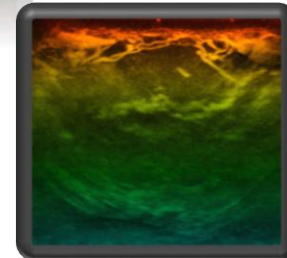
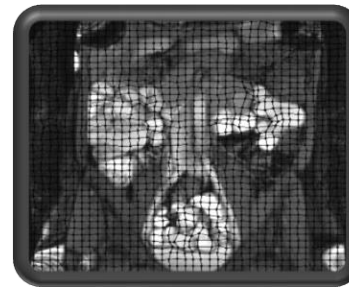
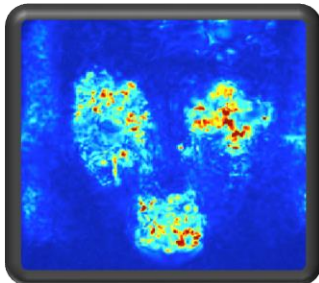
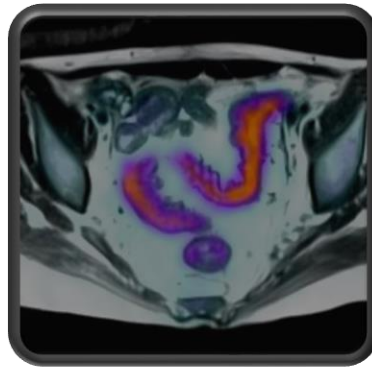
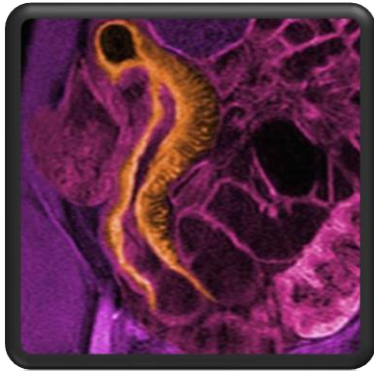


# Essentials of small bowel MRI

Stuart Taylor  
Professor of Medical Imaging  
University College London



# What do we want with MRI in IBD?



- Have robust and reproducible MRI protocols
- Diagnose IBD with high accuracy
- Evaluate disease activity
- Monitor treatment

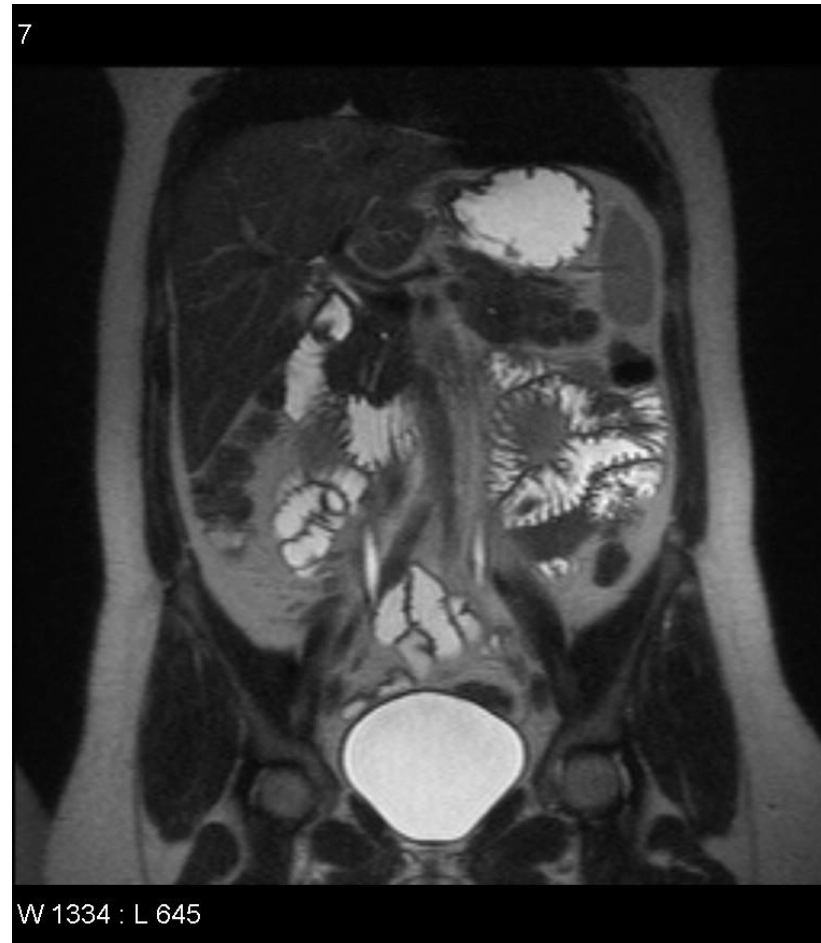
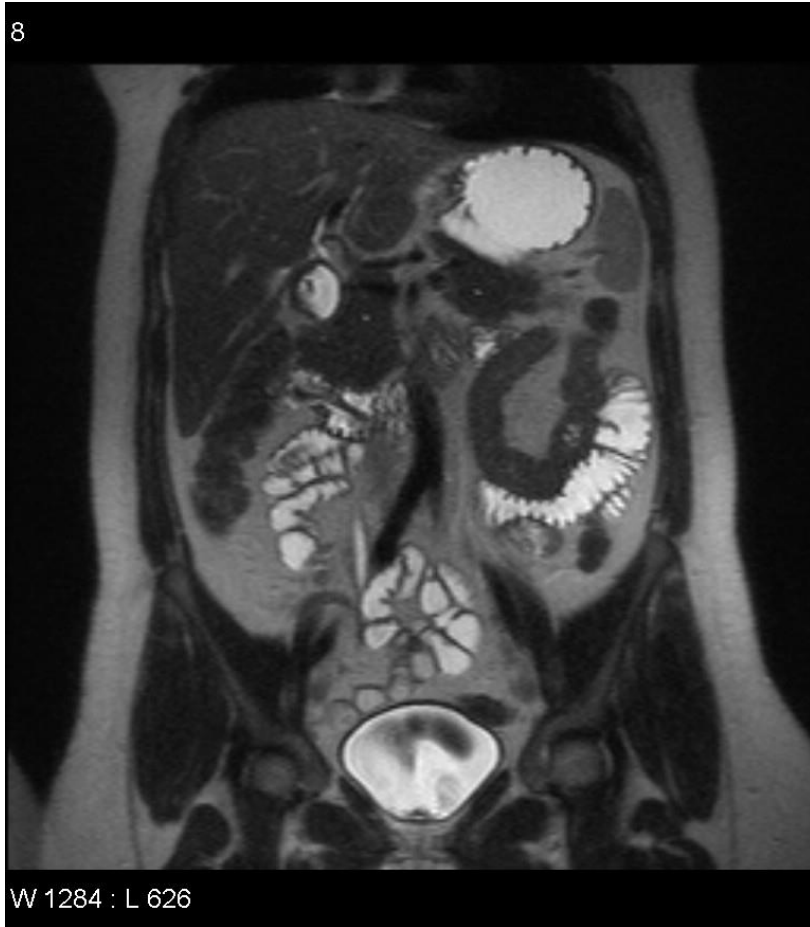
## **The first joint ESGAR/ ESPR consensus statement on the technical performance of cross-sectional small bowel and colonic imaging**

