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Selected Topics: Toxicology

NEGATIVE APPENDECTOMIES: EVALUATING DIAGNOSTIC IMAGING TECHNIQUES AT A GENERAL VS. A PEDIATRIC EMERGENCY

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☐ Abstract—Background: Although appendicitis is the most common pediatric surgical emergency, the path to diagnosis remains equivocal, with utilization of imaging modalities largely institution dependent. Objectives: Our objective was to compare imaging practices and negative appendectomy rates between patients transferred from nonpediatric hospitals to our pediatric hospital and primary patients presenting directly to our institution. Methods: We retrospectively reviewed all laparoscopic appendectomy cases performed at our pediatric hospital in 2017 for imaging and histopathologic results. Two-sample *z*-test was used to examine negative appendectomy rates between transfer and primary patients. The negative appendectomy rates of patients who received different imaging modalities were analyzed using the Fisher's exact test. Results: Of 626 patients, 321 (51%) were transferred from nonpediatric hospitals. The negative appendectomy rate for transfer patients was 6.5% and 6.6% for primary patients ($p = 0.99$). Ultrasound (US) was the only imaging obtained in 31% of transfer and 82% of primary patients. The negative appendectomy rate of US performed at transfer hospitals compared with our pediatric institution was not significantly different (11% vs. 5%, $p = 0.06$). Computed tomography (CT) was the only imaging obtained in 34% of transfer and 5% of primary patients. Both US and CT were completed for 17% of transfer and 19% of primary patients. Conclusion: The negative appendectomy rates of transfer and primary patients were not significantly different despite more frequent CT use at nonpediatric facilities. It may be valuable to encourage US utilization at adult facilities given the potential to safely reduce CT use in the evaluation of suspected pediatric appendicitis. © 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

☐ Keywords—appendicitis; pediatrics; emergency department; ultrasound; computed tomography

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INTRODUCTION

Acute appendicitis is the most common surgical emergency in children (1,2). Many children with suspected appendicitis initially present to nonpediatric hospitals and are subsequently transferred to pediatric referral centers for further workup and pediatric surgical evaluation (2,3). Radiographic evaluation for appendicitis is becoming standard of care, as it aids in identifying acute appendicitis while lessening chances of a negative appendectomy (removal of a normal appendix with no signs of inflammation on pathology) (2,3). However, making an accurate diagnosis may be challenging, and diagnostic delays con-

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tribute to increased risk of complicated appendicitis and increased hospital length of stay (4,5).

Diagnostic imaging practices for children with suspected appendicitis vary by institution (2,3,6). Ultrasound (US) is often the initial imaging of choice due to lack of radiation, low cost, and lack of need for contrast (7,8). However, US is dependent on availability and operator/reading radiologist experience (7–9). Other factors that affect appendix visualization include body habitus, increased age, and anatomical position of the appendix (10). Secondary to radiation concerns, computed tomography (CT) use at pediatric centers is typically reserved for cases of nondiagnostic US, concern for complicated appendicitis, or surgeon preference (7,8,11). CT remains the most commonly performed imaging modality to evaluate for appendicitis at nonpediatric hospitals (6,12).

There is a lack of studies in the literature comparing the negative appendectomy rates between patients who initially present to a nonpediatric hospital and those who initially present to a pediatric hospital. The objective of this study was to compare imaging practices and negative appendectomy rates between patients transferred from nonpediatric hospitals to our quaternary care pediatric hospital and primary patients presenting directly to our institution.

MATERIALS AND METHODS

Study Design

The study was conducted at an academic, quaternary care pediatric hospital in a suburban county in the southwestern United States. The annual emergency department (ED) census is approximately 96,000 visits; hospital surgeons perform about 500 appendectomies per year. Approximately 20 nonpediatric hospitals transfer patients to the study institution. Transfer patients with concern for appendicitis are routinely accepted by ED physicians and pediatric surgeons for medical management and surgical intervention. At our institution, US and CT are available 24 h daily and there is no standardized algorithm for abdominal pain. All imaging is reviewed by an attending radiologist physician, and imaging studies of transfer patients are reviewed by the attending pediatric surgeon. Our pediatric surgeons routinely perform appendectomies in patients up to 18 years of age. Patients were divided into two groups based on presentation institution.

