MEMORANDUM FOR 959 CSPS
ATTN: MAJ JAMES D COVELLI

FROM: 59 MDW/SGVU

SUBJECT: Professional Presentation Approval

1. Your paper, entitled **Diagnosis of Pediatric Appendicitis: Is MR Imaging More Appropriate than CT?** presented at/published to **Should Non-Contrast Rapid MRE Evaluation of Clinically Suspected Pediatric Appendicitis Trump CT after Equivocal Ultrasound? (No Publication Journal Assigned Yet) & American Roentgen Ray Society (ARRS), New Orleans, LA, 1-6 April 2017** in accordance with MDWI 41-108, has been approved and assigned local file #17059.

2. Pertinent biographic information (name of author(s), title, etc.) has been entered into our computer file. Please advise us (by phone or mail) that your presentation was given. At that time, we will need the date (month, day and year) along with the location of your presentation. It is important to update this information so that we can provide quality support for you, your department, and the Medical Center commander. This information is used to document the scholarly activities of our professional staff and students, which is an essential component of Wilford Hall Ambulatory Surgical Center (WHASC) internship and residency programs.

3. Please know that if you are a Graduate Health Sciences Education student and your department has told you they cannot fund your publication, the 59th Clinical Research Division may pay for your basic journal publishing charges (to include costs for tables and black and white photos). We cannot pay for reprints. If you are a 59 MDW staff member, we can forward your request for funds to the designated Wing POC at the Chief Scientist’s Office, Ms. Alice Houy, office phone: 210-292-8029; email address: alice.houy.civ@mail.mil.

4. Congratulations, and thank you for your efforts and time. Your contributions are vital to the medical mission. We look forward to assisting you in your future publication/presentation efforts.

   **LINDA STEEL-GOODWIN, Col, USAF, BSC**
   Director, Clinical Investigations & Research Support

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1. The author must complete page two of this form:
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   b. In Section 2, there may be funding available for journal costs, if your department is not paying for figures, tables or photographs for your publication. Please state “YES” or “NO” in Section 2 of the form, if you need publication funding support.

2. Print your name, rank/grade, sign and date the form in the author's signature block or use an electronic signature.

3. Attach a copy of the 59 MDW IRB or IACUC approval letter for the research related study. If this is a technical publication/presentation, state the type (e.g. report, QA/QI study, program evaluation study, informational report/briefing, etc.) in the "Protocol Title" box.

4. Attach a copy of your abstract, paper, poster and other supporting documentation.

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6. On page 2, have either your unit commander, program director or immediate supervisor:
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7. Submit your completed form and all supporting documentation to the CRD for processing (59crdpubspres@us.af.mil). This should be accomplished no later than 30 days before final clearance is required to publish/present your materials. If you have any questions or concerns, please contact the 59 CRD/Publications and Presentations Section at 292-7141 for assistance.

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10. If your manuscript is accepted for scientific publication, please contact the 59 CRD/Publications and Presentations Section at 292-7141. This information is reported to the 59 MDW/C. All medical research or technical information publications/presentations must be reported to the Defense Technical Information Center (DTIC). See 59 MDW 41-100, Presentation and Publication of Medical and Technical Papers, for additional information.

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   For presentations before professional societies and like organizations, the 59 MDW Public Affairs Office (PAO) will provide the needed review to ensure proper disclaimers are included and the subject matter of the presentation does not create any cause for DoD concern.

   If the sponsor of a conference or meeting is a DoD entity, an ethics review of your presentation is not required, since the DoD entity is responsible to obtain all approvals for the event.

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"The views expressed by those of the [author(s)] [presenter(s)] do not reflect the official views or policy of the Department of Defense or its Components"

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40-402."

"The animals and their ethical treatment were in compliance with the Animal Welfare Act of 1966, as amended.

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59 MDW FORM 3039, 20160628

Page 1 of 3 Pages
Should Non-Contrast Rapid MRI Evaluation of Clinically Suspected Pediatric Appendicitis Trump CT after Equivocal Ultrasound?

Electronic Poster: Diagnosis of Pediatric Appendicitis: Is MR Imaging More Appropriate than CT?

