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Factors affecting utilization of CT scan following ultrasound evaluation of suspected appendicitis

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Abstract

Context: When evaluating a pediatric patient in the emergency department for suspected appendicitis, a provider is often faced with the dilemma of deciding if a computed tomography (CT) scan is warranted when—as is most often the case—ultrasound results do not yield a definitive diagnosis. The potential risks of radiation must be weighed against numerous aspects of a patient's background, physical exam, and already-obtained workup.

Objectives: This study aims to aid in future decision making of providers in their evaluation of patients with suspected appendicitis, to help facilitate a more comprehensive answer to the “next-steps” in the question of equivocal ultrasound, and to create a pathway utilizing lab results, physical exam findings, and pertinent positives and negatives in patient history to facilitate a more objective decision-making process for ordering a CT scan.

Methods: A retrospective chart review was performed for patients who were evaluated for possible appendicitis at our institution between October 2016 and October 2017 and whose ultrasound results were equivocal. We determined what factors led to increased frequency of obtaining CT scans.

Results: Statistical analysis showed that several factors were independently associated with the increased likelihood of having a CT scan performed. When considered in combination with the other parameters, it was found that older children, males, report of right lower quadrant (RLQ) pain, and presence of RLQ tenderness on physical exam

were all associated with a significantly higher likelihood of having a CT scan performed.

Conclusions: When combined with present algorithms and protocols already in use, this information can assist the provider in making prudent decisions for their patients with the potential for reduced provider bias.

Appendicitis remains one of the most common etiologies for pediatric surgical emergency and occurs in approximately 70,000 patients per year [1]. Yet, despite how common the condition is, diagnosis continues to be challenging. In order to ease this diagnostic quandary, appendicitis scores and screening labs have been proposed and utilized with varying rates of success and accuracy [1, 2]. However, imaging remains the best modality for a definitive diagnosis.

Ultrasound has made significant strides over the last few decades with improved technological advances and, starting in 2010, became the recommended preferred first imaging modality for appendicitis according to the American College of Emergency Physicians [3]. Despite these advancements, there still remains a significant portion of abdominal ultrasounds that remain inconclusive, thus necessitating the emergency room practitioner to consider advanced imaging, such as computed tomography (CT) or magnetic resonance imaging (MRI). Questions remain if these imaging modalities, specifically CT with increased radiation exposure, are necessary in the setting of other information gathered during the course of a patient's workup. A study by Pearce et al. [4] suggested an incidence of malignancy in 1 of every 500 patients that is attributable to CT-related radiation in youth, with CT of the abdomen/pelvis most strongly associated with this finding.

In our study, we examined the trends of the current practice to inform us of the presence of factors associated with increased use of CT and the associated costs and risks of radiation with the view to aid in future decision making of providers in their evaluation of suspected appendicitis patients.

Beginning in 2017, our institution began utilizing ultrasound for evaluation of appendicitis outside of regular

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business hours. Prior to this, ultrasound was on-call only for the evaluation of emergent conditions in which it is the preferred imaging modality (namely, intussusception and ovarian/testicular torsion), leaving CT as the only imaging modality available for suspected appendicitis from mid-evening until morning. Following the implementation of the new practice, it was noticed that among the patients for whom ultrasound was inconclusive, fewer than expected were going on to have a CT scan performed. This was in spite of the higher sensitivity and specificity of this study and, with 24/7 in-house coverage, the relative ease of availability. It was hypothesized that other factors may be playing a significant role in determining the decision to obtain a CT scan, including patient demographics, history of present illness (HPI), physical exam findings, and laboratory data. A list of potential factors was drawn up upon discussion between physicians in the Department of Radiology and the Department of Emergency Medicine, with plans to perform a retrospective chart analysis to evaluate the presence of trends associated with the decision to obtain a CT scan in cases of equivocal ultrasound in patients evaluated in our emergency department (ED).

