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Diagnostic imaging practices for children with suspected appendicitis evaluated at definitive care hospitals and their associated referral centers

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ABSTRACT

Purpose: The purpose of this study was to compare rates of ultrasound (US) and computed tomography (CT) for suspected appendicitis at hospitals able to provide definitive surgical care with those from their associated referral hospitals.
Methods: A retrospective cohort study of children undergoing appendectomy using the Pediatric NSQIP Appendectomy Pilot Database (1/1/2013–8/31/2014) was performed. Imaging rates at the initial hospital of presentation were compared between groups after adjusting for differences in demographic characteristics.
Results: We identified 4859 patients from 28 definitive care hospitals, of which 35% underwent diagnostic imaging at a referral hospital prior to transfer (range: 20.3–70.4%). The overall odds of receiving a CT scan was 10.9-times greater (95% CI: 9.4–12.5) at referring hospitals compared to definitive care hospitals, and the odds were significantly higher for referral hospitals in 96% (27/28) of the geographic regions represented. The overall odds of an initial attempt at US prior to CT was 11.1 times greater (95% CI: 9.09–14.28), and the odds of receiving any ultrasound was 6.25-times greater (95% CI: 5.26–7.14) at definitive care hospitals compared to referral hospitals.
Conclusions: Children initially evaluated for suspected appendicitis at referring hospitals are much more likely to receive a diagnostic CT, and those imaged with CT are much less likely to receive an US as the initial diagnostic test.

The consequences of radiation exposure from computed tomography (CT) utilization in the pediatric population remain largely unknown, and ongoing concern surrounding cancer risk has led to widespread efforts to reduce its use [1–5]. Several recent studies have characterized a trend in decreasing CT utilization for the diagnostic evaluation of children with suspected appendicitis, although the modality remains the preferential imaging test at many hospitals [6–9]. Other studies have examined these trends in the context of different hospital types, with lower rates associated with diagnostic evaluation taking place at children's hospitals, teaching hospitals, and hospitals in urban locations compared to those which are rural and community-based [10–13].

While many of the studies cited above have suggested marked differences in CT utilization by hospital type, only a few single-center experiences have specifically examined the relative utilization of CT and ultrasound between hospitals able to provide definitive surgical care and their associated referral hospitals [8,12]. Characterizing the scope and degree of practice variation between these groups across a wide range of different geographic regions may not only provide insight into where radiation-reduction campaigns should focus, but also on the potential role (and scalability) that outreach partnerships between definitive care and referral hospitals may play in addressing ongoing disparities in CT utilization.

Given the considerations above, the main purpose of this study was to provide a contemporary assessment of the differences in CT utilization for definitive care hospitals and their associated referral hospitals. Furthermore, we wished to similarly explore differences in ultrasound utilization with an emphasis on compliance surrounding American College of Radiology (ACR) guidelines for attempting an ultrasound prior to

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CT for suspected appendicitis, an important process measure for minimizing radiation exposure [14].

1. Methods

1.1. Data source and study population

This study was a retrospective analysis of patients aged 3 to 18 who underwent an appendectomy for suspected appendicitis from January 2013 to August 2014 using the American College of Surgeon's Pediatric National Surgical Quality Improvement Program's (NSQIP-P) Appendectomy Pilot Database. Pediatric NSQIP was established in 2008 using the adult program as a conceptual framework, and currently provides a risk-adjusted comparative-performance data on the basis of adverse event rates for 59 participating hospitals [15]. Clinical information, including adverse event data and an extensive array of risk-adjustment variables, were abstracted for the NSQIP-P database by trained clinical reviewers using standardized definitions and a rigorous chart review process [15,16].

Between January 2013 and August 2014, NSQIP-P launched an appendectomy-focused pilot module that collected an extended set of resource utilization and outcome variables for children undergoing appendectomy for suspected appendicitis [17]. These included preoperative imaging utilization (CT and US) and the location where the tests were obtained (referring hospital before transfer, NSQIP hospital, or both). Twenty-eight of the 59 NSQIP-P hospitals participated in the pilot, and data from these hospitals formed the basis of the current analysis.

For the purpose of this analysis, NSQIP-P hospitals are referred to as "definitive care" hospitals (where the appendectomy was performed), and hospitals that transferred patients to the NSQIP-P hospitals for definitive care following diagnostic evaluation are referred to as "referring" hospitals. Imaging rates were only calculated for definitive care and referring hospitals when those hospitals were the initial site of presentation. The site of initial presentation was defined as the hospital where the first diagnostic imaging was obtained. In this regard, a referring hospital was always considered the initial site of presentation if imaging was obtained before transfer, while a definitive care hospital was only considered the initial site of presentation if a patient did not previously receive imaging at a referral hospital. Each NSQIP hospital and its set of referring hospitals represent a unique patient referral network; patients are not shared across definitive care-referring hospital networks.

