Disclosures

- Nothing to disclose
Outline

- Clinical diagnosis of acute appendicitis.
- Imaging modalities and their utility in the diagnosis of acute appendicitis
  - Ultrasound (US)
  - Computed Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
- Imaging for complications of acute appendicitis
Acute Appendicitis

- Most common condition that requires acute surgical intervention in the pediatric population.
- Continues to cause significant morbidity despite improvement in its diagnosis and treatment.
- Complicated appendicitis can be prevented by earlier diagnosis.
Epidemiology

- Approximately 70,000 – 80,000 children are diagnosed annually in the United States
  - 1/1000 children per year
- Lifetime risk
  - 9% for boys
  - 7% for girls
- Peak incidence between 11 and 12 years of age
- Uncommon in children under 2 years
Presentation

- Classic Symptoms of Acute Appendicitis
  - Crampy periumbilical pain that migrates to Right Lower Quadrant (RLQ)
  - Nausea and vomiting
  - Anorexia
  - Fever
  - Point tenderness is RLQ
  - Leukocytosis with left shift
# Alvarado and Pediatric Appendicitis Scores

<table>
<thead>
<tr>
<th>Clinical Variable</th>
<th>Alvarado Score</th>
<th>PAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration of pain</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Anorexia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Right lower quadrant tenderness</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Rebound pain</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Elevated temperature*</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Leukocytosis ($\geq 10,000/\mu\text{L}$)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Shift of WBC count to the left ($\geq 75%$ polymorphonucleocytes)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cough/percussion/hopping cause pain in the RLQ</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>
Diagnostic dilemma

- Clinical diagnosis of acute appendicitis is not always straightforward.
- Abdominal pain is a common complaint in the pediatric population:
  - 4% of doctor visits
  - Most times is a self-limited condition
    - Viral syndrome, gastroenteritis, constipation, pharyngitis, among others.
Diagnostic Dilemma

- What about the classical symptoms??
  - Only one third of patients present with classical clinical symptoms.
  - Scores: A large number of patients fall in the equivocal range.

- Patients younger than 5 years cannot describe symptoms clearly.

- False-negative appendectomy rate: 11.83% from 1998-2007*
  - Declining
    - 14.7% in 1998
    - 8.47% in 2007

Morbidity and Mortality

- Delayed diagnosis can lead to perforation
  - Complications: abscess, sepsis, infertility, bowel obstruction and death.

- Perforation rate in the pediatric population is approximately 30%*
  - Higher in preschool children

- Death from appendicitis in general population is 1%

Why imaging?

- Help diagnose appendicitis earlier, therefore preventing complications.
- Reduce negative appendectomy rate
- Reduce length of stay and cost of treatment
US for Pediatric Appendicitis

- Graded-compression US has been used since mid 1980’s in the diagnosis of appendicitis

- Diagnostic accuracy has varied widely
  - Pooled Sensitivity: 88%; Pooled Specificity: 94%*

- In experienced hands and with the appropriate patient, it is a great imaging modality

Advantages of US

- Good in pediatric population because of small patient size.
- Fast and inexpensive modality.
- Portable
- No radiation
- Assess the appendix for compression
- Assess patients clinically
Protocol of US in Appendicitis

- **Order: US Appendix**
  - Ask patient to point with one finger where it hurts the most and image there
  - Compress Right Lower Quadrant (RLQ) attempting to decompress air filled bowel
    - Psoas muscle and iliac vessels are visualized.
  - Identify ascending colon move transducer inferiorly to identify terminal ileum
  - The appendix should be 1-2 cm below terminal ileum
Normal findings

- Smaller than 6 mm
- Compressible
- No free fluid
- Normal hypoechoic muscular layer and echogenic mucosa
Normal findings

- Smaller than 6 mm
- Compressible
- No free fluid
- Normal hypoechoic muscular layer and echogenic mucosa
Acute appendicitis

- Larger than 6 mm
- Non-compressible
- Hypervascular
- Appendicolith
- Associated findings:
  - Periappendiceal fat
  - Free fluid: adjacent to appendix and RLQ
  - Abscess
- Point tenderness over appendix
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  - Free fluid: adjacent to appendix and RLQ
  - Abscess
- Point tenderness over appendix
Most cases: Not Visualized
Disadvantages

- Very limited in obese and gassy patients
- Limited in the setting of severe pain preventing adequate compression
- Operator dependent:
  - Gives up too fast.
  - Different location of appendix
Not that simple

- Appendix can be in different locations
- Most common is retrocecal
  - Air in cecum obscures its visualization

http://www.anatomyatlases.org/AnatomicVariants/OrganSystem/Images/08.shtml
Different location
Disadvantages

- Very limited in obese and gassy patients
- Limited in the setting of severe pain preventing adequate compression
- Operator dependent:
  - Gives up too fast.
  - Different location of appendix
  - Looking too superficial in the RLQ
Looking too superficial
Performance of ultrasound in the diagnosis of appendicitis in children in a multicenter cohort.

