Title
Defining the role of ultrasound in the imaging workup for suspected acute appendicitis in children at Rady Children's Hospital San Diego

Permalink
https://escholarship.org/uc/item/52c6k560

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Publication Date
2017

Supplemental Material
https://escholarship.org/uc/item/52c6k560#supplemental
Is sonography the most appropriate imaging modality for diagnosing acute appendicitis in children?

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San Diego Imaging Medical Group/Rady Children’s Hospital
UC San Diego Health
2017 ARRS Annual Meeting, April 30–May 5, New Orleans
Disclosure of commercial interest

Neither I nor my immediate family members have a financial relationship with a commercial organization that may have a direct or indirect interest in the content.
Background

- American College of Radiology considers ultrasound to be the most appropriate imaging modality for the initial evaluation of acute appendicitis: lack of ionizing radiation, high sensitivity, and low cost.
- Rady Children’s Hospital San Diego (RCHSD) has historically used CT or MR.
- On January 1, 2016, we implemented a protocol to use abdominal ultrasound ("U/S Appy"), and not computed tomography (CT) or magnetic resonance imaging (MR), in the initial assessment of suspected appendicitis.
In this quality improvement project we:

1. Highlight the limitations of sonography in diagnosis of acute appendicitis
2. Describe “non-visualized appendix” on imaging report
3. Show how to include “non-visualized” studies in sensitivity and specificity calculation
4. Highlight the advantages of sonography in diagnosis of acute appendicitis
5. Review the importance of adequate sonographer training/competence
Purpose

The goals of this retrospective chart review quality improvement project were to evaluate:

- If U/S is the more appropriate initial imaging modality based on diagnostic test performance variables (DTPV)
- DTPV = sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV)
- Which variables (gender, BMI, etc.) affect the DTPVs
Materials, Methods, and Procedures

- This was a retrospective chart review quality improvement project
- Patients with U/S Appy ordered between February 1, 2016 and March 31, 2016 were included in the test group (n=300)
- Patients with CT or MR ordered for suspected appendicitis between February 1, 2015 and March 31, 2015 were included in the control group (n=300)
Materials, Methods, and Procedures

• The following data was collected for each patient:
  – gender
  – age
  – body mass index (BMI)
  – sonographer
  – length of stay
  – pathology results
  – other imaging studies performed
  – pertinent history, physical exam results, and labs
Materials, Methods, and Procedures

- Positive predictive value, negative predictive value, sensitivity, and specificity of ultrasound results were calculated based on pathology results
“Appy score” positively correlates with appendicitis

Appy score (max of 10 points):

- RLQ pain (2pt)
- RLQ tenderness to palpation (2pt)
- WBC>11K (1pt)
- Neutrophils >75% (1pt)
- CRP >1 (1pt)
- Nausea/vomiting (1pt)
- Rebound tenderness (1pt)
- Fever > 38.0 (1pt)

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![Graph showing the correlation between Appy score and percent appendicitis.](chart_image)
Study groups were not statistically different in clinical presentation, gender, or BMI

**Test Group**: Patients with U/S Appy ordered between 2/1/16 and 3/31/16  
**Control Group**: Patients with CT Abdomen Pelvis or MR Appy studies ordered between 2/1/15 and 3/31/15

<table>
<thead>
<tr>
<th></th>
<th>Ultrasound (n=300)</th>
<th>CT/MRI (n=300)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical Presentation/Appy Score</strong></td>
<td>6.3 +/- 1.8</td>
<td>6.5 +/- 1.7</td>
</tr>
<tr>
<td><strong>% Females</strong></td>
<td>47%</td>
<td>47%</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>9.7 +/- 4.3</td>
<td>9.0 +/- 4.2</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>21.3 +/- 9.8</td>
<td>20.4 +/- 6</td>
</tr>
</tbody>
</table>

*Clinical presentation is defined by appy score  
*p<0.05
U/S: Normal Appendix

Appendix is identified, less than 6 mm in diameter, and compressible
Appendix is visualized, enlarged (8mm in diameter), and incompressible
Appendix visualized, enlarged (16mm in diameter), and mildly inflamed with associated appendicololith and decreased blood supply on Doppler
CT: Acute appendicitis with appendicololiths