S. A. Taylor<sup>1</sup> • F. Avni<sup>2</sup> • C. G. Cronin<sup>3</sup> • C. Hoeffel<sup>4</sup> • S. H. Kim<sup>5</sup> • A. Laghi<sup>6</sup> •  
M. Napolitano<sup>7</sup> • P. Petit<sup>8</sup> • J. Rimola<sup>9</sup> • D. J. Tolan<sup>10</sup> • M. R. Torkzad<sup>1</sup> • M. Zappa<sup>11</sup> •  
G. Bhatnagar<sup>1</sup> • C. A. J Puylaert<sup>12</sup> • J. Stoker<sup>12</sup>

**Open access so free to download!**

# BASIC PREPARATION

MRE/ MR enteroclysis

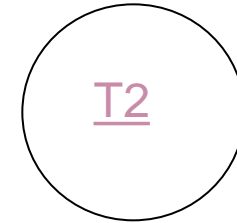
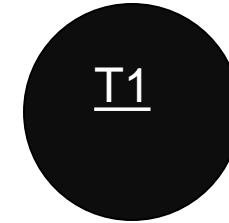


- There is no single preferred contrast agent for MRE Recommended agents include mannitol (with or without locust bean gum), PEG, sorbitol and lactulose amongst others (III)
- The optimal volume of oral contrast is 1000-1500 mL (III)
- Ingestion time of oral contrast without previous major small bowel resection should be 46-60 minutes (V)
- It is not recommended that laxative bowel preparation is administered (V)
- It is not recommended that a rectal water enema is administered before a routine examination (V)

# MR Enterography Technique



Most use Biphasic - low T1, high T2



Mannitol 2.5%

Mannitol 2.5% and Locust Bean Gum 0.2%

Methylcellulose 2%

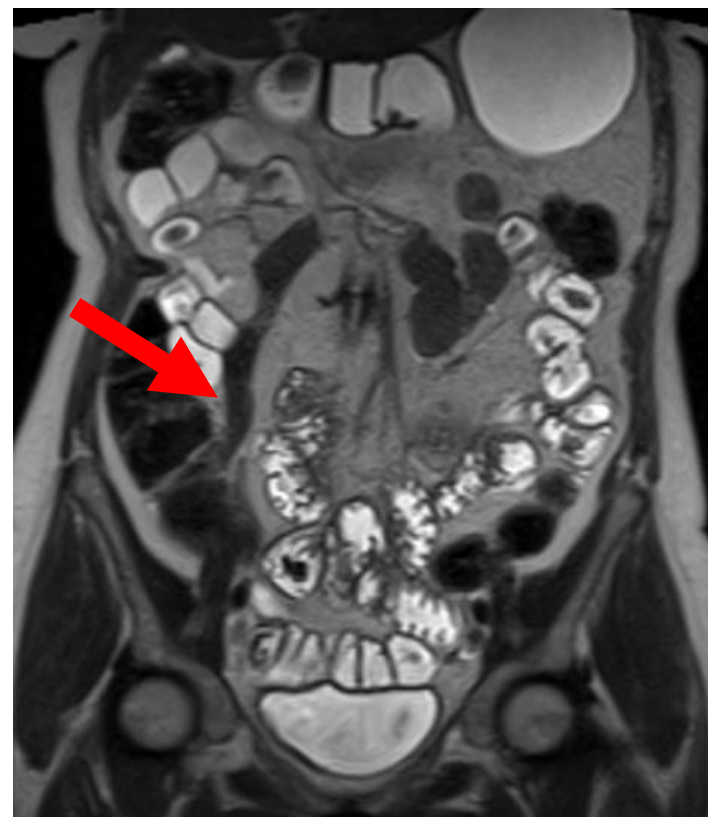
PolyEthyleneGlycol (PEG)

