Imaging Children with Acute Abdominal Pain -- Role/Protocols of US, CT, MR

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Evidence-based imaging approaches

Key surgical conditions:

- Malrotation & Midgut volvulus
- Pyloric stenosis
- Intussusception
- Appendicitis
Malrotation

- Rare: 3.9 per 10,000 live births
- 90% age <1yr (75% neonatal)
- Mortality 3-5%
- Associated syndromes, anomalies
- Difficult diagnosis in older children
The UGI series

Diagnostic Performance

- Imaging gold standard
- 15% FP  3-6% FN
- Volvulus: sensitivity 54%
3. How often is the cecum abnormally positioned in children with malrotation?

A. 20%
B. 50%
C. 80%
D. 100%
C. Cecum abnormally positioned in 80-85% of malrotation cases

- Ligamentous laxity in children
- False Positives:
  - Liver transplant
  - Spenomegaly
  - Dilated adjacent bowel
  - Enteral tubes
Helpful tips…

**UGI technique**

- Document first pass of barium through duodenum
- Document DJJ on frontal *and lateral*
- Do not overfill stomach
- Use manual palpation
- Review other imaging studies
- If doubt, SBFT or enema → cecum
- If clinical doubt, repeat UGI
Volvulus: a surgical emergency

Bowel gas pattern in neonates—
“sad sausages” vs
“happy polygons”
Clinical presentation in older children

- Tricky!
- Rarely bilious emesis
- Less specific symptoms
- Long average delays in diagnosis of 1.7 years to 5 years (3 published series)
Special situations

- Volvulus limited to the colon
  - Neonates: distal transverse colon
  - Older children: cecal
- Heterotaxy syndrome
- Paraduodenal hernias
- Acquired volvulus
Heterotaxy syndrome
malrotation and annular pancreas
Paraduodenal hernias
Cecal Volvulus around MACE

Malone antegrade catheterizable enema
4. What is the most common cause of GI obstruction in children?
A. Pyloric Stenosis
B. Intussusception
C. Appendicitis
Answer 2

A. Pyloric Stenosis

- Incidence: 2-5 per 1,000 births
- Peak age 4 wks (2-12 wks)

- Intussusception is 2\textsuperscript{nd} most common
- Appendicitis most common abd surgery
  - SBO rare-- perforated appendicitis (1-2%)
Pyloric Stenosis

- Earlier diagnosis
- Increased reliance on imaging
  - Clin exam: 72% sens, 97% spec
  - US exam: 97% sens, 100% spec
Question 3

5. Which of the following is NOT associated with pyloric stenosis?
   A. Family history
   B. Male gender
   C. Prematurity
   D. Erythromycin
C. Prematurity

- Male: female 4:1
- Mild increased incidence if family history
- Late gestation or neonatal use of systemic erythromycin associated with PS
Intussusception

- Lack of seasonality but associated with multiple viruses
- Peak age: 5-9 months (range 3mo-4 yrs)
- 10% spontaneous reduction
- 10% recur (50% at 48hrs)
- 5% lead points
# Diagnostic performance of imaging for intussusception

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal films</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Ultrasound</td>
<td>98-100%</td>
<td>88-100%</td>
</tr>
<tr>
<td>Enema*</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Reducibility

#1: duration of symptoms
- >48 hours

Age <3 months, dehydration, SBO

Sonography
- Trapped fluid
- Lack of color doppler
Burkitt lymphoma with small bowel wall tumor seeding and intussusception
Question 4
Intussusception

6. Which of the following enema techniques has the highest reduction rate?

A. Barium
B. Iodinated contrast
C. Air
D. US-guided Saline
## Air vs Liquid Enema Outcomes

### Studies with 100-1000 cases

<table>
<thead>
<tr>
<th></th>
<th># of studies</th>
<th>Wt Mean (SE)</th>
<th>P &lt; .001</th>
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</thead>
<tbody>
<tr>
<td><strong>Reduction (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>13</td>
<td>82 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>14</td>
<td>70 (1.7)</td>
<td></td>
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<tr>
<td><strong>Perforation (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>14</td>
<td>1.0 (0.4)</td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>12</td>
<td>0.3 (0.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td>1980's</td>
<td>1990's</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Reduction Rate (%)</td>
<td>Liquid</td>
<td>66 (5.6)</td>
<td>72 (2.5)</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>79 (2.9)</td>
<td>83 (1.8)</td>
</tr>
<tr>
<td>Perforation Rate (%)</td>
<td>Liquid</td>
<td>0.4 (0.2)</td>
<td>0.5 (0.3)</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>0</td>
<td>1.3 (0.3)</td>
</tr>
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</table>
Air Enema Intussusception Reduction
Intussusception Summary

