MR Enterography: How we do it

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Learning objectives

MR enterography is an effective technique for assessment of small bowel pathology. The diagnostic yield is comparable to CT enterography with the advantage of avoiding exposure to ionizing radiation.

In this exhibit we;

1. Discuss technical considerations relating to performance of standard MR enterography (MRE) including patient preparation, choice of contrast agent, patient positioning, sequences employed and timing of image acquisition.
2. Consider technical modifications that may be employed in complex cases, with pictorial examples. Additional techniques addressed include colonic imaging, post contrast imaging, duodenal assessment and high resolution imaging
3. Describe an MRE protocol that is well tolerated by patients, reliable and easy to implement in a busy radiology department

Background

Traditionally small bowel-follow through and small bowel enteroclysis have been the imaging studies of choice to image the small bowel. With improving technology there has been a shift towards the use of CT and MRI. Both CT and traditional enteroclysis result in high radiation doses which, in association with need for repeated in examinations, particularly with respect to Crohn's disease, may confer risk on this young patient population.

MR Enterography (MRE) has become a valuable tool in assessment of small bowel pathology, as it provides excellent soft tissue contrast and ability to obtain multiplanar imaging. There is avoidance of radiation exposure and the technical, logistical and poor patient acceptability factors associated with nasojejunal tube insertion required for traditional fluoroscopic or CT enteroclysis. The diagnostic yield is comparable to CT enterography. Appropriate use of MRE requires a carefully crafted protocol to depict signs of active inflammation as well as complications of inflammatory bowel disease. When used correctly MRE is invaluable differentiating between acute disease that can be managed medically and disease that requires surgery.

All sequences described relate to, and all are images acquired on Symphony 1.5 Tesla Siemens MRI system. (TE 4.48, TE2.24, EC 0)
STANDARD PROTOCOL

Patient Preparation

Patient preparation varies between institutions with reference to pre-procedural fasting time. (1) To our knowledge no rigorous studies have been performed regarding the benefits of various fasting time. Successful imaging has been achieved following short fasting time periods of as little as 4 hours.

No bowel preparation is required.

At hour institution we ask patients to fast from midnight the preceding evening

Choice of contrast Agent

Administration of enteric contrast medium is essential to achieve optimal distension of the bowel. The ideal agent is widely available, cheap, achieves good distension and importantly is palatable to patients.

<table>
<thead>
<tr>
<th>Type</th>
<th>Appearance</th>
<th>Advantages</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biphasic</td>
<td>a. Low signal T1W, high signal T2W</td>
<td>Good distension, widely available, cheap, acceptable to patients.</td>
<td>a. polyethylene glycol, methylcellulose, mannitol and water.</td>
</tr>
<tr>
<td></td>
<td>b. High signal T1W, low signal T2</td>
<td>Demonstrates pathology well</td>
<td>b. concentrated gadolinium chelates mixed with barium</td>
</tr>
<tr>
<td>Positive</td>
<td>High signal T1W and T2W</td>
<td>Demonstrates wall thickening clearly</td>
<td>Gadolinium chelates, ferrous &amp; manganese ions</td>
</tr>
<tr>
<td>Negative</td>
<td>Low signal T1W and T2W</td>
<td>Demonstrates small extraluminal abscesses clearly</td>
<td>Superparamagnetic particles e.g.</td>
</tr>
</tbody>
</table>
The most commonly used are the biphasic agents as they fulfill our above mentioned criteria. Hyperosmolar agents reduce water absorption improving distension but this can lead to significant side effects such as diarrhoea and abdominal cramps, particularly if ingested in large volumes, decreasing patient compliance with future studies. Polyethylene glycol is an iso-osmolar agent with similar properties to water but as it is not absorbed across the bowel wall. Improved distension is achieved in comparison with water. In the literature, reported volumes of oral contrast material vary considerably, but most studies report a total volume of 1-2 L. (2)

At our institution we use a single packet of Polyethylene glycol diluted in 1000mls of water. This is consumed over a 10-20 minute period. We attempt to achieve a minimum ingested volume of 1 L, although some symptomatic patients may be unable to comply. We do not routinely administer rectal contrast or prokinetic agents.

