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# Suspected appendicitis pathway continues to lower CT rates in children two years after implementation

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ABSTRACT

*Background:* We implemented a protocol to evaluate pediatric patients with suspected appendicitis using ultrasound as the initial imaging modality. CT utilization rates and diagnostic accuracy were evaluated two years after pathway implementation.
*Methods:* This was a retrospective observational study of patients <18 years evaluated for suspected appendicitis. CT rates were compared before and after implementation of the protocol, and monthly CT rates were calculated to assess trends in CT utilization.
*Results:* CT use decreased significantly following pathway implementation from 94.2% (130/138) to 27.5% (78/284; $p < 0.001$). Linear regression of monthly CT utilization demonstrated that CT rates continued to trend down two years after pathway implementation. Adherence to the pathway was 89.8% (255/284). Negative appendectomy rate was 2.4% (2/85) in the post-pathway period.
*Conclusions:* Adherence to a pathway designed to evaluate pediatric patients with suspected appendicitis using ultrasound as the primary imaging modality has led to a sustained decrease in CT use without compromising diagnostic accuracy.



## Introduction

Computed tomographic (CT) scans provide valuable diagnostic information for a variety of disease processes, which has led to increased rates of CT scan utilization over the years. This trend has also been demonstrated in children evaluated for abdominal pain in the Emergency Department.[1] However, CT scans have their own inherent dangers, including increased cancer risks from ionizing radiation exposure especially for pediatric patients.[2–6] Radiation exposure for a standard abdominal CT scan with no age or size adjustment is approximately 400 mA-seconds. The estimated lifetime risk of a cancer death attributable to radiation exposure from a single abdominal CT scan in a 1-year old is 0.18%, or approximately 1 death for every 550 abdominal CT scans obtained.[2] Additionally, although the financial costs of CT scans vary widely between institutions across the United States, avoiding routine use of CT scans to diagnose appendicitis can result in significant savings to the healthcare system.[6] While the costs of imaging tests vary by location, data from national databases estimate the cost of a CT scan at approximately $547, while a limited ultrasound (US) study to evaluate the appendix is approximately $88.[6]

Appendicitis is one of the most common diseases requiring surgery in children. US has been shown to be a highly effective imaging modality to visualize the appendix in suspected appendicitis cases while avoiding the radiation exposure associated with CT scan use.[7–9] Emergency Departments in hospitals across the country have implemented abdominal pathway protocols for suspected appendicitis, usually with the goal to reduce CT scan use while still maintaining high diagnostic accuracy. However, the majority of these institutions failed to compare their post-pathway outcomes to their pre-pathway data, and were therefore unable to measure the net effect attributed to the pathway intervention.[7,10–14]

Our freestanding children's hospital implemented an abdominal pathway protocol for suspected appendicitis patients to decrease radiation exposure without compromising diagnostic accuracy (Fig. 1). The purpose of our study was to evaluate institutional compliance with the pathway, as well as the effect of this protocol on CT scan utilization rates and diagnostic accuracy.