FUNDING RECEIVED FOR THIS STUDY: 

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IS THIS MATERIAL SUBJECT TO ANY LEGAL RESTRICTIONS FOR PUBLICATION OR PRESENTATION THROUGH A COLLABORATIVE RESEARCH AND DEVELOPMENT AGREEMENT (CRADA), MATERIAL TRANSFER AGREEMENT (MTA), INTELLECTUAL PROPERTY RIGHTS AGREEMENT ETC.?

MATERIAL IS FOR: 

PUBLISHED ABSTRACT (List intended journal.)

PUBLISHED POSTER (To be demonstrated at meeting: name of meeting, city, state, and date of meeting.)

PLATFORM PRESENTATION (At civilian institutions: name of meeting, state, and date of meeting.)

HAVE YOUR ATTACHED RESEARCH/TECHNICAL MATERIALS BEEN PREVIOUSLY APPROVED TO BE PUBLISHED/PRESENTED?

EXPECTED DATE WHEN YOU WILL NEED THE CRD TO SUBMIT YOUR CLEARED PRESENTATION/PUBLICATION TO DTIC

DATE

1 March 2016

59 MDW PRIMARY POINT OF CONTACT (Last Name, First Name, M.I., email)

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DUTY PHONE/PAGER NUMBER

210-292-5290

AUTHORSHIP AND CO-AUTHOR(S) List in the order they will appear in the manuscript.

LAST NAME, FIRST NAME AND M.I. GRADE/RANK SQUADRON/GROUP/OFFICE SYMBOL INSTITUTION (If not 59 MDW)

Covelli, James D Major/O4 959 CSPS

IS A 502 ISGUJAC ETHICS REVIEW REQUIRED (JER DOD 5500.07-R)? 

CERTIFY ANY HUMAN OR ANIMAL RESEARCH RELATED STUDIES WERE APPROVED AND PERFORMED IN STRICT ACCORDANCE WITH 32 CFR 219, AFMAN 40-401_IP, AND 59 MDW 41-108. I HAVE READ THE FINAL VERSION OF THE ATTACHED MATERIAL AND CERTIFY THAT IT IS AN ACCURATE MANUSCRIPT FOR PUBLICATION AND/OR PRESENTATION.

AUTHOR'S PRINTED NAME, RANK, GRADE

James D Covelli, Maj, O4

APPROVING AUTHORITY'S PRINTED NAME, RANK, TITLE

Robert M DeWitt, Maj, O4, Associate Program Director, Dept of Radiology

AUTHOR'S SIGNATURE

APPROVING AUTHORITY'S SIGNATURE

DATE

January 10, 2017

January 18, 2017
The abstract and slide presentation are approved.
Abstract No:
16-077
ePoster_16-077

Author(s):
James Covelli¹, Justin Costello¹, Christian Carlson¹

Institutions:
¹San Antonio Military Medical Center, San Antonio, TX

Purpose:
In lieu of potential radiation risks associated with CT, MR imaging has become much more prevalent in the evaluation of children with suspected appendicitis. While several studies have demonstrated its efficacy at dedicated stand-alone pediatric hospitals, the goal of this study is to determine if implementation of a MR pediatric appendicitis protocol is feasible in the non-subspecialty pediatric setting, where non-pediatric radiologists routinely perform interpretation.

Materials/Methods Used:
Pediatric appendicitis work-up algorithm was implemented at the San Antonio Military Medical Center emergency department in 2012 (diagram 1). Non-sedated MR imaging was obtained in patients with equivocal ultrasound findings and persistent clinical concern for appendicitis. MR protocols consisted of three whole abdomen T2 sequences through the abdomen (average scan time 11 minutes). No intravenous contrast was administered. Between 2012 and 2015, 415 pediatric patients (mean age 9.8 years old) underwent MRI of the abdomen after equivocal ultrasound evaluation. Non-pediatric radiologists interpreted the vast majority of MR exams.

Results:
Over the three year period of data acquisition, 10.2% (44/432) of patients were found to have appendicitis after surgery. Of those patients with pathologically proven appendicitis, 42 were true positives and 2 were false negatives by MRI, resulting in sensitivity and specificity of 95% and 99%, respectively. Additionally, negative and positive predictive values by MRI were 99% and 89%, respectively. Both false negative exams were surgically confirmed early appendicitis without inflammatory changes by MR imaging. Several non-appendiceal abnormalities were also found by MRI, including ovarian pathology (7/432), pyelonephritis (5/432) and terminal ileitis (3/432).