Volumen / Barium 0.1%

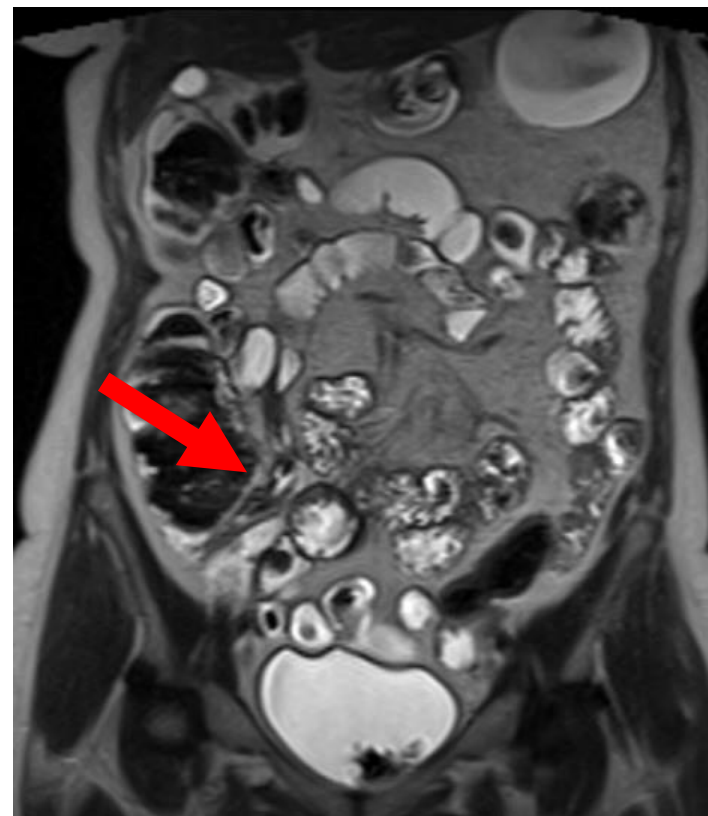
ispaghula

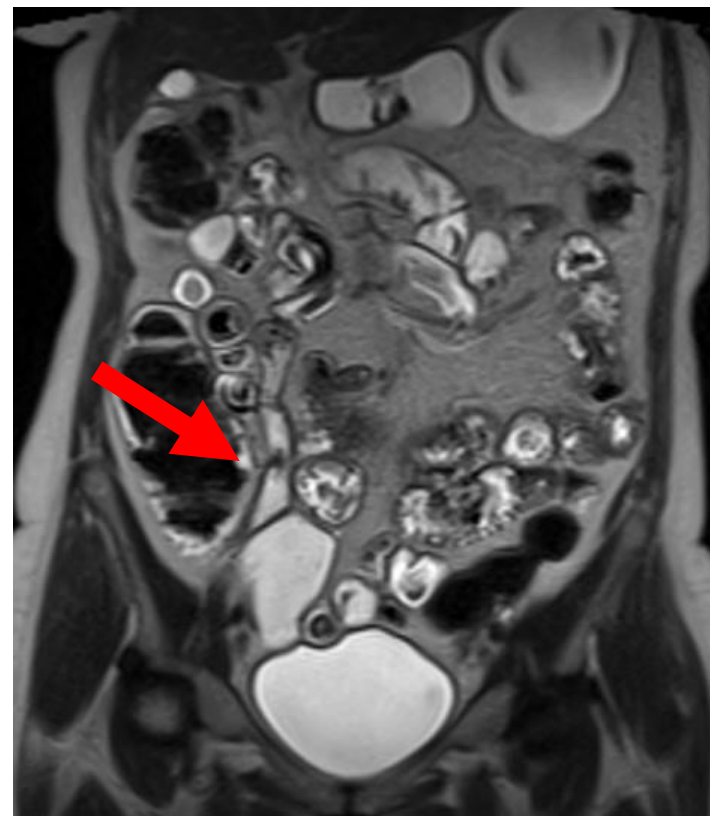
Young B et al. JCAT 2008

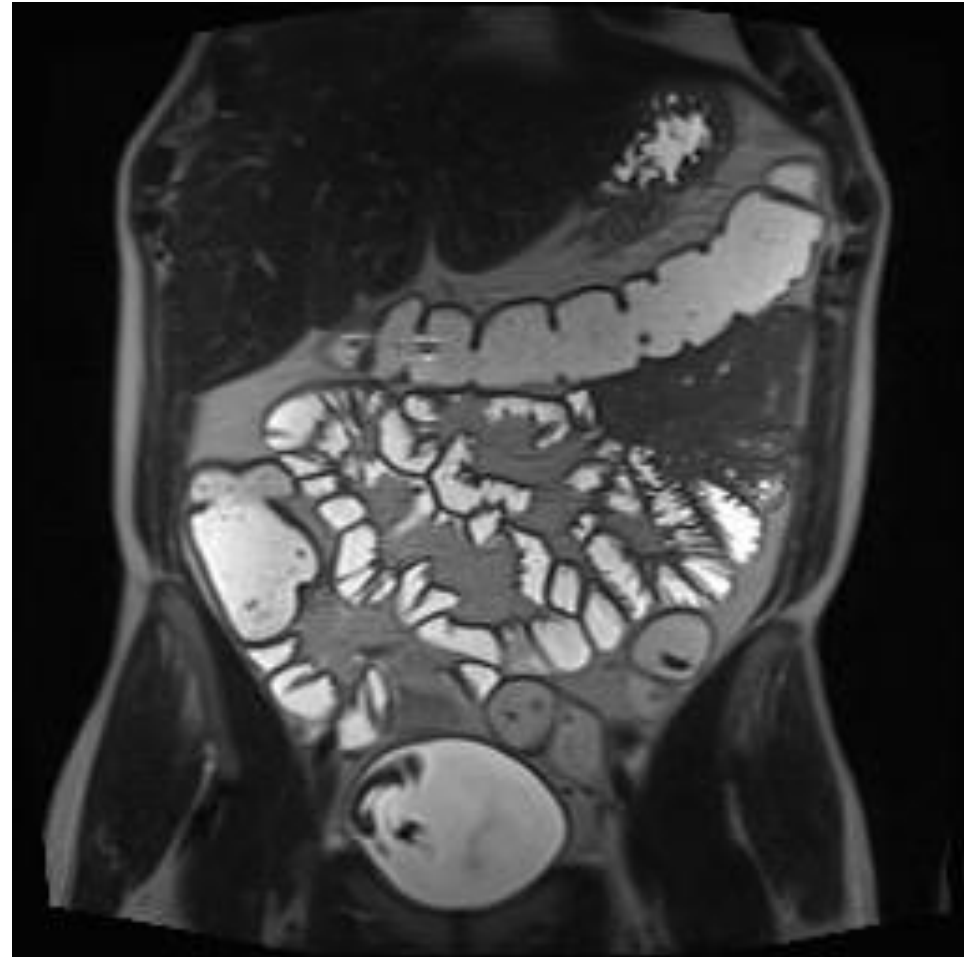
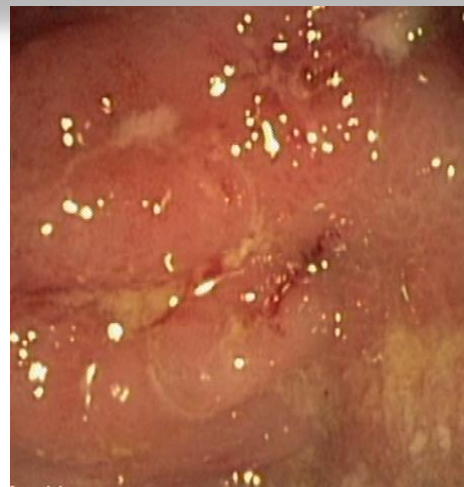
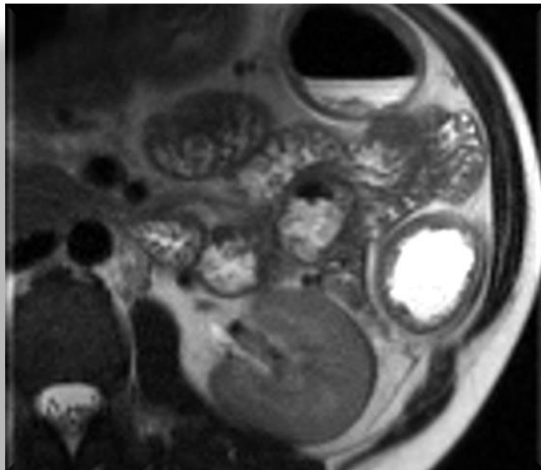
Kuehle C et al. AJR 2006