Data

The electronic medical record system at our pediatric hospital was queried based on International Classification of Diseases coding to identify all cases of acute appendicitis in children ages 3 years to 18 years during 2017. All cases were reviewed to ensure that a laparoscopic appendectomy was performed at our study hospital. Patients who underwent incidental appendectomies as part of another procedure or interval appendectomy after medical management for appendicitis were excluded from this study. Magnetic resonance imaging for evaluation of appendicitis is not utilized at our facility, and therefore, only patients who underwent evaluation with US or CT were included in this study. Patients with appendicitis who did not undergo appendectomy during hospitalization were also excluded.

Data were collected by two authors who created the standardized data abstraction protocol, which was audited by the senior author. Patient medical records were reviewed to ensure that the same pathological definitions for acute appendicitis were used. Pathologic findings were extracted from pathology reports. Appendices with neutrophil infiltration, perforation, gangrene, or abscess were characterized as positive for appendicitis. Discrepancies on interpretations of pathological reports were discussed and if consensus could not be achieved, a final decision was made by the senior author. We assessed interrater reliability via a 10% random audit of the collected data (Supplementary Table 1). Lastly, all data were screened for completeness by one author. All data were recorded in REDCap (Vanderbilt University, Nashville, TN) (13,14).

Variables

Data for demographic information, imaging results, and treatment outcomes were collected via chart review. Demographic data for transfer patients were acquired from medical records during re-evaluation at our pediatric facility (Table 1). Imaging results for transfer patients who did not receive repeat imaging at our facility were included for data analysis (Tables 2 and 3). If transfer patients received repeat imaging at our pediatric facility, our radiologists' imaging results superseded outside imaging results and were included for data analysis (Table 4).

Data Analysis

Effect size and power calculations are provided in Supplementary Table 2. Demographics were analyzed using one-way (between-groups) analysis of variance and χ^2 tests. The negative appendectomy rates of patients with only US, only CT, or both US and CT performed at nonpediatric hospitals vs. our pediatric institution were analyzed using the Fisher's exact test. Imaging diagnostic accuracy was compared between transfer and primary patient groups using the two-sample z-test for proportion. A separate χ^2 test with Monte Carlo simulation was used to test for association between imaging location and appendectomy outcome at nonpediatric hospitals and our

Table 1. Demographic Characteristics of All Patients

	Directly Admitted at Pediatric Hospital (n = 305)		Admitted from Transfer Hospital (n = 321)		*p* Value
	Appendicitis (n = 285)	Negative Appendectomy (n = 20)	Appendicitis (n = 300)	Negative Appendectomy (n = 21)	
Age (years)					
Mean (SD)	10.7 (4.2)	12.3 (4.0)	11.5 (3.6)	10.2 (3.7)	0.05
Median (range)	10.7 (0.1-19.6)	12.6 (5.0-18.1)	11.8 (0.3-19.7)	9.1 (3.4-15.7)	0.04
Sex					0.80
Male	182 (64%)	12 (60%)	181 (60%)	14 (67%)	
Female	103 (36%)	8 (40%)	119 (40%)	7 (33%)	
Time of admission					< 0.001
7 am–7 pm	143 (50.2%)	12 (60%)	82 (27.3%)	8 (38.1%)	
7 pm–7 am	142 (49.8%)	8 (40%)	218 (72.7%)	13 (61.9%)	
Ethnicity					0.50
Hispanic	177 (62.1%)	10 (50%)	172 (57.3%)	13 (61.9%)	
Not Hispanic	104 (36.5%)	10 (50%)	94 (31.3%)	5 (23.8%)	
No data	4 (1.4%)	0 (0%)	34 (11.3%)	3 (14.3%)	
Race					0.23
White	189 (66.3%)	13 (65%)	157 (52.3%)	10 (47.6%)	
Asian	17 (6%)	1 (5%)	16 (5.3%)	0 (0%)	
Black, biracial, or multiracial	1 (0.4%)	0 (0%)	4 (1.3%)	1 (4.8%)	
No data	78 (27.4%)	6 (30%)	123 (41%)	10 (47.6%)	
Body mass index					0.56
Underweight	12 (4.2%)	0 (0%)	13 (4.4%)	3 (14.3%)	
Normal	126 (44.2%)	6 (30%)	154 (51.3%)	13 (61.9%)	
Overweight	29 (10.2%)	1 (5%)	51 (17%)	2 (9.5%)	
Obese	52 (18.2%)	2 (10%)	63 (21%)	3 (14.3%)	
No data	66 (23.2%)	11 (55%)	19 (6.3%)	0 (0%)	