Conclusions:
MRI is an effective imaging modality for the evaluation of pediatric appendicitis and can be accurately interpreted by non-pediatric radiologists. Because of the lack of ionizing radiation and IV contrast, non-sedated, rapid MRI may be considered more appropriate than CT in the pediatric population, which is at higher risk for radiation-induced malignancies and also has less tolerance for IV placement.
Primary Track/Category:
Quality and Safety

Secondary Track/Category:
Clinical Education

Area of Focus:
Diagnostic Radiology

Disclaimer: The views expressed are those of the author(s)/presenter(s) and do not reflect the official views or policy of the Department of Defense or its Components.
Diagnosis of Pediatric Appendicitis: Is MR Imaging More Appropriate than CT?

San Antonio Military Medical Center
San Antonio, Texas

James D Covelli, MD
Justin E Costello, MD
Sundhas P Madireddi, MD
Christian L Carlson, MD
Neither the authors nor their immediate family members have a financial relationship with a commercial organization that may have a direct or indirect interest in the content of this exhibit.

The contents of this presentation are not the official views of, or are endorsed by, the U.S. Government, Department of the Air Force, Department of the Army, or any other governmental agency.
Purpose

- Prospective and retrospective studies have shown sensitivity and specificity of MRI to be comparable to CT.
- In lieu of potential radiation risks associated with CT, MRI has increased in children with suspected appendicitis.
- Several studies have demonstrated MRI efficacy at stand-alone pediatric hospitals.

The purpose of our study is to determine if implementation of an MRI pediatric appendicitis protocol is feasible in the non-subspecialty pediatric setting where non-pediatric radiologists and residents routinely perform interpretation.

10 year old female with perforated appendicitis
T2 Axial Fat Saturated image (left) and a coronal HASTE image (right) demonstrate a dilated fluid filled appendix with an appendicolith (arrow) and T2 hyperintense pelvic free fluid.
**Suspected Appendicitis?**

- In 2012, a pediatric appendicitis work-up algorithm was established for children aged 0-17 with suspected appendicitis in collaboration with SAMMC Radiology, Emergency Room, Pediatric Surgery, General Surgery and Pediatrics staff.
- Modifications were made to the algorithm to improve efficiency including:
  - Immediate ultrasound (US) review by radiologist
  - Orders for US and MRI were placed at the same time by the ER. If US was positive or clearly negative, the MRI order was cancelled
  - If equivocal US findings or non-visualization of the appendix, the patient was transported directly from US to MRI (instead of returning to the ER)
  - MRI scan time was reduced from 21 minutes to 11 minutes from 2012 to 2015 after determining the optimal sequences to arrive at diagnosis
- The latest algorithm (Figure 1) was implemented in 2015

![Flowchart of Appendicitis Algorithm](image)

**Figure 1.** Current SAMMC algorithm for all children 0-17 years of age with suspected appendicitis.

*This time was reduced from 21 minutes (in 2012) to 16 minutes in 2015 after reducing the total number of MRI sequences. Exams that did not include restricted diffusion took 11 minutes*
**Rapid MRI Protocol**

- A non-sedation MRI protocol was established using either 1.5T or 3T scanners and exams were worked in-between inpatient and scheduled outpatient exams.
- Multichannel torso coil was used
- Patient urinates prior to exam
- Technique for children ≥ 12 years
  - Breath hold
  - 4 mm slice thickness with 10% gap
- Technique for children < 12 years old
  - Free breathing
  - 3 mm slice thickness with 10% gap
- Trial sequences were found to have limited utility or did not add to or improve interpretation and were removed from our protocol:
  - In and out of Phase T1-weighted imaging
  - Sagittal and Coronal fat-saturation HASTE
  - VIBE
  - Diffusion-weighted MRI (DW-MRI)
  - TruFisp
  - SPARE

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**Current SAMMMC Rapid Appendicitis Protocol (protocol finalized in 2015)**

