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ORIGINAL CONTRIBUTION

Use of Computed Tomography in Diagnosing Appendicitis: Redundant, Expensive, Toxic, and Potentially Unnecessary

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Context: Computed tomography is routinely used for the diagnosis of appendicitis despite its high cost and its radiation exposure to patients.

Objective: To examine the usefulness and clinical relevance of computed tomography to diagnose appendicitis at a community-based academic medical center.

Methods: A retrospective review of medical records of patients who received a final diagnosis of appendicitis (according to *International Classification of Diseases, Ninth Revision*) from April 26, 2009, to July 27, 2009, was conducted. Emergency department and admission history, physical examination reports, ultrasonography and computed tomography reports, and operative and pathology reports were included in the review. A modified version of the pediatric appendicitis score (mPAS) was used to determine the utility of imaging vs physical and laboratory examinations.

Results: Charts from 36 patients, aged 8 to 22 years, were included. All patients had pathologic evidence of appendicitis. Imaging was mentioned in 20 of 36 operative reports, but no operative report mentioned imaging as a crucial factor in surgical decisions. Two of 5 patients with the elevated mPAS of 6 had undergone no imaging; operative decisions were based on history, physical examination, and laboratory results. Among the 35 patients who had mPAS values, 23 (65.7%) had an mPAS of 5 or greater. The average mPAS for all patients was 4.5. Thirty-one of 36 patients (86.1%) had typical physical examination indications for appendicitis.

Conclusion: Computed tomography was used as an initial part of the diagnostic workup in most patients, rather than as a tool for only atypical cases. A tiered approach—consisting of routine clinical evaluation with mPAS, followed by imaging in only atypical cases—would likely result in diagnostic accuracy similar to that obtained with early, routine imaging. Such an approach would also decrease expense and radiation exposure to young, developing bodies.

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Timely diagnosis and surgical intervention are associated with improved outcomes in patients with appendicitis.[1] In recent years, clinical history and physical examination have been routinely supplemented with imaging technology in the diagnosis of appendicitis.[1] Most imaging involves ultrasonography or computed tomography (CT). Whereas ultrasonography offers the benefits of low cost, minimal patient preparation, and no radiation exposure, CT offers an enhanced perspective on the extent of disease and is not as operator-dependent as ultrasonography. Thus, CT has a higher sensitivity than ultrasonography in diagnosing appendicitis.[1] However, CT is expensive to perform and increases the patient's exposure to potentially dangerous radiation.[1]

Research suggests that pediatric CT can result in increased lifetime radiation risk per dose, compared with that of CT in adults.[2] There is a small but statistically significant risk of radiation-induced malignancy for children who undergo even 1 CT scan. A study in 2001[3] showed that for a single abdominal CT scan in a 5-year-old child, there is a 26.1-per-100,000 lifetime risk of radiation-induced cancer in females and a 20.4-per-100,000 lifetime risk of such cancer in males.

Approximately one-third of pediatric patients with appendicitis present atypically, making diagnosis more challenging.[4] Because perforation carries the greatest risk of morbidity and mortality, early surgical intervention is desirable. Perforation rates have been found to be higher in younger children.[4] Several studies have shown fewer false-positive appendectomies in patients who undergo a single preoperative CT scan.[1] However, receiving more than a single preoperative scan does not show a decreased

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negative appendectomy risk in either men or women older than 45 years.[5]

One study[6] found that a protocol involving clinical evaluation from a pediatric surgeon, followed by selective use of imaging, lowered rates of negative appendectomies and minimized unnecessary radiation exposure in children. Another study[7] found that a preoperative CT scan did not increase diagnostic accuracy when compared with only a history, physical examination, and laboratory results. In the presence of strong clinical suspicion, a negative CT scan did not exclude the diagnosis of appendicitis. That study[7] suggested that CT scans may be useful for patients with atypical presentations. Wan and colleagues[3] found that ultrasonography, followed by CT if the ultrasonography results are negative, is the most cost-effective workup strategy for children with appendicitis.

