Published in final edited form as:

AJR Am J Roentgenol. 2013 December ; 201(6): 1348–1352. doi:10.2214/AJR.13.10678.

Do Clinical Outcomes Suffer During Transition to an Ultrasound-First Paradigm for the Evaluation of Acute Appendicitis in Children?

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Abstract

Objective—The objective of our study was to examine whether the rate of complicated appendicitis and the hospital length of stay (LOS) increased during the transition to an ultrasound-first paradigm for the imaging evaluation of acute appendicitis.

Materials and Methods—All pediatric patients with surgically proven appendicitis from 2005 to 2011 were identified by searching the hospital billing database for the discharge diagnosis codes for simple appendicitis (ICD-9 [International Classification of Diseases, 9th revision] code 540.9) and complicated appendicitis (ICD-9 codes 540.0 and 540.1). Annual trends of the proportions of these patients who underwent ultrasound and CT were determined and plotted for the study period. Correlation of complicated appendicitis and median hospital LOS with calendar year was assessed using the Spearman (ρ) rank correlation test.

Results—Eight hundred four patients met the inclusion criteria. The percentage of patients who underwent CT only showed a moderate downward association with year ($\rho = -0.32$, $p < 0.01$), and the percentage of patients who underwent ultrasound first showed a moderate upward trend ($\rho = 0.44$, $p < 0.01$). The percentage of patients with ultrasound as the only study performed before appendectomy increased moderately over the 7-year study period ($\rho = 0.33$, $p < 0.01$). The percentage of patients with complicated appendicitis and the median hospital LOS did not increase significantly over the study duration ($\rho = -0.01$, $p = 0.74$ and $\rho = -0.04$, $p = 0.25$, respectively).

Conclusion—The transition to an ultrasound-first pathway for the imaging workup of acute appendicitis in children occurred without evidence of a corresponding increase in the proportion of patients with complicated appendicitis or in the median hospital LOS.

Keywords

appendicitis; Image Gently; length of stay; perforation; ultrasound-first paradigm

Appendectomy is one of the most frequently performed surgical procedures in children, and its frequency in the United States has been increasing [1]. Ultrasound and CT are the most commonly used imaging modalities to evaluate patients with symptoms of acute appendicitis, particularly because the findings can lead to a change in the treatment plan in patients with acute appendicitis [2]. Over the past decade, the use of abdominal CT to evaluate suspected cases of appendicitis has been reevaluated because of broadening awareness of the risks of exposing pediatric patients to medical radiation [3–6]. As a result, there has been increasing support for an “ultrasound-first” paradigm in the imaging evaluation of appendicitis in which ultrasound is used as the initial imaging modality and CT is used if the ultrasound results are equivocal or raise additional questions, such as a possible abscess [7–12].

Key data on the ultrasound-first paradigm have been described elsewhere, including sensitivity, specificity, and negative appendectomy rate [2, 7, 10–15]. The purpose of our study was to investigate whether there was an increase in the rate of complicated appendicitis and in the median hospital length of stay (LOS) during the transition to an ultrasound-first pathway at our institution. We evaluated the records of all patients with a diagnosis of appendicitis and determined whether there was a trend of an increased rate of complicated appendicitis or an increased median hospital LOS during the transition period.

Materials and Methods

Hospital institutional review board approval was obtained for this HIPAA-compliant retrospective study. The transition to an ultrasound-first paradigm began in 2006, so we chose 1 year before the transition, 2005, as the start date of the study period. The hospital billing database was queried for all patients younger than 21 years old admitted between January 1, 2005, and December 31, 2011, who had a discharge diagnosis code for acute appendicitis (ICD-9 [International Classification of Diseases, 9th revision] 540), acute appendicitis with generalized peritonitis (ICD-9 540.0), acute appendicitis with peritoneal abscess (ICD-9 540.1), or acute appendicitis without mention of peritonitis (ICD-9 540.9). Medical records were reviewed to exclude patients who were transferred from another hospital or had imaging performed at another hospital. Patients who were readmitted after an initial admission in which there was nonsurgical treatment were included in the analysis, and the imaging performed during the first admission was used to categorize their imaging workup.