Note: *p*-Value of mean age was obtained using one-way between-groups analysis of variance (*homogeneity of variances* assumption met); *p*-value of median age was obtained using Kruskal–Wallis with interpretation of pairwise comparisons of medians. Sex, time of admission, and ethnicity were analyzed using χ^2 test; race and body mass index analyzed using χ^2 test with Monte Carlo simulation for patients with available data.

Table 2. Imaging Results for Transfer vs. Pediatric Institution

Evaluation for Appendicitis	Imaging Only at Transfer Hospital (n = 262)			Imaging Only at Pediatric Hospital (n = 323)			Imaging at Both Hospitals (n = 38)	
	US	CT	US & CT	US	CT	US & CT	Transfer	Pediatric
Unlikely	5 (2%)	3 (1%)	1 (0%)	6 (2%)	0 (0%)	3 (1%)	15 (39%)	1 (3%)
Suggestive or likely	95 (36%)	106 (41%)	52 (20%)	243 (75%)	15 (5%)	56 (17%)	23 (61%)	37 (97%)

US = ultrasound; CT = computed tomography.

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Table 3. Imaging Modality and Negative Appendectomy Rate

Imaging Modality	Appendicitis	Negative Appendectomy	*p* Value
Ultrasound (US)			0.06
Transfer hospital (n = 100)	89 (89%)	11 (11%)	
Pediatric hospital (n = 249)	236 (95%)	13 (5%)	
Computed tomography (CT)			0.55
Transfer hospital (n = 109)	104 (95%)	5 (5%)	
Pediatric hospital (n = 15)	14 (93%)	1 (7%)	
US & CT			0.75
Transfer hospital (n = 53)	49 (92%)	4 (8%)	
Pediatric hospital (n = 59)	53 (90%)	6 (10%)	

Note: *p*-Values were obtained using Fisher's exact test.

Table 4. Imaging Location and Negative Appendectomy Rate

Appendectomy	Imaging Only at Transfer Hospital(n = 262)	Imaging Only at Pediatric Hospital (n = 323)	Imaging at Both Hospitals (n = 38)	No Imaging at Pediatric Hospital (n = 3)	*p* Value
Negative	20 (7.6%)	20 (6.2%)	1 (2.6%)	0 (0%)	0.55
Positive	242 (92.4%)	303 (93.8%)	37 (97.4%)	3 (1005)	

Note: *p*-value was obtained using χ^2 test with Monte Carlo simulation.

pediatric institution. For each statistical test, a two-tailed p value of ≤ 0.05 was considered significant. All analyses were performed with IBM SPSS Statistics version 25 (IBM Corporation, Armonk, NY).

Ethics Statement

This study was approved by the institutional review board (IRB number 200341) at our institution, and the need for informed consent was waived given the retrospective nature of this study. All authors were trained on research ethics and data collection according to the established standards at our institution.