A 2010 study by Scheinfeld et al[8] indicated that no laboratory test is sufficient to offer reassurance that a CT scan is unnecessary in a young adult presenting with nontraumatic abdominal pain. The authors proposed that strategies other than relying on laboratory values be used to avoid excessive imaging.[8] In 2002, Samuel[9] proposed a clinical diagnostic scoring system for pediatric appendicitis. The pediatric appendicitis score (PAS) was developed as a diagnostic tool for assessing acute abdominal symptoms and diagnosing appendicitis in children.[9] A prospective validation of the PAS, undertaken in 2008, found that the PAS was useful, with a high validity for both ruling out and predicting appendicitis, depending on the score.[10]

The original PAS consisted of 8 criteria: (1) cough/percussion/hopping tenderness in the right lower quadrant (RLQ); (2) anorexia; (3) pyrexia; (4) nausea/emesis; (5) tenderness over the RLQ; (6) leukocytosis; (7) polymorphonuclear neutrophilia; and (8) migration of pain.[9] We used a modified version of the PAS (mPAS) in the present retrospective review of medical records.

We hypothesized that routine CT scans in the evaluation of acute appendicitis in children may lead to unnecessary radiation exposure, increased cost, and potential delays in treatment. In the present study, we examine the usefulness and clinical relevance of CT at a community-based academic medical center.

Methods

We conducted a retrospective chart review of all patients admitted with a diagnosis of appendicitis to the pediatrics ward at Winthrop University Hospital in Mineola, New York, from April 26, 2009, to July 27, 2009. All patients had a final diagnosis of appendicitis on the basis of criteria in *International Classification of Diseases, Ninth Revision* (ICD-9). Data were collected on the age and sex of each patient and on any indication of CT or ultrasonography imaging performed. If CT was performed, records were evaluated to identify the department that ordered the scan. Each patient's initial emergency department history and physical examination results, as well as pediatric admitting history and physical evaluation findings, were reviewed for documentation of clinical signs of appendicitis.

Medical records were reviewed by a fourth-year medical student (S.A.), who checked criteria for the process with an attending physician (R.V.M.) from the pediatrics department prior to review. Cases were selected on the basis of age and final ICD-9 diagnosis of appendicitis, with charts pulled by the medical records department of the hospital. The variables obtained were patient age, sex, imaging modality performed, and physical examination findings as documented on both the emergency department and admission documentation. Chart reviewers were not blinded in the present study.

To determine whether the imaging tests played an important role in clinical decision-making, the surgeons' preoperative and postoperative reports were reviewed for mention of the imaging. The type of surgical procedure involved was also recorded. Finally, the pathology reports of all surgical specimens were reviewed.

In Samuel's original PAS system,[9] each criterion of clinical and laboratory examination received 1 point, except for cough/percussion/hopping tenderness in the RLQ and tenderness over the RLQ, which each received 2 points. We initially attempted to use this PAS system in our chart reviews, but we found that certain data were often missing, including data on anorexia, pain migration, and tenderness with cough. Thus, we created an mPAS system based on Samuel's criteria[9] but compatible with the data available for extraction.

The mPAS consisted of the following 5 criteria: (1) nausea/emesis; (2) fever (temperature >38ºC); (3) RLQ tenderness; (4) white blood cell (WBC) count >10,000/μL; and (5) polymorphonuclear leukocytes + band neutrophil counts >7500/μL. Each criterion received 1 point, except RLQ tenderness, which received 2 points. An mPAS of greater than 4 indicated a high likelihood for appendicitis, and an mPAS of 4 or less indicated a less conclusive diagnosis. All data were recorded directly from the medical records.

Results

Charts from 36 patients, aged 8 to 22 years, with pathologic evidence of appendicitis were included in the restrospective analysis. The mPAS was determined for every patient except for 1 man, who had no differential WBC count recorded on his chart.

The *Table* shows the age, sex, PAS, mPAS, and whether CT was performed for each of the 36 patients. The average age of the patients was 15.4 years, and the average mPAS was 4.5. Our results suggest that there are no consistent

Table.
Characteristics of Cases, With PAS Values, in Retrospective Review of Medical Records of Patients With Appendicitis (N=36)

