Ultrasound in Emergency Medicine

IS PELVIC ULTRASOUND ASSOCIATED WITH AN INCREASED TIME TO APPENDECTOMY IN PEDIATRIC APPENDICITIS?

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Abstract—Background: Appendicitis is a common pediatric condition requiring urgent surgical intervention to prevent complications. Pelvic ultrasound (US) as a diagnostic aid has become increasingly common. Despite its advantages, evidence suggests US can lead to delayed definitive management. Objective: The objective was to test the hypothesis that US is associated with an increased time to appendectomy in children with acute appendicitis. Methods: A chart review was conducted of all children aged 0–17 years who presented to the pediatric emergency department (ED) with a discharge diagnosis of appendicitis. The primary outcome variable was the interval between initial evaluation to appendectomy between patients who received an US and those who did not. Results: Of 662 cases included, 424 patients (64%) underwent a pelvic US and 238 patients underwent an appendectomy without US. Median time interval from initial evaluation in the ED by a physician to appendectomy among patients who received an US was 9.7 h (interquartile range [IQR]: 6.8–15.0 h) compared with 5.5 h (IQR: 3.8–8.6 h) among patients who did not receive an US (Mann-Whitney, p < 0.001). The increased time to appendectomy in patients who received an US was dependent on the patient being female and presenting to the ED after hours (univariate analysis of variance test for interaction, p < 0.05). Conclusions: Female pediatric patients and those presenting after hours that undergo diagnostic imaging have a significantly increased time to appendectomy compared with those who do not undergo diagnostic imaging.  © 2014 Elsevier Inc.

Keywords—appendicitis; ultrasound; delay; pediatrics

INTRODUCTION

Appendicitis is the most common pediatric condition requiring urgent surgical intervention and is diagnosed in up to 8% of children evaluated in urgent care settings for abdominal pain (1–3). The incidence increases from an annual rate of 1–2 per 10,000 children between birth and 4 years of age, peaking in adolescence to 19–28 per 10,000 children younger than 14 years (4). There is also evidence that in the last 20 years, the incidence of appendicitis has increased (5). Children commonly present with nausea, vomiting, anorexia, low-grade fever, right lower-quadrant pain, abdominal tenderness, and guarding (4,6). While the incidence of appendicitis is <5% among children younger than 6 years of age, this age group often poses a diagnostic challenge because they present with less specific signs and symptoms (7). Consequently, delayed diagnosis is common and has been reported in up to 57% of cases in children younger than 6 years of age. Consistent with this, young children have a high rate of bowel perforation (70%), which correlates strongly with a delayed diagnosis (7). Perforation is rare in the first 12 h, but is increasingly common...
thereafter, consequentially, the rate of perforation is directly proportional to a delay in diagnosis (8). Therefore, early appendectomy is instrumental in avoiding the complications of appendicitis, which include perforation, peritonitis, abscess formation, and sepsis (7).

Historically, the diagnosis of appendicitis was largely based on the physician’s history and physical examination findings. During the last decade, however, the use of diagnostic imaging, primarily pelvic ultrasound (US) and computed tomography (CT), has superseded the clinical examination in directing the course of surgical management. The use of US for the diagnosis of acute appendicitis in children was first described in 1981 and increased dramatically during the next 2 decades (1,7,9). In a pooled analysis, US has been reported as sensitive (85%) and specific (94%) for diagnosing appendicitis (6). Advantages include its noninvasive nature and zero risk of exposure to ionizing radiation (7,10,11). Proponents of its use as a diagnostic modality cite a decreased negative appendectomy rate, decreased perforation rate, and decreased cost (1,12–14).

Despite its reported advantages, evidence suggests that diagnostic imaging leads to significant delays in definitive management, resulting in increased expenses without clear improvements in diagnostic accuracy or health outcomes (15–17). In children, the use of US has been found to be associated with a delay in surgery and an increase in hospital charges, without a reduction in perforation or complication rates (18). Similarly, York et al. found that the median time from emergency department (ED) evaluation to the operating room was significantly longer among children who received an US or CT scan compared with those who did not receive imaging (15).