Methods

This study was approved by Drexel University's IRB Committee (IRB approval number: 1804006250A001). A list of patients who underwent ultrasound for indications of "right lower quadrant pain" or "appendicitis evaluation" between October 2016 and October 2017 was compiled. Patients whose ultrasounds identified either the presence of appendicitis or a normal appendix were excluded from the study. Patients under the age of 2 years and over the age of 18 years were not included in the final analysis, along with patients whose emergency department courses could not be unequivocally tracked (due to either incorrect medical record numbers or involvement of facilities other than our emergency department). All patients had their care supervised by either a board-certified general pediatrician or pediatric emergency medicine physician, with discretion to obtain a CT scan ultimately at the discretion of the attending physician. A retrospective chart review of the cases was performed, examining variables in demographics, subjective history details, physical exam findings, laboratory variables, if the patient underwent a CT scan, and if the patient was ultimately diagnosed with appendicitis. The age and sex of the patient were recorded, as well as the duration of symptoms (in days).

History of present illness factors

We noted the presence, absence, or lack of documentation regarding history of right lower quadrant (RLQ) pain, left lower quadrant (LLQ) pain, "other" pain (e.g., headache, sore throat, back pain, and other factors that may be more suggestive of an alternative diagnosis), vomiting, diarrhea, fever, and anorexia/loss of appetite (LOA).

Table 1: Summary of laboratory values.

Lab value	N (% of total pts)	Mean	Standard deviation	Range
WBC count ($10^3/\text{mCL}$)	391 (91.57)	10.37	5.03	2–33.7
Bands (% of neutrophils)	47 (11)	3.57	4.67	0–20
CRP, mg/L	236 (55.27)	2.31	4.73	0–34

CRP, C-reactive protein; WBC, white blood cell.

Physical exam findings

For physical exam findings, we noted the presence of, absence of, or lack of documentation regarding RLQ tenderness, LLQ tenderness, diffuse/other abdominal tenderness, Psoas sign, Rovsing's sign, and guarding.

Laboratory values

We recorded the white blood cell (WBC) count, band count, and C-reactive protein (CRP) levels when performed in the course of the emergency department evaluation. Finally, the attending physician of record was recorded, in the hopes of identifying provider bias toward ordering CT scans in the event of inconclusive ultrasound.

Statistical analysis

Statistical analyses of the various factors (patient history, physical exam findings, and laboratory values) were performed utilizing Fisher's Exact Test and t-test (pooled and Satterthwaite method) where appropriate. A univariate analysis was then completed to determine if individual factors were associated with the increased use of CT scan. Finally, a multivariate analysis with backward selection was performed to determine what (if any) factors were associated with significant increases in use of CT scan when adjusted for the other factors. *p* values of <0.05 were considered statistically significant.

Results

A total of 427 patients between the ages of 2 and 18 were included in the study. There were 574 patients in the original data set of patients who underwent RLQ ultrasound for evaluation of pain/suspected appendicitis between October 2016 and October 2017. Among the patients in the original data set, 45 (7.8%) were excluded due to incorrect medical record numbers or because they were not evaluated in the emergency department. Six patients (1.0%) were excluded for being under age 2, and 12 (2.1%) were excluded for being over the age of 18 (our emergency department accepts pediatric patients up to age 22). This left a remaining set of 511 patients (89% of the original data set). Among these, 32 patients (6.3%) were excluded

Table 2: Prevalence of reported HPI details.

HPI	RLQ pain	Generalized Abd pain	LLQ pain	Other pain	Fever	Vomiting	Diarrhea	Anorexia/LOA
Yes/present	190 (44.71)	273 (64.24)	59 (13.95)	96 (22.54)	141 (33.10)	229 (53.88)	96 (22.75)	128 (34.88)
No/absent	235 (55.29)	152 (35.76)	364 (86.05)	330 (77.46)	285 (66.90)	196 (46.12)	326 (77.25)	239 (65.12)
ND	2	2	4	1	1	2	5	60

HPI, history of present; LLQ, left lower quadrant; LOA, loss of appetite; ND, not documented; RLQ, right lower quadrant.

Table 3: Prevalence of documented physical exam findings.

PE	RLQ tenderness	LLQ tenderness	Diffuse tenderness	Guarding	Rovsing's sign	Psoas sign
Yes/present	270 (63.98)	112 (27.12)	138 (33.41)	117 (35.03)	13 (14.13)	29 (29.00)
No/absent	152 (36.02)	301 (72.88)	275 (66.59)	217 (64.97)	79 (85.87)	71 (71.00)
ND	5	14	14	93	335	327

LLQ, left lower quadrant; ND, documented; PE, physical exam; RLQ, right lower quadrant.

because they had ultrasounds that positively identified appendicitis, and a further 52 (10.2%) were excluded because their ultrasounds identified a normal appendix. The identification (or inability to visualize) the appendix and its relative size were the criteria utilized to diagnose or rule out appendicitis; secondary signs of appendicitis were not considered. This left 427 patients (74.4% of the original data set) with inconclusive ultrasounds who were included in the final analysis.