Case	Age, y	Sex	PAS Standard[a]	PAS Modified[b]	CT Performed
1	17	F	6	5	Y
2	17	M	5	5	Y
3	19	M	7	6	Y
4	10	F	4	5	Y
5	17	M	5	4	Y
6	20	M	5	5	Y
7	12	M	3	3	Y
8	17	F	5	5	Y
9	9	M	7	6	Y
10	9	M	5	5	Y
11	18	M	6	5	Y
12	7	F	4	4	Y
13	22	M	3	2	Y
14	10	F	5	5	N
15	16	M	3	3	Y
16	14	M	6	5	Y
17	8	M	6	6	N
18	21	M	6	5	Y
19	10	M	4	3	Y
20	13	M	8	6	Y
21	20	F	2	2	Y
22	14	M	8	6	N
23	15	F	4	4	Y
24	17	F	3	2	Y
25	16	F	3	3	Y
26	21	F	6	5	Y
27[c]	22	M	1	NA	Y
28	22	F	5	5	Y
29	11	F	4	3	Y
30	21	M	7	5	Y
31	10	F	5	5	Y
32	20	F	5	5	Y
33	12	M	8	5	Y
34	11	M	5	5	Y
35	17	M	5	3	Y
36	21	F	5	5	Y

[a] The standard pediatric appendicitis score (PAS), as developed by Samuel,[9] consists of 8 criteria: (1) cough/percussion/hopping tenderness in the right lower quadrant (RLQ); (2) anorexia; (3) pyrexia; (4) nausea/emesis; (5) tenderness over the RLQ; (6) leukocytosis; (7) polymorphonuclear neutrophilia; and (8) migration of pain. Each criterion receives 1 point, except for cough/percussion/hopping tenderness and tenderness over the RLQ, each of which each receives 2 points. A standard PAS of 7 or greater (of a possible 10) indicates high validity for predicting appendicitis.

[b] The modified pediatric appendicitis score (mPAS) is based on 5 criteria: (1) nausea/emesis; (2) fever (temperature >38°C); (3) RLQ tenderness; (4) white blood cell count >10,000/µL; and (5) polymorphonuclear leukocytes + band neutrophil counts >7500/µL. Each criterion receives 1 point, except RLQ tenderness, which receives 2 points. An mPAS of greater than 4 indicates high likelihood for appendicitis, and an mPAS of 4 or less indicates a less conclusive diagnosis.

[c] The mPAS could not be determined for this patient, because no differential white blood cell count was recorded on his chart.

Abbreviations: CT, computed tomography; N, no; NA, not available; Y, yes.

trends between mPAS and any of the following: age, classic findings for appendicitis at physical examination, or mention of CT in the operative report. It should be noted that although 31 of 36 patients (86.1%) had abdominal physical examination findings that are seen with appendicitis, not all of these individuals had findings that were specific to appendicitis. Pathologic specimens of all patients showed evidence of appendicitis, ranging from acute appendicitis to acute gangrenous (ie, necrotizing and fibrinopurulent) appendicitis with perforation and periappendicieal abscess formation. Many patients also had acute serositis.

The operative reports mentioned results of imaging in 20 of the 36 cases, with 13 operative reports not mentioning imaging at all. In none of the cases was CT mentioned as a crucial factor in the surgical decision-making process.

Three patients did not receive CT scans, according to the charts. These 3 patients had a mean mPAS of 5.7, compared to a mean mPAS of 4.3 among the 32 patients who received CT scans and had mPAS determined (*Table*). One unscanned patient was a girl, aged 10 years, with an mPAS of 5 and RLQ pain, a typical finding for appendicitis. The surgeon admitted this patient presumably because of her history of 10 days of abdominal pain, a fecalith, RLQ pain, and a WBC count of 19,000/µL. A laparoscopic appendectomy was performed on the girl, yielding the pathologic finding of acute, focally gangrenous appendicitis.

A second unscanned patient was a boy, aged 14 years, with an mPAS of 6 and a physical examination that was positive for appendicitis. A laparoscopic appendectomy was performed on the boy, resulting in the pathologic finding of focal acute appendicitis with associated periappendicitis. The third unscanned patient was a boy, aged 8 years, with an mPAS of 6 and a physical examination that was positive for appendicitis. An open appendectomy was performed on the boy, with the pathologic examination revealing acute appendicitis with serositis and marked reactive lymphoid hyperplasia.

Twenty-three of the 35 calculated mPAS values (65.7%) were 5 or greater. However, 9 of the 35 mPAS values (25.7%) were 3 or less. The distribution of patients' mPAS values are shown in *Figure 1*.

Regarding department orders for CT, 30 of 36 CT orders (83.3%) were made by the emergency department of the study hospital, 2 CT orders (5.5%) were made by the emergency department of a referring hospital, and 1 CT order (2.8%) was made by the gastrointestinal service (for a patient whose mPAS was 5). Three charts had no data regarding which department placed the CT order.