Although it has not yet been clearly demonstrated that US leads to increased complication rates in appendicitis, limited findings suggest that in children, time to appendectomy is greater when diagnostic imaging is performed. To date, there have been no large studies determining if routine use of US is associated with a delay to appendectomy or an increased rate of appendicitis-related complications. The objective of this study was to test the hypothesis that diagnostic pelvic US is associated with an increased time to appendectomy in children with acute appendicitis. The results could provide a rationale for more selective imaging and earlier surgical evaluation in specific situations.

METHODS

This study was conducted as a retrospective cross-sectional study using a chart review. The hypothesis was that a diagnostic pelvic US compared with no US is associated with greater time to appendectomy in children presenting with acute appendicitis. The study included all children aged 0–17 years who presented to the pediatric ED at an academic tertiary care center from January 1990 to January 2012 with a discharge diagnosis of appendicitis based on International Classification of Disease, 10th revision diagnostic codes. The ED is part of an academic tertiary care pediatric trauma center and has approximately 40,000 annual visits, serving a catchment of >1.8 million children.

Any patients who were transferred from another center were excluded because the logistics associated with the transfer could have contributed to delays. Hemodynamically unstable patients or those who presented with clear signs of peritonitis suggestive of appendiceal perforation were excluded because it was believed they will often undergo CT or urgent surgery to rule out the presence of a suppurative complication. Patient charts were obtained using the hospital’s medical records service based on the discharge diagnosis of appendicitis. The chart review included physicians’ clinical notes, nursing records, radiology, and operative reports.

The primary outcome variable was the total length of time from the patient’s initial evaluation in the ED by a physician until the first incision of appendectomy. The time to appendectomy for patients who received an US to diagnose appendicitis was compared with that of those who received an appendectomy without a diagnostic US. Secondary outcomes included the incidence of complications related to perforation, including abscess, peritonitis, ileus, and sepsis.

Every US was performed by a technician using Puy laert’s graded compression technique and interpreted by one of two staff radiologists with subspecialty training in pediatric radiology (19). The final diagnosis of appendicitis was made by a staff pathologist based on histologic examination of the excised appendix at the time of surgery.

An a priori subgroup analysis using sex, age, and time of presentation as covariates was based on the rationale that male patients have fewer competing diagnoses so that the time to appendectomy was postulated to be shorter. Children younger than age 6 years are at higher risk for perforation due to nonspecific presentation and anatomical differences. Patients that present during night-time hours (5:00 PM to 8:00 AM) are more likely to undergo delays in diagnostic imaging and appendectomy due to limited availability of technical support during these hours.

From the hospital chart, the following data were extracted by trained research assistants: sex, age, highest preoperative temperature, white blood cell count, presence or absence of vomiting, appendectomy technique (open or laparoscopic), time and day of ED presentation, and time of surgery. Time of first assessment by an ED physician was determined from nursing records and
corroborated by the physician’s clinical notes. If this time was discrepant between the physician’s chart and nurse’s notes, the latter was taken as correct, as it is often more accurate and consistent. Time of first incision of appendectomy was determined from the anesthesiologist’s sedation record. Charts with missing data pertaining to the primary outcome were excluded from the analysis.

STATISTICAL ANALYSIS

Data were entered into an Excel spreadsheet and imported into IBM SPSS software (version 20; IBM SPSS, Armonk, NY) for analysis. Descriptive statistics were used to describe demographic and clinical features. Categorical variables were compared using Pearson’s χ² test. Continuous variables were compared using Student’s t-test. The Mann-Whitney U statistic was used to compare the time interval between groups. Exploratory subgroup analyses were carried out to examine the effects of biologically plausible covariates using univariate analysis of variance (ANOVA) with a test for interaction. All tests for significance were two-sided and a 5% level of significance was used and upon which to reject the null hypothesis. Based on a sample size calculation for comparison of two independent means, 175 children were needed in each group to have an 80% chance of detecting a clinically meaningful difference in time to surgery of 3 h between groups, assuming a type I error rate of 5%, and a standard deviation (SD) of 10 h (20).