RESULTS

During the study period, 680 children were diagnosed with appendicitis. We excluded 18 patients who did not undergo appendectomy during their hospital admission and 36 patients who underwent an incidental or interval appendectomy. Of the remaining 626 children who underwent primary laparoscopic appendectomy, 305 (49%) were admitted after presenting directly to our ED and 321 (51%) were admitted as transfers from a nonpediatric hospital. Demographic data of all included patients are described in detail in Table 1. Primary patients with appendicitis were, on average, younger when compared with transfer patients (10.7 vs. 11.5 years, $p = 0.05$). There was no statistically significant difference with respect to sex, ethnicity, race, or body mass index. There was a significant association between admission status (transfer, direct) and admission time ($p < 0.001$), such that primary patients with appendicitis were more likely to arrive between the hours of 7:00 AM and 7:00 PM ($z = 2.98$), whereas those transferred with appendicitis were more likely to arrive between 7:00 PM and 7:00 AM ($z = 2.62$).

Overall, 162 (62%) of 262 transfer patients who solely had diagnostic imaging at a nonpediatric hospital underwent CT scan with or without US, and 74 (23%) of 323 primary patients underwent CT scan with or without US (Figure 1). Of 262 patients who received imaging only at the transfer hospital, 95 (36%) patients had US results concerning for appendicitis, and 106 (41%) patients had CT results concerning for appendicitis (Table 2). In 323 patients who received imaging only at our pediatric hospital, 243 (75%) patients had an US concerning for appendicitis, and 15 (5%) patients had a CT scan concerning for appendicitis (Table 2). There were 38 patients who received imaging at both the nonpediatric hospital and our pediatric institution; the proportion of imaging concerning for appendicitis at nonpediatric hospitals was 61%, compared with 97% at our pediatric institution (Table 2). Of these 38 patients with repeated imaging, 26 (68%) received US upon arrival to our institution, 9 (24%) received

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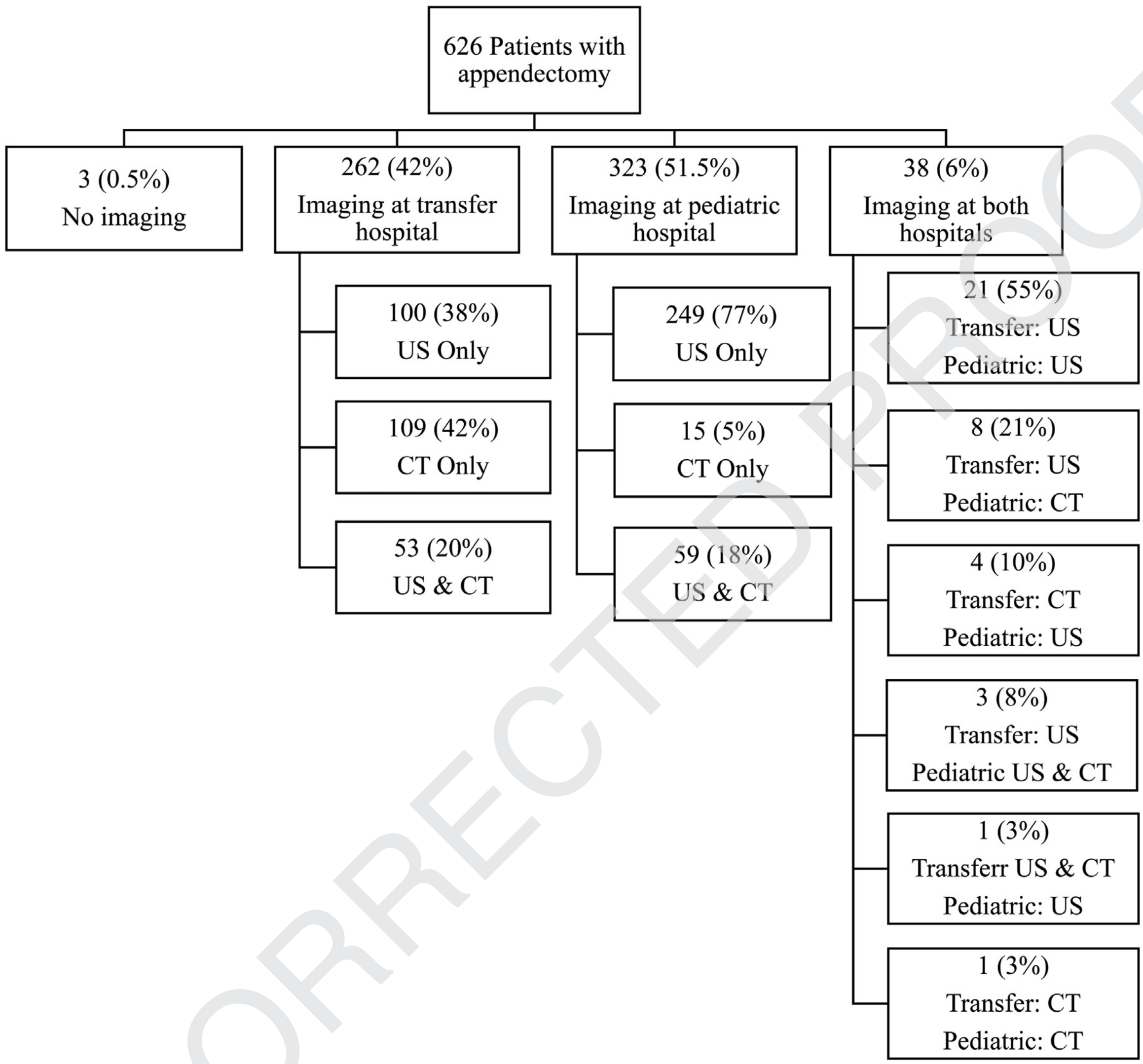