Appendix is dilated up to 1 cm in maximum diameter, with hyperemic walls, multiple appendicololiths within its lumen. There is right lower quadrant inflammatory change.
The appendix is visualized and has a diameter of 8.6 mm. Appendiceal wall appears thickened and hyperenhancing. No free fluid.
A 5.5 x 5.6 x 6.7 cm abscess (see arrows) within the right lower quadrant, most likely sequelae of a ruptured appendicitis. Small amount of free fluid within the abdomen/pelvis.
Abnormal appendix, measuring up to 1.4 cm and demonstrating wall thickening, and hyperenhancement. There is prominent periappendiceal stranding, with ill-defined enhancement. There is a moderate amount of free pelvic fluid.
## Imaging modality

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Non-visualized</th>
<th>Positive appys that were non-visualized on U/S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U/S (n=300)</td>
<td>53%</td>
<td>13%</td>
<td>92%</td>
<td>96%</td>
<td>72%</td>
<td>18%</td>
</tr>
<tr>
<td>CT (n=195)</td>
<td>96%</td>
<td>96%</td>
<td>98%</td>
<td>99%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>MR (n=105)</td>
<td>97%</td>
<td>96%</td>
<td>97%</td>
<td>99%</td>
<td>2%</td>
<td>0%</td>
</tr>
</tbody>
</table>

U/S Appy currently has lower diagnostic test performance than CT or MRI
Non-visualized appendix on U/S does not equate to negative study

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Non-visualized</th>
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</tr>
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<td>CT (n=195)</td>
<td>96%</td>
<td>96%</td>
<td>98%</td>
<td>99%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>MR (n=105)</td>
<td>97%</td>
<td>96%</td>
<td>97%</td>
<td>99%</td>
<td>2%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The appendix was non-visualized in 72% of the U/S studies – 18% of these were positive on further imaging and on pathology. Therefore, one cannot assume the patient does not have appendicitis if the appendix was non-visualized on U/S (this assumption can be made, however, for CT and MRI).
Additional studies were ordered more often after U/S Appy vs. CT/MR

• Test group (U/S Appy): 0.8 ± 0.8 additional studies per patient
  – 33% had CT abdomen pelvis after U/S
  – 15% had MRI Appy after U/S
  – 1% had both CT and MRI after U/S
• Control group (CT/MRI): 0.2 ± 0.5 additional studies per patient
Sedation and average length of stay

• Sedation was more likely to be used with CT (7.7%) or MR (2.9%) vs. U/S (0%)
• Average length of stay was greater for CT/MRI cases (1.5 ± 4 days) vs. U/S (1.0 ± 1.7 days)
Gender: Diagnostic test performance of U/S Appy decreases for females vs. males

<table>
<thead>
<tr>
<th>Gender</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Non-visualized</th>
<th>Positive appys that were non-visualized on U/S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (140)</td>
<td>45%</td>
<td>12%</td>
<td>83%</td>
<td>92%</td>
<td>73%</td>
<td>16%</td>
</tr>
<tr>
<td>Male (160)</td>
<td>58%</td>
<td>14%</td>
<td>97%</td>
<td>100%</td>
<td>69%</td>
<td>21%</td>
</tr>
<tr>
<td>Overall</td>
<td>53%</td>
<td>13%</td>
<td>92%</td>
<td>96%</td>
<td>72%</td>
<td>18%</td>
</tr>
</tbody>
</table>
BMI: Diagnostic test performance of U/S Appy decreases for BMI > 30

<table>
<thead>
<tr>
<th>BMI</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Non-visualized</th>
<th>Positive appys that were non-visualized on U/S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI &lt; 30</td>
<td>55%</td>
<td>12%</td>
<td>96%</td>
<td>93%</td>
<td>67%</td>
<td>27%</td>
</tr>
<tr>
<td>(n=197)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI &gt; 30</td>
<td>0%</td>
<td>20%</td>
<td>N/A</td>
<td>100%</td>
<td>82%</td>
<td>11%</td>
</tr>
<tr>
<td>(n=11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>53%</td>
<td>13%</td>
<td>92%</td>
<td>96%</td>
<td>72%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Additional advanced imaging (MR or CT) was ordered in 82% (9/11) of the cases when BMI > 30 vs. 46% when BMI < 30. BMI could not be calculated for 92 patients, due to lack of height and/or weight data.
## Sonographer: Diagnostic test performance is influenced by sonographer proficiency

