Appy Hour:
MRI as a useful 1st line imaging modality

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SCORCH 2015

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DISCLOSURES

- Advisor to OCA Ventures
SPECIAL THANK YOU: to Dr. M. Callahan, Boston Children’s Hospital, from whom the title of this talk was blatantly stolen.

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Take Home Points

• US is a useful 1st-line imaging modality but it may have significant limitations in many institutions.

• MRI is an emerging modality that seeks to combine the best of both US (no radiation) and CT (not operator dependant).

• With use of clinical screening (a scoring system, like APS), we can limit imaging and resource utilization.
Requisite Slide on Appendicitis

- The most common atraumatic cause of a surgical abdomen in children
- Important to make prompt diagnosis as both morbidity and mortality increase with delay and perforation
- Many other illnesses, surgical and non-surgical, may mimic acute appendicitis
- A challenging but less common diagnosis in younger children
General Imaging Goals

• Make a **prompt, safe & accurate** diagnosis

• What does that mean?
  • Make a timely diagnosis
    • Limit time in the ED
    • Before perforation
  • Imaging vs admission for observation
  • Limit number of imaging tests done (ie X-ray, MRI, US, CT)
  • Limit radiation exposure
  • Make the correct diagnosis

• *Increasingly important:* Cost-efficient diagnosis
Specific Imaging Goals

- Diagnose or exclude appendicitis
- Evaluate for complications of appendicitis (such as abscess)
- Diagnose alternative causes of pain
- Do all this with least amount of discomfort and harm (e.g., radiation) to child
Imaging Modalities

- **Plain films:**
  - Unless concern for bowel obstruction or perforation, no role

- **US:**
  - No radiation
  - Operator dependent

- **CT:**
  - Radiation
  - Non-operator dependent

- **MRI:**
  - No Radiation
  - Non-operator dependent
Imaging Modalities: US

- Problems with US:
  - Operator dependant
  - Requires experience and practice
  - Body habitus limitations
  - Obscured by bowel
  - Radiology and sonographer confidence, especially off-hours
  - Length of exam time
Imaging Modalities: CT
CT: Technique

- Lots of ways to perform:
  - IV contrast? YES
  - Oral Contrast? I prefer it.
  - Rectal Contrast? We use it.
  - Full abdomen and pelvis? Just pelvis?
- Our “Appy CT”: Pelvic CT with IV and enteric (rectal) contrast
- No matter what, same downside: Radiation Exposure
Imaging Modalities: US vs CT

- Much controversy about how and when to use CT or US
- Much of the evidence seems to indicate that while CT is statistically more sensitive, US can be rather good and avoids radiation
Abdominal ultrasound is specific but insufficiently sensitive in diagnosing appendicitis

Question Among children with acute abdominal pain concerning for appendicitis, what is the diagnostic accuracy of abdominal ultrasound (US), compared with pathology, operative reports, or telephone follow-up, in diagnosing appendicitis? Design Secondary analysis of a prospective, observational study. Setting 10 pediatric emergency departments across the United States. Participants Children, ages 3 to 18 years, with acute abdominal pain concerning for appendicitis. Intervention Abdominal US obtained by clinicians at their discretion. Outcomes Final diagnosis of appendicitis was determined by pathology, operative reports, or telephone follow-up. Main Results US had an overall sensitivity of 72.5% (95% CI, 58.8% to 86.3%) and specificity of 97.0% (95% CI = 96.2% to 97.9%), positive likelihood ratio (+LR) of 24.5 (95% CI, 15.6 to 38.3), and negative likelihood ratio (–LR) of 0.28 (95% CI, 0.24 to 0.34), 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%), +LR 11.8 (95% CI, 7.7 to 18.2), and –LR 0.02 (95% CI, 0.009 to 0.05). Conclusions US 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.

Commentary 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.

George A. Taylor, MD, FACR
Harvard Medical School
Boston, Massachusetts
Pediatrics, March 2014
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.
OBJECTIVE: Accurate, timely diagnosis of pediatric appendicitis minimizes unnecessary operations and treatment delays. Preoperative abdominal-pelvic computed tomography (CT) scan is sensitive and specific for appendicitis; however, concerns regarding radiation exposure in children obligate scrutiny of CT use. Here, we characterize recent preoperative imaging use and accuracy among pediatric appendectomy subjects.