- Sonography for diagnosis
- Air enema superior to liquid
- No barium
- US-guided saline enema avoids radiation
- Delayed repeat enema?
Appendicitis

- Lifetime risk 7%
- >260,000 cases (70,000 children)/yr USA
- Peak age 10-19 yrs (rare under 3 yrs)
- Clinical presentation overlaps benign conditions (eg, gastroenteritis)
- Children poorly localize pain
Question 4

7. What are the sensitivity and specificity of CT for the diagnosis of acute appendicitis in children?

A. 90%, 90%
B. 95%, 90%
C. 90%, 95%
D. 95%, 95%
Answer 4

D. 95% sensitivity and specificity for CT

Similar accuracy to adults if performed with meticulous technique
Imaging of appendicitis in children

- CT false positives & negatives: 5%
- Less fat, more difficult CT dx
- CT > US in kids in USA since 2002!
- CT appendix size cut point: >7mm
Question 5

What is the role of the vermiform appendix?

A. There is no known function
B. There is a function
Biofilms in the large bowel suggest an apparent function of the human vermiform appendix.”


“We propose that the human appendix is well suited as a "safe house" for commensal bacteria, providing support for bacterial growth and potentially facilitating re-inoculation of the colon in the event that the contents of the intestinal tract are purged following exposure to a pathogen.”
MDCT for Appendicitis

Many Approaches

- kV 120, mAs 50-175
- Avoid delayed or repeat imaging
- IV contrast
- Trend of decreased use of enteral contrast
  - Caveat: role of enteral contrast more important in young children with little intraperitoneal and retorperitoneal fat
  - National push from Emergency Physicians to abandon oral contrast use to improve TAT
Creatinine in Children

Suggested cut-off levels

- Neonates* to 6 months: >0.3
- 6 months-1 year: >0.6
- 1-5 yrs: >0.8
- 6-12 yrs: >1.0
- For children >12 years old: creat >1.1
- For adults >21 years old: creat >1.5

based on Schwartz formula (muscle mass)
Power-Injectable Venous Catheters:

Quality of enhancement &
Quality of life issue for patients

Children:
- PICCs (4,5 Fr)
- Central lines (8-10 Fr)

IV flow rates 2-5 ml/sec
Rectal and IV contrast CT

Appendix size same throughout life
Cocktail Party Factoids

From birth to death, the human vermiform ("worm-like") appendix size stays the same—it is a 5-10cm long and 0.5-1cm wide pouch.

The only other mammals known to have appendices are rabbits, opossums and wombats, and their appendices are markedly different than the human appendix.

[W Parker, Duke]
Alternative Diagnoses at CT, US

Mesenteric lymphadenopathy
Ovarian cyst
Pyelonephritis
Ureteral Stone
TOA
Omental infarction
Ileo-colicitis

* up to 50% of cases
CT and US for Appendicitis

Meta-analysis

- A Doria et al. Radiology 2006
- Children, adults sens, spec
- 15 peds, 29 adult articles
- CT higher sens for both peds, adults
## Children Results

### Pooled Sensitivities and Specificities

<table>
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<tr>
<th></th>
<th>Peds US</th>
<th>Peds CT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>88% CI 0.86-0.90</td>
<td>94% CI 0.92-0.97</td>
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<tr>
<td><strong>Specificity</strong></td>
<td>94% CI 0.92-0.95</td>
<td>95% CI 0.94-0.97</td>
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</table>
What does this mean?

- For every 10,000 kids (11 y/o) scanned with US instead of CT, 280 cases of appendicitis would be missed
  - 13 future cancers may be prevented
Imaging Algorithm in Suspected Appendicitis

- Pain control in ED
- Sonography
  - If negative, CT scan
Spontaneous Resolution vs. Perforating Appendicitis

- Likely that most people experience self-limited degrees of appendiceal inflammation at some time in their lives
  - 22% infants at autopsy had signs of subacute appendicitis
  - Contributes to false neg/positive rates

Effectiveness vs. Efficacy

- Flum et al., U Washington, JAMA 2001
- Measured ‘bad outcome’ over 13 year trend
  - Diffusion of CT, US, laparoscopy
- “These data suggest that on a population level, diagnosis of appendicitis has not improved with the availability of advanced diagnostic testing”
13yr trend result:
No improvement in NA or perf rates

Possible explanations:
(1) misapplication of imaging exams to wrong patients, or at wrong time
(2) misinterpretation/mistrust of exam interpretation by clinicians after hours by less experienced imagers (e.g., residents)
(3) availability and belief that laparoscopy is less invasive than laparotomy
Summary

1. Imaging depends on clinical ddx
2. In older children, CT is a useful tool
3. In younger children, fluoro and US more common tools