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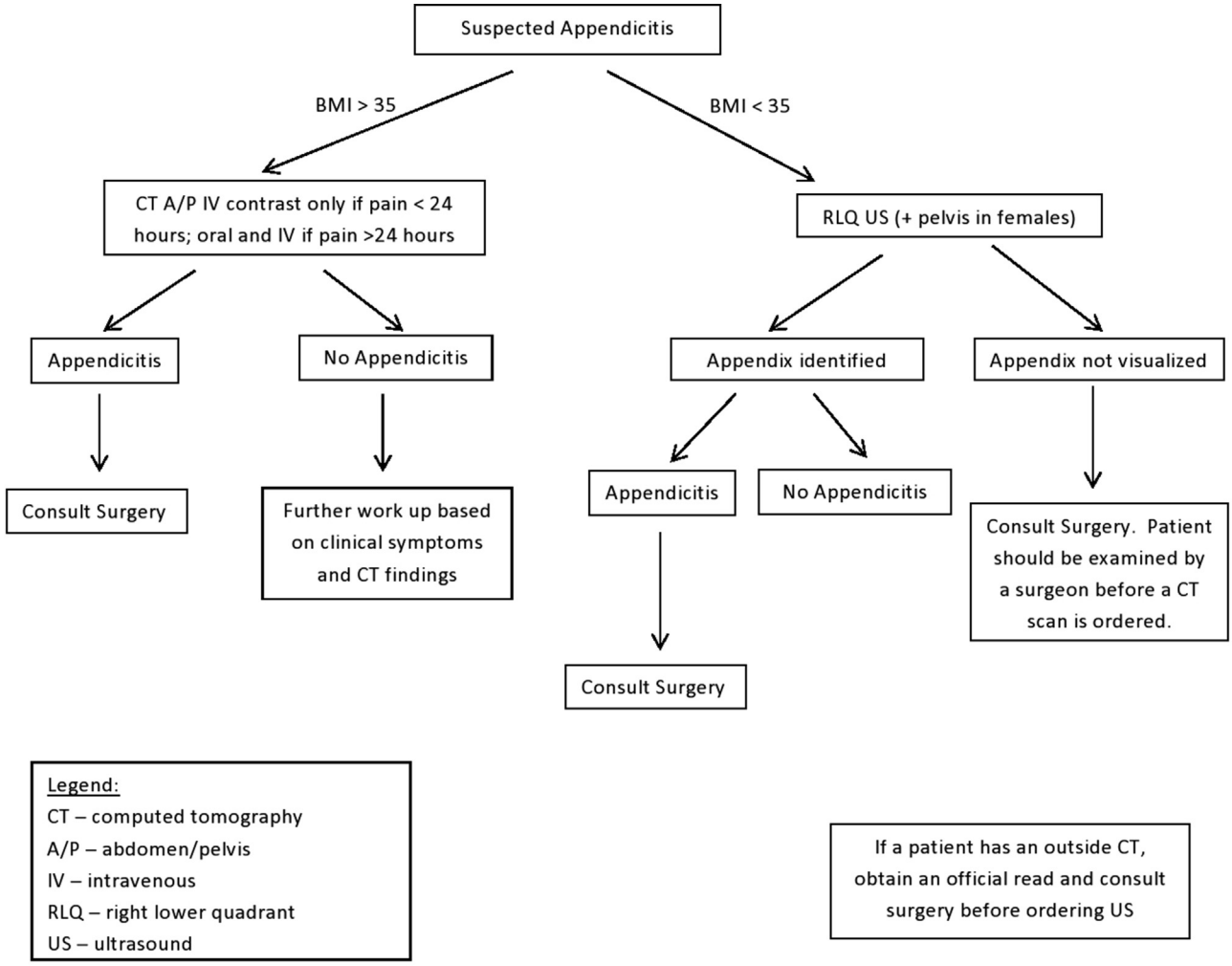


**Fig. 1.** Suspected appendicitis pathway algorithm.

## Methods

This was a retrospective observational study of patients evaluated for suspected appendicitis in the Emergency Department at a freestanding children's hospital. After receiving approval from the Institutional Review Board, all charts of patients who underwent abdominal imaging with CT or US in the Emergency Department were reviewed. Subjects were excluded if they were 18 years of age or older, underwent imaging for a suspected disease process other than appendicitis, or arrived with imaging (US, CT or MRI) from an outside source. It is uncommon for patients to arrive to our hospital with US or MRI imaging, as the vast majority of imaging obtained from non-pediatric centers are CT scans. Although in our clinical protocol we have guidelines in place to review outside imaging prior to ordering any new imaging on patients (Fig. 1), we chose to exclude all patients with outside imaging from inclusion in this study to more accurately evaluate the effect of our protocol on CT utilization rates at our hospital.

CT rates for diagnosis of appendicitis were compared before (July 2011–June 2012) and after (January 2013–June 2014) implementation of the protocol (July 2012), and monthly CT rates during the post-pathway period were calculated to assess trends in CT utilization. Data was compared using student's *t*-tests for continuous variables and chi-square tests for categorical variables. Criteria to confirm adherence to the pathway included: (1) US only was performed; (2) US and surgical evaluation were obtained prior to CT; or (3) CT was obtained in patients with a BMI $\geq$ 35. Pathology results were reviewed to determine effect on diagnostic accuracy.