To determine the trend of imaging usage over the study period in patients with acute appendicitis, the numbers of patients who underwent CT only, ultrasound only, both CT and ultrasound, or neither were tabulated for each year. The number of imaging studies

performed was adjusted by the number of cases of acute appendicitis in that year. These data were plotted to determine trends. The significance of the trends of ultrasound and CT usage over the study period was determined using the Spearman (ρ) rank correlation test.

For each patient record, the following information was tabulated: ICD-9 code assigned, sex, admission date, and discharge date. Reports from abdominal CT and ultrasound (if performed) were obtained from the department of radiology's PACS. Admission clinical data of WBC count, granulocyte percentage, and temperature were recorded. Hospital LOS was calculated from the admission and discharge dates. For the purposes of data analysis, ICD-9 codes 540.0 and 540.1 (coding for peritonitis and peritoneal abscess, respectively) were pooled into a category called "complicated appendicitis" and were compared with ICD-9 code 540.9, which constituted the "uncomplicated appendicitis" group. (ICD-9 code 540 for general acute appendicitis was not used during the study period.)

For each year, admission clinical data (temperature, WBC count, and granulocyte percentage), age, and sex were tabulated. For the age and WBC count variables, which showed a normal distribution, the mean was calculated. For the temperature and granulocyte percentage variables, which were not normally distributed, the median was calculated. To evaluate whether patient admission characteristics changed over the duration of the study, the Pearson (r) correlation test and Spearman (ρ) rank correlation test were used on the normally distributed and nonnormally distributed data, respectively. The Spearman test was also used to evaluate whether the sex ratio had changed over the duration of the study.

The number of cases of complicated acute appendicitis and the number of cases of uncomplicated acute appendicitis were tabulated for each year, and the fraction of cases with complicated appendicitis was calculated by dividing the number of cases of complicated appendicitis by the total number of cases of appendicitis for that year. Whether there was a monotonic trend of the annual percentage with complications over the duration of the study was assessed using the Spearman rank correlation test. The median LOS was calculated for each year and whether there was a mono-tonic trend of LOS duration over the study period was also assessed using the Spearman rank correlation test. Correlation between the rate of complicated appendicitis and the median LOS was also calculated. All statistical tests were performed using statistics software (SPSS, version 19, SPSS).

Results

The initial hospital database search yielded 976 patients who had discharge ICD-9 diagnosis codes of 540.0, 540.1, or 540.9. No patient had the general acute appendicitis code of 540. After the records of the 172 transferred and readmitted patients (i.e., duplicates) were eliminated, 804 patients remained in the study group. The number of patients for each year and for the study period overall, as well as demographic information and baseline clinical information, are listed in Table 1. There was no statistically significant trend over the study period for age ($r = 0.01$, $p = 0.85$), percentage of males ($\rho = -0.04$, $p = 0.28$), or WBC count ($r = -0.05$, $p = 0.19$). There was a borderline significant trend for granulocyte percentage ($\rho = 0.07$, $p = 0.06$), and a statistically significant trend, albeit small in magnitude, for temperature ($\rho = -0.10$, $p = 0.004$) was noted.

Table 2 shows the numbers and percentages of patients who underwent CT only, ultrasound only, both CT and ultrasound, or neither for each year and for the study period overall. The percentage of patients in each workup category is plotted by year in Figure 1. The percentage of patients who underwent CT alone showed a statistically significant downward trend over the study duration ($\rho = -0.32, p < 0.01$). The percentage of patients who underwent ultrasound as a first-line study, including patients who underwent subsequent CT for further evaluation, showed a statistically significant upward trend over the study duration ($\rho = 0.44, p < 0.01$), as did the number of patients with ultrasound as the only study performed ($\rho = 0.33, p < 0.01$). The number of patients who underwent no imaging before appendectomy decreased weakly but significantly ($\rho = -0.23, p < 0.01$).

The number of cases of complicated appendicitis (and the percentage of these cases relative to the number of cases of appendicitis per year) and the median LOS are tabulated for each year in Table 3 and are plotted in Figure 2. The median hospital LOS was 3 days (range, 1–30 days; interquartile range, 2–6 days) and the overall rate of complicated appendicitis was 35.1% (Table 3). There was strong and statistically significant correlation between the rate of complicated appendicitis and the median hospital LOS ($\rho = 0.74, p < 0.01$). The proportion of patients with complicated appendicitis did not change significantly over the study duration ($\rho = -0.01, p = 0.74$). The median LOS also did not show a significant change over the study duration ($\rho = -0.04, p = 0.25$). A post-hoc power analysis using our sample size of 804 patients showed that we had greater than 99% power to observe a significant correlation coefficient even if the true population correlation coefficient was as small as 0.2.