Mittal MK¹, Dayan PS, Macias CG, Bachur RG, Bennett J, Dudley NC, Bajaj L, Sinclair K, Stevenson MD, Kharbanda AB; Pediatric Emergency Medicine Collaborative Research Committee of the American Academy of Pediatrics.

Abstract

OBJECTIVES: The objectives were to assess the test characteristics of ultrasound (US) in diagnosing appendicitis in children and to evaluate site-related variations based on the frequency of its use. Additionally, the authors assessed the test characteristics of US when the appendix was clearly visualized.

METHODS: This was a secondary analysis of a prospective, 10-center observational study. Children aged 3 to 18 years with acute abdominal pain concerning for appendicitis were enrolled. US was performed at the discretion of the treating physician.

RESULTS: Of 2,625 patients enrolled, 965 (36.8%) underwent abdominal US. US had an overall sensitivity of 72.5% (95% confidence interval [CI] = 58.8% to 86.3%) and specificity 97.0% (95% CI = 96.2% to 97.9%) in diagnosing appendicitis. US sensitivity was 77.7% at the three sites (combined) that used it in 90% of cases, 51.6% at a site that used it in 50% of cases, and 35% at the four remaining sites (combined) that used it in 9% of cases. US retained a high specificity of 96% to 99% at all sites. Of the 469 (48.6%) cases across sites where the appendix was clearly visualized on US, its sensitivity was 97.9% (95% CI = 95.2% to 99.9%), with a specificity of 91.7% (95% CI = 86.7% to 96.7%).

CONCLUSIONS: Ultrasound sensitivity and the rate of visualization of the appendix on US varied across sites and appeared to improve with more frequent use. US had universally high sensitivity and specificity when the appendix was clearly identified. Other diagnostic modalities should be considered when the appendix is not definitively visualized by US.
The diagnosis of appendicitis in children continues to be a challenging endeavor, despite advances in laboratory and imaging diagnosis. There is increasing concern for life-time radiation-induced malignancy risk associated with the use of computed tomography (CT). The study by Mittal et al provides both good and bad news about the use of US as the primary imaging modality for the diagnosis of suspected appendicitis. The good news in this multicenter observational study is that US had a specificity rate of >96% across all centers studied. The bad news is that the sensitivity was only 77% at the clinical sites with the highest utilization, and as low as 35% in those sites with the lowest use. This study makes clear that, regarding US for appendicitis, practice makes “better,” but not “perfect.” Thus, increasing a center’s experience with US will only go so far in improving diagnosis. Fortunately, there are several studies showing that US followed by CT in patients with nondiagnostic US studies is an efficient and effective approach. 1 Used together with validated decision support rules, the high specificity of US for appendicitis eliminates the need for many CT scans while preserving overall diagnostic accuracy in the clinical environment. 2 Early studies also point to a potential role for MRI as a substitute for CT in diagnostic protocols.
Computed Tomography
Computed Tomography

- Excellent modality for the evaluation of acute appendicitis

- Diagnostic accuracy better than US
  - Pooled Sensitivity: 94%; Pooled Specificity: 95%*

- Not operator dependent

- Identifies other pathology easier than US

Computed Tomography

- Although a great test, it is not perfect.
- Maximize the protocol to visualize appendix.
- Visualization of appendix is directly related to amount of peritoneal fat*
  - Little peritoneal fat: seen in 36% of cases
  - Moderate to marked fat: seen in 69% of cases

Suspected appendicitis in children: diagnostic importance of normal abdominopelvic CT findings with nonvisualized appendix.

Garcia K¹, Hernanz-Schulman M, Bennett DL, Morrow SE, Yu C, Kan JH.

Abstract

PURPOSE: To determine whether lack of visualization of the appendix on otherwise normal abdominopelvic computed tomographic (CT) images can help exclude appendicitis in the pediatric population.