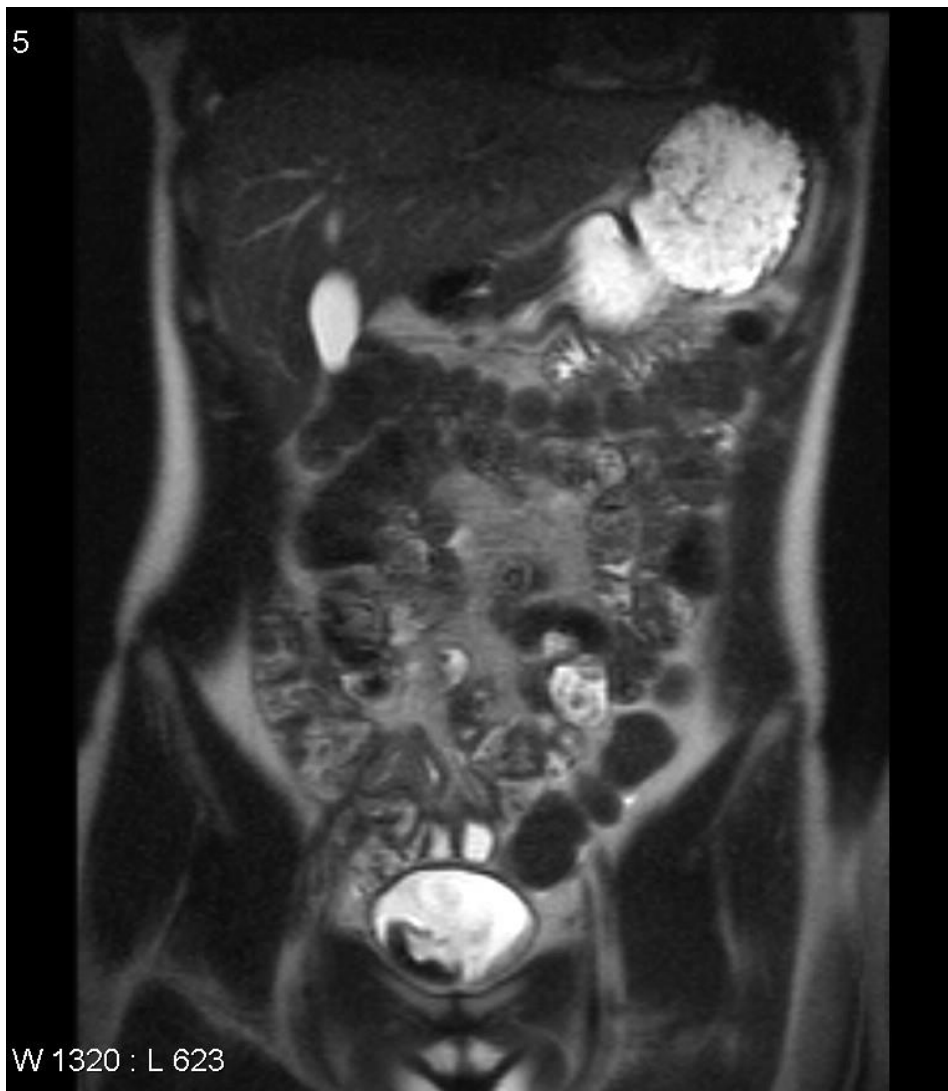






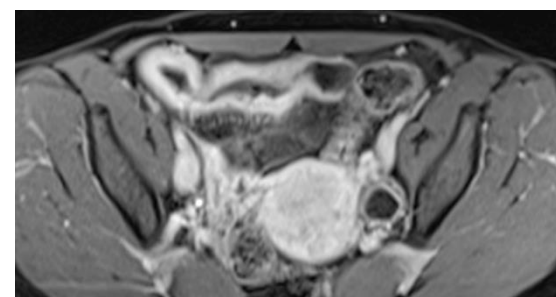
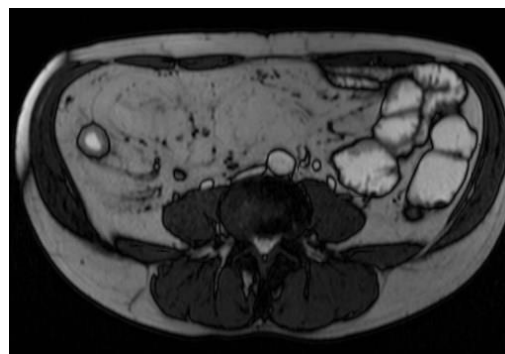
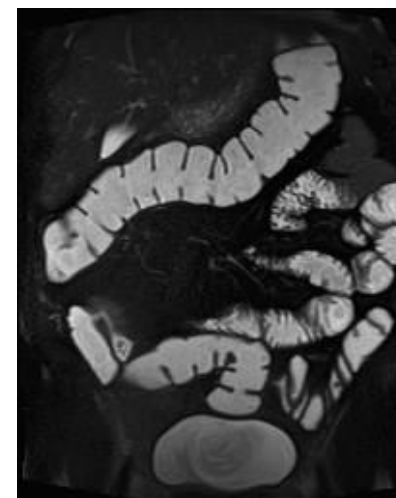
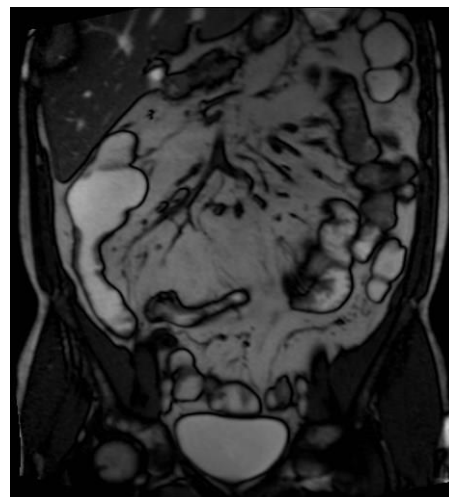
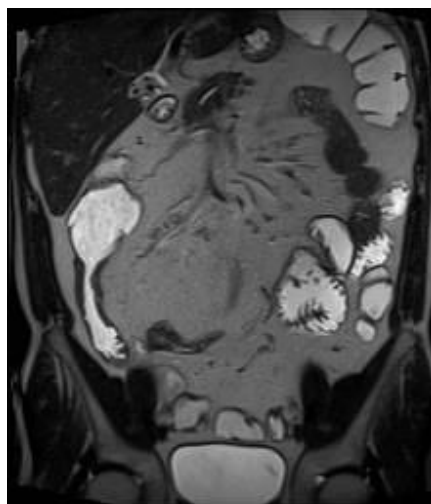


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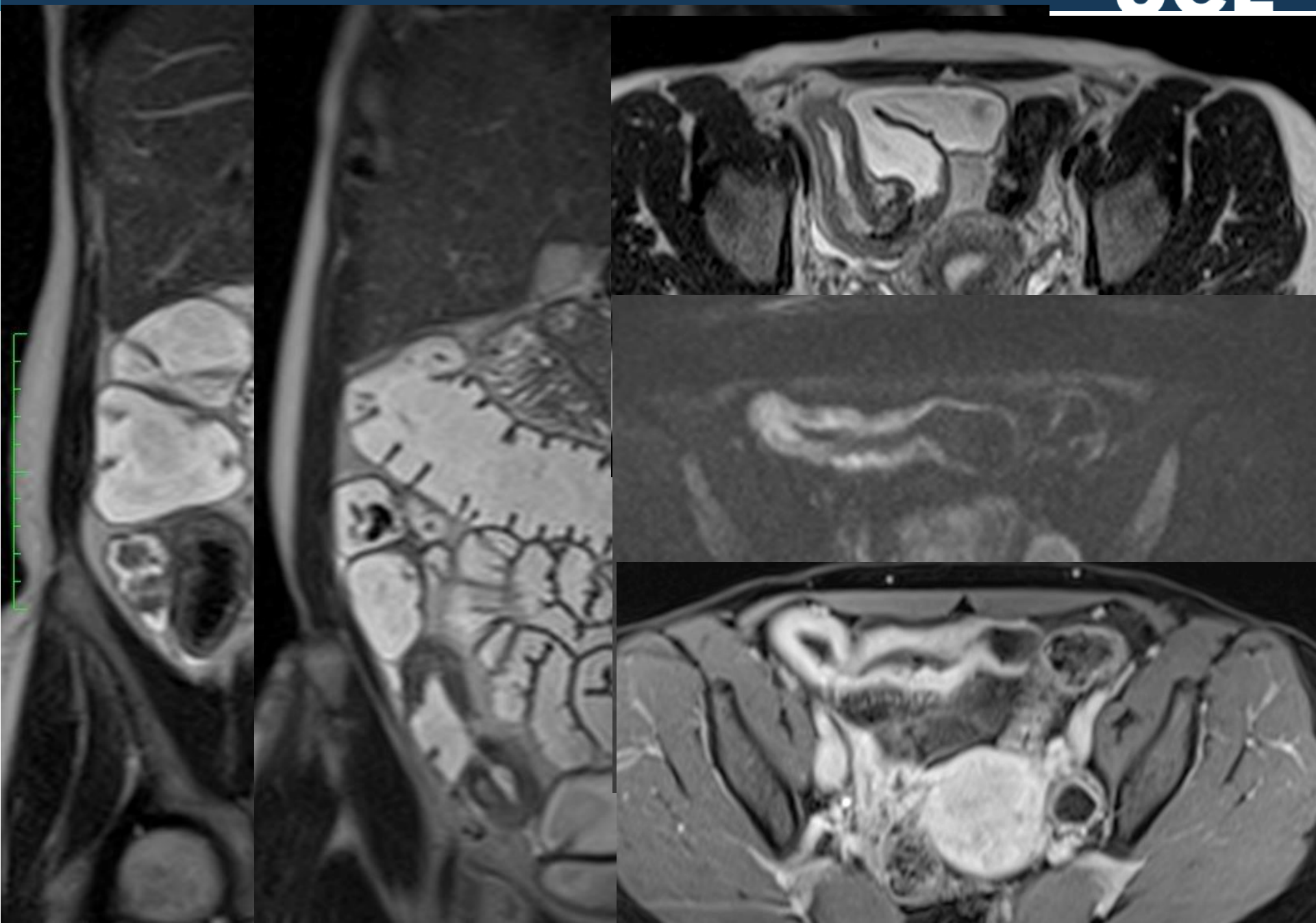