Figure 1. Diagnostic imaging utilization. CT = computed tomography; US = ultrasound.

CT, and 3 (8%) received both US and CT at our institution (Figure 1).

After examining imaging trends, we compared all histopathologic diagnoses between imaging modalities performed at nonpediatric hospitals and our pediatric institution. The negative appendectomy rate of diagnostic US performed at transfer hospitals compared with our pediatric institution was not significantly different (11% vs. 5%, $p = 0.06$) (Table 3). The negative appendectomy rate of CT and a combination of US and CT at transfer hospitals was also not significantly different compared with those performed at our pediatric institution (Table 3). There was no significant difference in the total negative appendectomy rate in transfer patients compared with primary patients (6.5% vs. 6.6%, $p = 0.99$). There was also no significant difference in negative appendectomy rates among patients who received imaging solely at transfer hospitals, solely at our hospital, and patients who received repeat imaging at our pediatric hospital (Table 4).

DISCUSSION

Acute appendicitis is a diagnostic challenge in children presenting with abdominal pain, and accurate imaging is frequently necessary to confirm the diagnosis. Due to the lack of radiation, US is the preferred mode of evaluation at facilities with trained operators and radiologists. However, this may not always be available at nonpediatric hospitals (9,10). The utility of US at nonpediatric hospitals to diagnose appendicitis is constrained by nondiagnostic rates as high as 74%, which warrant follow-up CT for diagnostic evaluation if clinical concern for appendicitis remains (10,11,15,16). In our study, there was

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disparity in US and CT use for the diagnosis of pediatric appendicitis between patients directly seen at our pediatric hospital and patients transferred from nonpediatric hospitals, with more transfer patients receiving CT scans for radiographic evaluation.

