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The use of a score-based protocol in pediatric appendicitis decreases CT scan utilization when evaluating children in a community hospital

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Abstract

Background: The Pediatric Appendicitis Score (PAS) is a validated scoring system assessing children with abdominal pain. Prior to 2016, children with abdominal pain in our community hospital were evaluated primarily using CT scans. A protocol using PAS and ultrasound (US) as the primary radiologic modality was adopted in 2016 for evaluating children with abdominal pain. The protocol consisted of three tiers with low PAS requiring no radiologic evaluation; moderate PAS requiring US and high PAS requiring initial surgical consultation. Retrospective chart review of children presenting with clinically suspected appendicitis was performed from January 2015 through December 2017, representing 1 year before and 2 years after implementation of PAS protocol. PAS scoring was assigned retrospectively to patients not scored in the emergency physician's note, and statistical analysis of the patient cohorts was performed using SPSS, version 17. This study was approved by the University of Nevada Institutional Review Board.

Results: Application of PAS scoring system increased use of US as the primary radiologic test from 59% pre-protocol to 91% post protocol and decreased use of CT scans from 41 to 8% ($p < .05$). Physician adherence to protocol improved from 59 to 71%, increasing further to 81% in the 2nd year post-protocol ($p < .05$). The highest rate of non-compliance was noted when providers ordered an US in patients with a low PAS, followed by ordering any radiologic tests in patients with a high PAS.

Conclusion: Implementation of PAS-based protocol altered clinician behavior in a community hospital when evaluating children with clinically suspected appendicitis. Improved adherence to the protocol over time with significant decrease of CT scans ordered thereby reducing radiation exposure in the pediatric population. Future improvements will be aimed at decreasing radiologic testing in patients with a low PAS and involving surgeons earlier with patients who have a high PAS as clinical acceptance to the protocol matures.

Keywords: Pediatric Appendicitis Score, CT scan, Ultrasound, Evaluation, Community Hospital

Background

Appendicitis is the most common surgical disease in children and can be clinically challenging to diagnose.

This has prompted an increased use of CT scans over the years to aid in the diagnosis. An abdominal CT delivers approximately 8 millisieverts (mSV) of radiation [1]. The average person in the USA receives more than 3 mSV of background radiation (excluding medical sources) per year, rendering an abdominal CT almost three times the average person's annual exposure [2]. Studies have shown exposure to CT can increase the risk

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of developing leukemia and brain tumors in pediatric patients [3]. Therefore, the benefit of CT scan utilization for diagnostic purposes must be weighed against the cost of radiation exposure and potential for future oncogenesis.

Validated scoring systems, such as the Pediatric Appendicitis Score (PAS) and the Alvarado Score, have been shown to help physicians accurately predict appendicitis in pediatric patients presenting with abdominal pain [4, 5] (Table 1). The use of clinical practice guidelines applied in the emergency department (ED) to potential pediatric appendicitis patients has been shown to decrease the use of CT scans [6].

Prior to 2016, children with clinically suspected appendicitis in our institution were evaluated primarily using CT scans. At the start of 2016, our ED adopted a protocol utilizing PAS as the principal method for evaluation of possible pediatric appendicitis to try and decrease the use of CT scans and thereby radiation exposure. The protocol consisted of three tiers with low PAS requiring no radiologic evaluation, moderate PAS requiring ultrasound (US), and high PAS requiring initial surgical consultation. The primary goal was to increase the use of

US as the primary radiologic evaluation and encourage earlier surgical involvement.

Methods

A retrospective chart review of pediatric patients (under 18 years of age) presenting with clinically suspected appendicitis was conducted from January 2015 through December 2017. This review covered the 1 year before and 2 years after implementation of the PAS protocol. The protocol divided patients into three groups based on their PAS. If the PAS was 0 to 2, the patient was to be discharged with a follow-up call or instructions to return to ER within 8 to 12 h for re-evaluation. If the PAS was 3 to 6, an abdominal ultrasound (US) was to be obtained. If the US was positive, a surgical consultation was obtained. If US was negative or inconclusive, the ER physician was given the option to obtain an abdominal CT scan or call the surgeon to discuss management. If the PAS was 7 to 10, the ER physician was to obtain a surgical consultation without initial imaging.