MATERIALS AND METHODS: The study was institutional review board approved and HIPAA compliant. One thousand one hundred thirty-nine children suspected of having appendicitis were referred for CT examination between July 2002 and December 2006. Exclusion criteria included CT diagnosis of appendicitis or other cause of symptoms and lack of clinical follow-up. Consensus review was performed by two pediatric radiologists to determine normal examinations, leaving a final study group (nonvisualized appendix) of 156 patients (mean age, 9.6 years; boys, 7.2 years; girls, 10.2 years) and a control group (visualized appendix) of 421 patients (mean age, 11.0 years; boys, 9.8 years; girls, 11.2 years). In the control group, there were 168 subjects with a partially visualized (PV) appendix and 253 with a fully visualized (FV) appendix. Pericecal fat was graded according to published criteria. Diagnosis was confirmed at surgery or clinical follow-up. Negative predictive values were calculated with 95% confidence intervals (CIs).

RESULTS: There were three false-negative findings (study group, two; control group, one [FV]). The negative predictive value of a normal CT examination in pediatric patients with a nonvisualized appendix was 98.7% (95% CI: 95.5%, 99.8%); that with a visualized appendix, 99.8% (95% CI: 98.7%, 99.99%); that with a PV appendix, 100% (95% CI: 97.8%, 100%); and that with a FV appendix, 99.6% (95% CI: 97.8%, 99.99%).

CONCLUSION: Pediatric abdominopelvic CT images with nonvisualized appendix have a high negative predictive value, without significant difference from cases with a PV or even FV appendix. The false-negative rate was similar to those reported in two adult series.
Computed Tomography

- Different ways to order
  - Abdomen/Pelvis versus Pelvis only
Suspected appendicitis in children: focused CT technique for evaluation.

Fefferman NR\textsuperscript{1}, Roche KJ, Pinkney LP, Ambrosino MM, Genieser NB.

Author information

Abstract

\textbf{PURPOSE:} To determine the accuracy of a focused computed tomographic (CT) technique with oral and intravenous contrast materials for the diagnosis of appendicitis.

\textbf{MATERIALS AND METHODS:} Ninety-three abdominal-pelvic contrast material-enhanced CT scans obtained during 6 years in 54 girls and 39 boys (age range, 1-18 years) with right lower quadrant pain were retrospectively reviewed. The detected abnormal findings were recorded as being in the region above the upper pole of the right kidney, between the upper pole of the right kidney and the lower pole of the right kidney (RLP), or below the iliac crest. Sensitivity, specificity, and positive and negative predictive values were calculated. \textit{chi(2)} analysis was performed to determine whether there were significant differences among patient groups according to region of detected disease.

\textbf{RESULTS:} Fifty-five scans were abnormal: 38 showed appendicitis; and 17, other diseases. No scans, except two that showed pneumonia, had key findings above the RLP. Nineteen scans showed key findings between the RLP and the iliac crest. Thirty-three scans had diagnostic findings only below the iliac crest. The sensitivity (97\%), specificity (93\%), positive predictive value (90\%), and negative predictive value (98\%) of interpretation with all images for the diagnosis of appendicitis were the same as those of interpretation with only the focused images.

\textbf{CONCLUSION:} CT performed to diagnose appendicitis can be limited to the region below the RLP.
Computed Tomography

- Different ways to order
  - Abdomen and Pelvis versus Pelvis only
  - Intravenous contrast
  - Enteric contrast:
    - Oral versus rectal contrast

- Appendicitis Protocol at our hospital
  - Pelvis Only with IV and rectal contrast
Computed tomography

- Normal appendix: tubular and blind ending structure arising from cecum
  - Air/contrast filled
  - 7 mm or less in children
  - The appendix can be larger and normal as long as there is no surrounding inflammation
- No RLQ inflammatory changes
- Another cause for pain
CT- Acute appendicitis

- Abnormal appendix
  - Thick measuring greater than 7 mm in diameter from outer to outer wall
  - Fluid filled
  - Hyperenhancement of wall
  - Wall discontinuity in perforation
- Appendicolith
- Surrounding inflammation and free fluid
- Reactive lymph nodes
- Complications
Main disadvantage of CT

- Radiation exposure
  - Children are more radiosensitive than adults
  - 5 mSv with correct age-adjusted parameters*
    - Low but not negligible as it is not known how this will increase cancer risk

Radiation reduction

- Dedicated pediatric CT parameters
  - Which can adjust dose to age and size
- Limiting the area of imaging
- Combining sonography and/or appendicitis scoring techniques with CT
Effectiveness of a staged US and CT protocol for the diagnosis of pediatric appendicitis: reducing radiation exposure in the age of ALARA.

Krishnamoorthi R¹, Ramarajan N, Wang NE, Newman B, Rubesova E, Mueller CM, Barth RA.