Ethics approval was obtained from our institution’s office of research ethics review board.

RESULTS

Participants

A total of 1127 patient charts were assessed for eligibility based on the discharge diagnosis of appendicitis. Of these, 414 cases were excluded as follows: 325 were transferred from another facility, 36 received a diagnostic CT scan instead of an US, 43 cases had a missed appendicitis (perforation before diagnosis) and therefore did not have an immediate appendectomy, and in 10 cases, data directly related to the primary outcome variable was missing. Another 51 cases were excluded because the patient was discharged before receiving a diagnostic US. A total of 662 cases were included in the final analysis (Figure 1). Of these, 424 patients (64%) underwent a diagnostic pelvic US and 238 patients underwent an appendectomy without US.

Demographic and Clinical Features

Table 1 describes the demographic and clinical features of patients based on whether or not they received an US. The sample consisted of a male-to-female ratio of approximately 1.9:1. There were no significant differences in mean age between groups, but significantly more patients who received an US were female. Significantly more patients who presented with typical features of appendicitis (eg, fever, vomiting, anorexia, peripheral pleocytosis) did not undergo an US.

Table 1. Clinical and Demographic Features by US Status

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Ultrasound (n = 424)</th>
<th>No Ultrasound (n = 238)</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean (SD)</td>
<td>11.7 (3.6)</td>
<td>11.9 (3.5)</td>
<td>−0.35 to 0.78</td>
<td>0.45</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>171 (40.3)</td>
<td>55 (23.1)</td>
<td>0.10 to 0.24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WBC (× 10⁶ cells/μL), mean (SD)</td>
<td>14.9 (5.3)</td>
<td>16.4 (4.6)</td>
<td>0.64 to 2.25</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Fever, n (%)</td>
<td>138 (32.5)</td>
<td>99 (41.6)</td>
<td>−0.17 to −0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Vomiting, n (%)</td>
<td>234 (55.2)</td>
<td>165 (69.3)</td>
<td>−0.21 to −0.06</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Anorexia, n (%)</td>
<td>208 (49.1)</td>
<td>138 (58.0)</td>
<td>−0.17 to −0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Dysuria, n (%)</td>
<td>34 (8.0)</td>
<td>25 (10.5)</td>
<td>−0.08 to 0.02</td>
<td>0.35</td>
</tr>
<tr>
<td>Pain ≥72 h, n (%)</td>
<td>56 (13.2)</td>
<td>30 (12.6)</td>
<td>−0.05 to 0.06</td>
<td>0.92</td>
</tr>
</tbody>
</table>

CI = confidence interval; SD = standard deviation; WBC = white blood cell count; US = ultrasound.
Median time interval from initial evaluation in the ED by a physician to appendectomy among patients who received an US was 9.7 h (interquartile range [IQR]: 6.8–15.0 h) compared with 5.5 h (IQR: 3.8–8.6 h) among patients who did not receive an US (p < 0.001) (see Figure 2). Based on the subgroup analysis, however, the increased time to appendectomy in patients who received an US was dependent on the patient being female and presenting to the ED after hours. The mean time to appendectomy among females who received an US was 13.1 h (SD 6.9 h) compared with 6.9 h (SD 3.1 h) among females who did not receive an US (univariate ANOVA test for interaction, p = 0.02). In contrast, the mean time to appendectomy among males who received an US was 11.8 h (SD 6 h) compared with 7.7 h (SD 4.5 h). Mean time to appendectomy among patients who presented after hours and who received an US was 14.9 h (SD 6.4 h) compared with 7.8 h (SD 5.0 h) in patients who presented after hours but did not receive an US (univariate ANOVA test for interaction, p < 0.01). There was no significant interaction between younger age (younger than 6 years) and US status on time to appendectomy (univariate ANOVA test for interaction, p = 0.08).