Supine or Prone Imaging

Prone - Advantages

• Improved separation of bowel loops, better mural evaluation.
• Provides maximal small bowel coverage on coronal imaging
• Decreased scan time due to abdominal compression

Supine - Advantages

• More comfortable
• Less anxiety
• Quicker overall study time

Studies have shown that prone imaging provides superior luminal distension but this does not result significant improvement in lesion detection or characterization.(3)

We therefore image in the supine position which is easier for patients and decreases scan time

Choice of initial standard imaging sequences

The main diagnostic T2 weighted sequences employed in MR enterography include
1. True fast imaging with steady-state prescession (TruFISP)

2. Fast imaging employing steady state acquisition (SSFP)

3. Balanced fast field echo (FFE) sequences - single shot technique; HASTE, SSFSE, single shot turbo spin-echo.

**TruFISP**

Advantages

- fast
- highest signal noise ratio per unit time
- T1 & T2 weighting therefore strong contrast between tissues with different ratios of T1 & T2
- insensitive to flow artefact (antiperistaltic not required)
- Images can be produced within a few seconds, no need to breathe hold

Disadvantages

- susceptible to "black boundary artefact" which can lead to overestimation of bowel wall thickness (Fig 4)

**Balanced fast field echo (FFE) sequences (HASTE)**

Advantages

- ultrafast acquisition time
- heavily T2 weighted
- excellent correlation between biological activity and T2 weighted wall signal.
- resistant to magnetic susceptibility and chemical shift artefacts

Disadvantages

- sensitive to motion and flow artefact. (Fig 5 & 6)

*Our initial standard sequences are;*

**Coronal balanced SSFP (TruFISP)**

**Axial balanced SSFP**
Timing of image acquisition

There is considerable variety between institutions on the optimal timing of image acquisition.

_in our institution TruFISP imaging is performed 20 minutes after ingestion of enteric contrast. If contrast has reached the pelvic loops the patient is recalled for further imaging at 40 minutes. If contrast has only reached the jejunum a 40 min delay is employed._

This reduces visits to the MR table and imaging time.(4) Further sequential images are then taken at 20 minute intervals until contrast reaches the caecum. (Fig 7 & 8)

MODIFICATIONS TO THE TECHNIQUE

Delayed Imaging of colon

Usually an MRE is considered complete when contrast has reached the caecum but up to 40% of Crohn's case will involve both small and large bowel.

While direct visualisation colon is usually achieved via colonoscopy, imaging may be useful in certain cases. Administration of rectal contrast can be time consuming and less acceptable to patient than oral ingestion. Our experience has been colonic distension with MRE has been sufficient to allow assessment of the colonic wall in the majority of cases. (Fig 9 & 10)

_Thus we recommend delayed imaging to the rectum in patients with Crohn's Disease._

Post contrast imaging

While not necessary in all cases, contrast enhanced imaging is now widely used in assessment of the small bowel, particularly in relation to Crohn's disease, to assess disease activity and evaluate patients with penetrating disease.

It can help differentiate active inflammation from chronic fibrotic change and thus identify patients who are suitable for medical rather than surgical management.
It allows evaluation of response to treatment. The degree of enhancement and thickening has been shown to have an excellent correlation with Crohn's disease activity index (CDAI). (Fig 10 & 11)

**We perform post contrast imaging to assess for active inflammation in patients with Crohn's disease. Post contrast images are obtained between 60-80 seconds post injection**

**Per oral hypotonic duodenography**

The duodenum can be notoriously difficult to evaluate radiologically.

As nasojejunal intubation is not performed with MRE evaluation of the duodenum becomes possible. We advocate performance of per oral hypotonic duodenography cases of suspected duodenal pathology.

**Method**

1. The patient ingests 1000mls of water.
2. They should be then brought immediately to the MR table.
3. Localising sequences are first performed.
4. 20mg of intravenous buscopan is administered.
5. The patient then lies in a right lateral position for a minute before next imaging sequence obtained. (This results in excellent distension of the duodenum.)

