The American Journal of Surgery 217 (2019) 469–472

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

A simple algorithm to improve quality while reducing resource utilization in evaluation of suspected appendicitis in children

Joseph R. Esparaz [a, *], Greg C. McGovern [a], Alyssa R. Mowrer [a], Ryan T. Nierstedt [b], Elise A. Biesboer [c], Breanna M. Elger [b], Richard H. Pearl [a, b], Charles J. Aprahamian [a, b]

[a] Department of Surgery, University of Illinois College of Medicine, Peoria, IL, USA
[b] Children's Hospital of Illinois at OSF Saint Francis Medical Center, Peoria, IL, USA
[c] University of Illinois College of Medicine, Peoria, IL, USA

ARTICLE INFO

Article history:
Received 23 July 2018
Received in revised form
7 November 2018
Accepted 8 November 2018

ABSTRACT

Background: With similar effectiveness of ultrasonography, our institution replaced CT imaging with ultrasound for diagnosing appendicitis in children. An unexpected consequence was the overutilization of ultrasound. Our objective was to establish measures that could help prevent this overuse.
Methods: A retrospective chart review of 327 consecutive pediatric patients evaluated for appendicitis between October 2014 and September 2015 at our institution was performed. Data on clinical, radiographic, and histopathologic findings were reviewed. Diagnostic accuracy of US and white blood cell (WBC) values was determined. An algorithm was created.
Results: 327 (100%) patients received an ultrasound for suspected appendicitis. WBC of 10,000/μl was determined to be the primary discriminant for management and ultrasound utilization. If a WBC ≥10,000/μL had been utilized as criteria for imaging, 49.5% fewer patients would have received an ultrasound.
Conclusions: Clinical exam, WBC count, and surgery consultation prior to ultrasonography can lessen then need for ultrasound utilization in children with suspected appendicitis.

Published by Elsevier Inc.

Introduction

Acute appendicitis remains one of the most prevalent causes of abdominal pain requiring surgical intervention in pediatric and adult patients.[1] In the United States alone, there are approximately 280,000 appendectomies performed annually.[2] From these, the most common age group for acute appendicitis falls in the 2–3rd decade.[3]

In the pediatric population, abdominal pain accounts of 5–10% of all emergency room visits.[4] Among this population, acute appendicitis is the most common indication for an emergency pediatric surgery.[4] The accurate diagnosis of appendicitis in children remains challenging due to the inability of a pediatric patient to describe their symptoms in detail when compared to the adult patient. As a result, imaging has become heavily relied upon to establish a diagnosis of acute appendicitis.

CT imaging has been demonstrated as the leading diagnostic imaging technique due to a sensitivity and specificity near 95% with a negative predictive value of 71–96%.[5] However, approximately 1 in 500 pediatric patients receiving a CT scan may develop a malignancy due to that radiation exposure in their lifetime.[5] As a result, significant efforts have been made to limit CT scanning in the pediatric population due to concern for radiation exposure and future risks of malignancy. Due to these concerns, ultrasound has become more prevalent as an initial diagnostic modality.

A proposed solution for this scenario is the development of an algorithm that identifies patients with a high likelihood of appendicitis based on laboratory values, patient history, and a surgeon's physical exam in an effort to reduce ultrasound utilization.

* Corresponding author. University of Illinois College of Medicine Department of Surgery, 624 NE Glen Oak Avenue, Peoria, IL, 61603-3135, USA.
E-mail addresses: JEsparaz@gmail.com (J.R. Esparaz), mcgovern.gregory@gmail.com (G.C. McGovern), mowrer.alyssa@gmail.com (A.R. Mowrer), ryannierstedt@gmail.com (R.T. Nierstedt), ebiesbo2@uic.edu (E.A. Biesboer), Breanna.elger@gmail.com (B.M. Elger), rhpearl@uic.edu (R.H. Pearl), Charles.J.Aprahamian@osfhealthcare.org (C.J. Aprahamian).

https://doi.org/10.1016/j.amjsurg.2018.11.009
0002-9610/Published by Elsevier Inc.

Methods

Study design

This study was reviewed and approved by the University of Illinois College of Medicine at Peoria Institutional Review Board (#00000688). Following approval, our study team conducted a retrospective review of pediatric patients who received a single level abdominal ultrasound in the emergency department for suspected appendicitis at the Children's Hospital of Illinois. The study population consisted of patients <18 years of age who presented to our institution's Level I pediatric trauma center between October 2014 and September 2015. Our patient cohort was identified utilizing the Current Procedural Terminology (CPT) code for single organ abdominal ultrasound with reasoning for the exam including but not limited to right lower quadrant pain, abdominal pain, and concern for appendicitis. Collected data variables included: white blood cell count (WBC), reasoning for ultrasound imaging, radiologist interpretation, as well as any applicable CT imaging, subsequent appendectomy procedures, and relevant histopathological findings. Concerns for appendicitis were identified by radiologist evaluation of ultrasound imaging. A normal appearing appendix on ultrasound was considered negative for appendicitis. In contrast, an enlarged appendix or secondary signs including *peri*-appendiceal fluid and/or hyperemia were considered appendicitis. However, the final diagnosis was confirmed with a positive histopathologic analysis. Patients were then divided into two groups based on their WBC <10,000/μL or >10,000/μL respectively. Both positive and negative predictive values of WBC on the radiographic evaluation for appendicitis were determined for each group.

Statistical analysis

Statistical analyses were performed using R version 3.4.3. Contingency tables were produced to assess the sensitivity, specificity, positive and negative predictive value of ultrasound and WBC. McNemar's chi-square tests were used to compare the sensitivity and specificity of ultrasound alone and ultrasound combined with a WBC greater than 10,000. A p value of <0.05 was considered statistically significant.

Results

Three hundred and twenty-seven (327) children were included in this retrospective review. Patient ages ranged from 2 to 17 years. All patients were evaluated in the emergency department and received an ultrasound for suspected appendicitis. One hundred and sixty-five children had a WBC <10,000/μL with only five of those patients receiving an appendicitis diagnosis. Three of those underwent appendectomy based on clinical exam while the remaining two had ultrasound imaging. A total of 162 patients had a WBC >10,000/μL, with 51 of those patients receiving a positive appendicitis diagnosis. There were 33 cases of ultrasound identified appendicitis and 31 (94%) of those patients had a WBC >10,000/μL. Of these 33 visualized on ultrasound, all were acute appendicitis on final pathology (Fig. 1).

The table below (Table 1) displays the sensitivity, specificity, positive predictive value, and negative predictive value for ultrasound only, WBC >10,000/μL only, and ultrasound in patients that have WBC >10,000/μL. In our case, the sensitivity was much lower when an ultrasound was used only or in conjunction with WBC. WBC alone had a 91.1% sensitivity at our institution.

Based on these results, an algorithm (Fig. 2) was developed to reduce unnecessary ultrasound imaging for suspected pediatric appendicitis. For any case of suspected appendicitis with WBC >10,000/μL, the pediatric surgical team should be consulted promptly to determine if formal ultrasound is necessary. If any patient had a WBC >10,000/μL with RLQ focal tenderness, an ultrasound may not be necessary, pending a surgical exam. And, if any patient had a WBC <10,000/μL with RLQ focal tenderness, observation or next-day follow up in an outpatient clinic should be considered.

With application of the algorithm, 49.5% fewer ultrasounds would have been performed, and 94% of patients with ultrasound diagnosed appendicitis would have been evaluated by the pediatric surgical team. Our ultrasound sensitivity was 59%. The negative predictive value of the primary discriminant WBC >10,000/μL was 97%; however, when combined with ultrasound it was 91.4%.

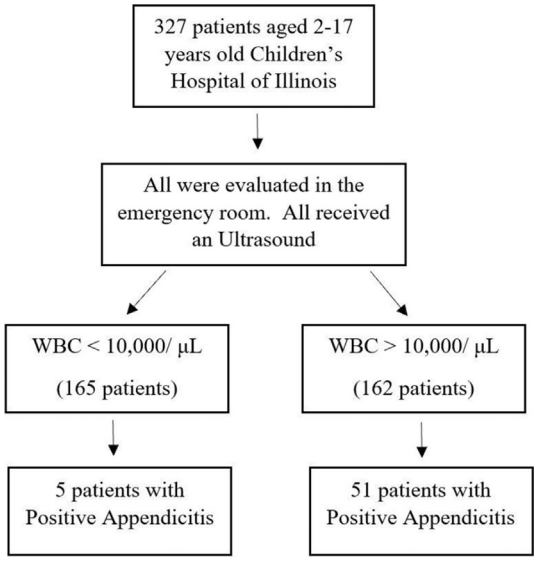

Fig. 1. Population/demographic flow chart.

Table 1
Data comparing diagnostic modality.