<table>
<thead>
<tr>
<th>Sonographer</th>
<th>sensitivity</th>
<th>specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Non-visualized</th>
<th>Positive appys that were non-visualized on U/S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n=101)</td>
<td>52%</td>
<td>4%</td>
<td>85%</td>
<td>100%</td>
<td>60%</td>
<td>16%</td>
</tr>
<tr>
<td>B (n=36)</td>
<td>50%</td>
<td>10%</td>
<td>100%</td>
<td>100%</td>
<td>67%</td>
<td>14%</td>
</tr>
<tr>
<td>C (n=36)</td>
<td>63%</td>
<td>8%</td>
<td>100%</td>
<td>100%</td>
<td>69%</td>
<td>8%</td>
</tr>
<tr>
<td>D (n=8)</td>
<td>0%</td>
<td>0%</td>
<td>N/A</td>
<td>N/A</td>
<td>88%</td>
<td>13%</td>
</tr>
<tr>
<td>E (n=22)</td>
<td>83%</td>
<td>20%</td>
<td>100%</td>
<td>100%</td>
<td>59%</td>
<td>5%</td>
</tr>
<tr>
<td>F (n=71)</td>
<td>52%</td>
<td>41%</td>
<td>100%</td>
<td>94%</td>
<td>45%</td>
<td>13%</td>
</tr>
<tr>
<td>G (n=10)</td>
<td>25%</td>
<td>0%</td>
<td>100%</td>
<td>N/A</td>
<td>60%</td>
<td>30%</td>
</tr>
<tr>
<td>H (n=16)</td>
<td>67%</td>
<td>0%</td>
<td>80%</td>
<td>N/A</td>
<td>56%</td>
<td>13%</td>
</tr>
<tr>
<td>Overall</td>
<td>53%</td>
<td>13%</td>
<td>92%</td>
<td>96%</td>
<td>72%</td>
<td>18%</td>
</tr>
</tbody>
</table>
There is potential for improved diagnostic test performance by advanced training and experience
Sonographer: Specificity is strongly correlated with experience

\begin{align*}
y &= 0.004x + 0.361 \\
R^2 &= 0.118 \\
y &= 0.006x - 0.060 \\
R^2 &= 0.788 \\
y &= -0.002x + 0.691 \\
R^2 &= 0.187
\end{align*}
Approximately 1 out of every 4 appendicitis cases with Appy Score > 7 had a positive U/S Appy study.
Conclusion

- On average, more studies were ordered per patient after U/S Appy (0.8 +/- 0.8) vs CT or MR (0.2 +/- 0.5)
- Sedation was more likely to be used with CT (7.7%) or MR (2.9%) vs. U/S (0%)
- Average length of stay was greater for patients who had CT/MRI ordered (1.5 ± 4 days) vs. U/S (1.0 ± 1.7 days)
- All Diagnostic Test Performance Variable (DTPV) values were lower for females compared to males, and for BMI > 30
- DTPV was greatly influenced by sonographer proficiency

Rady Children's UC San Diego Health Sciences
Significance of Conclusions

• “Non-visualized appendix” on U/S should not be interpreted as a negative study since it affects the sensitivity and specificity

• Ultrasound requires sedation less often, generates less total studies ordered per patient, and is associated with decreased average length of stay

• With increased experience/training of sonographers, there is improve “U/S Appy” diagnostic test performance
Limitations of U/S in diagnosis of acute appendicitis

- High proportion of non-visualized studies that were actually positive on further imaging/pathology
- BMI > 30
- Females
- Sonographer proficiency
- Increased experience and/or training of sonographers may greatly improve “U/S Appy” diagnostic test performance
Advantages of U/S compared to CT and MRI

• Sedation used less often
• Less total studies ordered per patient
• Decreased average length of stay
Thank you for viewing E2492