Abstract

PURPOSE: To evaluate the effectiveness of a staged ultrasonography (US) and computed tomography (CT) imaging protocol for the accurate diagnosis of suspected appendicitis in children and the opportunity for reducing the number of CT examinations and associated radiation exposure.

MATERIALS AND METHODS: This retrospective study was compliant with HIPAA, and a waiver of informed consent was approved by the institutional review board. This study is a review of all imaging studies obtained in children suspected of having appendicitis between 2003 and 2008 at a suburban pediatric emergency department. A multidisciplinary staged US and CT imaging protocol for the diagnosis of appendicitis was implemented in 2003. In the staged protocol, US was performed first in patients suspected of having appendicitis; follow-up CT was recommended when US findings were equivocal. Of 1228 pediatric patients who presented to the emergency department for suspected appendicitis, 631 (287 boys, 344 girls; age range, 2 months to 18 years; median age, 10 years) were compliant with the imaging pathway. The sensitivity, specificity, negative appendectomy rate (number of appendectomies with normal pathologic findings divided by the number of surgeries performed for suspected appendicitis), missed appendicitis rate, and number of CT examinations avoided by using the staged protocol were analyzed.

RESULTS: The sensitivity and specificity of the staged protocol were 98.6% and 90.6%, respectively. The negative appendectomy rate was 8.1% (19 of 235 patients), and the missed appendicitis rate was less than 0.5% (one of 631 patients). CT was avoided in 333 of the 631 patients (53%) in whom the protocol was followed and in whom the US findings were definitive.

CONCLUSION: A staged US and CT imaging protocol in which US is performed first in children suspected of having acute appendicitis is highly accurate and offers the opportunity to substantially reduce radiation.
Value of Focused Appendicitis Ultrasound and Alvarado Score in Predicting Appendicitis in Children: Can We Reduce the Use of CT?

Blitman NM, Anwar M, Brady KB, Taragin BH, Freeman K.

Abstract

OBJECTIVE: The purpose of this study was to evaluate the effectiveness of focused appendicitis ultrasound combined with Alvarado score to accurately identify appendicitis in children in whom it is suspected, thereby reducing unnecessary CT examinations and associated radiation exposure.

MATERIALS AND METHODS: We retrospectively evaluated the focused appendicitis ultrasound, CT, clinical, and laboratory findings of 522 consecutively registered children (231 boys, 291 girls; mean age, 13.04 [SD, 5.02] years; range, 0.74 months-21 years) who underwent focused appendicitis ultrasound for abdominal pain in a pediatric emergency department from January 2008 through October 2009. All children underwent surgery or clinical follow-up to exclude missed appendicitis. Sonographic findings were characterized as positive, negative, or inconclusive (appendix not visualized). Alternative diagnoses were noted. Alvarado score (0-10 points based on multiple clinical criteria) was determined. Focused appendicitis ultrasound and Alvarado score results were compared with surgical and pathologic reports.

RESULTS: Both focused appendicitis ultrasound results and Alvarado score were associated with likelihood of surgery for appendicitis (p = 0.0001). Focused appendicitis ultrasound had conclusive results: 105 positive and 27 negative in 132 of 522 (25.2%) children. In the 390 of 522 (74.7%) children with inconclusive focused appendicitis ultrasound findings, 43 of 390 (11.0%) eventually had a diagnosis of appendicitis with CT (n = 26) or Alvarado score (n = 17). Among children with inconclusive focused appendicitis ultrasound findings and an Alvarado score less than 5 (241/522, 46.1%), only one patient had appendicitis. The negative predictive value (NPV) of inconclusive ultrasound findings and low Alvarado score combined was 99.6%. Among children with inconclusive focused appendicitis ultrasound findings and an Alvarado score of 5-8, the NPV decreased to 89.7%.

CONCLUSION: Children with inconclusive focused appendicitis ultrasound findings and a low Alvarado score are extremely unlikely to have appendicitis (NPV, 99.6%). Avoiding unnecessary CT of these patients is a safe approach to diagnosis.
Pediatric CT dose reduction for suspected appendicitis: a practice quality improvement project using artificial Gaussian noise--part 1, computer simulations.

Callahan MJ¹, Kleinman PL, Strauss KJ, Bandos A, Taylor GA, Tsai A, Kleinman PK.

Abstract

OBJECTIVE: The purpose of this study was to develop a departmental practice quality improvement project to systematically reduce CT doses for the evaluation of suspected pediatric appendicitis by introducing computer-generated gaussian noise.