1.2. Statistical analysis

1.2.1. Univariate analysis

Demographic and clinical characteristics of patients were compared between those initially presenting at a definitive care hospital and those presenting at a referring hospital. Characteristics were summarized using frequency distributions for categorical variables. Rates of CT utilization, US utilization and compliance with American College of Radiology guidelines for children with suspected appendicitis (attempting an US prior to CT if a CT is obtained) were compared between definitive care hospitals and referring hospitals in aggregate and at the level of each definitive care hospital and its associated referring hospitals. The rate of ACR compliance was calculated for each hospital by dividing the number of patients receiving both an US and CT by the number of patients receiving a CT (with or without an US). Categorical variable comparisons were evaluated for significance using χ^2 test (significance set at $\alpha = 0.05$).

Unadjusted odds ratios were calculated for US and ACR compliance comparing definitive care hospitals with referring hospitals in aggregate and at the level of each definitive care hospital and its associated referring hospitals. Odds ratios were evaluated for significance using a likelihood ratio test (significance set at $\alpha = 0.05$). As we considered ultrasound the recommended initial diagnostic imaging modality for suspected appendicitis in all children, and furthermore, considered compliance with ACR imaging guidelines (attempting an US before a CT) an important process measure to minimize radiation exposure, the odds ratios for US utilization and ACR compliance were not adjusted for differences in demographics and patient characteristics.

1.2.2. Multivariate analysis

Using the likelihood ratio test in our logistic regression analysis to assess significance of odds ratios, factors independently associated with use of CT utilization were identified. Covariates were included in the regression if they were significant in the univariate analysis or described in existing literature to be associated with differential rates of CT utilization [6,10,18–20]. A logistic regression model was developed that included gender, age, race, obesity, insurance status and hospital type. Obesity was included as an age adjusted binary variable. Ages were divided into tertiles and treated as a categorical variable (1–6, 7–12, 13–18 years). Hospital type was included in the model as a binary variable, comparing definitive care hospitals with their referring hospitals. Adjusted odds ratios were compared between definitive care hospitals and referring hospitals in aggregate and at the level of each definitive care hospital and its associated referring hospitals. Statistical analysis was performed using SPSS Statistics (IBM, version 22.0, IBM, Armonk, NY). A p-value of <0.05 was considered significant. The Boston Children's Hospitals Institutional Review Board deemed this study exempt from full committee review (IRB-P00014936).

2. Results

2.1. Cohort characteristics

A total of 4859 patients were included from the 28 participating hospitals (median: 137 patients; range: 11–378). This analysis represents data from hospitals in 24 unique states. Twenty per cent of the patients in this cohort were evaluated at hospitals in the Northeast, 34% in the South, 34% in the Midwest and 12% in the West. The population was predominantly white (58.6%), ages 7–12 (51%) and commercially insured (45.1%). Thirty-five per cent (1716/4859) underwent initial imaging at a referring center prior to transfer to a definitive care center (range by definitive care hospital: 20.3–70.4%). Compared to those initially evaluated at referral hospitals, patients initially evaluated in the definitive care hospitals were more Hispanic (26 vs. 21%, $p < 0.001$) and have commercial insurance (47 vs. 42%, $p < 0.001$) (Table 1).

2.2. Univariate analysis

The rate of CT utilization was 42.4% among all hospitals, and this rate was nearly three-fold higher for referral hospitals (overall: 76.9%; range by hospital: 37.1–100%) compared to definitive care hospitals (overall: 23.4%; range by hospital: 0–55.2%, $p < 0.001$) (Fig. 1). The overall rate of US utilization was 65%, and this rate was more than twice as high at definitive care hospitals (overall: 79.4%; range by hospital: 0–100%) compared to referral hospitals (overall: 38.6%; range by hospital: 3.1–81.5%, $p < 0.001$). The overall odds of receiving an ultrasound at a definitive care hospital were 6.3 times greater (95% CI: 5.3–7.1) than at a referring hospital. The odds of ultrasound utilization was significantly lower for referring hospitals in 82% (23/28) of the definitive care-referring hospital networks (Fig. 2a).

The overall rate of compliance with ACR guidelines was 32%, and compliance was more than four-fold higher at definitive care hospitals (overall: 64%; range by hospital: 0–100%) compared to referral hospitals (overall: 13.4%; range by hospital: 0–43%, $p < 0.001$). The overall odds of compliance were 11.1 times greater (95% CI: 9.1–14.3) at definitive care hospitals compared to referring hospitals, and the odds of compliance were significantly lower for referring hospitals in 64% (18/28) of the definitive care-referring hospital networks (Fig. 2b).