The plots in Figure 1 show that the primary change in modality utilization occurred during the 5-year period of 2005–2009. As a sensitivity analysis, all statistical analyses were repeated over this 5-year time period and found to yield similar results. CT alone showed a downward trend ($\rho = -0.32, p < 0.01$); ultrasound first, an upward trend ($\rho = 0.44, p < 0.01$); ultrasound only, an upward trend ($\rho = 0.32, p < 0.01$); and no presurgical imaging, a weak albeit statistically significant downward trend ($\rho = -0.21, p < 0.01$). As with the full study period, both the fraction of patients with complicated appendicitis ($\rho = 0.08, p = 0.07$) and the median LOS ($\rho = 0.04, p = 0.32$) showed no statistically significant trend during this shorter period.

Discussion

The advantages of CT and ultrasound, as well as their sensitivities, specificities, positive predictive values, and negative predictive values, for the diagnosis of acute appendicitis have been discussed extensively in the literature [2, 16–23]. A staged protocol of first performing ultrasound and then performing CT if necessary has been shown to be cost-effective and follows the principle of ALARA (as low as reasonably achievable) and the goal of the Image Gently campaign [7–12, 14, 24]. Our study now provides data to suggest that in a routine hospital setting (without either a special research study protocol or research study selection bias) the transition to the ultrasound-first paradigm was not associated with an increase in the proportion of patients with complicated appendicitis or a change in the median LOS.

At our institution, an urban tertiary care children's hospital, we embarked on an initiative to decrease the use of CT and increase the use of ultrasound by encouraging (but not requiring) the ultrasound-first paradigm for the imaging workup of appendicitis. This approach involved communication between radiologists, surgeons, and emergency clinicians and providing in-house sonographers 24 hours a day. Over the study period, there was progressive compliance with the protocol: The rate of ultrasound as the first-line modality—33% at the beginning of the study period—had increased to approximately 90% by the end of the study period. Our utilization data were gathered only from the cohort of patients with proven appendicitis; still, the final rate of ultrasound first in our study was 90%, which is the same as the compliance rate of 90% reported in [25] and greater than the compliance rate of 51% reported in [11].

The use of CT as the first and only diagnostic test decreased from 43% to less than 10% by the end of the study. Still, the ultimate CT utilization rate at the end of the study period was greater (35%) because of patients who underwent CT after an initial ultrasound. The CT usage rate in this cohort is not directly comparable to other reported cohorts in the literature, which had different entry criteria, but it was below the overall CT usage rates of 42% and 61% from two other studies that used the ultrasound-first paradigm [11, 12].

In the literature, appendiceal perforation rates range from 21% to 73% with rates as high as 88% in the youngest children [1, 2, 26]. In our cohort, the overall perforation rate was 35.1%. In addition to being associated with increased morbidity and mortality, appendiceal perforation is also associated with increased hospital LOS in studies evaluating older children and adults [26–28]. This association was also shown in our cohort consisting exclusively of children in which there was very strong correlation between the rate of complicated appendicitis and increasing LOS. There have been variable data as to the effect of imaging on the rate of perforation [15, 29–33], but we did not observe a significant increase in complications over the study period. The very high statistical power in our study virtually rules out (with 99% confidence) a type II error for an association of meaningful magnitude.

Our study had several limitations. First, because of the retrospective nature of the study, we have limited data about why specific tests were or were not performed in specific patients. Second, we evaluated only the patients who had proven appendicitis rather than all the patients who presented with suspected appendicitis. We chose this population to investigate whether outcomes worsened in patients with proven appendicitis; patients without appendicitis could not have experienced complicated appendicitis. Third, there is a chance that patients in the ultrasound-first pathway had missed appendicitis at our institution and had complicated appendicitis diagnosed at another institution. Although this scenario is possible, it is unlikely because of the geography of the health care institutions in our catchment area. Our institution is the dominant health care provider in the area with three hospitals and 129 other health care facilities (as of 2011). Last, the purpose of our reported associations was to show a secular trend. Associations with time are inherently ecologic and can be especially susceptible to various confounding factors because many things change over time and our measures of a single variable (imaging work-up) were limited.