MATERIALS AND METHODS: Two hundred MDCT abdominopelvic examinations of patients younger than 20 years performed with girth-based scanning parameters for suspected appendicitis were reviewed. Two judges selected 45 examinations in which the diagnosis of appendicitis was excluded (14, appendix not visualized; 31, normal appendix visualized). Gaussian noise was introduced into axial image series, creating five additional series acquired at 25-76% of the original dose. Two readers reviewed 270 image series for appendix visualization (4-point Likert scale and arrow localization). Volume CT dose index (CTDivol) and size-specific dose estimate (SSDE) were calculated by use of patient girth. Confidence ratings and localization accuracy were analyzed with mixed models and nonparametric bootstrap analysis at a 0.05 significance level.

RESULTS: The mean baseline SSDE for the 45 patients was 16 mGy (95% CI, 12-20 mGy), and the corresponding CTDIvol was 10 mGy (95% CI, 4-16 mGy). Changes in correct appendix localization frequencies were minor. There was no substantial trend with decreasing simulated dose level (p = 0.46). Confidence ratings decreased with increasing dose reduction (p = 0.007). The average decreases were -0.27 for the 25% simulated dose (p = 0.01), -0.17 for 33% (p = 0.03), and -0.03 for 43% (p = 0.65).

CONCLUSION: Pediatric abdominal MDCT can be performed with 43% of the original dose (SSDE, 7 mGy; CTDIvol, 4.3 mGy) without substantially affecting visualization of a normal appendix.
Pediatric CT dose reduction for suspected appendicitis: a practice quality improvement project using artificial gaussian noise—part 2, clinical outcomes.

Callahan MJ, Anandalwar SP, MacDougall RD, Stamoulis C, Kleinman PL, Rangel SJ, Bachur RG, Taylor GA.

Abstract
OBJECTIVE. The purpose of this study was to determine the effect of a nominal 50% reduction in median absorbed radiation dose on sensitivity, specificity, and negative appendectomy rate of CT for acute appendicitis in children. MATERIALS AND METHODS. On the basis of a departmental practice quality improvement initiative using computer-generated gaussian noise for CT dose reduction, we applied a nominal dose reduction of 50% to abdominal CT techniques used for bowel imaging. This retrospective study consisted of 494 children who underwent a CT for suspected acute appendicitis before \( n = 244 \); mean age, 133 months) and after \( n = 250 \); mean age, 145 months) the nominal 50% dose reduction. Test performance characteristics of CT for acute appendicitis and impact on the negative appendectomy rate were compared for both time periods. Primary analyses were performed with histologic diagnosis as the outcome standard. Volume CT dose index and dose-length product were recorded from dose reports and size-specific dose estimates were calculated. RESULTS. The nominal 50% dose reduction resulted in an actual 39% decrease in median absorbed radiation dose. Sensitivity of CT for diagnosis of acute appendicitis was 98% (95% CI, 91-100%) versus 97% (91-100%), and specificity was 93% (88-96%) versus 94% (90-97%) before and after dose reduction, respectively. The negative appendectomy rate was 4.5% (0.8-10.25%) before dose reduction and 4.0% (0.4-7.6%) after dose reduction. CONCLUSION. The negative appendectomy rate and performance characteristics of the CT-based diagnosis of acute appendicitis were not affected by a 39% reduction in median absorbed radiation dose.
What else can be done to reduce radiation exposure??
Magnetic Resonance Imaging
Magnetic Resonance Imaging

- **Advantages**
  - No radiation
  - Not operator dependent like CT
  - CT like images

- **Disadvantages**
  - Long scan times
  - Limited availability
  - Highly sensitive to motion
  - Scary for children: noise and small space
  - Expensive
Evidence for MRI

MRI for clinically suspected pediatric appendicitis: an implemented program.

Moore MM, Gustas CN, Choudhary AK, Methratta ST, Hulse MA, Geeting G, Eggli KD, Boal DK.

Author information

Abstract

BACKGROUND: Emergent MRI is now a viable alternative to CT for evaluating appendicitis while avoiding the detrimental effects of ionizing radiation. However, primary employment of MRI in the setting of clinically suspected pediatric appendicitis has remained significantly underutilized.

OBJECTIVE: To describe our institution's development and the results of a fully implemented clinical program using MRI as the primary imaging evaluation for children with suspected appendicitis.