METHODS: We retrospectively reviewed children who underwent operations for presumed appendicitis at a single tertiary-care children’s hospital and examined preoperative CT and ultrasound use with subject characteristics. Preoperative imaging accuracy was compared with postoperative and histologic diagnosis as the reference standard.

RESULTS: Most children (395/423, 93.4%) who underwent an operation for appendicitis during 2009–2010 had preoperative imaging. Final diagnoses included normal appendix (7.3%) and perforated appendicitis (23.6%). In multivariable analysis, initial evaluation at a community hospital versus the children’s hospital was associated with 4.4-fold higher odds of obtaining a preoperative CT scan \((P = .002)\), whereas preoperative ultrasound was less likely (odds ratio 0.20; \(P = .003)\). Ultrasound and CT sensitivities for appendicitis were diminished for studies performed at community hospitals compared with the children’s hospital. Girls were 4.5-fold more likely to undergo both ultrasound and CT scans and were associated with lower ultrasound sensitivity for appendicitis.

CONCLUSIONS: Widespread preoperative imaging did not eliminate unnecessary pediatric appendectomies. Controlling for factors potentially associated with referral bias, a CT scan was more likely to be performed in children initially evaluated at community hospitals compared with the children’s hospital. Broadly-applicable strategies to systematically maximize diagnostic accuracy for childhood appendicitis, while minimizing ionizing radiation exposure, are urgently needed.
Imaging Modalities: MRI

- Growing body of evidence that MRI is an effective way to image patients with suspected appendicitis
Background: Cross-sectional imaging increases accuracy in diagnosing appendicitis. We hypothesized that a radiation-free imaging pathway of ultrasonography selectively followed by MRI would not change clinical end points compared with computed tomography (CT) for diagnosis of acute appendicitis in children.

Methods: We retrospectively reviewed children (<18 years old) who had diagnostic imaging for suspected acute appendicitis between November 2008 and October 2012. Before November 2010 CT was used as the primary imaging modality (group A); subsequently, ultrasonography was the primary imaging modality followed by MRI for equivocal findings (group B). Data collected included time from triage to imaging and treatment and results of imaging and pathology.

Results: Six hundred sixty-two patients had imaging for suspected appendicitis (group A = 265; group B = 397, of which 136 [51%] and 161 [41%], respectively, had positive imaging for appendicitis). Negative appendectomy rate was 2.5% for group A and 1.4% for group B. Perforation rate was similar for both groups. Time from triage to antibiotic administration and operation did not differ between groups A and B. There was higher proportion of positive imaging and appendectomies in group A and thus more negative imaging tests in group B (ultrasonography and MRI), but diagnostic accuracy of the 2 imaging pathways was similar.

Conclusions: In children with suspected acute appendicitis, a radiation-free diagnostic imaging of ultrasonography selectively followed by MRI is feasible and comparable to CT, with no difference in time to antibiotic administration, time to appendectomy, negative appendectomy rate, perforation rate, or length of stay.
Imaging Modalities: MRI


Diagnostic accuracy and patient acceptance of MRI in children with suspected appendicitis.
Thieme ME1, Leeuwenburgh MM, Valdehueza ZD, Bouman DE, de Bruin IG, Schreurs WH, Houdijk AP, Stoker J, Wiarda BM.

OBJECTIVE:
To compare magnetic resonance imaging (MRI) and ultrasound in children with suspected appendicitis.

METHODS:
In a single-centre diagnostic accuracy study, children with suspected appendicitis were prospectively identified at the emergency department. All underwent abdominal ultrasound and MRI within 2 h, with the reader blinded to other imaging findings. An expert panel established the final diagnosis after 3 months. We evaluated the diagnostic accuracy of three imaging strategies: ultrasound only, conditional MRI after negative or inconclusive ultrasound, and MRI only. Significance between sensitivity and specificity was calculated using McNemar's test statistic.

RESULTS:
Between April and December 2009 we included 104 consecutive children (47 male, mean age 12). According to the expert panel, 58 patients had appendicitis. The sensitivity of MRI only and conditional MRI was 100% (95% confidence interval 92-100), that of ultrasound was significantly lower (76%; 63-85, P < 0.001). Specificity was comparable among the three investigated strategies; ultrasound only 89% (77-95), conditional MRI 80% (67-89), MRI only 89% (77-95) (P values 0.13, 0.13 and 1.00).