As previously noted, 31 patients, with a mean mPAS of 4.5, had typical physical examination indications for appendicitis. Three patients, with a mean mPAS of 4, did not have such physical examination indications, and physical examination findings were not recorded for 2 patients. Typical physical examination indications included RLQ pain or tenderness to palpation, McBurney point tenderness, and Rovsing sign. Ultrasonography was performed in 1 case, for a patient who also had a CT scan. The ultrasonogram revealed normal ovarian blood flow with no torsion, and the patient's CT scan revealed tip appendicitis. This patient's mPAS was 5.

As shown in *Figure 2*, 1 CT examination revealed negative results, indicating a minimal amount of free pelvic fluid in an otherwise normal study. That patient, who had an mPAS of 3, had tenderness diffusely and at the McBurney point, as documented on the patient's admission history and physical report. According to the surgeon's report, the patient was clinically diagnosed preoperatively as having appendicitis. The final pathology report for the patient indicated acute appendicitis with serositis. Thus, the CT results for this patient yielded a false-negative result, which the surgeon ignored and chose to operate on the basis of clinical findings. The 32 patients with positive CT results had mPAS scores ranging from 2 through 6, with 1 of the patients having an undetermined mPAS.

Two of the 5 patients who had an mPAS of 6 did not receive a CT scan, indicating that the clinician's examination was perceived to be sufficient to take the patient to surgery without imaging. Arguably, the 3 patients with an mPAS of 6 who received CT scans may not have required this imaging. On the basis of the surgeon's operative reports, the CT results had an influential role in diagnostic decisions in only 3 of 12 patients (25%) with an mPAS of 4 or less.

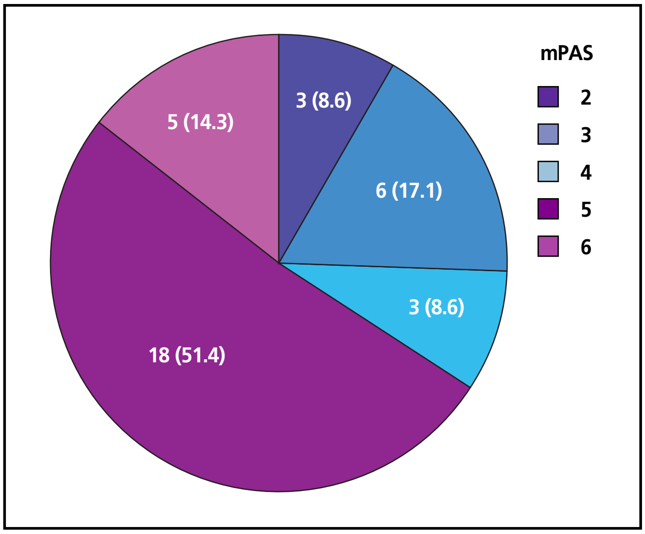

Figure 1. *Distribution of patients' modified pediatric appendicitis score (mPAS) values, with higher values indicative of greater diagnostic certainty for appendicitis (n=35). Results shown as No. (%). No patient had an mPAS of 1.*