MATERIALS AND METHODS: A four-sequence MRI protocol consisting of coronal and axial single-shot turbo spin-echo (SS-TSE) T2, coronal spectral adiabatic inversion recovery (SPAIR), and axial SS-TSE T2 with fat saturation was performed on 208 children, ages 3 to 17 years, with clinically suspected appendicitis. No intravenous or oral contrast material was administered. No sedation was administered. Data collection includes two separate areas: time parameter analysis and MRI diagnostic results.

RESULTS: Diagnostic accuracy of MRI for pediatric appendicitis indicated a sensitivity of 97.6% (CI: 87.1-99.9%), specificity 97.0% (CI: 93.2-99.0%), positive predictive value 88.9% (CI: 76.0-96.3%), and negative predictive value 99.4% (CI: 96.6-99.9%). Time parameter analysis indicated clinical feasibility, with time requested to first sequence obtained mean of 78.7 +/- 52.5 min, median 65 min; first-to-last sequence time stamp mean 14.2 +/- 8.8 min, median 12 min; last sequence to report mean 57.4 +/- 35.2 min, median 46 min. Mean age was 11.2 +/- 3.6 years old. Girls represented 57% of patients.

CONCLUSION: MRI is an effective and efficient method of imaging children with clinically suspected appendicitis. Using an expedited four-sequence protocol, sensitivity and specificity are comparable to CT while avoiding the detrimental effects of ionizing radiation.
Evidence for MRI

Utility of MRI after inconclusive ultrasound in pediatric patients with suspected appendicitis: retrospective review of 60 consecutive patients.

Herliczek TW, Swenson DW, Mayo-Smith WW.

Abstract

OBJECTIVE: The purpose of this study is to examine the utility of appendix MRI in evaluation of pediatric patients with right lower quadrant pain and inconclusive appendix sonography findings.

MATERIALS AND METHODS: A search of the radiology electronic database was performed for all appendix MRI examinations performed of pediatric patients within 24 hours after inconclusive appendix sonography from December 1, 2009, through April 26, 2012. Sixty patients underwent appendix MRI within 24 hours of inconclusive sonography and represented the study cohort. MRI examinations were reviewed independently by two radiologists blinded to the diagnosis and were graded as “positive,” “negative,” or “indeterminate” for acute appendicitis. The final diagnosis was established by review of the surgical and pathology reports and patients’ electronic medical records.

RESULTS: Ten of 60 patients (17%) had acute appendicitis. Both readers graded the same 12 examinations as positive and the same 48 examinations as negative for acute appendicitis, with a kappa value of 1.00 (expected agreement, 0.695). No MRI examination was interpreted as indeterminate. The sensitivity and specificity of MRI for acute appendicitis in children with inconclusive appendix ultrasound findings were 100% (95% CI, 0.72-1.00) and 96% (95% CI, 0.87-0.98), respectively. The positive predictive value for the examination was 83%, the negative predictive value was 100%, and overall test accuracy was 97%.

CONCLUSION: Our study shows that MRI has a sensitivity of 100% and specificity of 96% for appendicitis in pediatric patients after inconclusive appendix sonography. We think that MRI may supplant CT as the secondary modality to follow inconclusive appendix sonography.

Koning JL, Naheedy JH, Kruk PG.

Abstract

OBJECTIVE: Unenhanced MRI has emerged as a useful tool for diagnosing pediatric acute appendicitis. The use of contrast-enhanced MRI for diagnosing pediatric appendicitis has not been documented. The purpose of this study is to examine the diagnostic performance of contrast-enhanced MRI for acute appendicitis and alternative entities in the pediatric population presenting with acute abdominal pain.

MATERIALS AND METHODS: A retrospective review was conducted of 364 consecutive pediatric patients undergoing contrast-enhanced MRI for the evaluation of possible appendicitis at a single institution between November 2012 and September 2013.

RESULTS: There were 132 cases of pathologically confirmed appendicitis out of 364 pediatric patients (36.3%) included in the study. Overall sensitivity and specificity were 96.2% (95% CI [91.4-98.4%]) and 95.7% (95% CI [92.3-97.6%]), respectively. Positive predictive value and negative predictive value were 92.7% (95% CI [86.6-96.3%]) and 97.8% (95% CI [94.7-99.1%]), respectively. The appendix was visualized in 243 cases (66.8%). Imaging confirmed alternative diagnoses in 75 patients, including most commonly colitis, enteritis or terminal ileitis (n = 25, 6.9%), adnexal cysts (n = 25, 6.9%) and mesenteric adenitis (n = 7, 1.9%).