As administration of Buscopan can interfere with the normal transit of contrast through the alimentary tract we perform duodenography at the end of standard MRE where indicated. (5)

**High resolution T2 weighted imaging**

Abscess or fistula tracts can be difficult to identify on standard sequences, particularly with the use of positive enteric contrast agents. Addition of high resolution T2 weighted imaging may be useful in selected cases. (Fig 13 & 14)

**We perform high resolution T2 weighted imaging as adjunct in patients with suspected fistulas or abscess not apparent on initial sequences.**

Images for this section:
Fig. 1: Coronal TruFisp image from MRE. Considerable food debris in stomach which remained distended throughout the study in this non fasting patient.
Fig. 2: Fig.1 Coronal TruFisp. Adequate luminal opacification post overnight fasting.
Fig. 3: Coronal TruFisp image from MRE study. Patient was unable to take full volume of contrast resulting in suboptimal distension and non diagnostic study.
**Fig. 4:** Coronal TruFISP image. Known Crohn's disease. There is circumferential wall thickening in the distal and terminal ileum. (arrow) Note black boundary artefact which can lead to over estimation of wall thickness. There is also local fibrofatty proliferation and vas recta engorgement with mild proximal small bowel dilatation and pseudo sacculation.

**Fig. 5:** HASTE sequence from MRE. Intraluminal flow void secondary to flow artefact
Fig. 6: TruFISP sequence in same patient produces homogenous luminal opacification
**Fig. 7:** Coronal TruFisp images from MRE. Sequential imaging was performed at 20 minutes, 60 minutes and 90 minutes. Initial imaging reveals inadequate distension of ileum.
Fig. 8: Delayed image at 60 minutes demonstrates short segment of terminal ileum which is mildly thick walled (arrowed) in this patient with known Crohn’s Disease.
**Fig. 9:** Delayed TruFisp coronal image demonstrates thickening of the wall of the transverse colon with mucosal ulceration in this patient with Crohn’s disease.

![Image of delayed TruFisp coronal image showing thickening of the wall of the transverse colon with mucosal ulceration in a patient with Crohn's disease.](image)

**Fig. 10:** Axial TruFISP. Wall thickening in the sigmoid and rectum in keeping with involvement by Crohn’s disease.

![Image of axial TruFISP showing wall thickening in the sigmoid and rectum in a patient with Crohn's disease.](image)

**Fig. 11:** Ultrafast T1 gradient echo pre contrast demonstrates long segment of ileal thickening in this patient with long term Crohn’s disease and worsening abdominal pain.

![Image of ultrafast T1 gradient echo pre contrast showing long segment of ileal thickening in a patient with Crohn's disease.](image)
**Fig. 12:** Post contrast reveals stratified appearance of bowel wall. Hyperaemia results in hyperenhancement of mucosal and serosal layer with submucosa of intermediate to low signal intensity. This is indicative of active inflammation and is an indicator of suitability for medical management.
**Fig. 13:** Ileal wall thickening with adjacent well circumscribed area of high signal intensity in keeping with a small bowel loop
Fig. 14: Axial high resolution T2 images confirm appearance actually represent localised ileal perforation with adjacent fluid collection.
Conclusion

With 8 years of experience, including in excess of 450 studies, the protocol we employ has been refined and optimized according to available evidence and experience and is outlined below. The technique has evolved into an accurate, efficient, clinically accepted method of imaging the small bowel that is well tolerated by patients.

Preparation

Patient is instructed to fast from midnight.

Single packet of polyethylene glycol (Klen prep) diluted in 1000mls water should be consumed within 10 -20 minutes.

First images at 20 mins post commencement of contrast.

Sequences

Coronal balanced SSFP (TruFISP)*

Axial balanced SSFP

Review

-If contrast at jejunal loops reimage in 40 minutes and 20 minute intervals thereafter until contrast reaches caecum.

-If contrast reached pelvic loops reimage in 20 min intervals until contrast reaches caecum.

Suggested standard protocol

1. For assessment of colonic involvement of Crohn's disease

Sequential delayed images until contrast reaches rectum. Axial and coronal balanced SSFP

2. To assess disease activity in Crohn's Disease
Coronal and axial 3 dimensional ultrafast gradient echo precontrast

Coronal and axial 3 dimensional ultrafast gradient echo post contrast at 60 - 80 seconds.

3. To assess duodenal pathology - hypotonic duodenography;

Patients ingests 1000mls of water.

Administer 20mg intravenous buscopan

Right lateral position for one minute

Coronal and axial balanced SSFP (TruFISP)

4. Addition of high resolution T2 weighting imaging to assess for suspected abscess or fistula if suspected but not demonstrated on prior sequences

Modifications

Personal Information

References