CONCLUSION:
In children with suspected appendicitis, strategies with MRI (MRI only, conditional MRI) had a higher sensitivity for appendicitis compared with a strategy with ultrasound only, while specificity was comparable.

KEY POINTS:
• In children, MRI has a higher sensitivity for appendicitis than ultrasound. • Ultrasound followed by MRI in negative or inconclusive findings is accurate. • The tolerance for ultrasound and MRI in children is comparable. • MRI can be performed in children in an emergency setting.
Imaging Modalities: MRI

- Why consider MRI?
  - Non-operator dependant
  - No radiation
  - CT-like images, therefore comfort among wide array of clinically-oriented physicians (compared to ultrasound) and general radiologists

- Downsides to MRI:
  - Limited availability (long wait time to get scanned)
  - Cost
  - Motion artifact
  - Longer exam (compared to CT)
  - Noise/scary
  - Claustrophobia

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Our Story

- A large tertiary (or quaternary) adult hospital with a separate but attached pediatric hospital

- Some shared services including in radiology:
  - CT, MRI, PET-CT, nuclear medicine shared
  - X-ray, fluoro and US in peds radiology
  - More than 50% of peds US done outside of the department (portable or on the adult side)

- Peds radiology physically in-house 365 days/year but not 24/7; general attending radiologists cover off hours when no peds person available

- Separate Pediatric ED for with a growing population
Our Story

• Sonographers are part of a general pool, with certain branded as “pediatric”, but none 100% peds
• Lead peds sonographer helps with quality control and education
• 1 of 3 “peds” sonographers rotate daily through the peds department M-F
• Try to have cases done in main dept. by “peds” branded sonographers
• Off hours (overnight/weekend) and portables: Shared amongst all sonographers

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Our Story

• Lead 3 year QI project to raise the bar for peds sonography
• Largely successful
• Appendicitis we continued to struggle, especially off-hours
• Review of appy US (most off-hours):
  • ~70% of cases read as indeterminate
  • ~30% of cases that did move the needle didn’t do so reliably
  • Especially an issue off-hours, with general radiologists and general sonographers
• Review of literature and discussions with outside colleagues prompted evaluation of new program to use MRI \textit{AFTER} US.
Imaging Modalities: MRI

• After initial meeting with the ED and surgery, decided to launch trial of program **using it as 1st line**
  • Done in conjunction with the ED, pediatric surgery, pediatrics and child life
  • Did not require IRB approval (per IRB, after formal proposal)
  • Began Feb. 9, 2015
  • M-F, exams ordered through ED 8AM – 5PM
  • Age guidelines: 7 and up (no sedation)
  • 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

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Imaging Modalities: MRI

- Our current protocol: 4 sequences
  - Ax SS FRFSE T2 FS (breath hold)
  - Ax pre-con (LAVA)
  - Ax and Cor post (LAVA)

- Debated value of DWI and IV contrast
  - Our experience supports use of contrast
  - Not using DWI at this time

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Imaging Modalities: MRI

- First 5 positive cases, \textit{in order}
- In each case, consider if US would have been likely to make the diagnosis
MRI Case 1: 8 yo male, APS 6

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MRI Case 1: 8 yo male, APS 6
MRI Case 2: 10 yo male, APS 5

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MRI Case 3: 8 yo male, APS 5
MRI Case 4: 10 yo female, APS ≥3

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MRI Case 5: 17 yo male, APS 7
Imaging Modalities: MRI

- Through October 14, 2015
- 107 cases total
- Try to place in terms of:
  - Positive
  - Equivocal Positive
  - Indeterminate
  - Equivocal Negative
  - Negative
Imaging Modalities: MRI

- Through October 14, 2015
- 107 cases total
- 30 called Positive or Equivocal Positive
- 28/30 cases have (+) Pathology
- 1/30 considered positive by surgery; elected to treat with antibiotics and follow-up with surgery
- 29/30 considered True Positive
- 1/30 managed non-operatively and called FP
- Vast majority of other cases have follow-up at least through discharge, with no known FN cases

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MRI False Positive: 11 year old abd pain

APS Value Not Provided

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MRI False Positive: 11 year old, abd pain

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12 yo boy, APS 6; Considered (+) but no path (yet)
(+) MRI after Indeterminate US
13 yo with (+) MRI; APS 6; Surgery thought clinically negative
13 yo with (+) MRI; APS 6; Surgery thought clinically negative
Imaging Modalities: MRI

- Time to get patients on the table (goal is average of 120 minutes or less):
- Time from exam order to start imaging (Since May 1):
  - Average: 88 min.
  - Median: 70 min.