CONCLUSION: Contrast-enhanced MRI is capable of accurately diagnosing acute appendicitis while detecting many alternative entities of abdominal pain, and it allows good visualization of the appendix. Further evaluation is needed to determine whether contrast-enhanced MRI provides an advantage over non-enhanced MRI for imaging evaluation of acute abdominal pain in the pediatric population.
Given advantages and mounting evidence for MRI in the diagnosis of acute appendicitis, we decided to start an Appy MRI program in our ED which started on 2/9/15.
Our MRI Program

- Done in conjunction with the ED, pediatric surgery, pediatrics and child life department.
- Did not require IRB approval
- M-F, exams ordered through ED 8AM – 5PM
- Age guidelines: 7 years and older
- Limited length of study (goal < 20 min.)
- Goal: Consistently move the needle towards or away from appendicitis, limiting the use of CT
- Support Image Gently and ALARA principles
Our current MRI protocol

- Axial SS FSE T2 FS (breath hold)
- Coronal SS FSE (breath hold)
- Axial pre-contrast
- Axial and Coronal post (LAVA)
MRI in Appendicitis

- **Negative**
  - Normal appendix less than 7 mm thick
  - No inflammation or large amount of free fluid

- **Positive**
  - Fluid-filled and thick appendix measuring >7mm
  - Wall hyperenhancement
  - Appendicolith
  - Inflammatory changes
  - Free fluid
  - Abscess
MRI in Appendicitis

- Normal appendix can be difficult to visualize in MRI
- Like in CT the lack of secondary findings is highly suggestive of a normal study*
- Try to place results in terms of:
  - Positive
  - Equivocal positive
  - Indeterminate
  - Equivocal negative
  - Negative

MRI in Appendicitis

- Alternative diagnosis and unexpected findings:
  - Most negative cases have no clear alternate diagnosis
  - Hydronephrosis
  - Musculoskeletal abnormality
  - Horseshoe kidney
  - Ovarian cyst
Right Hydronephrosis
Horseshoe Kidney
Right ovarian hemorrhagic cyst
Our MRI Program so far...

- Through 7/7/2015
- 65 cases total
- 11 called Positive or Equivocal Positive
  - 10/11 cases have positive pathology
  - 1/11 managed non-operatively with clinical findings not suggesting appendicitis (false positive)
  - Vast majority of other cases have follow-up at least through discharge, with no known false negative cases
Dealing with MRI disadvantages

- **Long Scan Times**
  - Time to image patients (scan time goal is average of 20 minutes or less):
    - Time from start to finish imaging (April/May/June):
      - Average: 21 minutes
      - Median: 19 minutes
Dealing with MRI disadvantages

- Limited availability
  - Time to get patients on the table (goal is average of 120 minutes or less):
    - Time from exam order to start imaging (April/May/June):
      - Average: 97 minutes
      - Median: 78 minutes
  - Using Pediatric Appendicitis Score to guide which cases get MRI
Prospective evaluation of a clinical pathway for suspected appendicitis.

Saucier A¹, Huang EY, Emeremni CA, Pershad J.

Abstract

OBJECTIVE: To evaluate the diagnostic accuracy of a clinical pathway for suspected appendicitis combining the Samuel's pediatric appendicitis score (PAS) and selective use of ultrasonography (US) as the primary imaging modality.

METHODS: Prospective, observational cohort study conducted at an urban, academic pediatric emergency department. After initial evaluation, patients were determined to be at low (PAS 1-3), intermediate (PAS 4-7), or high (PAS 8-10) risk for appendicitis. Low-risk patients were discharged with telephone follow-up. High-risk patients received immediate surgical consultation. Patients at intermediate risk for appendicitis underwent US.

RESULTS: Of the 196 patients enrolled, 65 (33.2%) had appendicitis. An initial PAS of 1-3 was noted in 44 (22.4%), 4-7 in 119 (60.7%), and 8-10 in 33 (16.9%) patients. Ultrasonography was performed in 128 (65.3%) patients, and 48 (37.5%) were positive. An abdominal computed tomography scan was requested by the surgical consultants in 13 (6.6%) patients. The negative appendectomy rate was 3 of 68 (4.4%). Follow-up was established on 190 of 196 (96.9%) patients. Overall diagnostic accuracy of the pathway was 94% (95% confidence interval [CI] 91%-97%) with a sensitivity of 92.3% (95% CI 83.0%-97.5%), specificity of 94.7% (95% CI 89.3%-97.8%), likelihood ratio (+) 17.3 (95% CI 8.4-35.6) and likelihood ratio (-) 0.08 (95% CI 0.04-0.19).