## Results

Patients in the pre- and post-pathway implementation groups had similar baseline characteristics, although the pre-pathway group had a slightly higher weight (46.7 versus 41.4 Kg), which was not clinically relevant (Table 1). In the post-pathway period, US sensitivity was 70.8% and US specificity was 96.5%, while CT sensitivity was 91.3% and CT specificity was 90.9% (Table 2). While there were no changes in the accuracy of CT scans over time, Table 2 demonstrates that the diagnostic accuracy of US to detect appendicitis improved significantly over time with an increase in sensitivity from 19.2% to 70.8%. No subject with nondiagnostic or equivocal US findings underwent a second ultrasound exam to diagnose appendicitis.

CT use decreased significantly following pathway implementation from 94.2% (130/138) to 27.5% (78/284) ($p < 0.001$; Table 3). Linear regression of monthly CT utilization demonstrated that CT rates continued to trend down two years after pathway implementation (Fig. 2). Negative appendectomy rates remained low in

**Table 1**
Patient characteristics.

| | Total | July 2011–June 2012 | January 2013–June 2014 | p-value |
|---|---|---|---|---|
| | N = 422 | N = 138 | N = 284 | |
| Age, mean ± SD, yr | 10.1 ± 4.3 | 10.5 ± 4.4 | 9.9 ± 4.3 | 0.18 |
| Male, n (%) | 184 (43.6) | 56 (40.6) | 128 (45.1) | 0.44 |
| Weight, mean ± SD, Kg | 43.1 ± 23.4 | 46.7 ± 24.6 | 41.4 ± 22.6 | 0.03[a] |

SD – standard deviation.
[a] Significant at 0.05 level.

**Table 2**
Accuracy of ultrasound and CT scans over time.

| | July 2011–June 2012 | January 2013–June 2014 | p-value |
|---|---|---|---|
| Ultrasound sensitivity, % | 19.2 | 70.8 | <0.001[a] |
| Ultrasound specificity, % | 91.4 | 96.5 | 0.173 |
| Ultrasound positive predictive value, % | 45.5 | 88.9 | 0.003[a] |
| Ultrasound negative predictive value, % | 75.3 | 89.3 | 0.004[a] |
| CT sensitivity, % | 97.2 | 91.3 | 0.554 |
| CT specificity, % | 84.9 | 90.9 | 0.427 |
| CT positive predictive value, % | 71.4 | 80.8 | 0.419 |
| CT negative predictive value, % | 98.8 | 96.2 | 0.704 |

[a] Significant at 0.05 level.

**Table 3**
Outcomes.

| | July 2011–June 2012 | January 2013–June 2014 | p-value |
|---|---|---|---|
| CT rates, % | 94.2 | 27.5 | <0.001[a] |
| Negative appendectomy rates, % | 20.0 | 2.4 | 0.002[a] |

[a] Significant at 0.05 level.

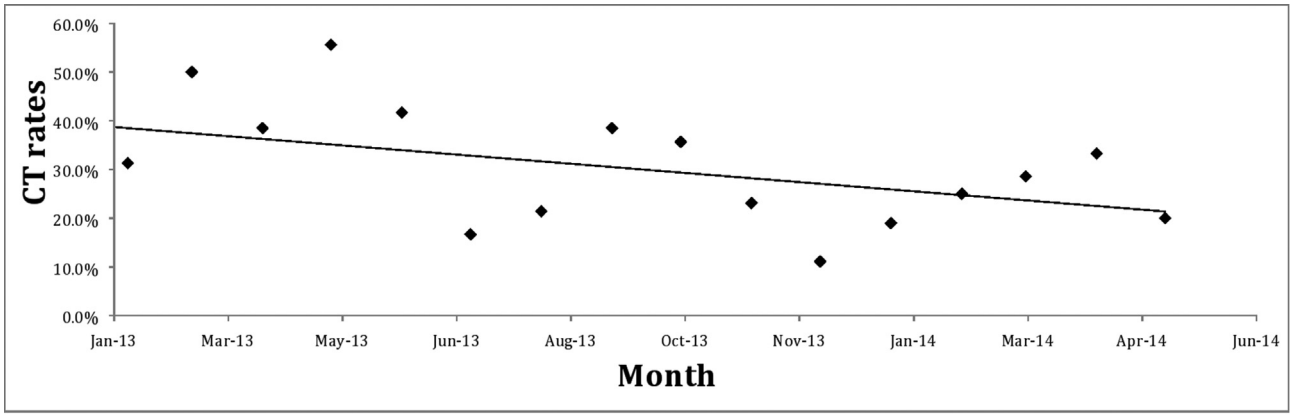


**Fig. 2.** Monthly CT rates post abdominal pathway implementation.

the post-pathway period and actually decreased after implementation of the pathway (Table 3). Overall adherence to the pathway was 89.8% (255/284).