W 1320 : L 623

- **It is recommend to use the following sequences (V)**
- **Axial and coronal fast spin echo (FSE) T2W sequences without fat saturation**
- **Axial and coronal steady state free precession gradient echo (SSFP GE) sequences without fat saturation**
- **An axial or coronal FSE T2W sequence with fat saturation**
- **Non-enhanced coronal T1W sequence with fat saturation followed by contrast-enhanced coronal and axial T1W sequences with fat saturation**
- **In patients with known or suspected IBD, contrast-enhanced sequences should be in the enteric (45 s) or portal venous phase (70 s)**

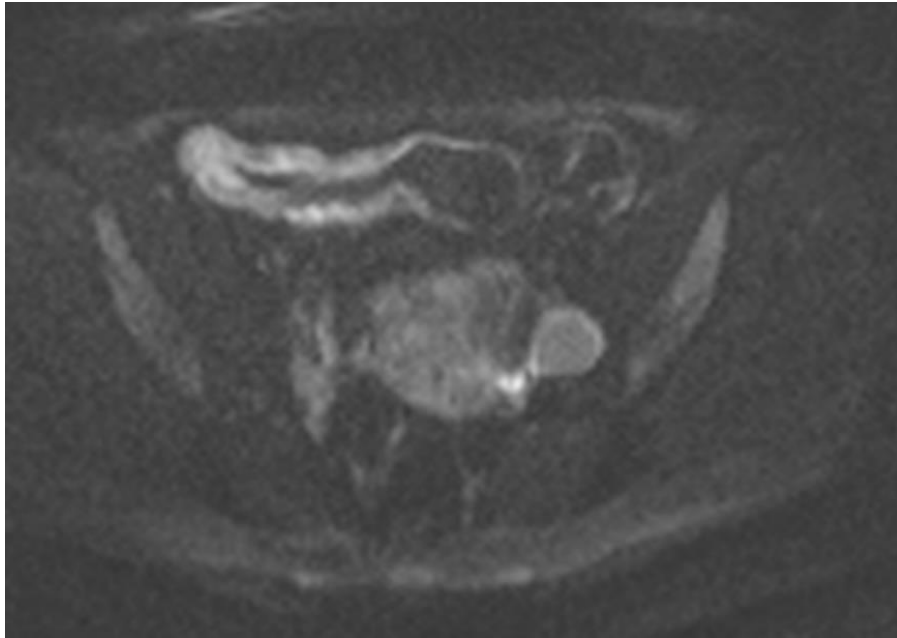






- Optional additional sequences include an additional FSE T2W sequence with fat saturation, axial and coronal SSFP GE sequences with fat saturation, **cine motility** and **diffusion weighted imaging (V)**
- *Free breathing technique if diffusion-weighted sequences are performed (IV)*
- *DWI should include lower b values ranging from 0 or 50 and upper b values ranging from 600 to 900 (IV)*
- *Maximal slice thickness for a diffusion-weighted sequence should be 5 mm (V)*







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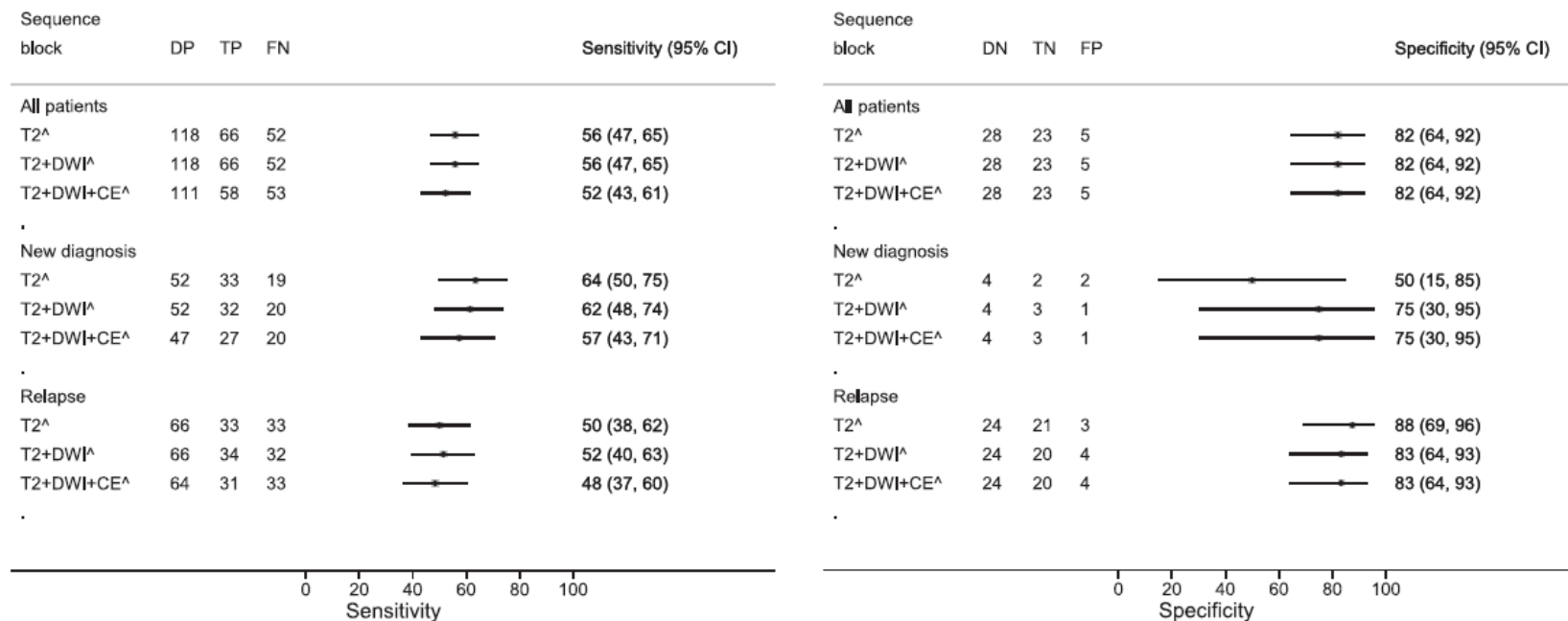
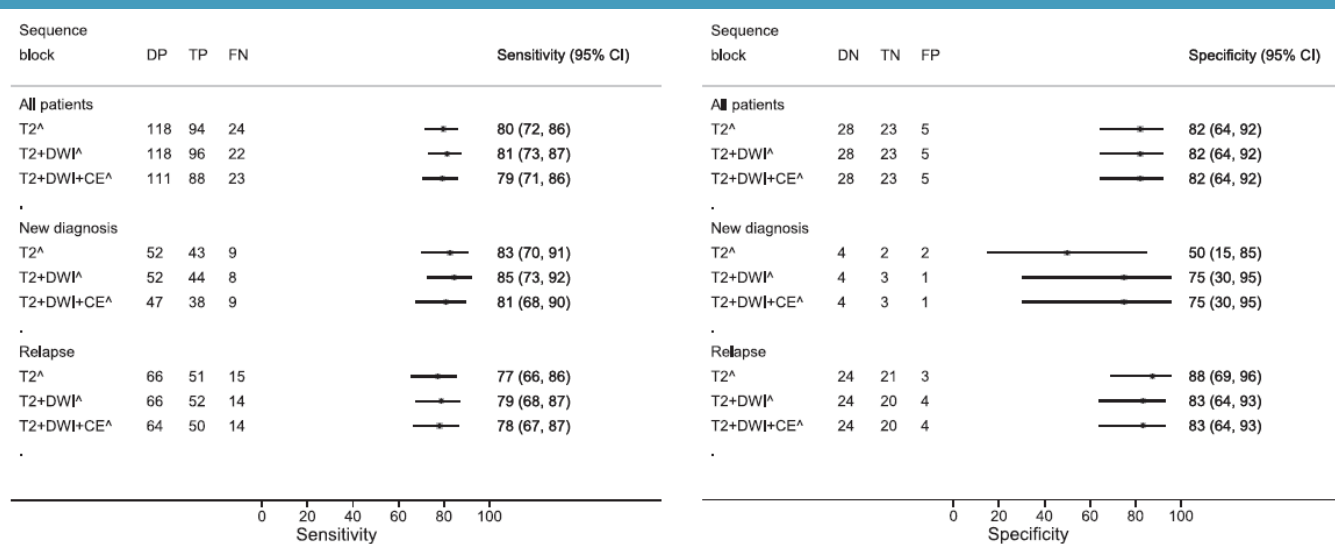