Charts were then abstracted for demographic data, PAS, any imaging obtained, any surgical intervention, and length of stay. The PAS was assigned retrospectively

Table 1 Pediatric Appendicitis Score

Finding	Points
Nausea/vomiting	1
Anorexia	1
Fever	1
Migration of pain	1
Leukocytosis	1
Neutrophelia	1
RLQ tenderness	2
Hopping/ percussion tenderness	2

to patients not scored in the emergency physician’s note. There were three time periods reviewed: (1) 1 year prior to protocol implementation, (2) first year of protocol, and (3) second year of protocol. Patients in these groups were compared for protocol adherence and use of imaging studies as well as surgical intervention and pathologic findings. Statistical analysis of the patient cohorts was performed using SPSS, version 17 and R statistics. Statistical significance was assigned to p values < .05.

Results

Over the three time periods reviewed, 1758 pediatric patients were evaluated in our ER with symptoms concerning for appendicitis. The pre protocol group was compared to the first and second year post protocol groups with no significant differences in demographics (Table 2). After application of the PAS protocol, there was a significant decrease in the usage of CT as the primary radiologic test in the first post protocol year compared to the pre protocol year (42 to 16%). There was a further decrease in the second post protocol year (16 to 8%), demonstrating increasing compliance with the protocol. The use of US as the primary radiologic modality concomitantly increased significantly in the first and second year post protocol implementation.

Approximately one-third of the patients who presented in each time frame underwent appendectomy. There was a minimal increase in the negative appendectomy rate over time (12.5% pre protocol; 18% in second year post protocol) (Table 3). The vast majority of procedures performed were laparoscopic appendectomies at greater than 90%. The diagnosis of appendicitis was based on pathologic findings. The length of stay for non-perforated appendectomies was 25 h in the pre protocol time frame. There was no significant difference in the first and second post protocol groups (28 h and 30 h).

Analysis found protocol violations present in 42% of patients in the pre protocol group, which was applied retrospectively for comparison. After implementation of the PAS protocol, the violations dropped to 27% in the

first year and 20% in the second year which was statistically significant (Table 4). The reasons for protocol violations were most frequently obtaining imaging in either the low PAS group (29 to 27%) and the high PAS group (29 to 17%). The second most common reason for protocol violations was CT scans being ordered before US (58 to 16%) but this became significantly less frequent in the second post protocol year (8%).

Subset analysis of the negative appendectomy patients demonstrated that all but one in each time frame received an imaging study (Table 5). One third to one half of those studies were interpreted as positive for appendicitis. Indications for surgery in the normal or equivocal studies were based on clinical appearance. The PAS score in this subset averaged 5.3 to 6.

US sensitivity improved over the study period (Table 6). Specificity remained high throughout the study period, greater than 96%. US reading of the “appendix not seen” ranged from 59 to 66% of the readings. Missed appendicitis on US dropped from 31% in the pre protocol time frame to 11% and 14% respectively.

Review of patients with low PAS found that 2.5 to 8% of them returned for re-evaluation (Table 7). There were two patients in the pre protocol year and two patients in the first post protocol year who were discharged and later returned and underwent surgery at their second visit. This number increased to 10 patients (26%) in the second post protocol year. Appendicitis was found in 50 to 100% of these re-evaluated patients who underwent surgery.