Our results are consistent with other retrospective studies in which there is significant difference in imaging modalities for pediatric appendicitis between children's hospitals and nonpediatric hospitals (2,3,12,17). In a retrospective study from a tertiary-care pediatric hospital, 87% of referral patients received a diagnosis of appendicitis by CT, compared with 9% at a pediatric facility (3). Furthermore, in a large retrospective cohort study of over 20,000 pediatric patients who underwent appendectomy for acute appendectomy, presentation at a referral, nonpediatric hospital was the strongest predictor of CT use (6). A recent meta-analysis has revealed no significant difference in diagnostic accuracies between US and advanced imaging in children with possible appendicitis (18). A study evaluating radiation dosage for pediatric abdominal CT scans revealed that only 17% of transfer CT scans were performed according to published best-practice guidelines, and CT imaging performed at outside hospitals have higher radiation relative to those obtained at pediatric centers (19,20). The lack of diagnostic advantage combined with radiation exposure from CT emphasizes the need to reduce CT use (7,18). Nonpediatric hospitals in our study may be utilizing CT to obtain firm surgical indication to justify a patient's transfer to a pediatric hospital.

The results of our study are both encouraging and reflective of the need for further US use to diagnose pediatric appendicitis. As such, nonpediatric hospitals should investigate their own imaging practices and US education to minimize radiation exposure in children (18,19). A 3-year analysis of over 250,000 children from the Kids Inpatient Database (KID) reported an overall negative appendectomy rate of 6.7%, similar to our reported rate (21). However, this study does not report the number of transfer patients or type of imaging acquired. Educational sessions and implementation of a reporting template reduced the rate of equivocal US interpretations from 24% to 9% at a single pediatric center (15). Similar to our study, there was no significant reduction of negative appendectomies in referral centers compared with our pediatric hospital, despite increased use of CT scans. We found no significant difference in the negative appendectomy rate of diagnostic US or CT performed at nonpediatric hospitals compared with those performed at our institution, suggesting that US should be the main diagnostic study and its use should be emphasized at nonpediatric hospitals. Interestingly, in a single-center study conducted at a pediatric center, patients who received multiple imaging studies at nonpediatric hospitals and pediatric hospitals had a higher negative appendectomy rate, 5.5% and 13.7%, respectively (2). When CTs at nonpediatric hospitals are deemed equivocal by pediatric radiologists, US can provide a definitive diagnosis in almost 90% of transfer patients (22). In our study, the negative appendectomy rate was 2.6% for patients who received imaging at both hospitals, suggesting that repeated diagnostic imaging may aid in cases that are diagnostically challenging.

This study also found that transfer patients with concern for appendicitis were slightly older than patients who were directly evaluated at a pediatric hospital. Furthermore, transfer patients were more likely to present to a pediatric hospital at night. In Farach et al., primary patients were significantly more likely to arrive during daytime hours, whereas transfer patients were significantly more likely to present during the nighttime (17). This is possibly due to the diagnostic challenge of pediatric appendicitis, which requires significant time spent at a referring hospital during the day prior to transfer to a pediatric institution for definitive care. Moreover, Farach et al. found that children with concern for appendicitis are less likely to directly present to a pediatric ED than to be transferred to one (17).

Limitations

One major limitation of this study is its retrospective nature at a single institution, which may limit the generalizability of our results to other tertiary pediatric centers. Due to the retrospective nature and lack of standardized sonographic criteria for appendicitis, not all secondary findings were included in the radiologist interpretations and thus, it is not evident which findings are "suggestive" or make appendicitis "likely" on US or CT evaluation. The implications of missing elements from radiological reports from transfer hospitals are unknown. Additionally, US capabilities at nonpediatric hospitals may differ from those at our institution and influence preference for diagnostic radiographic evaluation.

CONCLUSION

Our study compares negative appendectomy rates and imaging practices between nonpediatric hospitals and a pediatric quaternary care referral hospital. Patients from referring hospitals have a similar negative appendectomy rate compared with those who initially present to our pediatric institution. There remains a disparity between CT utilization rates at nonpediatric hospitals and pediatric centers. Our findings highlight the need to improve access to US and pediatric US education to diagnose pediatric appendicitis, particularly at nonpediatric hospitals.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jemermed.2022.12.018.

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