- **Axial T2-weighted fat saturated images**
- **Axial half-Fourier acquisition single shot turbo spin echo (HASTE)**
- **Coronal half-Fourier acquisition turbo spin echo (HASTE)**
  - Coronal HASTE FOV: Entire abdomen and pelvis
  - Axial HASTE and T2 FS FOV: Inferior endplate of L3 through the pubic floor
  - 256 x 256 matrix

Figure 2. *Current SAMMMC rapid MRI appendix protocol*
Radiologist and Clinician Education

- Between 2012 and 2015, 506 patients under the age of 18 (mean age 9.8 years) with clinically suspected appendicitis, and equivocal findings or non-visualization of the appendix on ultrasound, underwent MRI of the abdomen using our rapid MRI appendix protocol.
- The majority of exams were performed during overnight and weekend hours when a pediatric radiologist was unavailable.
- Approximately 40 residents (PGY2-PGY5) and 40 non-pediatric subspecialty attending radiologists interpreted >90% of the examinations.
- The primary focus was to identify key findings of appendicitis and alternative explanations for the patient's symptoms on MRI.
- A key component of instituting the protocol was training non-expert radiologists and residents.

Many methods (figure 3) were also employed in 2012-2013 to educate surgeons, pediatricians, and emergency physicians who were well experienced in CT and not as comfortable with MRI.

As a result, in the initial phases of our protocol, many patient's underwent CT after MRI for confirmation.

<table>
<thead>
<tr>
<th>Methods to Educate Clinicians</th>
<th>Departments of Radiology, Emergency Medicine, General and Pediatric Surgery and Pediatrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Rounds</td>
<td>Sharing literature documenting similar accuracy of MRI compared to CT</td>
</tr>
<tr>
<td>Literature</td>
<td>Robust Image Gently Campaign, fliers, posters, patient education pamphlets</td>
</tr>
<tr>
<td>ALARA Campaign</td>
<td>Included radiology residents and staff, general surgery residents and pediatricians</td>
</tr>
<tr>
<td>Workstation teaching</td>
<td>Interdepartmental radiologic-surgical-pathologic correlation</td>
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</table>

Figure 3. Methods used at SAMMC to educate other physicians.
In addition to didactic teaching, direct feedback was also highly effective. We maintained a database of over 500 cases at SAMMC for radiologist review with direct feedback provided to the interpreting radiologist when possible:
- MRI technique (motion, spatial resolution, etc)
- Pathology and surgical reports
- 1 month clinical follow up
- Alternative explanations for patient symptoms
- Good examples of positive and negative cases
- False positives, false negatives

### Table: Important concepts used in our exam interpretation

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
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<tbody>
<tr>
<td>Visualization of the appendix</td>
<td>A normal appendix does not need to be identified to exclude appendicitis. I.e. appendix is not seen and there is no free fluid or inflammation = no appendicitis.</td>
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<tr>
<td>Peri-appendiceal inflammation</td>
<td>Present in nearly all cases of acute appendicitis</td>
</tr>
<tr>
<td>Appendiceal wall thickening</td>
<td>Circumferential wall thickening &gt;2 mm was nearly always present in acute appendicitis</td>
</tr>
<tr>
<td>Small amount of free-fluid and appendix is not visualized</td>
<td>Appendicitis unlikely. May be physiologic or secondary to alternative pathology (ovarian, gastroenteritis, etc)</td>
</tr>
<tr>
<td>Appendiceal tip</td>
<td>If RLQ fluid of inflammation, should visualize full appendiceal length to exclude tip appendicitis</td>
</tr>
<tr>
<td>Size</td>
<td>Appendix was considered dilated when &gt;6mm; however, size is not a standalone criteria as the appendix may be enlarged without inflammatory changes</td>
</tr>
<tr>
<td>Alternative pathology</td>
<td>Assessing for alternative pathology is critical</td>
</tr>
</tbody>
</table>

Figure 4. *MR Findings that support or disfavor the diagnosis of appendicitis*
Protocol Efficiency

- We compared the time parameters of the first 50 and last 50 rapid MRI exams performed at SAMMC for suspected appendicitis
- Interval changes between first and last exam
  - Abdominal radiograph removed from initial protocol
  - Radiologist reviews US images and determines immediately if MRI is warranted. If so, the patient is sent directly to the MRI Suite
  - Female patient no longer required to fill their bladder (for ovarian evaluation) resulting in decreased ER wait time
  - Decreased number of MR sequences from 7 to 3