Discussion

The use of clinical scoring systems to evaluate children with possible appendicitis has been used for over 20 years [7]. Our findings concur that a protocol based system can decrease the use of CT and increase the use of US to help diagnose pediatric appendicitis. If a patient presented to our ER pre protocol, 42% would undergo CT scan. By the end of the study, CT usage as the first modality dropped to 8%. Parenthetically, US usage

Table 2 Demographics and radiologic tests

Demographic	Pre-protocol	Post protocol year 1	Post protocol year 2
Total patients	400	927	431
Gender—M/F	190/210 (49% M)	441/486 (48% M)	134/237 (47% M)
Age	9.67 years	9.46 years	9.77 years
Length of symptoms	3.4 days	3.5 days	2.0 days
PAS Score	3.6	3.0	4.3
Number of patients with radiologic tests	220 (55%)	455 (50%)	380 (88%)
US obtained first	129 (58%)	381 (84%)	345 (91%), p < .001
CT obtained first	88 (42%)	71 (16%)	33 (8%), p < .001
Total CTs completed (% of all patients)	133 (37%)	151 (16%)	112 (25%)

Table 3 Procedures and findings

Procedures/findings	Pre-protocol (400)	Post protocol year 1 (927)	Post protocol year 2 (431)
Operative procedure	127 (32%)	143 (15%)	125 (29%)
Laparoscopic appendectomy	120 (95%)	132 (92%)	117 (94%)
Open appendectomy	7 (5%)	11 (8%)	8 (6%)
Acute appendicitis	100 (79%)	107 (75%)	88 (70%)
Perforated appendicitis	11 (9%)	15 (10%)	14 (11%)
Normal appendix	16 (12%)	15 (15%)	14 (18%)
Length of stay—non perforated	25 h (4–168)	28 h (4–500)	30 h (4–166)
Length of stay—perforated	108 h (32–208)	92 h (23–216)	135 h (65–280)

increased from 58 to 92% in those needing radiologic evaluation.

Both ultrasound (US) and computed tomography (CT) have been shown to improve diagnostic accuracy in appendicitis [8]. There is more evidence over the past decade that implementation of diagnostic algorithms can decrease CT utilization thereby decreasing radiation exposure in the pediatric population [9–11]. Ultrasound has been an important tool for the diagnosis of appendicitis since the 1990s [12]. There have been substantial advances in ultrasound technology and the graded compression technique that have allowed for improved visualization of the appendix [13]. US presents an advantage over other imaging modalities as it is noninvasive, can be rapidly performed, and is relatively inexpensive [14].

Ultrasound, however, is highly operator dependent. While technical expertise and diagnostic accuracy is improving in high volume centers, for smaller community hospitals, this can present some challenges and doubts as to accuracy. False-negative ultrasound results may lead to delayed diagnosis, increased risk of perforation, and increased sepsis-related morbidity. False-positive results may lead to unnecessary surgery and risk of complications. CT scans provide more detailed images than US, but they carry an increased risk of exposure to ionizing radiation. Over the past decade, there has been more attention given to the risks of radiation exposure in the pediatric population. Despite publication of evidence-based reviews and Cochrane recommendations for increased use of US, the surgeons in our community hospital were continuing to see a large number of CT scans

ordered on pediatric patients with abdominal pain, usually before consulting with them [15]. This concern led to the implementation of the Pediatric Appendicitis Score in our institution and this retrospective study was used to evaluate our own outcomes with this change in practice. Increased focus on US usage as the primary modality improved our sensitivity from 42 to 60–80%, comparable to other studies [16].

Our findings after initiating the PAS protocol concur with other recent reviews and supports the conclusion that protocols alter clinician behavior [11]. The number of CT scans ordered decreased over time with improving compliance with the protocol. This was evidenced by an increase in ultrasounds ordered and fewer violations in the post protocol group compared to the pre protocol group. Protocol violations were most common in patients with a low PAS, where our study revealed that many clinicians opted to order an imaging study. In those with a high PAS, we found that many clinicians ordered imaging before notifying the general surgeon on call. Time of presentation and clinical presentation may have altered the clinical decision making in these cases.