	US	WBC over 10,000	WBC over 10,000 & US
Sensitivity	58.9%	91.1%	55.4%
Specificity	97.1%	59.0%	98.2%
Positive Predictive Value	80.5%	31.5%	86.1%
Negative Predictive Value	92.0%	97.0%	91.4%

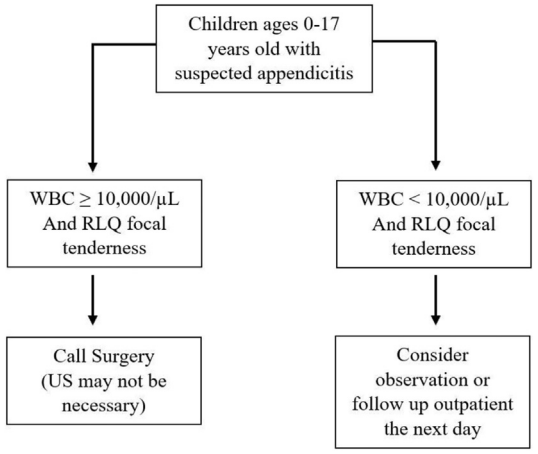

Fig. 2. Rule out appendicitis algorithm.

Discussion

Abdominal pain continues to be a common indication for health care evaluation in children. Pediatric emergency room visits for abdominal pain typically turn into appendicitis rule outs. Historically, the rate of a negative appendectomy, or normal appendix on pathology, has been as high as 20%.[3] However, most current reports demonstrate that this rate has decreased significantly to 1–12%, likely due at least in part to the advances of medical imaging.[5] With this improvement, an unexpected consequence has arisen—the overemphasis of imaging in the diagnosis of acute appendicitis. Many of these patients undergo a CT scan due to its high sensitivity and specificity.[6] Radiation exposure may be more significant as they will likely receive additional scans throughout their lifetime. A recent study suggested children who had CT scans have a higher than average risk of developing cancer later in life.[7] To help with identification of acute appendicitis without imaging, several clinical prediction scores, such as the Alvarado score, are being used.[7] However, some believe their accuracy alone is inferior, necessitating supplemental imaging to aid in the diagnosis.[8] Several retrospective studies focusing on pediatric hospitals have reported a trend towards the increasing use of ultrasound and decreasing use of CT.[8–10]

Similar to the widespread trends to minimize or avoid ionizing radiation in the pediatric population, our institution has reached exemplary status regarding CT usage in children. Our NSQIP data shows us at less than 10% utility in pediatric patients in the evaluation for appendicitis. However, this has resulted in the unnecessary overutilization of ultrasound imaging in the evaluation of appendicitis at our hospital. In addition to creating a burden on resources, inconclusive results have led to not only a lower than expected positive predictive value, but an increase in observation admissions. This scenario is especially apparent during nighttime hours when there is limited staffing available and potentially less experience in the evaluation of pediatric abdominal pain. This often leads to an over dependence on the diagnostic work up. Another limitation of ultrasound imaging is the reliance on operator skill of the performing and interpreting providers.[11] Occasionally, radiologists and ultrasound technicians at certain times of day may have less experience, leading to the omission of commentary on the presence or absence of secondary signs such as inflammation or fluid affecting diagnosis.

To help combat the overuse of ultrasound for pediatric abdominal pain, we developed an alternative diagnostic method. As with any ideal diagnostic test, the initial screening must be affordable, quick, easy to interpret, and accurate. Pearl et al., stated that 91% of acute or perforated appendicitis had a leukocytosis of more than 10,000/mm^3 on admission.[12] We focused on this white blood cell count. For both males and females with greater than 10,000/μL white blood cell count, a surgery consult would be requested without prior ultrasound imaging. The decision for additional imaging would be deferred to the surgery team. In prior studies, females did have a significantly higher than normal pathology rate.[12] Based on this data, an ultrasound may be more beneficial in females if clinical presentation is unclear or inconsistent. For any patient, male or female, with a white blood cell count of less than 10,000/μL, we believe physicians can safely opt for observation or outpatient follow up the next day.

If this algorithm had been successfully implemented, nearly 50% of potentially unnecessary ultrasounds at our institution would have been avoided. In addition, 94% of the patients with ultrasound proven appendicitis would have been rightfully evaluated by the surgical team. A significant savings of over $100,000 may have been achieved from this small data set alone. We believe that by implementing our algorithm, primary care physicians and prompt care providers could limit unnecessary ultrasounds and arrange follow-up the next day.