## Discussion

Adherence to a pathway designed to evaluate pediatric patients with suspected appendicitis using ultrasound as the primary imaging modality led to a sustained decrease in CT use without compromising diagnostic accuracy in our study. Rates of CT utilization for this common pediatric surgical problem decreased by two-thirds in the post-pathway period, while the negative appendectomy rate was also reduced.

CT scans provide useful diagnostic information for a variety of medical conditions, and therefore their use has become widespread over the past several decades. However, the increased risk of cancer from ionizing radiation exposure has led to a movement to decrease unnecessary CT scans in the pediatric population. The clinical areas where this has the biggest impact are evaluation of children with suspected appendicitis and work-up of children who sustain blunt abdominal trauma.[15,16] The risks of radiation-induced malignancy vary based on age of patient and the dose of radiation exposure; however, it has been estimated that every 1000 to 1200 abdominal or head CTs performed on patients less than 15 years of age will lead to the development of a fatal cancer.[17,18] In our hospital, the reduction in CT rates from 94.2% to 27.5% avoided CT scans

in 190 patients during the post-pathway period, which saved over $87,000 in healthcare costs during this 18-month period.[6]

While recent studies have proposed MRI as first-line imaging approach to evaluate for appendicitis in children, the benefit of US as the initial imaging modality is that it avoids ionizing radiation exposure and is also less expensive than CT scans.[19–22] In one study that evaluated the use of MRI to evaluate appendicitis in children, the median length of time to perform an MRI was 21 min, necessitating the need for sedation in young children.[19] A CT scan requires only seconds to complete. Relying on MRI to diagnose appendicitis also has the potential to increase length of stay in the Emergency Department, as approximately 2 h lapsed before an MRI was performed after it was first ordered in this study.[19]

Healthcare costs in the United States lack transparency, so the true costs of these different imaging modalities are unclear. Reimbursement for imaging exams are broken down into two components: a technical component (cost of the procedure) and a professional component (cost of interpretation of the exam). As Medicaid is the largest insurer of children in the United States, Medicaid physician fee schedules may provide some insight into the different costs of these imaging techniques. However, these fee schedules vary widely between different state Medicaid programs.[23] In the state of Arkansas, the Medicaid fee schedule reimburses for an MRI abdomen/pelvis without contrast (CPT 74181 and 72195) at $1,059.67, with $840.29 attributed to the technical component and $219.38 reimbursed for the professional component. In contrast, a CT abdomen/pelvis with contrast (CPT 74177) receives a reimbursement of $315.22 ($206.27 technical component and $117.51 professional component), and a limited abdominal ultrasound (CPT 76705) receives a reimbursement of $80.30 ($27.30 technical component and $53.00 professional component).

Before the availability of current imaging techniques, a negative appendectomy rate as high as 20% for suspected appendicitis was considered acceptable. Currently published negative appendectomy rates have decreased to under 10% in the adult population and to under 5% in older children, possibly due to the availability of imaging studies.[24–32] However, for young children under the age of 5, negative appendectomy rates remain as high as 17%.[31] Other studies that analyzed the negative appendectomy rates in both adults and children failed to demonstrate a benefit from CT scan use.[33–39] Our study showed that the negative appendectomy rate improved when US replaced CT as the primary imaging modality. The reason for this finding is not entirely clear, although it could be attributed to false positive rates with CT. Some studies have demonstrated false positive findings when CT scans are used to diagnose appendicitis, although these false-positive errors are fairly low.[40] Accuracy of CT scans for diagnosing appendicitis is partly determined by prevalence of the disease in the population undergoing imaging.[41,42] Equivocal findings for appendicitis can be found on CT scans, although the majority of these patients are eventually found to not have appendicitis.[42] As CT scans began to be commonly ordered for all children with abdominal pain and less clinical evidence of appendicitis at our hospital, equivocal findings for appendicitis increased and may have led to our high negative appendectomy rates seen in the pre-pathway period. With our abdominal pain pathway in place, CT scans for suspected appendicitis were ordered more judiciously. The fact that our negative appendectomy rate did not worsen, and in fact improved, demonstrates that using US to initially evaluate for appendicitis is safe and effective.