By replacing CT with ultrasound as first-line imaging for clinically suspected appendicitis, there was a modest increase in negative appendectomy rate, which did not prove statistically significant. Mandatory imaging in clinically suspected appendicitis can decrease the negative appendectomy rate, but this also requires subjecting pediatric patients to ionizing radiation, in the case of CT use, or relying on operator-dependent ultrasounds [17]. The protocol deemed imaging unnecessary in patients with a high PAS, based on the idea that surgeon

Table 4 Protocol violations

Protocol violations	Pre-protocol (400)	Post protocol year 1 (927)	Post protocol year 2 (431)
Number of protocol violations	167 (42%)	272 (27%)	89 (20%), $p < .001$
Imaging in patients with PAS < 3	49 (29%)	95 (34%)	24 (29%)
Imaging in patients with PAS > 7	49 (29%)	23 (8%)	15 (17%)
CT done without US	86 (58%)	71 (16%)	33 (8%)

Table 5 Negative appendectomy

Negative appendectomies	Pre-protocol (16)	Post protocol year 1 (18)	Post protocol year 2 (23)
Imaging testing performed	15 (93%)	17 (93%)	22 (93%)
Positive imaging for appendicitis	8 (53%)	6 (33%)	9 (40%)
Averaging PAS	6	5.3	5.3

prediction for appendicitis is more accurate than imaging or clinical findings, alone and in these cases, the benefits of definitive surgical treatment outweighed the risks of imaging or missing appendicitis [18].

Conclusions

Implementation of a PAS protocol altered clinician behavior in a community hospital when evaluating children with clinically suspected appendicitis, demonstrated by increased adherence to the protocol over time and a significantly lower number of CT scans ordered thereby reducing radiation exposure in the pediatric population. Future improvements will be aimed at decreasing radiologic testing in patients with a low PAS and involving surgeons earlier with patients who have a high PAS.

Limitations

Limitations of our study are comparable to other retrospective reviews. It is possible that patient charts did not provide a complete clinical picture of the patient. It is difficult to assess in a chart review whether a physician had a specific reason for ordering an imaging study in patients with a higher or lower score. There often is not documentation of timing of calls to a surgeon or even hallway discussions in the ED which may have led to imaging documented prior to official consultation.

Table 6 Evaluation of ultrasound

Ultrasound findings	Pre-protocol (129)	Post protocol year 1 (382)	Post protocol year 2 (345)
Appendix not seen	74 (57%)	232 (60%)	229 (60%)
Positive appendicitis	23 (53%)	26 (11%)	33 (14%)
Normal appendix	30 (23%)	88 (23%)	53 (23%)
Positive appendicitis	1 (1%)	0	0
Positive appendicitis	21 (16%)	53 (14%)	63 (28%)
Negative appendix	3 (2%)	6 (3%)	10 (4%)
Sensitivity	42%	81%	62%
Specificity	96%	97%	86%

Table 7 Re-evaluated patients with low PAS

Re-evaluation with low PAS	Pre-protocol (14)	Post protocol year 1 (24)	Post protocol year 2 (38)
Number of patients undergoing appendectomy	2 (14%)	2 (8%)	10 (26%)
Pathology findings	1—positive appy 1—perforated appy	1—positive appy 1—normal appy	5—positive appy 2—perforated appy 3—normal appy

Based on the positive impact of implementation of use of PAS and guidelines for evaluation of abdominal pain in our pediatric patients, we continue to see an increase in compliance with these guidelines. Future improvements will be aimed at decreasing radiologic testing in patients with a low PAS and involving surgeons in patient care sooner in those with a high PAS. The use of longer observation prior to surgical intervention may also improve our negative appendectomy rate.

Abbreviations

PAS: Pediatric Appendicitis Score

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Authors' contributions

FH designed the study and aided in the collection of data, analysis and interpretation of the data, and writing of the manuscript. BM aided in the collection of data and the writing of the manuscript. PE aided in the collection of the data. BT aided in the writing of the manuscript. All authors have read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of the University of Nevada Institutional Review Board. No reference number was provided. Consent to participate was not applicable.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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