, and corn bread with dips. As for me, I have no idea why people use a fork and knife to eat chicken or any other fowl on the bone. I am hoping that in the future I won't get quite so many curious looks when I use my hands to nibble on a chicken thigh or scoop curries with bread or firm vegetables.

Noted by WVR, MD
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