It is not surprising that the diagnostic accuracy of US for the diagnosis of appendicitis improved over the study period since US has long been shown to be user-dependent.[43,44] There was no change in sonography or radiology staff when this study began. In-house training was provided to the sonographers, but all of the sonographers were inexperienced with appendiceal ultrasounds since our hospital had not been performing them prior to this time period. When ultrasound was first used to evaluate for appendicitis at our hospital, there was a learning curve before the sonographers became adept with this skill. There was also a learning curve for the radiologists who were interpreting the images.[41] Our radiologists did not perform the ultrasound exams themselves, so having the radiologists work closely with the sonographers to give feedback regarding both important positive and negative findings of appendicitis (ie – nonvisualization of appendix with no secondary signs) was a process that improved significantly over time.

Several studies in both children and adults have demonstrated lower sensitivity of US in detecting appendicitis in overweight or obese individuals. While the data from these studies demonstrated a statistically significant decrease in ultrasound sensitivity for diagnosis of appendicitis in teenagers and adults, the studies in children failed to show this trend to be statistically significant.[45,46] Obese children do have a statistically higher risk of non-visualization of the appendix with ultrasound, so a BMI of 35 was chosen as the limit for ultrasound use in our protocol as this indicates at least class II obesity in all age groups.[47] For these obese patients, a negative, nondiagnostic, or equivocal ultrasound finding would not be reliable to rule out appendicitis. Still, the lack of convincing data on this topic should prompt us to re-evaluate our protocol and consider using ultrasound as the primary imaging modality in our obese pediatric population, too.

In the post-pathway period, it was rare for a CT scan to be ordered prior to obtaining an ultrasound exam. The most common reason why the protocol was not adhered to was that general surgery was not consulted for evaluation prior to obtaining a CT scan. The protocol was created as a collaborative effort between the surgery and emergency medicine departments, and our department works closely with the emergency medicine department staff for a variety of conditions and injuries, such as trauma. However, when new personnel was involved, such as the hiring of new emergency medicine attendings and fellows, it took time to orient them to the protocol regarding early surgical evaluation before ordering CT scans on patients with suspected appendicitis. This likely contributed to our protocol adherence rate not being closer to 100%.

Evaluating and quantifying the effect of a policy is important for several reasons, including to ensure that the policy is having the anticipated desired effect, and that the effect is due to the mechanism hypothesized. For example, Antevil and colleagues hypothesized that the negative appendectomy rate would decrease after implementation of their pathway due to more selective use of CT scans.[48] However, while the negative appendectomy rate decreased significantly after this intervention, CT scan rates stayed the same, suggesting that the mechanism was not due to more selective CT scan utilization as the authors had concluded. Our study demonstrated that implementation of the abdominal pathway protocol successfully led to a decrease in rates of CT scans without negatively affecting the negative appendectomy rate.

One reason why our protocol was successful was that it was developed as a collaborative effort between the Surgery and Emergency Medicine departments. Both departments were invested in this project and in ensuring that we decreased CT utilization within our pediatric population. As we move forward, it is important that we continue to intermittently monitor adherence to the protocol to ensure that our rates of CT scans do not begin to and that our pathway does not have any negative unintended consequences such as an increase in missed appendicitis rates with initial ED evaluation. While our study focused on implementation of this protocol in a freestanding children's hospital, these pathways can also be successfully carried out for children being evaluated in the

Emergency Departments at adult hospitals. There is no reliable way to determine how often CT is used to diagnose appendicitis in hospitals across the country, but for centers still using CT as the primary imaging modality, this study demonstrates that US can be implemented safely and effectively as the initial imaging modality during evaluation of suspected appendicitis in the pediatric population.

## Conclusions

Our study evaluated the effects of an abdominal pathway for suspected appendicitis at a freestanding children's hospital to ensure that our patients received the best quality of care while minimizing their risks. Implementation of this protocol enhanced both quality and safety of patient care. Continued adherence to and effectiveness of a voluntary pathway that relies on safe imaging is reassuring and highlights the importance of ongoing assessment of the long-term impact of an institution's pathways.

## Conflict of interest

None of the authors have any financial conflicts of interests to declare, nor any relationships with organizations that could affect objectivity or inappropriately influence findings. There were no funding sources for this project.

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