Complication Rates

Overall complication rates were frequent (Table 2) and consisted entirely of either perforation or abscess. The rate of appendiceal abscess was similar among patients who received an US compared with those who did not. In contrast, significantly more patients who had an appendiceal perforation had an appendectomy without receiving an US. In an effort to explain the increased number of perforations in the non-US group, a post-hoc analysis was undertaken to ascertain whether or not patients who did not receive an US had a longer duration of symptoms and were therefore more likely to perforate. Significantly more perforations were seen in patients with symptoms ≥ 72 h (33 of 86 or 38.4%) compared with patients with symptoms < 72 h (75 of 576 or 13%) (Pearson χ² = 35.2; p < 0.01). However, there were no significant differences between imaging groups based on the proportion of patients who had symptoms for < 72 h or ≥ 72 h (Pearson χ² = 0.5; p = 0.83).

DISCUSSION

In the last 10–15 years, the diagnostic challenge of pediatric appendicitis has prompted the expanded use of diagnostic imaging in the form of US or CT (1,15). Although these modalities have greatly increased the diagnostic accuracy of acute appendicitis, there remains the possibility that universal and widespread application of diagnostic imaging, particularly US, can lead to unnecessary delays in definitive management (1).

This single-center retrospective cross-sectional study demonstrated that a diagnostic pelvic US is associated with a significantly increased time to appendectomy among females and those who presented to the ED after hours. The high rate of preoperative US for suspected appendicitis found in this study (64%) is consistent with the results of a survey of 344 members of the American Pediatric Surgical Association. The use of imaging was reported in > 67% of cases for the preoperative evaluation of appendicitis (21). In addition, York et al. reported a > 50% rate of preoperative imaging in their review of 197 children investigating the impact of imaging on outcomes of children who underwent appendectomy (15).

The 1.9:1 ratio of males to females in our sample was consistent with one of the largest epidemiologic reports of acute appendicitis (4). To date, no broadly accepted explanation exists to account for this phenomenon. In contrast to the findings of no sex differences by some authors, a significantly greater proportion of female patients underwent US in our study (15). However, this is consistent with the findings of Applegate et al., who found 52% of females underwent preoperative imaging compared

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Table 2. Complication Rate by Ultrasound Status

<table>
<thead>
<tr>
<th>Complication</th>
<th>Ultrasound (n = 424)</th>
<th>No ultrasound (n = 236)</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforation, n (%)</td>
<td>55 (13.0)</td>
<td>53 (22.5)</td>
<td>−0.16 to −0.03</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Abscess, n (%)</td>
<td>11 (2.6)</td>
<td>7 (3.0)</td>
<td>−0.04 to 0.02</td>
<td>0.99</td>
</tr>
</tbody>
</table>

CI = confidence interval.
with 26% of males in their retrospective review of 299 children, and those of Roosevelt and Reynolds, who found that among pediatric patients who did not receive preoperative imaging, a greater percentage of them (71%) were male (18,22). This might be explained by the need to delineate the presence of competing diagnoses, such as tubal pathology, or minimize the risk of infertility as a secondary complication of appendiceal perforation (23,24).

During the last 2 decades, the use of US has increased in an effort to improve diagnostic accuracy in children with suspected appendicitis. However, its effect on appendectomy outcomes has been inconsistent. The overall perforation rate in our study was 16%, and was significantly higher in patients who did not undergo an US. It is possible that higher perforation rates are unavoidable in certain age groups. Several investigators have shown no improvement in length of stay, time to definitive management, health care costs, negative appendectomy rate, and incidence of perforation with the use of US in individuals suspected of having appendicitis (18,22,25–28). Despite this, the issue of whether or not US increases the rate of appendicitis complications remains contentious. In a retrospective review of 736 pediatric patients who underwent appendectomy, Puig et al. found a perforation rate of 21%, but only among patients who underwent an US (29). In their review, however, 87% of patients underwent an US, making direct comparisons with our patients difficult (29). In contrast, Mardan et al., using a prospective cohort design of all age groups, found that the use of US decreased the negative appendectomy rate and reduced the frequency of perforation. Limitations of this study included a lack of statistical analysis and questionable comparability of the patient groups, as they were from different countries (30). Perforation rates as high as 20%–30% have been reported in children who had no preoperative imaging (17,22). In a study of 299 children, Applegate et al. reported no significant differences in perforation rates, whether the patient underwent CT, US, or no imaging. However, patients who underwent both US and CT had higher perforation rates (22). York et al. found similar perforation rates between imaged and non-imaged cases in their review of 197 children being evaluated for appendicitis (15).