## Influence of diffusion weighted imaging and contrast enhanced T1 sequences on the diagnostic accuracy of magnetic resonance enterography for Crohn's disease

Gauraang Bhatnagar<sup>a</sup>, Sue Mallett<sup>a</sup>, Richard Beable<sup>b</sup>, Rebecca Greenhalgh<sup>c</sup>, Rajapandian Ilangovan<sup>c</sup>, Hannah Lambie<sup>d</sup>, Evgenia Mainta<sup>c</sup>, Uday Patel<sup>c</sup>, François Porté<sup>c</sup>, Harbir Sidhu<sup>a</sup>, Arun Gupta<sup>c,e</sup>, Anthony Higginson<sup>b</sup>, Andrew Slater<sup>f</sup>, Damian Tolan<sup>d</sup>, Ian Zealley<sup>g</sup>, Steve Halligan<sup>a</sup>, Stuart A Taylor<sup>a,\*</sup>, on behalf of the METRIC study investigators

73 patients read by 2 radiologist from a pool of 13  
T2 and SSFP GE images  
T2 and SSFP GE images plus DWI  
T2 and SSFP GE images Plus DWI and post contrast enhancement

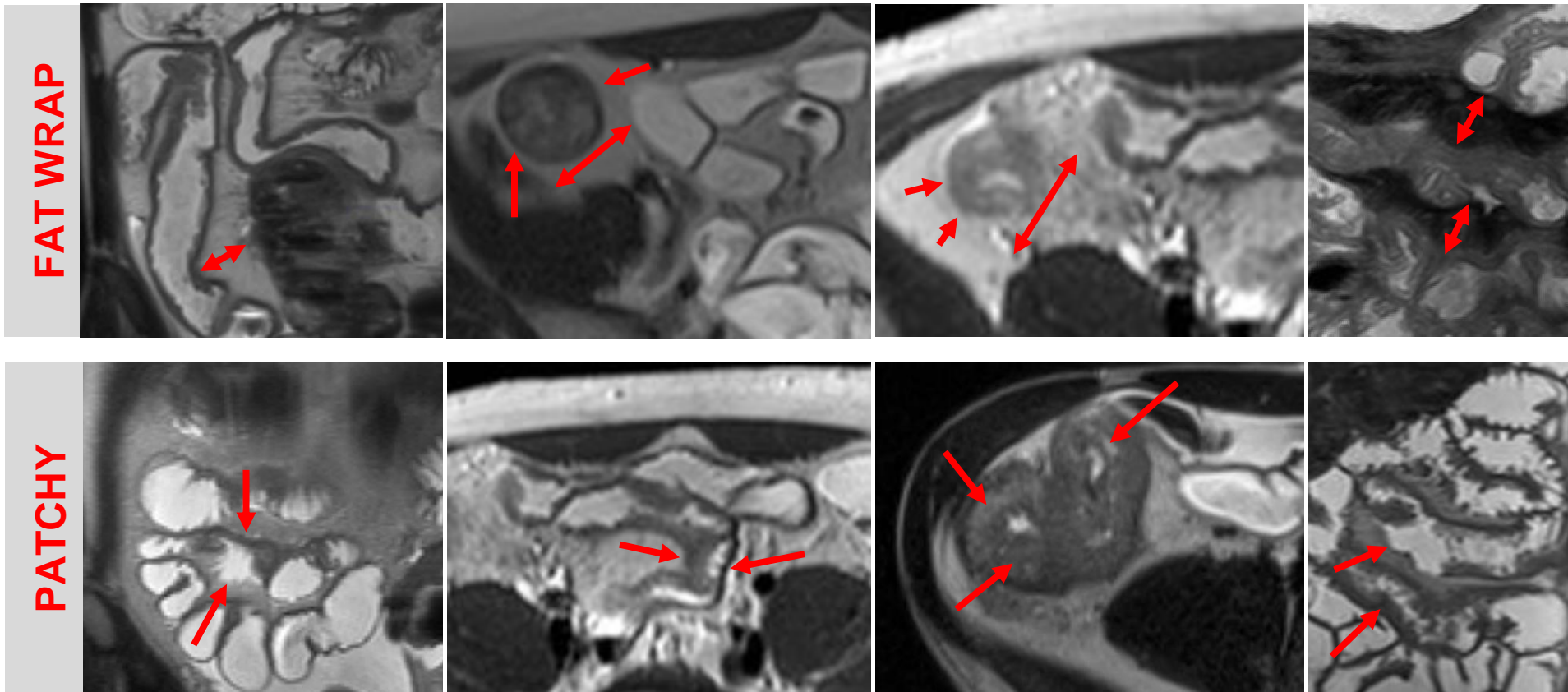
## Disease presence



## Disease extent

# Role of MRI

Diagnosis



# First large, prospective, multicentre head-to-head comparison



## Diagnostic accuracy of magnetic resonance enterography and small bowel ultrasound for the extent and activity of newly diagnosed and relapsed Crohn's disease (METRIC): a multicentre trial