In conclusion, during the transition to an ultrasound-first paradigm of imaging acute appendicitis in a large urban tertiary care center, there was no observable increase over time of the proportion of patients with complicated appendicitis or the median hospital LOS. This transition served to limit medical radiation exposure in children with suspected appendicitis without observable adverse consequences.

Acknowledgments

This study was supported in part by grants (CTSA grants UL1RR025750, KL2RR025749, and TL1RR025748) to H. W. Cohen from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH), and NIH Roadmap for Medical Research.

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Fig. 1.

Plots show modality use over 7-year study period.

A and **B**, Percentage of patients who underwent CT only showed downward trend over study duration (**A**), whereas percentage of patients with ultrasound as only study performed before appendectomy increased (**B**).

C and **D**, Percentage of patients who underwent ultrasound as first-line study showed upward trend over study duration (**C**), whereas number of patients who underwent no imaging before appendectomy decreased (**D**).

Fig. 2.

Plots show percentage of patients with complicated appendicitis and median length of stay (LOS) over 7-year study period.

A and B, Percentage of patients with complicated appendicitis (**A**) and median LOS (**B**) showed no statistically significant trend over study period.

Table 1
Demographic Information and Baseline Clinical Information for the Study Period and by Year

Year	No. of Cases	Male Patients (%)	Age ^a (y)	Temperature (°C) ^b	WBC Count ^a (1/ μ L)	Granulocytes ^b (%)
2005–2011	804	62	12.0 $\pm$ 4.4	37.2 (36.8 – 37.8)	16.1 $\pm$ 5.5	82.0 (75–87)
2005	133	59	11.9 $\pm$ 4.4	37.3 (36.9 – 37.8)	16.3 $\pm$ 5.8	82.0 (73–87)
2006	112	69	12.1 $\pm$ 4.4	37.2 (36.8 – 37.9)	16.3 $\pm$ 5.3	81.5 (75–86)
2007	107	66	12.4 $\pm$ 4.5	37.4 (36.9 – 37.9)	16.2 $\pm$ 5.6	81.0 (74–86)
2008	119	64	11.6 $\pm$ 4.4	37.4 (36.9 – 37.9)	16.8 $\pm$ 5.7	83.0 (77–87)
2009	98	55	12.3 $\pm$ 3.8	37.1 (36.8 – 37.8)	15.8 $\pm$ 5.5	82.5 (75–88)
2010	113	60	11.1 $\pm$ 4.8	37.1 (36.8 – 37.7)	15.4 $\pm$ 5.5	83.5 (77–88)
2 011	122	58	12.7 $\pm$ 4.2	37.0 (36.8 – 37.5)	15.4 $\pm$ 5.5	82.5 (75–88)

^aMean $\pm$ SD.

^bMedian (interquartile range).

Table 2
Number and Percentage of Patients Who Underwent Various Imaging Examinations for the Study Period and by Year

Year	Total No. of Patients	No. (%) of Patients Who Underwent				
		CT Only	Ultrasound Only	Ultrasound and CT	Ultrasound or Both Ultrasound and CT	Neither Ultrasound Nor CT
2005–2011	804	156 (19)	362 (45)	191 (24)	553 (69)	95 (12)
2005	133	57 (43)	26 (20)	18 (14)	44 (33)	32 (24)
2006	112	38 (34)	31 (28)	22 (20)	53 (47)	21 (19)
2007	107	21 (20)	35 (33)	30 (28)	65 (61)	21 (20)
2008	119	16 (13)	64 (54)	31 (26)	95 (80)	8 (7)
2009	98	5 (5)	60 (61)	30 (31)	90 (92)	3 (3)
2010	113	10 (9)	74 (65)	26 (23)	100 (88)	3 (3)
2011	122	9 (7)	72 (59)	34 (28)	106 (87)	7 (6)

Table 3
Number and Percentage of Patients With Complicated Appendicitis and Median Hospital Length of Stay (LOS) for the Study Period and by Year

Year	Total No. of Patients	No. (%) of Patients With Complicated Appendicitis	Median LOS (d)
2005–2011	804	282 (35.1)	3
2005	133	32 (24.1)	2
2006	112	47 (42.0)	4
2007	107	46 (43.0)	3
2008	119	52 (43.7)	4
2009	98	32 (32.7)	3
2010	113	40 (35.4)	3
2011	122	33 (27.0)	2