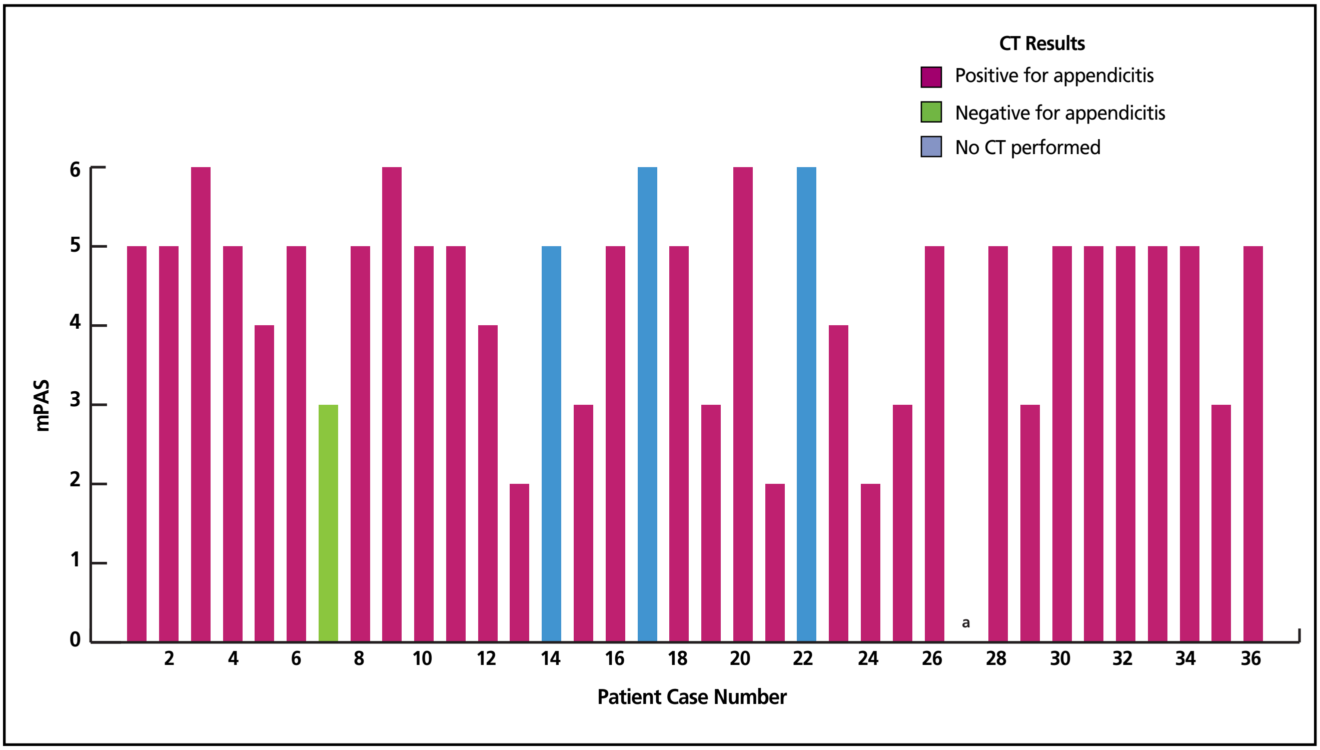

Figure 2. *Correlation of computed tomography (CT) results for appendicitis with modified pediatric appendicitis score (mPAS) values, according to patient case number.* [a]*The mPAS could not be determined for patient 27, because no differential white blood cell count was recorded on his medical record.*

Comment

Our retrospective review of medical records confirmed that CT was a routinely used diagnostic procedure in the evaluation of possible appendicitis in children at the study hospital. This finding may reflect procedural or cultural values in this particular hospital rather than a thoughtful clinical approach.

On the basis of the review of medical records, we saw no correlation between clinical judgment and CT use in the diagnosis of appendicitis. More than 90% of the patients received a CT scan, regardless of their mPAS or physical examination results. It appears that CT was an initial part of the diagnostic workup, as opposed to a tool used for atypical cases. A majority of patients had high mPAS results (ie, $\geqslant$5). According to Goldman and colleagues,[10] a standard PAS of 7 or greater (of a possible total of 10) had high validity for predicting appendicitis. Although our PAS was modified, it is likely that an mPAS of 5 or greater had a similarly high predictive ability for appendicitis.

The present study provides evidence that CT may be unnecessarily used for many cases of appendicitis. However, further investigation involving a greater number of patients would be beneficial. In addition, obtaining a wider range of patients from different hospital settings, including academic, community-based, and children's hospitals, may reveal whether our findings could be accounted for by specific practice patterns at the hospital in which the study was conducted. A larger sample size may also yield more information regarding the diagnostic usefulness of ultrasonography in appendicitis diagnosis, given that only 1 patient received ultrasonography in our chart review. Furthermore, data obtained from other countries would help identify and account for differences in national practice patterns.

Recent studies[11,12] have supported the idea that a clinical protocol for the diagnosis and management of appendicitis in children can safely incorporate decreased use of CT. Such decreased use of imaging may be supported by medical circumstances in the United States that are not present in certain other countries. For example, a recent study[13] from the Netherlands recommended imaging before appendectomy, pointing out that more than 2500 unnecessary appendectomies were performed in that country in 2010.

Conclusion

We believe that a tiered approach—consisting of routine clinical evaluation and mPAS, followed by imaging in only atypical cases—would likely result in diagnostic accuracy similar to that obtained with early, routine imaging. Such an approach would also decrease expense and radiation exposure to young, developing bodies.

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