<table>
<thead>
<tr>
<th>Time Parameter Comparison Between the First 50 and Last 50 Rapid Appendicitis MRI Exams</th>
</tr>
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<tbody>
<tr>
<td></td>
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<tr>
<td>---------------------------</td>
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<tr>
<td>Average number of sequences</td>
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<tr>
<td>Average repeated sequences</td>
</tr>
<tr>
<td>US Duration</td>
</tr>
<tr>
<td>MRI scanning duration</td>
</tr>
<tr>
<td>US Start to MRI Finish</td>
</tr>
</tbody>
</table>

Figure 5. MRI Time Considerations

8 year old male with appendicitis
Left: Coronal HASTE image demonstrating a dilated fluid filled appendix
Right: Axial T2 FS image demonstrating a thickened T2 hyper intense edematous appendiceal wall (arrows) with intraluminal T2 hyper intense fluid
Statistical Analysis

506 patients* clinically suspected of having appendicitis aged 17 years or younger with equivocal ultrasound (or non-visualization of the appendix) underwent rapid MRI appendicitis imaging at SAMMC between April 2012 and Dec 2015.

* 6 cases were equivocal on MRI and were not included in the statistical analysis. These patients were admitted for observation and all were discharged without acute appendicitis

MRI was classified as either positive or negative

Positive
- MRI findings consistent with appendicitis
- MRI secondary signs of appendicitis (e.g. free fluid with right lower quadrant, inflammation and no appendix visualized)

Negative
- Normal MRI appearance of the appendix
- Appendix not visualized but no secondary signs of appendicitis (inflammation or free fluid)

11% of all patient's suspected of having appendicitis were true positives (confirmed by surgery or pathology).

<table>
<thead>
<tr>
<th></th>
<th>95% CONFIDENCE INTERVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity by MRI</td>
<td>96%</td>
</tr>
<tr>
<td>Specificity by MRI</td>
<td>98%</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>85%</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6. Statistical Analysis

16 year old female with tip appendicitis.

Left: Axial T2 FS images demonstrate a dilated appendiceal tip with appendicolith and inflammation (arrow)

Right: Coronal HASTE demonstrating a dilated appendiceal tip (arrow)
**Alternative Diagnoses**

- Our exams proved useful in assessing alternative causes for the patients' clinical presentation. And many abnormalities would be more difficult to interpret on ultrasound or CT.
- Several non-appendiceal abnormalities were found to likely explain the patients' symptoms.
- All patients' records were reviewed for 1 month following discharge to determine if any returned with appendicitis.

### Non-appendiceal abnormalities

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Ovarian Pathology</td>
<td>3%</td>
</tr>
<tr>
<td>Pyelonephritis</td>
<td>2%</td>
</tr>
<tr>
<td>Rectus Abdominus Edema/Tear</td>
<td>1%</td>
</tr>
<tr>
<td>Terminal Ileitis</td>
<td>3%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1%</td>
</tr>
<tr>
<td>Other findings (mesenteric adenitis, cholelithiasis, large stool burden, UTI, Right hip osteonecrosis, right inguinal hernia)</td>
<td>11%</td>
</tr>
</tbody>
</table>

*Figure 7. Alternative diagnoses.*

7 year old female with terminal ileitis
Axial T2 FS demonstrates circumferential thickening of the terminal ileum (arrow)

5 year old female with ovarian torsion
Axial T2 FS demonstrates an enlarged left ovary with peripheralization of the follicles and pelvic free fluid.
Conclusions

1. MRI is an effective imaging modality for the evaluation of pediatric appendicitis and can be accurately interpreted by non-pediatric radiologists.

2. Because of the lack of ionizing radiation and IV contrast, non-sedated, rapid MRI may be considered more appropriate than CT in the pediatric population, which is at higher risk for radiation-induced malignancies and also has less tolerance for IV placement.

3. Clear communication with training of radiology residents, non-pediatric radiologists, clinicians and pediatric radiologists is paramount in guaranteeing the success of MRI in a predominantly adult medical center.
References


Contact: James D Covelli, MD
James.d.covelli.mil@mail.mil