General demographics

Of the 427 patients, 251 (58.8%) were female and 176 (41.2%) were male. The mean patient age was 10.72 years (standard deviation, 4.51 years; range, 2–18 years). The mean duration of symptoms was 2.72 days (standard deviation, 3.46 days; range, 1–28 days). A CT scan was performed in 274 patients (64.2%) with equivocal ultrasound; the remaining 153 cases (35.8%) did not have a CT scan performed. Of the 274 patients who underwent a CT scan, a diagnosis of appendicitis was made in 40 patients (14.6%). Other diagnoses that were found included mesenteric adenitis, acute gastroenteritis, and inflammatory bowel disease, among others that were less frequent. There was no statistically significant correlation between equivocal ultrasound and pelvic ultrasound in female patients because the variables that would lead to pelvic ultrasound were unrelated to the strongly correlated variables that led to CT scan. Of note, a CT scan was only obtained in patients with a positive ultrasound if the results of the ultrasound were not available in a timely manner. This occurred in three patients in the study period.

Laboratory values

We collected data on three laboratory values: WBC count, CRP level, and band count. The WBC count was measured in 91.6% of the patients included in the final analysis of the study, with a mean value of 10.4 (range, 2–33.7). CRP was measured in 55.3% of the patients, with a mean value of 2.3 (range, 0–34.0). The band count was documented in a smaller percentage of patients (11%), with a mean of 3.6 (range, 0–20.0). For a general summary of lab values, please refer to Table 1.

History of present illness and physical exam findings

For a general summary of the prevalence of reported HPI details and physical exam findings at time of emergency department visit, please refer to Tables 2 and 3. Please note that the percentage of yes/no answers refers to the portion of patients in which the detail was definitively documented (i.e., not the original number of 427). ND refers to number of cases in which the variable was not documented.

Discussion

Our study demonstrated that several parameters were statistically significant when considering obtaining a CT scan with an equivocal ultrasound. A summary of the presence of reported historical findings, physical exam findings, and laboratory values can be seen in Table 4. Older children and males were associated with a greater likelihood of having a CT scan, as was a reported history of RLQ pain or generalized abdominal pain, the presence of

Table 4: Univariate analysis of parameters. Statistically significant are parameters noted by *.

Parameter	Odds ratio	95% Confidence limits	p-Value
*Age	1.055	1.009–1.103	0.0182
*Sex (male)	1.537	1.021–2.315	0.0396
*RLQ pain	2.207	1.457–3.342	0.0002
*Gen. Abd. pain	0.603	0.393–0.925	0.0205
LLQ pain	1.083	0.606–1.935	0.7868
Other pain	0.903	0.564–1.447	0.6725
Fever	1.302	0.849–1.996	0.2266
Vomiting	1.275	0.857–1.898	0.2313
Diarrhea	0.694	0.435–1.106	0.1244
Anorexia/LOA	0.756	0.484–1.181	0.2188
Duration (# of days)	0.993	0.938–1.051	0.8109
*RLQ tenderness	2.316	1.532–3.502	<0.001
LLQ tenderness	1.480	0.927–2.364	0.1006
Rovsing's sign	6.231	0.769–50.490	0.0866
Diffuse tenderness	1.006	0.656–1.542	0.9794
Guarding	1.577	0.969–2.566	0.0669
Psoas sign	1.517	0.588–3.908	0.3886
WBC count	1.020	0.977–1.066	0.3595
Band count	0.988	0.863–1.131	0.8583
*CRP	1.115	1.014–1.226	0.0252

CRP, C-reactive protein; LLQ, left lower; LOA, loss of appetite; RLQ, right lower quadrant; WBC, white blood cell.

Table 5: Multivariate analysis with backward selection. Only statistically significant parameters were included.

