MR Enterography; Technique and applications

Dr Tanya Chawla
Division of Abdominal Imaging
1. All of the following are biphasic oral contrast agents except:

- a) Water
- b) VoLumen ®
- c) Blueberry juice
- d) Locust bean gum
- e) Methylcellulose
2. The following MRI findings correlate highly with activity in Crohn’s disease *Except*

a) T2 hyperintensity within the bowel wall
b) Mural thickening
c) Lymphadenopathy
d) Degree of enhancement
e) Pattern of enhancement
Overview

• MRI
  • Technique
  • Performance characteristics
  • Radiation implications of CT

• Crohns’

• Concept /utility of imaging and damage score

• Role of diffusion weighted imaging (DWI)

• Other applications
Why MRI?

- Visualization of entire GI tract
- Luminal distension pre-requisite
  - Avoids false positives
  - Overlooking diseased segments
- Absence of ionizing radiation
- Multi-planar capability
- Superior soft tissue and anatomical resolution
- Dynamic and functional information
- Better safety profile of contrast media
- Repeated imaging pre and post Rx not an issue
<table>
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<th>Technique</th>
<th>Crohn’s</th>
<th>Other apps</th>
<th>Conclusion</th>
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Medical Imaging • University Health Network • Mount Sinai Hospital • Women's College Hospital • University of Toronto
Contrast agents

- Homogenous and uniform distension
- High contrast between lumen and bowel wall
- Relatively low cost
- Absence of serious side effects

"THE BAKER’S HALF-DOZEN" drink from 7 cups at the same time
## Contrast agents

<table>
<thead>
<tr>
<th>Type</th>
<th>Benefits</th>
<th>Disadvantage</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>Detect wall thickening</td>
<td>May mask enhancement</td>
<td>Dilute gadolinium chelate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited in subtle mucosal disease</td>
<td>Manganese chloride</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ferrous ammonium citrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Blueberry juice</td>
</tr>
</tbody>
</table>

Increased T1 signal intensity causes by paramagnetic effect
## Contrast agents

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<th>Type</th>
<th>Benefit</th>
<th>Disadvantage</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Bowel inflammation more detectable Inter-loop abscesses</td>
<td>Reduced conspicuity of bowel wall Mask low signal lesions</td>
<td>SPIO USPIO Ferumoxsil</td>
</tr>
</tbody>
</table>

*Induce local field inhomogeneity and shorten T1 and T2 relaxation*

_Achiam et al Eur Rad; Jan 2010_
Biphasic
Water, Mannitol
VoLumen®, Polyethylene glycol (PEG)
LBG, methylcellulose
Practical points

- Patient NBM for 4-6 hours prior
- Ingest 1500 mls /45 minute period
- +/-erythromycin (promotes gastric emptying)
- Prone
  - eliminate peristaltic and respiratory movement
  - Reduce scan volume(13 cms to 9 cms)
  - Help separation of bowel loops
  - No improvement in lesion detection (Cronin et al 2008)
- Gadolinium 0.1-0.2 mmol/kg with delay of 40-80s
- Time to peak enhancement typically 60-70 s
  - (Lauenstein et al 2005)
- Routine buscopan
  - Divided dose
Trouble shooting
Benefits?

- **Enterography**
  - Better tolerance and patient compliance
  - Non invasive
  - No additional procedure or radiation
  - Distension less reliable
  - ?sensitivity diminished

- **Enteroclysis**
  - 8F catheter/120-150 ml/min
    - Invasive
    - Additional admin and cost
    - Reliable uniform distension
    - Improved sensitivity for subtle /early stage disease
    - Helpful if low grade obstruction
    - Useful if patient unable to orally ingest
## MRI sequences

<table>
<thead>
<tr>
<th>Type of sequence</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2W/SSFSE/HASTE</td>
<td>+/- fat saturation, Assess mural inflammation and changes in peri-enteric fat, Sensitive to flow voids, Poor mesenteric info due to k space</td>
</tr>
<tr>
<td>Balanced or hybrid gradient echo sequence/B-FFE, FIESTA or True FISP</td>
<td>Intermediate contrast, Short TR &lt;3 msec, Motion free T2W imaging of the bowel</td>
</tr>
<tr>
<td>T1W imaging FSPGR</td>
<td>2D or 3D, Parallel or SENSE imaging, 0.2mmol/kg at rate of 2 ml/sec, Acquisitions at 30, 70 sec coronal, 90 sec axial volume</td>
</tr>
</tbody>
</table>

Routine administration of hyoscine Double dose
Artifacts
## Parameters for 1.5T

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Axial FISP</th>
<th>Coronal FISP</th>
<th>Axial RARE</th>
<th>Coronal RARE</th>
<th>3D VIBE</th>
<th>2DTrue FISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR msec</td>
<td>4.3/2/2</td>
<td>4.3/2.2</td>
<td>1000/90</td>
<td>1000/90</td>
<td>4.1/1.1</td>
<td>500/75</td>
</tr>
<tr>
<td>Flip angle</td>
<td>50</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>FOV</td>
<td>320-400</td>
<td>320-400</td>
<td>320-400</td>
<td>320-400</td>
<td>320-400</td>
<td>400</td>
</tr>
<tr>
<td>Parallel factor</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Thickness</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2.5</td>
<td>10</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>125</td>
<td>125</td>
<td>62.5</td>
<td>62.5</td>
<td>62.5</td>
<td>1930</td>
</tr>
<tr>
<td>Time acq</td>
<td>19</td>
<td>21</td>
<td>15-20</td>
<td>15-20</td>
<td>15-18</td>
<td>25</td>
</tr>
</tbody>
</table>
Bowel peristalsis assessment

- High temporal
- High spatial resolution
- Evaluation of mechanical bowel obstruction, strictures, areas of diminished motility
- Tru FISP(SSFP)<1s/frame
- HASTE(SSFSE)
- 1 or more slice selections
- Multiple repeated measurements if needed
- Free breathing
Crohns’ disease

• Chronic relapsing auto-immune disorder
• Incidence of Crohns’ has increased by 31% since 1991
• MR sensitivity and specificity 88-98% and 78-100%
• Trans-mural and chronic inflammation
• 50% of patients with chronic inflammation require resection

• Surgery not curative
  – Endoscopic evidence of recurrence in 66% within 3 months
  – On average clinically active disease within 2-3 years of intestinal resection
  – Despite advances in medical therapy risk of surgery constant over last 30 years
Making the diagnosis

Clinical indices

Serum markers

Endoscopy

Stool Markers

Imaging
### Meta-analysis

<table>
<thead>
<tr>
<th>Modality</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>89.7%</td>
<td>95.6%</td>
</tr>
<tr>
<td>MRI</td>
<td>93.0%</td>
<td>92.8%</td>
</tr>
<tr>
<td>Scinitgraphy</td>
<td>87.8%</td>
<td>84.5%</td>
</tr>
<tr>
<td>CT</td>
<td>84.3%</td>
<td>95.1%</td>
</tr>
</tbody>
</table>

- Per patient basis US performed better in predicting the absence of IBD
- MR less operator dependent and better at assessing proximal disease
- MR slightly better performance using enteroclysis technique vs. oral enterography
- Use of a modality that does not use radiation is preferable

Horsthuis et al, Radiology 2008;247
Radiation exposure in cohort of patients with IBD

• Population based cohort of 215 patients assessed
• Total effective dose of diagnostic ionizing radiation was estimated
• CD=103 and UC=112
• Mean age of diagnosis 38.6 and 39.4 yrs respectively

Peloquin et al AJG 2008;103:2015-2022
Findings

- Background dose annually 3 mSv
- Annual median effective dose
  - CD 3.1 mSv/yr
  - UC 1.2 mSv/yr
- Adjusting for time since symptom onset CD patients 2.46X total effective dose compared with UC (P=001)
- Difference in effective dose was due to twice the number of CT scans in CD sub-group
- CT enteroclysis changed management 62% of patients with CD
Factors contributing to cumulative dose in patients with CD

- 409 patients with CD identified
- Cumulative effective dose calculated over a 14 year period
- Complete data in 399
- CT accounted for 77.2 % of diagnostic radiation
- Mean CED 36.1 mSv
- RISKS higher
  - Early age at diagnosis (<17)
  - Upper GI tract disease
  - Penetrating disease
  - Requirement for infliximab or intravenous steroids
  - Multiple surgeries

*Desmond et al ; Gut 2008*
What are we looking for?

- Is there inflammatory disease?
- Number, length and location of involved segments
- What sub-type is it?
- If there is stenosis;
  - Inflammatory or fibrotic
- Inflammatory activity
  - Grade severity (mild, moderate or severe)
- Are there mesenteric complications?
  - Abscess or fistula
Imaging findings that correlate with presence of disease (overlap with CT)

- Mural thickening
- Hyper enhancement of diseased segments
- Mural stratification
- Mesenteric vascular engorgement
- Fibro-fatty proliferation
- Increased SI/attenuation
- Mesenteric fluid
- Mesenteric adenopathy
MR findings that correlate with clinical/endoscopic/biochemical signs of disease activity

<table>
<thead>
<tr>
<th>MR finding that correlates with activity</th>
<th>T weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickening and enhancement</td>
<td>T1</td>
</tr>
<tr>
<td>Increased mesenteric vascularity</td>
<td>T1</td>
</tr>
<tr>
<td>Lymph node enhancement</td>
<td>T1</td>
</tr>
<tr>
<td>Increased mural signal</td>
<td>T2</td>
</tr>
<tr>
<td>Increased mesenteric fat signal</td>
<td>T2</td>
</tr>
</tbody>
</table>

Wall thickness of >3 mm sensitivity of 83-91%
Specificity of 86-100%

Maccioni ,Abdomin Imaging 2010 ;35
MRI findings associated with pathological inflammatory grading

<table>
<thead>
<tr>
<th>MRI FINDINGS</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickening</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Degree of enhancement (delayed)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pattern of enhancement</td>
<td>P=0.02</td>
</tr>
<tr>
<td>Relative T2W hyperintensity</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Blurred wall enhancement</td>
<td>P=0.018</td>
</tr>
<tr>
<td>Comb sign</td>
<td>P=0.004</td>
</tr>
<tr>
<td>Fistula</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Abscess</td>
<td>P=0.049</td>
</tr>
</tbody>
</table>
What is the utility of image based scoring systems?

- Detection of active inflammation no longer main goalpost
- Not sufficient to guide therapeutic decision making
- Disease severity most crucial aspect in diagnostic algorithms
- Magnetic resonance index of disease activity
- MaRIA correlates highly with CDEIS
MaRIA score

- Objective MRI based score
- Activity and severity of CD
- Includes parameters such as bowel wall thickening
- Excludes nodal enlargement (low prevalence and high variability)
- Significant correlation with
  - Clinical activity
  - Endoscopic activity
  - C-reactive protein levels
## Image analysis

<table>
<thead>
<tr>
<th>Imaging finding</th>
<th>Pattern</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mural thickening (distended lumen)</td>
<td>&lt;3 mm</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>≥4 mm</td>
<td>Thickened</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-6 moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;6 severe</td>
</tr>
<tr>
<td>Bowel wall SI</td>
<td>Homogenous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stratified(T2W)</td>
<td>Sub-mucosal edema or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fat present</td>
</tr>
<tr>
<td>Bowel wall enhancement T1W dynamic post gad</td>
<td>Homogenous (hyper or moderate)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stratified double layer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triple layer</td>
<td></td>
</tr>
</tbody>
</table>
Target sign

- Enhancing mucosa and serosa
Halo sign

Dark submucosal layer due to fibrosis
Correlates with elevated CRP
Suggests active disease
True FISP; High resolution T2W images show areas of ulceration as foci of high T2 signal intensity
Acute inflammatory subtype: mucosal fold thickening and wall edema

Sinha R et al. Radiographics 2009;29:1847-1867
Hyperenhancement

• Early and most sensitive sign of active inflammation
• Seen in absence of significant mural thickening
• If Asymmetric = CD
Hyperenhancement
Coronal imaging

Coronal FISP (A) and post gadolinium coronal T1W (B and C)
Coronal imaging
Pseudo-sacculation
Detection of intestinal fibrosis

- Pharmacological treatment
- Surgical management
DWI in CD of small bowel and colon?

- Relatively few studies published
- Good sensitivities of DWI for assessing acute inflammation
- Significant decrease of ADC values in acutely inflamed segments as c/w healthy segments
- Absolute value of ADC shows great interstudy variability
Does DWI allow you to forego luminal distension?

- No
- Mandatory for assessment of bowel wall thickness
- Improved visual assessment and depiction of mural enhancement
MRI; fibrosis

- On **T2W** imaging
  - *Reduction in signal intensity of thickened bowel wall*
  - *Low bowel wall signal intensity*

- On **T1W** imaging
  - *Reduction in bowel wall enhancement*
  - *Absent or minimal trans-mural enhancement*
  - Overall sensitivity, specificity and accuracy of MRI are 58%, 76% and 65% respectively
Diffusion weighted imaging (DWI)

- Derives image contrast from differences in motion of water molecules between tissues
- Study aimed to assess
  - Accuracy of DWI MRC without oral and rectal preparation in detection of colonic inflammation evaluated by conventional OC
  - Correlated with clinical and biological IBD indices

Oussalah et al
Gut 2010 59:1056-1065
Study design and results

- 96 patients (UC=35, Crohns=61) underwent MRC with DWI
- 68 had endoscopy within 48 hrs
- MR score better accuracy in UC (p=0.003)

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
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<tbody>
<tr>
<td>Ulcerative colitis</td>
<td>89.47%</td>
<td>86.67%</td>
</tr>
<tr>
<td>Crohns</td>
<td>58.33%</td>
<td>84.48%</td>
</tr>
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</table>
Results

- In UC total MR score correlated with total modified Baron score $p=0.0001$ and the Walmsley index $p<0.0001$
- Crohns disease the MR score correlated with simplified endoscopic activity score $p=0.001$ and the CDAI $p=0.004$
- Accuracy of DWI for predicting endoscopic inflammation higher in UC
- Due to contiguous disease vs. segmental involvement in Crohns
Mesenteric changes and hyperemia
Stenotic CD
Crohn's disease; fistulizing
Concept of intestinal damage

- Outcome measures thus far
  - Focused on clinical and endoscopic activity for assessing patient response to therapy
  - 2011 introduction of a Lemann score
  - Based on damage location, extent and severity
  - Combined findings on MRI with surgical history, OGD and ileo-colonoscopy
Lémann score

• Aims to change symptom driven approach to damage driven approach

• Assessment of cumulative damage in a spectrum of patients with differing clinical stages

• Potential applications include
  • Identification of early disease
  • Those in whom early aggressive management may avoid complications/damage
  • Identify risk factors for progression
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How does MR perform in pick up of small bowel tumours?

- No large series performed
- Retrospective study (1) using enteroclysis
  - 91 patients with 30 path proven tumours
  - Sensitivity of 91-94%
  - Specificity of 97%
  - No IV contrast administered
- Series (2) assessing MR enteroclysis for small bowel neoplasms in symptomatic patients
  - Accuracy 96.6%
  - High inter-observer agreement

1. Van Weyenberg. Radiology 2010;254
2. Masselli Radiology 2009;251
Polyposis syndromes

- Peutz-Jegher, Gardner, Cowden
- NF, juvenile polyposis
- PJ:
  - Autosomal dominant
  - Multiple hamartomatous polyps and pigmented mucocutaneous lesions
  - Lifetime risk of malignancy around 60%
  - Variable surveillance protocols
Comparison with CT?

- More sensitive for detection of mucosal lesions
  - Better soft tissue characterization
  - Better detection of more subtle abnormality
  - CE may fail to depict neoplastic disease in \( \approx 18.9\% \) of cases (sub-mucosal)
  - Capsule retention in as many as 10-25\%
CT and MRI faceoff
CT and MRI faceoff
Feasibility in surveillance of polyps with patients with PJ syndrome?

• **Capsule**
  • Safe, feasible and sensitive for surveillance particularly in pediatric population
  • Capsule better at detection of small 6-10mm lesions
  • Larger polyps; more clinically relevant
  • Seen in absence of adequate distension on MRE
  • MRE better at localization
Celiac disease

- No role in diagnosis
- Provide
  - Morphologic information
  - Extra intestinal findings
- Poor response to medical therapy
- Those with recurrent symptoms despite gluten withdrawal
- RCD

- Villous atrophy
- Reversal fold pattern 63-68%
- Small bowel malignancy
- Lymphadenopathy
- Ulcerative jejunitis
- Enteropathy associated T cell lymphoma (EATL)
Role of MRI in SBO?

- High grade SBO
  - CT
  - Availability, cost, unstable patient
  - MRI; finite role: pregnant or pediatric patient

- Low grade SBO (enteroclysis)
  - If benign look for generalized mural thickening
  - Low signal intensity bands course through mesenteric fat
  - Clumping of loops
  - Malignant: localised mural thickening; +/- mass; peritoneal thickening and enhancement
SBO due to ileal disease
SBO due to ileal disease
RLQ pain. Normal appendix on US
Intestinal TB

- Relatively rare manifestation
- Ileocecal region involved in 90% of affected cases
- Only 15% have concomitant thoracic disease
  - Cecum and ascending colon > terminal ileum
  - Asymmetric thickening ICV and medial wall of cecum
  - Deformed cecum
  - adenopathy
Intestinal TB

• Free or loculated ascites; thin mobile septa
• Smooth peritoneal thickening and enhancement
• Misty mesentery with enlarged nodes
• Early stage disease may overlap with CD or lymphoma
Benign lesions
Malignant lesions

- 60-70% of symptomatic SB lesions are malignant
- 40% adenocarcinomas
  - *Duodenum* 50%
  - *Jejunum* 30%
  - *Ileum* 20%
- Short segment Ix

**Adenocarcinoma**
- Eccentric thickening/irregular margins
- Annular /lumen effacing
- Delayed enhancement
- Nodal enlargement not consistent feature
- Mets to liver, peritoneum
Carcinoid

- Represent 33% of SB malignancies
- Appendix (50%) or distal ileum
- 10% develop syndrome
- SB carcinoids
  - Avidly enhancing/submucosal
  - Multi focal polypoidal lesions
  - May also show uniform mural thickening (Bader et al)
- Mesenteric
  - isointense to muscle on T1W and T2W
  - 2-4 cms in diameter
  - Spiculated tissue at periphery
Small bowel carcinoid
**GIST**

- Most common mesenchymal neoplasm of the GI tract
- Gastric 60%
- Small bowel 30%
- Multiple in setting of NF1
- Originate from m.propria
- 70-80% benign

- Small bowel GIST
  - Bleeding
  - Intussusception
  - Chronic anemia

- Exoenteric mass
- Heterogeneity
- Lack of adenopathy
- Avid enhancement
Epigastric pain and obstructive symptoms
Ischemic stricture
Lymphoma

- Primary
- Secondary as part of widespread lymphoma
- NH B cell most common subtype
  - Distal ileum
- T cell ➔ celiac

- Pleomorphic
  - Single segment or multi-centric
  - Exoenteric mass
  - Annular mural thickening
  - Aneurysmal ulceration
  - Non obstructing
Conclusion

• Pivotal modality in assessment of small bowel disease

• Continuing improvements in technology
  • Robust, reproducible, radiation free alternate
  • Balance against cost and availability issues
  • Increased concern re radiation implications will result in higher utilization
  • Be aware of scoring systems/impact on management
  • Utilize additional functional tools for increased confidence
1. All of the following are biphasic oral contrast agents except:

a) Water
b) VoLumen ®
c) Blueberry juice
d) Locust bean gum
e) Methylcellulose
2. The following MRI findings correlate highly with activity in Crohn’s disease

Except

a) T2 hyperintensity within the bowel wall
b) Mural thickening
c) Lymphadenopathy
d) Degree of enhancement
e) Pattern of enhancement