This study does have some recognized limitations. First, this algorithm was applied in a retrospective manner. Next, this algorithm was developed as a tool to help prevent the routine ordering of an ultrasound in children with abdominal pain prior to physical exam and laboratory evaluation. This adjustment in practice may have some unexpected consequences for the surgical patient, provider, and hospital system. Depinet et al., evaluated a risk stratification process for diagnosing acute appendicitis.[9] Implementation of their algorithm led to a desired decreased CT usage, but increased the number of ultrasounds performed causing a strain on resources.[9] One additional possible outcome of a decrease in the ultrasound burden may be a subsequent increase in requests for surgery consultation for otherwise low risk patients. While some rural communities may struggle with prompt surgical evaluation, teaching hospitals may demonstrate the most benefit from the execution of this algorithm due to the availability of surgical residents to help evaluate patients prior to ordering additional imaging.

In addition, the limitation of relying heavily upon the lab value of WBC count was recognized. To address this issue, the algorithm was designed to incorporate clinical judgement. Depending on several factors including clinical suspicion of the examining provider, reliability of the patient's family to comply with close follow up, and objective data interpretation, the algorithm allows for either observation with short term hospital stay or discharge from the ED with short term follow up scheduled with a physician as soon as the next day. Appendicitis is not a diagnosis that stops and starts, but progresses. This flexibility, however, is also an advantage, especially when examining older patients. For example, a 17-year-old patient may be more likely to recognize and communicate their pain symptoms. This patient may be identified as one that could be safely discharged from the ED with follow up in 24 h with a physician. This situation must also outline specific concerning symptoms to the patient and family that should necessitate a prompt return to the ED. Conversely, when considering a much younger patient, such as a 2-year-old, with a possible appendicitis, this patient may be more appropriate for a short-term hospital observation due to the limited ability of the patient to communicate sings of worsening symptoms. Ultimately, the emergency room physician, as the front-line provider, has the potential for the most significant impact on initial imaging or simple observation.

To determine whether the algorithm that we have developed in this retrospective study will limit unnecessary ultrasound utilization and not negatively impact the management of suspected appendicitis in children, we have embarked upon a prospective trial of the algorithm. We believe in simplifying the diagnostic steps to acute appendicitis. Returning to the basics with a surgical history, physical exam, and a white blood cell count may be all we need.

Conflicts of interest

The authors report no conflicts of interest or competing interests.

Sources of funding

The authors report no external funding source for this study.

Ethical compliance

This study was approved by the University of Illinois College Of Medicine at Peoria Institutional Review Board (#00000688). All

subjects were consented utilizing an IRB approved informed consent form.

Prior presentations

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.11.009.

References

1. Partain KN, Patel AU, Travers C, et al. Improving ultrasound for appendicitis through standardized reporting of secondary signs. *J Pediatr Surg*. 2017;52:1273–1279.
2. Livingston E, Woodward W, Sarosi G, et al. Disconnect between incidence of nonperforated and perforated appendicitis. *Ann Surg*. 2007;245(6):886–892.
3. Lourenco P, Brown J, Leipsic J, et al. The current utility of ultrasound in the diagnosis of acute appendicitis. *Clin Imag*. 2016;40:944–948.
4. Gergory S, Kuntz K, Sainfort F, et al. Cost-effectiveness of integration a clinical decision rule and staged imaging protocol for diagnosis of appendicitis. *Value Health*. 2016;19:28–35.
5. Lofvenberg F, Salo M. Ultrasound for appendicitis: performance and integration with clinical parameters. *BioMed Res Int*. 2016, 5697692.
6. Alter SM, Walsh B, Lenehan PJ, et al. Ultrasound for diagnosis of appendicitis in a community hospital emergency department has a high rate of nondiagnostic studies. *J Emerg Med*. 2017;52(6):833–838.
7. Meulepas JM, Ronckers CM, Smets AM, et al. Radiation exposure from pediatric CT scans and subsequent cancer risks in The Netherlands. *J Natl Cancer Inst*. 2018:djy104.
8. Smith MP, Katz DS, Lalani T, et al. ACR appropriateness criteria – right lower quadrant pain – suspected appendicitis. *Ultrasound Q*. 2015;31(2):85–91.
9. Depinet H, Von Allmen D, Towbin A, et al. Risk stratification to decrease unnecessary diagnostic imaging for acute appendicitis. *Pediatrics*. 2016;138(3):e1–e10.
10. Bachur RG, Hennelly K, Callahan MJ, et al. Advance radiologic imaging for pediatric appendicitis, 2005-2009: trends and outcomes. *J Pediatr*. 2012;160:1034–1038.
11. Zhang H, Liao M, Chen J, et al. Ultrasound, computed tomography or magnetic resonance imaging – which is preferred for acute appendicitis in children? A meta-analysis. *Pediatr Radiol*. 2017;47:186–196.
12. Pearl RH, Hale DA, Molloy M, et al. Pediatric appendectomy. *J Pediatr Surg*. 1995;30(2):173–181.