Body MRI In The Emergency Department

Ethan A. Smith, MD
Associate Professor, Radiology
Co-Director, Thoracoabdominal Imaging
Cincinnati Children’s Hospital Medical Center
Cincinnati, OH
Disclosures

• No relevant financial disclosures.
Goals

• Current role of body MRI the work up and diagnosis of Emergency Department (ED) patients.
• Review the literature supporting MR in specific conditions
  – Appendicitis
    • Discuss clinical experience implementing an appendicitis MR protocol
  – Ovarian pathology
  – Genito-urinary tract abnormalities
  – Others...
Current State

- Sheinfeld, et al. (Pediatr Radiol 2017)
  - MRI usage per ED visit = 0.36%
    - Brain >>>>> Body/MSK
    - Headache, neurological symptoms, pain, r/o appendicitis
  - Females > males
  - Use increased with age
    - Sedation, cooperation issues

Barriers to MRI in the ED

• Availability
  – Scanner
  – Technologist
  – Sedation/anesthesia

• Perceived cost

• Time
  – ED = speed!

• Limited indications?
Acute Appendicitis
Currently...

• Most common imaging paradigms for pediatric appendicitis involve US and/or CT
  – Physical examination?

• Varies depending on centers
  – Most children’s hospitals
    • US→CT
  – Community (non-university) hospitals
    • CT often first line

Currently...

- **US:**
  - Visualization: 24.4% (U of Michigan)*
  - Diagnostic performance:
    - Sensitivity: 88% (67%)
    - Specificity: 94% (96%)
  - Limitations:
    - Obesity?
    - Location?
    - Availability
    - Operator dependence

The Problem

• CT:
  – Diagnostic performance:
    • Sensitivity: 94%
    • Specificity: 95%
  – Problems:
    • Radiation exposure
    • Up to 10% cases still equivocal
    • Limited soft tissue contrast resolution
    • Lower spatial resolution vs. US

*Doria et al. Radiology 2006; 241:83-94*
Contrast Resolution in Action

8 year-old boy – RLQ pain
Ultrasound ± MRI

• Potential positives:
  – No ionizing radiation
  – Superior soft tissue contrast resolution
  – Allows diagnosis of numerous extra-appendiceal conditions
  – Not limited by habitus
Ultrasound ± MRI

• Potential drawbacks:
  – Length of exam (25 min realistic)
  – Motion artifacts
    • Motion artifact
      – Fast sequences, new techniques (e.g., multivane, propeller)
    • Respiratory
      – Trigger
  – Low specificity?
  – Cost? (maybe not...)
The Literature

- Johnson et al. (AJR 2012)
  - 42 children (mean 11.5 years)
  - No contrast, free breathing MRI at 3T
  - Results compared to CT and/or US
    - Sens $\rightarrow$ 100%; Spec $\rightarrow$ 99%
    - NPV $\rightarrow$ 100%

- Moore et al. (Pediatr Radiol 2012):
  - 4-sequence protocol (SSFSE)
  - 208 children with suspected appendicitis
    - Sensitivity $\rightarrow$ 97.6% [87.1-99.9%]
    - Specificity $\rightarrow$ 97.0% [93.2-99.0%]
    - NPV $\rightarrow$ 99.4% [96.6-99.9%]
The Literature

• Orth et al. (*Radiology* 2014):
  – 81 children prospectively enrolled
    • Mean age = 12.3 yr; range, 4-17 yr
  – US vs. noncontrast, nonsedated abdominal MRI
  – 30 (37%) → path-proved acute appendicitis
  – When equivocal interpretations considered positive:
    • Sensitivity → 93.3%
    • Specificity → 98%
    • NPV → 96.2%

Example Protocol

• 1.5 or 3 Tesla scanner
• Scan time: 15-25 min
• Coverage: “bladder to bladder”
• T2-weighted imaging only
  – SSFSE (breath hold vs. free breathing)
    • Axial and coronal *without* fat-sat
    • Axial *with* fat-sat (SPAIR)
  – Coronal STIR (single shot)
  – ± FSE (axial) without fat-sat (high-resolution)
Equivocal Pediatric Appendicitis: Unenhanced MR Imaging Protocol for Nonsedated Children—A Clinical Effectiveness Study

**Purpose:** To determine retrospectively the clinical effectiveness of an unenhanced magnetic resonance (MR) imaging protocol for evaluation of equivocal appendicitis in children.

**Materials and Methods:** Institutional review board approval was obtained. Pediatric patients (≤18 years old) underwent unenhanced MR imaging and contrast material–enhanced computed tomography (CT) of the appendix between December 2013 and November 2014 and December 2013 and November 2014.
C.S. Mott Experience

- Retrospective review
- “Equivocal US” cases
- 103 patients → MRI (non-contrast)
- 58 patients → contrast enhanced CT
  - Historical controls
- Imaging findings compared to
  - Surgical/pathology reports
  - 30 days of clinical follow up

C.S. Mott Experience

• MRI performance
  – Sensitivity 94.4% (CI 72.7%-99.9%)
  – Specificity 100% (CI 95.8%-100%)

• CT performance
  – Sensitivity 100% (CI 71.5%-100%)
  – Specificity 97.9% (CI 88.7%-100%)

• MRI visualized appendix in 74.8%

So...