Given that the incidence of perforation is inversely related to age and directly related to duration of symptoms, it was somewhat unexpected that a higher perforation rate was not seen in our patients who underwent an US, despite an increased time to appendectomy in that group (31). There are several possible explanations for this observation. First, perforated patients in our study might have presented with peritoneal signs, prompting surgical intervention without the use of diagnostic imaging. As such, patients who underwent an US may have represented a group with atypical findings. Indeed, the results in Table 1 support this possibility. Second, the time to definitive management may not have been of sufficient duration to increase the rate of perforation. Lack of a clear explanation of this phenomenon reflects a limitation of the retrospective nature of the chart review.

Although there are no pathognomonic clinical features of appendicitis, the occurrence of right lower-quadrant pain, fever, vomiting, and anorexia are consistent with a diagnosis, and leukocytosis has been reported to have a high positive predictive value (4,6,32,33). Not surprisingly, our patients with clinical and laboratory features consistent with appendicitis were significantly less likely to undergo an US. Although it is speculative, this might have reflected a heightened clinical suspicion in these patients that obviated the need for preoperative imaging.

In support of our hypothesis, the median time from ED assessment to appendectomy was significantly longer in patients who received an US. A statistically significant interaction between US status and sex and US status and time of presentation in two separate univariate models indicated that the increased time to appendectomy was significant if the patient was female or if they presented between the hours of 5:00 PM and 8:00 AM. During these times, access to pelvic US to rule out appendicitis are limited based on the need to call in an US technician, and this might have contributed to an increased time to definitive management. Females almost universally undergo US at our center, so an increase in time to appendectomy is more apparent among them. Our findings are consistent with those of several studies. Lee et al. retrospectively reviewed 766 patients of all ages who underwent appendectomy and found the mean duration of ED evaluation of 5.2 h (SD 5.4 h) was prolonged by US or CT to 6.4 h (SD 7.4 h) and 7.8 h (SD 10.8 h), respectively. Although the duration of time in the ED did not affect the rate of perforation, patients with postoperative complications (primarily infection) had longer ED evaluations. It is unclear whether these complications were due to a longer time in the ED (33). Similarly, in a retrospective review of 197 children with suspected appendicitis, York et al. found a significantly increased time from ED triage to incision in patients who underwent either US or CT imaging (12.1 h) compared with those who did not (5.4 h). There were no differences in diagnostic accuracy or outcomes between imaged and nonimaged patients (15). Garfield et al. retrospectively studied 124 adult and pediatric patients who underwent operative exploration for presumed appendicitis in a teaching hospital (34). Two thirds of patients received either CT or US, or both. Preoperative imaging was significantly associated with an increased preoperative ED length of stay with no apparent improvement in
diagnostic accuracy. US increased the length of stay from 6.6 h to 10 h and CT added 9 h to the length of stay (34).

Finally, at a pediatric academic tertiary care center, Roosevelt and Reynolds retrospectively reviewed the charts of 231 children who had an appendectomy for presumed appendicitis (18). Forty-three percent underwent a preoperative US. Time from ED triage to the operating room was significantly greater in the US group (17.1 h) compared with the non-US group (10.4 h), although rates of complications and perforation were similar between the groups (18).

In the literature, the use of US as a preoperative tool has been found to be associated with lower negative appendectomy rates and an increased time to appendectomy without improvements in diagnostic accuracy or outcomes. The evidence as to whether or not US is associated with decreased rates of perforation is inconsistent and the variability in findings is likely due to unmeasured center-specific factors, such as surgical experience and operative wait times. Our data indicate that increased time to appendectomy was associated with diagnostic US in females and patients who presented after hours. The liberal use of US in certain populations may be an unavoidable strategy to minimize the number of healthy children who undergo general anesthesia and appendectomy. However, our results and those of other studies clearly show an increased time to appendectomy among imaged patients. Until adverse consequences of surgical delay have been clearly delineated, the most pragmatic course would seem to reflect a trade-off between minimizing unnecessary surgery and expediting time to definitive management. This would suggest that imaging should be reserved for patients in whom clinical findings are not entirely suggestive of appendicitis. Two pediatric studies have shown that a protocol for selective imaging based on risk stratification or surgical evaluation can reduce the number of imaging studies with minimal loss of diagnostic accuracy and reduced perforation rates (16,31).

Extending our findings to the adult patient is susceptible to certain limitations. Some studies have found a similarly increased time to appendectomy among patients imaged with a CT compared with nonimaged patients (15). In Canada, however, far fewer children undergo CT compared with US to diagnose appendicitis, and this ratio is often reversed in the adult population, making comparisons difficult.

Limitations

The retrospective nature of our study design introduces several caveats to the interpretation of the results. Factors such as the need for vascular access, bladder-filling procedures, and access to a sonographic technologist and radiologists’ interpretation may also have influenced the time to appendectomy. We were not able to fully elucidate the relative contributions of these factors that may be amenable to improved access to care. Second, our study reflects data obtained at a single institution functioning within a socialized health care model. Therefore, factors such as competing emergent trauma studies might be unique to a tertiary care trauma center. Third, our study design is subject to a degree of selection bias in that reasons for obtaining diagnostic imaging may have depended on severity of clinical presentation, a factor that was not ascertained in the chart review. Finally, our study included only those patients in whom a diagnosis of appendicitis was certain. If all patients being evaluated for suspected appendicitis were included, we would have been able to ascertain the degree to which diagnostic US was able to identify other pathologies and provide a more comprehensive understanding of the utility of US in the evaluation of the patient with right lower-quadrant pain.

Future Studies

Most studies to date have relied on a retrospective design to evaluate the role of preoperative diagnostic imaging in suspected appendicitis. Future endeavors should include a prospective evaluation that controls for the severity of clinical presentation and other factors, such as age and sex, in an effort to identify the clinical spectrum of patients who would benefit most from imaging studies. Furthermore, the ability to identify specific causes of delay could prompt interventions aimed at expediting and, therefore, improving access to definitive management.

CONCLUSIONS

To summarize, this pediatric study has demonstrated that among female patients and those who present after hours, an increased time from ED assessment to appendectomy is associated with diagnostic US in cases of acute appendicitis. To our knowledge, this is the largest pediatric study to date that has specifically examined the relationship between US as a diagnostic modality and time to appendectomy. It is hoped that these findings will prompt future work to ascertain which patients are most likely to benefit from diagnostic imaging.

REFERENCES

ARTICLE SUMMARY

1. Why is this topic important?
Ultrasound (US) is an increasingly utilized diagnostic modality in the case of undifferentiated acute abdominal pain in children. The possibility of an increased time to definitive management associated with imaging should be an important consideration in the diagnostic evaluation.

2. What does this study attempt to show?
This study is designed to show that US is associated with an increased time to appendectomy in pediatric patients with appendicitis.

3. What are the key findings?
The findings of this study demonstrate that female pediatric patients and those who present after hours and undergo an US have a significantly increased time to appendectomy compared with those who do not undergo diagnostic imaging.

4. How is patient care impacted?
In cases of pediatric acute abdominal pain, the decision to perform a diagnostic US requires careful consideration of the time of presentation and sex of the patient in order to avoid diagnostic delays and effect timely management.