CONCLUSIONS: Our protocol demonstrates high sensitivity and specificity for diagnosis of appendicitis in children. Institutions should consider investing in resources that increase the availability of expertise in pediatric US. Standardization of care may decrease radiation exposure associated with use of computed tomography scans.
PAS in Article

- **PAS Score**
  - 0-3: Low likelihood
  - 4-7: Intermediate likelihood
  - 8-10: Elevated likelihood

- **In the article:**
  - 196 patients followed
  - 65 positive appendicitis cases
  - 0/65 positive cases had low PAS
  - 31% of intermediate cases were positive
  - 85% of elevated cases were positive
  - 1 of 3 negative appendectomies had a low PAS
Dealing with MRI disadvantages

- Motion and Scary for children
  - No sedation has been used
  - Patients over 7 years of age
  - Child life involved in program preparing patients for the MRI
  - Short scan time
Dealing with MRI disadvantages

- **Cost**
  - We have been tracking payment
  - Difficult to accurately gauge cost
  - Comparing MRI alone to US +/- CT or MRI
  - An area of future research
What we have learned so far?

- MRI is excellent imaging modality for acute appendicitis without ionizing radiation.
Complicated Appendicities
Presentation and Symptoms

- The longer the symptoms the more likely to have complications
- More common in children younger than 5 years
- Generalized abdominal pain
- Very elevated fever and white count
Imaging Findings

- Very dilated appendix which
- Wall discontinuity
- Large amount of free fluid
- Pneumoperitoneum
- Extraluminal appendicolith
- Abscess
Importance

- Although different opinions on how to treat, some surgeons prefer non-operative treatment of complicated appendicitis:
  - Treat abscess, antibiotics and then do interval appendectomy
  - Hostile abdominal environment for surgery
  - Decreases further complications
  - Earlier recovery
What imaging modality?

- Ultrasound or now with MRI to start
- Abscess: IR consult for percutaneous drainage
- Vast majority of cases a CT will be ordered
  - Evaluate for additional collections
  - Better delineate anatomy
- IR will drain the abscess
  - With CT or US Guidance
Complications after Appendectomy

- Patients with persistent fever and abdominal pain despite appendectomy

- When to image?
  - Immediately post op patients will have heterogeneous free fluid
  - Post operative abscess takes at least 5 days to develop
Postoperative timing of computed tomography scans for abscess in pediatric appendicitis

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Received: January 7, 2015; Received in revised form: March 10, 2015; Accepted: March 27, 2015; Published Online: May 16, 2015

Abstract

Background
One-quarter to one half of pediatric appendicitis patients present with ruptured appendicitis and about 3%–25% go on to form postoperative intra-abdominal abscesses. The optimal timing of postoperative imaging for suspected abscess formation has been a subject of debate.

Methods
All patients who underwent appendectomy for complex appendicitis and were not discharged before postoperative day (POD) #5 from April 2012–October 2014 were identified. Patients were stratified into groups for comparison as follows: group 1 had postoperative computed tomography (CT) scans before POD#7 (n = 26) and group 2 did not (n = 169). Group 2 was further divided into those who were afebrile (group 2a, n = 106) or febrile (group 2b, n = 63) at POD#5.

Results
A total of 195 patients met criteria. Early use of CT scans resulted in more drainage procedures (group 1, 73.1% versus group 2b, 28.6%, P < 0.001) and a higher recurrent CT scan rate (38.5% versus 9.5%). The groups had equivalent lengths of stay (11.9 versus 9.8 d, P = 0.10) and readmission rates due to abscesses (19.2% group 1 versus 6.3%, group 2b, P = 0.12) with no septic events. In total, 130 of the 169 patients (76.9%) in group 2 had resolution of symptoms before discharge without intervention with readmission for abscess in only 5.9%.

Conclusions
Waiting until POD#7 before scanning led to fewer drainage procedures and recurrent CT scans without increasing length of stay or readmission rates. Most complex appendicitis patients still admitted at POD#5 had resolution of symptoms without need for intervention.
Complications after Appendectomy

- What imaging modality?
  - Start with ultrasound to look for fluid on at least day 5 post appendectomy
  - A CT may be needed to confirm presence of abscess and for drainage planning
Conclusions

- Acute appendicitis, although common, remains a diagnostic dilemma and can cause significant morbidity.

- CT remains the gold standard in the imaging of acute appendicitis but utilizes ionizing radiation.

- MRI is an excellent modality for the diagnosis of acute appendicitis but is not always feasible.

- CT is still widely used, especially in the setting of complicated appendicitis. Therefore, radiation reducing techniques are critically important.
Thank You! Special thanks to Dr. Rich Heller.

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