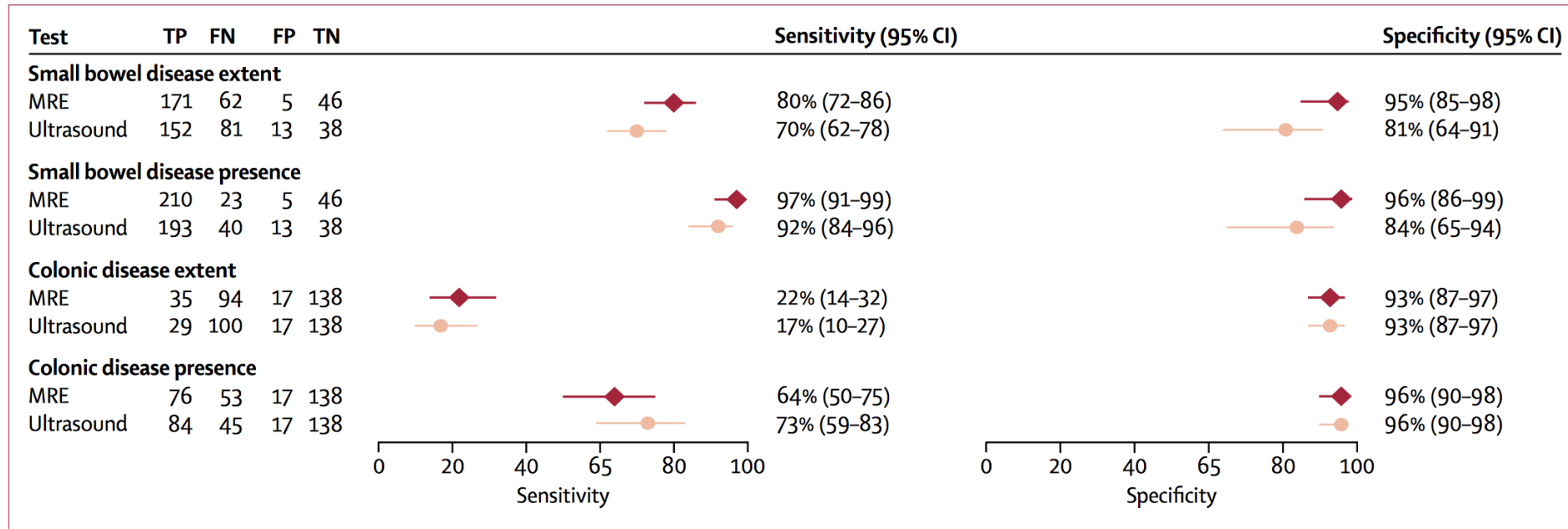
*Stuart A Taylor, Susan Mallett, Gauraang Bhatnagar, Rachel Baldwin-Cleland, Stuart Bloom, Arun Gupta, Peter J Hamlin, Ailsa L Hart, Antony Higginson, Ilan Jacobs, Sara McCartney, Anne Miles, Charles D Murray, Andrew A Plumb, Richard C Pollok, Shonit Punwani, Laura Quinn, Manuel Rodriguez-Justo, Zainib Shabir, Andrew Slater, Damian Tolan, Simon Travis, Alastair Windsor, Peter Wylie, Ian Zealley, Steve Halligan, on behalf of the METRIC study investigators\**

### Summary

*Lancet Gastroenterol Hepatol*  
2018; 3: 548-58

**Background** Magnetic resonance enterography (MRE) and ultrasound are used to image Crohn's disease, but their comparative accuracy for assessing disease extent and activity is not known with certainty. Therefore, we did a

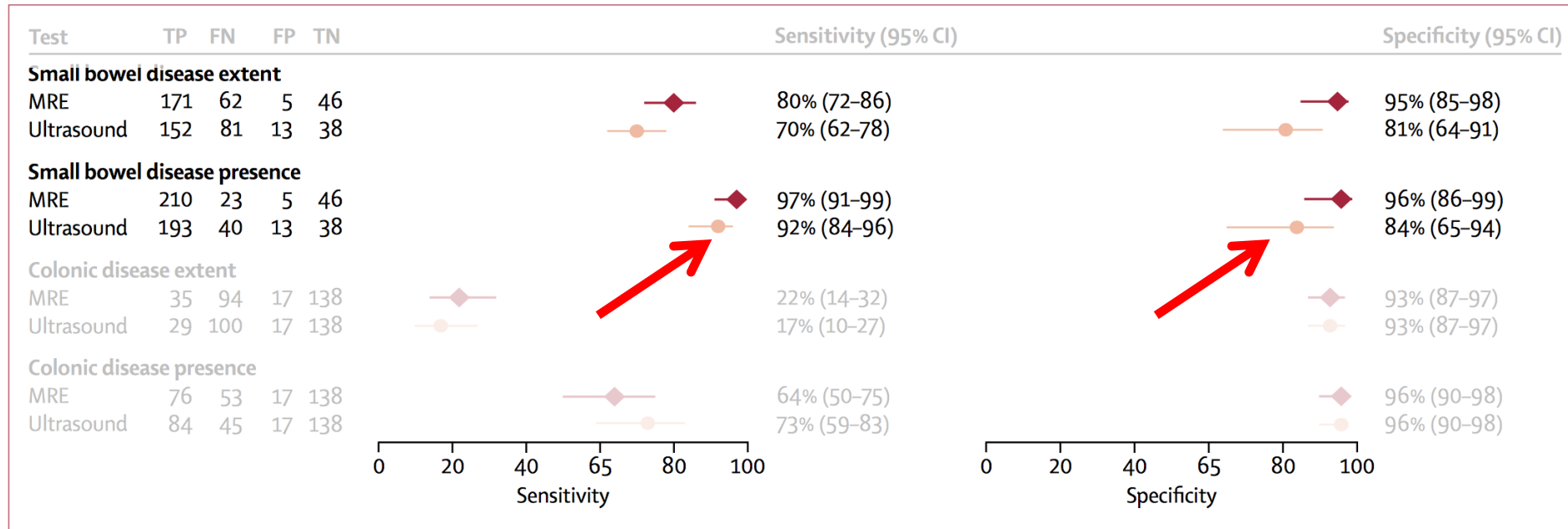
# OVERALL



**Figure 2: Sensitivity and specificity of MRE and ultrasound for the extent and presence of small bowel and colonic disease against the consensus reference standard**

FN=false negative. FP=false positive. MRE=magnetic resonance enterography. TN=true negative. TP=true positive. Error bars represent 95% CI.