Parameter	Point estimate	95% Wald confidence limits	Standardized estimate	p-Value
Age	1.051	1.002–1.102	0.1233	0.0429
Sex (male)	1.901	1.219–2.965	0.1745	0.0046
RLQ pain	1.625	1.017–2.597	0.0422	0.0422
RLQ tenderness	1.854	1.165–2.952	0.0092	0.0092

RLQ, right lower quadrant.

RLQ tenderness on physical exam, and the CRP. When adjusted for the other parameters, several values remained statistically significant, as outlined in Table 5: age, male sex, history of RLQ pain, and presence of RLQ tenderness on exam.

Abdominal pain accounts for 5–10% of pediatric emergency room visits, and acute appendicitis is one of the most common diagnoses requiring surgical intervention [1, 5]. Despite the introduction of various algorithms, there remains an emphasis on imaging, particularly in the pediatric population, when reported history and physical exam findings may be less reliable. Furthermore, there is a great deal of variety in practice among emergency

departments with respect to stepwise evaluation of suspected appendicitis, even among dedicated pediatric emergency departments and despite the advent of pediatric-specific protocols. The two most commonly cited pediatric appendicitis risk scores (the Pediatric Appendicitis Score [PAS] and the Alvarado Score for Acute Appendicitis) have shown significant differences in sensitivity when evaluated by different investigators [1, 6]. Some institutions utilize stepwise approaches prior to obtaining imaging, including initial labs and in some cases evaluation by a surgeon. However, imaging remains a stalwart of the appendicitis workup, as reflected across multiple studies [5, 7]. Ultrasound, while sparing the patient from potentially malignancy-inducing radiation, is heavily operator-dependent. A review by Glass et al. [8] showed a significant variation in sensitivity (from 44% to 88%) and specificity (from 90% to 97%) in studies examining the use of ultrasound in pediatric appendicitis. MRI is likewise radiation-sparing, while lacking the operator dependency of ultrasound; however, this study frequently necessitates sedation in the pediatric population, making it an unfeasible alternative in many institutions. The study by Poortman et al. [7] reinforced the practice that ultrasound should be obtained prior to CT to reduce the risk of radiation-associated malignancies (demonstrating that CT following inconclusive ultrasound had a sensitivity of 100%, specificity of 86%, PPV of 92%, and NPV of 100%); however, another study by Alter et al. [9] has demonstrated that many institutions obtain CT even if ultrasound is equivocal. Our institution's current practice is to obtain CT following unequivocal ultrasound only if there is significant concern for complicated appendicitis (at the discretion of the treating surgeon).

Our results would appear to reinforce some observations published in the existing literature, yet there are conflicting findings in some other studies. Our study showed that males and older children were more likely to have a CT scan performed when ultrasound was inconclusive; this practice may reflect the literature that has repeatedly demonstrated that appendicitis is more commonly diagnosed in male patients, especially older children. It is also possible that an ultrasound-first protocol would negate the need for further imaging in female patients if an ovarian etiology of the symptoms is found (such as in Sayed et al. [5], in which an ovarian cyst was found to be the final diagnosis in 18 out of 45 female patients [40%] whose ultrasound was negative for appendicitis). With respect to history and physical exam findings, our univariate analysis showed statistical significance with reports of RLQ and generalized pain, as well as RLQ

tenderness; however, when analyzed in combination with the other parameters, only RLQ pain and tenderness remained statistically significant.

In their review of ultrasound of the pediatric appendix, Gongidi and Bellah [10] noted that pain localized to the RLQ (as evidenced by asking a child to show “where it hurts” instead of pointing to a specific area) is more strongly correlated with a diagnosis of acute appendicitis. In their meta-analysis of diagnostic accuracy in pediatric appendicitis, Benabbas et al. [1] noted that Rovsing’s sign was the physical exam finding most strongly associated with appendicitis, which was not reflected in our study ($p=0.086$). However, our study had a relatively low number of patients with this sign documented in their chart (less than 25% of patients). Our study did not show an association between WBC count and the likelihood of having a CT performed ($p=0.3595$). The PAS developed by Samuel [6] includes a cutoff point of WBC=10,000, with 1 point being awarded for values higher than this number. Esparaz et al. [11] demonstrated that if a WBC count of 10,000 were utilized as a criterion for imaging, the number of ultrasounds would be reduced by nearly 50%; a WBC count of over 10,000 was 91.1% sensitive for appendicitis. However, their protocol dictated that labs were drawn prior to consideration of imaging; in our institution, bloodwork is most often obtained in conjunction with initial imaging (and also afterwards, if initial imaging is inconclusive).