- Evidence supports that MR for appendicitis works as well as CT...
- ... but there are other things to consider.
Additional Considerations

• Obtaining the images
  – Ultrasound first?
  – Cost and availability
  – Known perforation?

• Interpreting the images
  – Sensitivity
  – Free fluid vs. inflammation

12 year old boy with retrocecal appendix and acute appendicitis.
Obtaining the Images
Ultrasound First?

- My opinion = YES!
- Mott MRI appendix experience
  - Over 700 US/year
  - Well under 200 MRI/year
- Imler, et al 2017
  - Looked at US vs. MRI as “first line”
    - 82 pediatric/young adult patients
  - Conclusion: MRI first = more cost, more time

*Imler, et al. Acad Emerg Med 2017; 24: 569-577*
Cost

- Full MRI abdomen pelvis with contrast costs more than CT
- However...
  - Can get creative...
  - Billing charges
    - MRI abdomen without contrast

13 year old boy with acute appendicitis.
Availability

• To be acceptable to Emergency Department...
  – Must be readily available
  – Must be a 24 hour service

• Can be a major challenge to overcome
  – On-call techs?
  – Different imaging paradigms for day/night?
Known Perforation

- What if the US is clearly positive for perforation?
  - Is non-contrast MRI adequate for surgical/IR planning?

- My opinion
  - The way we do it...NO
  - If further imaging is needed, I still recommend CT
  - Contrast enhanced MRI w/ diffusion an option

13 year old boy with perforated appendicitis and pelvic abscess.
Interpreting the Images
Reader Comfort

• What is equivocal?
  – Appendix visualization
    • Normal appendix can be very hard to see on MRI
  – Appendix diameter
    • Can be above 6 mm and still be normal
    • Shown on CT and US

No inflammation = No appendicitis

10 year old girl.
Appendix not seen.
No inflammation = no appendicitis!
Free Fluid vs. Inflammation

• What about fluid in the pelvis?
• What about fluid around the appendix?

• Free fluid is different than inflammation!

• Inflammation = appendicitis
• Free fluid = nonspecific
Free Fluid vs. Inflammation

15 year old girl.
Pelvic free fluid, but no inflammation.
Free Fluid vs. Inflammation

12 year old boy.
Inflammation and acute appendicitis.
Appendicitis MRI

• In summary...
  – Established literature
  – Some technical and practice considerations
  – But the bottom line is...

IT WORKS!
Ovarian Torsion
4 year old girl

Acute abdominal pain and vomiting.
4 yo Girl – Pain, Vomiting
4Y Girl – Pain, Vomiting
4Y Girl – Pain, Vomiting
Ovarian torsion, 
Normal appendix.
Ovarian Torsion

- Twisting of ovarian pedicle
  - Results in decreased blood flow (often venous)
- MRI findings of ovarian torsion
  - Ovarian enlargement
  - Peripherally displaced follicles
    - May be hemorrhagic; ↑ T1W signal
  - Subacute ovarian hemorrhage
  - Peri-ovarian soft tissue edema
  - Decreased enhancement (if contrast given)

Duigenan, et al. AJR 2012; 198: w122-w131
Genitourinary Tract Abnormalities
15 year old girl.

Right lower quadrant pain.
15Y Girl – RLQ Pain (3T)
Obstructing ureteral calculus
Case 6: Follow-Up

3 days later...
A Similar Case... (3T)

12Y Boy – RLQ Pain
6 year old girl.

Abdominal pain and fever.
6Y Girl – RLQ Pain
Acute Pyelonephritis (Enterococcus)
A Similar Case...

17Y Girl – RLQ Pain
Other Diagnoses...
13 year old boy.

Abdominal pain.
13Y Boy – Abdominal Pain
13Y Boy – Abdominal Pain
13Y Boy – Abdominal Pain (1.5T)
Omental Infarct
Companion Case

10 year old boy with abdominal pain.
Companion Case

10 year old boy with omental infarct.
16 year old girl.

Abdominal pain for several months.
16Y girl – abdominal pain for months.
Previously undiagnosed Crohn’s disease

Obstruction secondary to terminal ileal stricture.
Conclusions

• Exact role of body MRI in ED evolving
• Limiting factor = operational challenges
  – Time, availability, cost
• MRI is effective for diagnosing acute appendicitis
  – Performance equivalent to CT
• Other conditions can also be diagnosed
  – Ovarian torsion
  – Urinary tract infection & calculi
  – More rare causes of abdominal pain
Thank You!

ethan.smith@cchmc.org
References: