MRI of bowel

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I have no relevant disclosures
Objectives

• Why do it?
• How good is it?
• How do we do it?
• What are we looking for?
• Are there are additional advanced applications that can help me?
• What is the utility of scoring systems?
• Can I use it for non IBD?
Why perform MRE

- Additional information to clinical / endoscopic assessment
- Highly predictive of tissue inflammation
- Can be used to evaluate disease activity
- Identify both stricturing and penetrating complications
- Less invasive and risky
- **MRE reliable tool for assessment of therapeutic response**
- Potential risk of obstruction and device retention with CE
Performance characteristics

• Sensitivity and specificity for the detection of CD; 93% and 92.8% respectively
• Similar performance to CTE
• Hafez et al MRE influence therapeutic strategy
  – 61% of patients overall
  – Retrospective review 55% escalation of medical therapy and 32% triaged to surgery
  (2)

• Potential indications include
  – Surveillance of known CD
  – Evaluation in setting of incomplete or normal ileocolonoscopy (but high clinical suspicion)
  – First line diagnostic approach in pediatric CD

Ha et al Dig Dis Sci 2011,56(10)2906-13
TECHNIQUE
Practical points

- Patient NBM for 4-6 hours prior
- Ingest 1500-2000mls /45-60 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
## 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

<table>
<thead>
<tr>
<th>Type</th>
<th>Benefit</th>
<th>Disadvantage</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Bowel inflammation more detectable</td>
<td>Reduced conspicuity of bowel wall</td>
<td>SPIO, USPIO, Ferumoxsil</td>
</tr>
<tr>
<td></td>
<td>Inter-loop abscesses</td>
<td>Mask low signal lesions</td>
<td></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
### 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</td>
</tr>
<tr>
<td></td>
<td>Assess mural inflammation and changes in peri-enteric fat</td>
</tr>
<tr>
<td></td>
<td>Sensitive to flow voids</td>
</tr>
<tr>
<td></td>
<td>Poor mesenteric info due to k space</td>
</tr>
<tr>
<td>Balanced or hybrid gradient echo sequence/B-FFE,FIESTA</td>
<td>Intermediate contrast</td>
</tr>
<tr>
<td></td>
<td>Short TR &lt;3 msec</td>
</tr>
<tr>
<td></td>
<td>Motion free T2W imaging of the bowel</td>
</tr>
<tr>
<td>T1W imaging FSPGR</td>
<td>2D or 3D</td>
</tr>
<tr>
<td></td>
<td>Parallel or SENSE imaging</td>
</tr>
<tr>
<td></td>
<td>0.2mmol/kg at rate of 2 ml/sec</td>
</tr>
<tr>
<td></td>
<td>Acquisitions at 30, 70 sec coronal, 90 sec axial volume</td>
</tr>
</tbody>
</table>

Routine administration of hyoscine
Double dose
## 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>2D True 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>
High resolution images

• Potential for focused evaluation of a segment of small bowel suspected of being diseased
• Combination of fat sat tru FISP
• SSFSE
• Small FOV (160-250)
• Images acquired perpendicular to bowel segment
• Contiguous thin sections 2-3 mm
• Matrix of 128-256 X 128-256
Clinical impact?

- Improved diagnostic confidence
- Depicts apthous ulcers and trans mural and mesenteric changes
- Allows accurate characterization and classification
- Time trade off = 3 mins per study
Potential findings on high res T2W

- **Serosal hypervascularity**
  - Tiny serpentine vessels with high signal next to serosa
  - Predictive of acute or acute on chronic disease

- **Mucosal findings (best depicted on true FISP)**
  - Deep/linear ulcers
  - Cobblestoning

- **Sensitivity and specificity on MRI**
  - Superficial 69 and 99%
  - Deep 94 and 99%
3T imaging

- Increased SNR 1.7 -1.8 fold
  - Improve spatial resolution
  - Diminish scan time
- T1W shortening effect of gadolinium more pronounced
  - Increased CNR
  - Improved conspicuity of enhancing lesions
  - Decreased volume of gad required
- Fat suppression more pronounced at 3 T than 1.5 T due to wider diff in processional frequencies
Disadvantages of 3T

• Trade off
  – Increased artifacts
  – Increasing energy deposition
  – Double field strength quadruples SAR
  – Limitation in RF specific sequences
  – Relevant in abdo imaging as SAR proportional to volume being imaged
Imaging findings and Phenotype
Active inflammation

- Mucosal ulceration
- Stratified pattern enhancement
- Bowel wall thickening
  - sub-mucosal edema
  - Inflammatory infiltrate
- Restriction on DWI
- Adenopathy
- Comb sign
Fibro-stenosing disease

• Wall thickening
  – Collagen deposition

• Homogenous mural enhancement

• Luminal narrowing
  – Pre-stenotic dilation

• Pseudopolyps
  – Healing process
  – Seen along mucosa

• Fibrotic stricture
  – Low T1 and Low T2W
  – Absence of edema
  – Minimal to no hyperemia
Penetrating disease

- Extension of inflammation along the serosa
  - Formation of blind ending sinus tract
  - Communication with another structure (fistula)
  - Can result in abscess
  - Reactive mesenteric changes
Bowel wall thickening

- Best assessed in SSFSE or post gad TIW images
- Normal wall 1-3 mm
- Provided adequate distension
- Ranges from 5-10 mm in CD diseased segments
- Thickening may diminish in areas of remission
Edema

- Useful sign of active of severe inflammation
- Best done on fat sat T2 sequences
- Helps discriminate from intra-mural fat
- Seen as ↑ intra mural T2 signal
Bowel wall enhancement

- Correlates with
  - Degree of inflammation and disease activity
- Pattern of enhancement is useful in assessing active disease
- Homogenous enhancement non specific : seen in active and chronic disease

- Layered pattern of enhancement ; more specific for active inflammation
- Enhancement ↓ in patients going into remission
- DWI hyperintensity also correlates with disease activity

Buisson et al Aliment Pharmacol Ther 2013 37(5) 537-45
Halo sign

Dark submucosal layer due to fibrosis
Mural ulceration

- Usually seen in severe disease
- Improve confidence by use of fat sat
- More common along mesenteric border
- May vary from
  - Linear lesions (fissures)
  - Mucosal defects in thickened hyperenhancing wall

Direct sensitivity for ulcers (65-70%)
- When combined with edema ↑ sensitivity to
Correlates with elevated CRP
Suggests active disease
Hyperenhancement
Coronal imaging

Coronal FISP (A) and post gadolinium coronal T1W (B and C)
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>

Zappa M et al. Which magnetic resonance imaging findings accurately evaluate inflammation in small bowel Crohn’s disease? A retrospective comparison with surgical pathologic analysis. Inflamm Bowel Dis. 2011 Apr;17(4):984-93
DCE imaging

- Useful surrogate of inflammation
- Actively inflammed bowel shows increased enhancement
- Increases over time until plateau reached
- Enhancement pattern and dynamics vary when disease is inactive
Semi quantitative analysis

- Peak uptake
- Slope of enhancement curve
- Clinical disease activity

• Correlate with inflammatory activity on BX
Quantitative analysis

Pharmacokinetic models

- Convert SI to tissue concentration of gadolinium
- Calculate parameters that reflect tissue perfusion

Inflamed segments show faster $K_{\text{trans}}$ from intravascular space to the EC space
Advanced techniques
Motility

- Motility changes in terminal ileum show significant correlation to histopathological changes
- Both for active and chronic disease
- Not only for disease presence
- But also for disease severity
- Therefore motility changes more useful for grading activity than predicting disease activity
Bowel motility

- High temporal
- High spatial resolution
- Fast T2W cine sequences
- Repeated acquisitions in a single plane with one breath hold
- Allow quantitative and qualitative assessment
- Evaluation of mechanical bowel obstruction, strictures, areas of diminished motility
2 part analysis

Qualitative

• Qualitative
• Primary visual assessment
• Overview of motility
• Direct comparison with other segments in same patient is a useful internal standard

Quantitative

• Bowel wall motion and peristalsis are measured as a change in cross-section diameter over time
• Software plots this as graph over time
Is there a value added benefit?

- 40 patients with and without cine MRI
- Cine depicted 35 more disease related findings than did standard MRI ($p=0.007$)

Menys et al

- 28 patients with CD
- Showed a significant difference in motility between inflamed and non-inflamed T1
- Quantified motility using a motility index (MI)
- MI negatively correlated to the acute inflammation score assigned at time of biopsy
- *Quantified motility* may therefore be used to assess disease activity

Menys et al ESGAR 2011
DWI in CD of small bowel and colon?

- Relatively few studies published
- Restricted diffusion is a good surrogate for acute inflammation
- Hyperintensity on high B-value DWI images and reduced apparent diffusion co-efficient (ADC)
  - Significant decrease of ADC values in acutely inflamed segments as c/w healthy segments
  - Absolute value of ADC shows great inter study variability
- Combination of DWI and DCE MR improves sensitivity for detection of active inflammation
DWI

- Utility in distinguishing active vs chronic disease
- Also invaluable in patient unable to receive gadolinium

- Can perform as either
  - BH ss
  - OR free breathing using multiple averages
  - Free breathing allows greater SNR and smaller section thickness (4-6 mm)
  - Use b value of 800 or more to reduce impact of shine through
T2w thick slab projection

T2w

Fusion T2w/DWI

FIESTA

T1w early

Length: 0.900 cm (5.400 pix)

T1w equilibrium
DWI

- Sensitivity, specificity and accuracy of 86%, 81.4% and 82.4% for detection of disease active segments

Kiryu et al. JMRI 2009; 29(4): 880-6
Detection of complications

- **Strictures**
  - Wall thickening
  - Upstream dilation and obstruction
  - Fibrotic low T1W and low T2W

- **Fistula**
  - Natural progression of ulceration to extra luminal extension
  - Sinus or fistula into adjacent bowel, skin or organs

- **Appear as linear tracts of high T2W signal**
- **Network of intersecting tracts that may tether the adjacent loops**
- **DWI useful in detection**
- **Equivalent to post gad sequences in detection**

**DIAGNOSTIC CLUE**
- Look for angulated and inflamed loop fixed to a structure
Phlegmon and abscess

- Extension of ulceration into the mesentery
- Heterogeneous on T1W
- Intermediate to low on T2W
- Show intense peripheral enhancement
- DWI useful for imp conspicuity
- Delayed acquisitions help discriminate
Inflammation vs. fibrosis

- Why is distinction important?
- Impacts patient management
- Decision to optimize immunosuppression
- Intervene early;
  - Stricturing
  - Penetrating complication
Role of MTF

- Has potential for determining the collagen content of the bowel wall
- Quantify fibrosis
- Contrast determined by fraction of immobilized phospholipid cell membranes in tissue

- 2 data sets acquired
- With and without application of a off resonant pre pulse that saturates low mobility pool of hydrogen nuclei
- Tissues with fibrosis have a high MT effect
- Relative signal intensity in each data set allow calculation of the MTR (ratio)
Clinical utility of MT

- Prospective study with 31 pts
- $1.5 \, T$ scanner
- Patients classified using clinical data, standard MRI and histopathology
- MT ratios of small bowel wall were computed

- Normal bowel wall
- Intermediate MTR of $25.4 \pm 3.4\%$
- Bowel wall with fibrosis MTR was significantly increased
  - $35.3 \pm 4\% \, p<0.0001$
- Acute inflammatory stenosis; MTR same or lower than normal bowel wall

Pazahr et al MAGMA (2013) 26:291-301
MRI disease severity scores

• Validated, robust and readily useable
• Facilitates quantification of inflammatory activity between and within patients over time
MaRIA score

- Objective MRI based score
- 2008 (30 patients with anastamotic recurrence MRE and ileocolonscopy) 6-24 months after resection
- Includes parameters such as bowel wall thickening, enhancement, T2W hyperintensity
- Excludes nodal enlargement (low prevalence and high variability)
- MRI and the endoscopic Rutgeerts score $\kappa = 0.67$
- Inter observer agreement for MRI score $\kappa = 0.89$
How is MaRIA calculated?

- MaRIA=[1.5 x wall thickness]
- +[0.02 x relative contrast enhancement]
- +[5 x edema]+[10 x ulcers]
Objectives

1. Accuracy of MRE to detect endoscopic mucosal healing (CDEIS < 3.5)
2. Compare magnitude of changes between endoscopy and MRE
3. Characterize responsiveness of each MRE character
4. Assess relationship between MRE changes to changes in disease activity and biomarkers

Ordas et al. Gastroenterology 2014;143:374-382
Study design

- Quantification of endoscopic lesions globally and per segment using CDEIS
- Ulcer healing defined as absence of ulcers in a segment that were present at baseline
- MH based on CDEIS <3.5

- MRE variables
  - Bowel wall thickening
  - Enhancement
  - Presence of ulcers
  - Mural edema
  - Nodes>10 mm
  - Comb sign
  - Fluid, fat and fatty proliferation
  - Global MaRIA calculated as sum of each segment
- MH score of <7 and ulcer healing score of <11
### Table 3. Diagnostic Accuracy of MRE (MaRIA per Segment) to Predict Endoscopic Ulcer Healing and Mucosal Healing

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>Sp</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulcer healing, MaRIA &lt;11, %</td>
<td>94</td>
<td>69</td>
<td>94</td>
<td>67</td>
<td>90</td>
</tr>
<tr>
<td>Mucosal healing (CDEIS &lt;3.5), MaRIA &lt;7, %</td>
<td>85</td>
<td>78</td>
<td>92</td>
<td>63</td>
<td>83</td>
</tr>
</tbody>
</table>

NPV, negative predictive value; PPV, positive predictive value; S, sensitivity; Sp, specificity.
Results

- MRE detected ulcer healing with 90% accuracy
- Endoscopic remission with 83% accuracy
- Mean CDEIS and MaRIA scores significantly changed at week 12
- MRE as reliable as endoscopy at assessing healing

- No significant changes in CDEIS or MaRIA scores were seen in segments with persistent ulcers
- Magnitude of change in CDEIS score correlated with MR score \((t=0.51, p<0.001)\)
Potential impacts

• Imaging has an important role in monitoring response to therapy

• Direct visualization of areas of affected mucosa may be compromised

• Ambiguity regarding
  – Which score to use
  – Utility in clinical practice
  – What level of improvement required to terminate disease progression

• Repeated ileocolonoscopy challenge
  – Bowel prep, invasive nature
Potential pitfalls

- Normal enhancement
- Jejunum > ileum
- Under distended segments
  - Wall thickening
  - Inc enhancement
  - Can conceal strictures and ulcers
- Post surgical changes
  - Stricturoplasty may mimic disease
- Adequate contrast
- Delayed imaging
- Motility imaging
  - Helps discriminate fixed narrowing from lack of distension
  - Not all SBO due to strictures
Conclusion

• Main utility of MRI is to guide therapeutic management
  – When inflammation and fibrosis co-exist
  – Imaging should aim to describe dominant feature
  – Cine imaging value add feature
  – DWI role still being evaluated
    • Utility in non gad studies
    • Discriminating bowel from collection
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
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
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
• Ileo-cecal 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

  - 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/sub mucosal
  – 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
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