- It was taking almost an hour to get patients up to US from the ED after exam 1st ordered in computer
Imaging Modalities: MRI

- Time to image patients (scan time; goal is average of 20 min. or less):
  - Time from start exam to finish imaging (Since May 1):
    - Average: 20 min.
    - Median: 19 min.
  - Time from start exam to finish imaging (Since Aug. 1):
    - Average: 19.7 min.
    - Median: 18.5 min.
Clinical Scoring

- Use of a clinical scoring system
- APS score (we don’t use “PAS” so as not to confuse with “PAAS” of asthma score)
- We have had no cases of APS 0, 1 or 2 be read as Positive or Equivocal/Positive (and only one APS 3, which may have been higher).

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Clinical Scoring
Saucier A, et al. Prospective evaluation of a clinical pathway for suspected appendicitis
Pediatrics 2014;133:e88–e95

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 (2) 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.
## Clinical Scoring

<table>
<thead>
<tr>
<th>Pediatric Appendicitis Score</th>
<th>Alvarado Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough/percussion/heel tapping tenderness at RLQ 2</td>
<td>Migration of pain 1</td>
</tr>
<tr>
<td>Anorexia 1</td>
<td>Anorexia 1</td>
</tr>
<tr>
<td>Low-grade fever ≥38.0°C 1</td>
<td>Nausea/vomiting 1</td>
</tr>
<tr>
<td>Nausea/emesis 1</td>
<td>Right lower quadrant tenderness 2</td>
</tr>
<tr>
<td>RLQ tenderness on light palpation 2</td>
<td>Rebound pain 1</td>
</tr>
<tr>
<td>Leucocytosis (&gt;10,000/mm3) 1</td>
<td>Increase in temperature (&gt;37.3°C) 1</td>
</tr>
<tr>
<td>Left shift (&gt;75% neutrophilia) 1</td>
<td>Leucocytosis (&gt;10,000/mL) 2</td>
</tr>
<tr>
<td>Migration of pain to RLQ 1</td>
<td>Polymorphonuclear neutrophilia (&gt;75%) 1</td>
</tr>
</tbody>
</table>

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Clinical Scoring

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

• In the paper:
  • 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

• Interestingly, 1 of 3 negative appendectomies had a low PAS

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Clinical Scoring

- Our data since July 31
  - 35 cases
  - 0-3 Score: 2 cases (both 3s), 0/2 positive (0% of cases)
  - 4-6 Score: 24 cases, 9/24 positive (37.5% of cases)
  - 7+ score: 9 cases, 7/9 positive (78% of cases)
Imaging Modalities: MRI

- Alternative diagnosis & unexpected findings:
  - Most negative cases have no clear alternative diagnosis
  - Hydronephrosis
  - Musculoskeletal
  - Horseshoe kidney
  - Ovarian cyst
MRI: Alternative & Incidental Findings
MRI: Alternative & Incidental Findings
MRI: Alternative & Incidental Findings
Imaging Modalities: MRI

- Cost
  - We have been tracking payment
  - Difficult to accurately gauge cost
  - Un-negotiated charges (technical fees only):
    - Pelvic MR without and with contrast: $2240
    - US LTD: $775
    - CT Pelvis with: $1830
  - Comparing MRI alone to US +/- CT or MRI
  - Time savings by going straight to MRI?
  - An area of future research

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Conclusion

• In our setting, if the patient has a reasonable likelihood of having appendicitis (APS of 3 or higher), we recommend imaging.

• US in experienced hands is often diagnostic, but this is tough to achieve without round-the-clock in-house pediatric radiologists and sonographers

• A focused MRI offers a reliable way to image patients with suspected appendicitis, and does so without ionizing radiation

• Role for US in girls if alternative diagnosis (eg cyst) would end work-up

• Future: Ultra-low dose CT?