There were several limitations to the study. The fact that our study was a retrospective study, the short time period that was evaluated (12 months), and the relatively small sample size certainly limit the generalizability of the results. Although our institution has CRP values available within 1 h, we recognize that this may not be the case at every institution and would thus again limit the generalizability of the results. The 427 cases included in this study comprise documentation carried out by a multitude of providers under the supervision of 41 different attending physicians. The variability in the degree of thoroughness in charting abdominal exams means that several of the tracked variables did not have large sample sizes, despite the size of the overall patient population. Similarly, some providers opted not to pursue laboratory work based on the information available, which explains why many patients did not have bloodwork done. Furthermore, it was shown that relatively few patients had band counts due to institutional policy.

The “signs” included for evaluation in this study (Rovsing and Psoas) are by no means exhaustive; it was observed that these and other signs were not frequently utilized in documentation. We did not have a definitive way to track revisits of patients who did not have an

ultrasound performed at their initial visit; these patients would most likely not have had another ultrasound performed if they revisited the emergency department in a short time period, so the potential exists for appendicitis-positive patients that would not be included in the data set. There is inherent variability among attending physicians in their decision to obtain CT scans when ultrasound studies are inconclusive, which can be based on a variety of factors, including (but not limited to) personal experience/expertise and aversion to radiation; this is where perhaps the greatest applicability of our study lies.

The large number of providers (41) supervising the care of the patients in our study encompasses an incredibly vast degree of experience and, as a result, potential bias. Although most providers had a relatively small sample size of patients (only 11 of the 41 providers supervised more than 10 patients in this study), it was observed that the tendency to order CT scans skewed heavily in both directions among individual providers. If bias can be recognized in the face of a significant body of literature, it may be possible to develop a reliable, cost-effective, *and* time-effective protocol while maintaining standard of care. There is a multitude of options for next steps and future directions of this study. Specifically, re-evaluation of the electronic medical record for any revisits to the ER would help to increase the sample size and provide more information on the factors that lead to the use of CT scans.

Future studies should be focused on improving the balance between the parameters involved in evaluating pediatric appendicitis through the application of evidence-based medicine. An additional study that may yield interesting results would be a prospective study utilizing the variables identified in this study to determine if these factors, in combination with CT scan, truly do lead to an increased frequency of acute appendicitis. Although this study did not evaluate the physician’s “gestalt” vs the outcomes, this is an important consideration with the management of acute pediatric appendicitis. Studies, including the paper from the 2020 paper by Simon et al. [12], showed that physician gestalt for acute appendicitis diagnosis performed well, especially in low-risk patients. Future considerations for this data set would be to examine just this—the gestalt vs the outcome—and perhaps test the proposed work-up algorithm against physician gestalt. Finally, perhaps adopting a low-dose CT scan protocol for such studies would be helpful. According to the paper by Yi et al. [13], low-dose CT is effective at diagnosing acute pediatric appendicitis and would be useful in decreasing radiation exposure in our patients.

Conclusions

In the setting of concern for acute appendicitis, imaging remains the best modality to determine a definitive diagnosis and the best patient care. Although ultrasound has made significant strides over the last few decades, there remains a significant portion of abdominal ultrasounds that remain inconclusive, and any potential further imaging with CT or MRI also raise significant questions. In order to aid in future decision making of providers in their evaluation of suspected appendicitis patients and to help facilitate a more comprehensive answer to the “next steps” to take in the question of equivocal ultrasound, we examined the trends of the current practice to inform us of the presence of factors associated with increased use of CT and the associated costs and risks of radiation. This study highlighted several parameters associated with an increased probability of the utilization of CT that were statistically significant, including older children, males, a reported history of RLQ pain or generalized abdominal pain, the presence of RLQ tenderness on physical exam, and CRP. With this knowledge, our aim is for clinicians to be able to make more informed decisions on the next steps in the workup when there is a suspected appendicitis, taking into consideration cost, radiation exposure, and best-practice guidelines.

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