## DETECTION – MRE slightly more sensitive and specific (not significant)

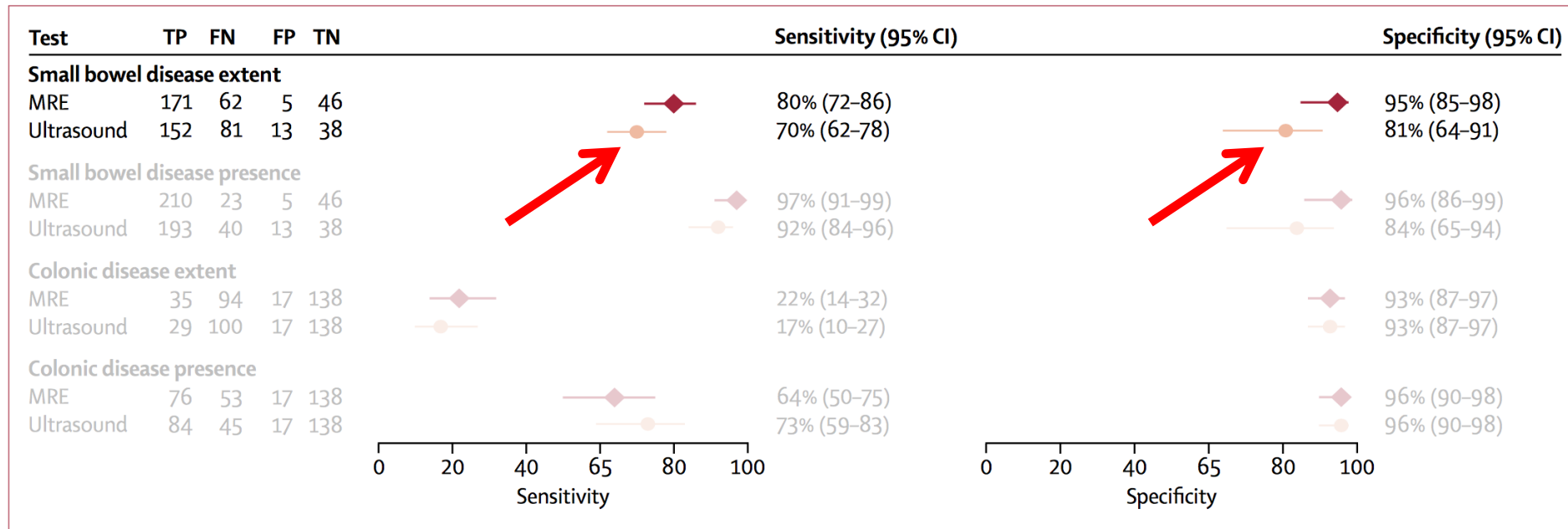


**Figure 2: Sensitivity and specificity of MRE and ultrasound for the extent and presence of small bowel and colonic disease against the consensus reference standard**

FN=false negative. FP=false positive. MRE=magnetic resonance enterography. TN=true negative. TP=true positive. Error bars represent 95% CI.



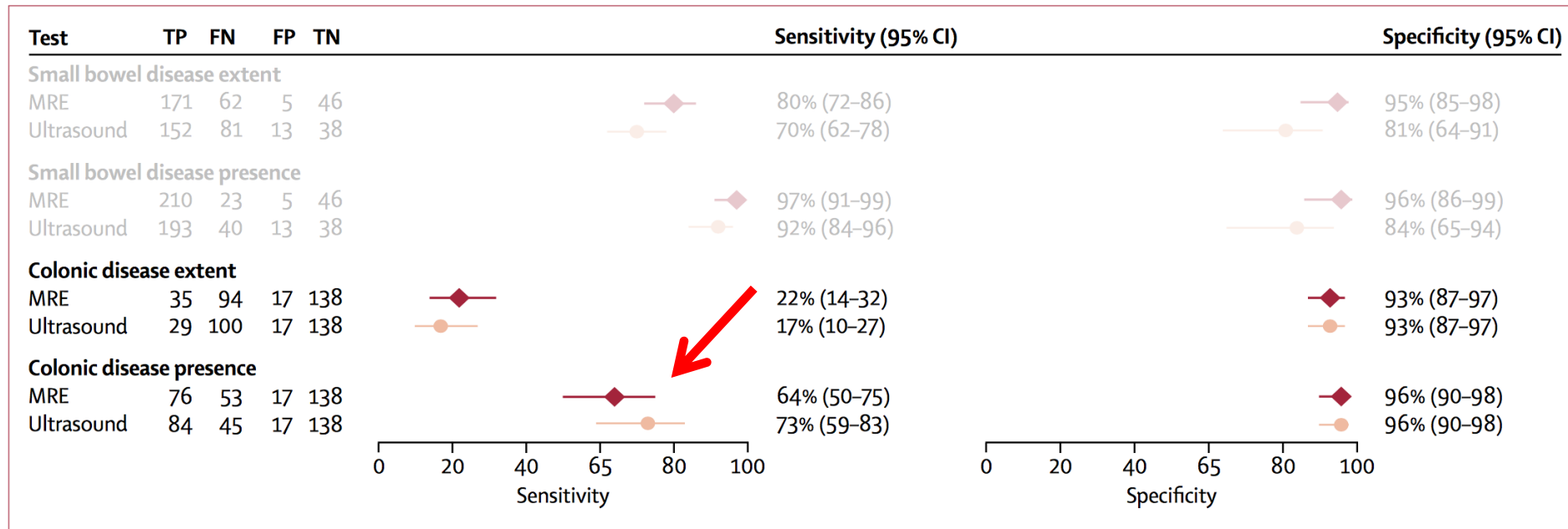
## MAPPING – MRE is 10% more sensitive and 14% specific (both significant)



**Figure 2: Sensitivity and specificity of MRE and ultrasound for the extent and presence of small bowel and colonic disease against the consensus reference standard**

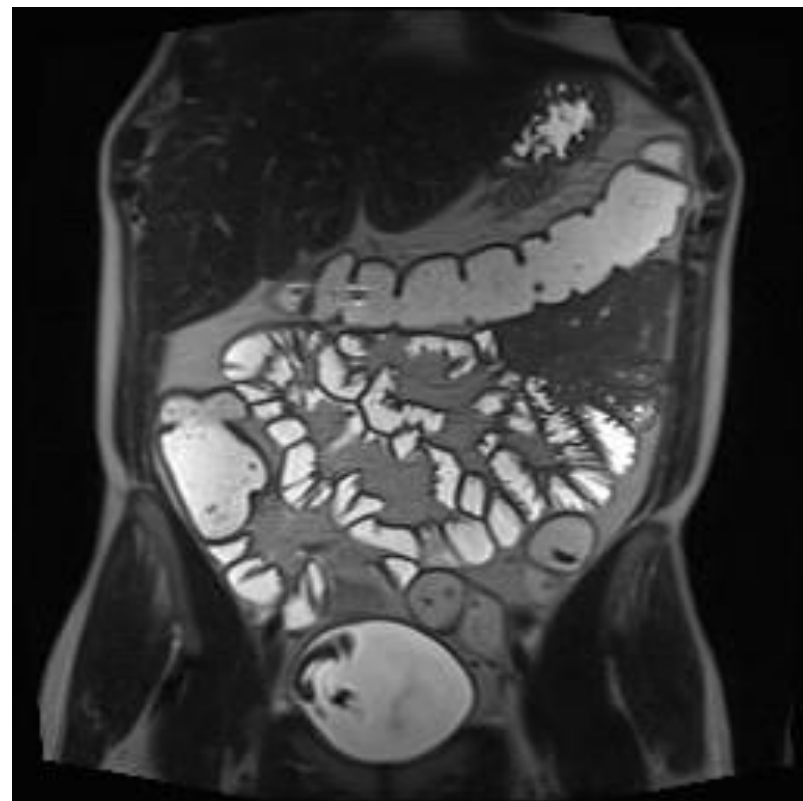
FN=false negative. FP=false positive. MRE=magnetic resonance enterography. TN=true negative. TP=true positive. Error bars represent 95% CI.

## COLON – US 10% more sensitive (not significant except new diagnosis cohort)

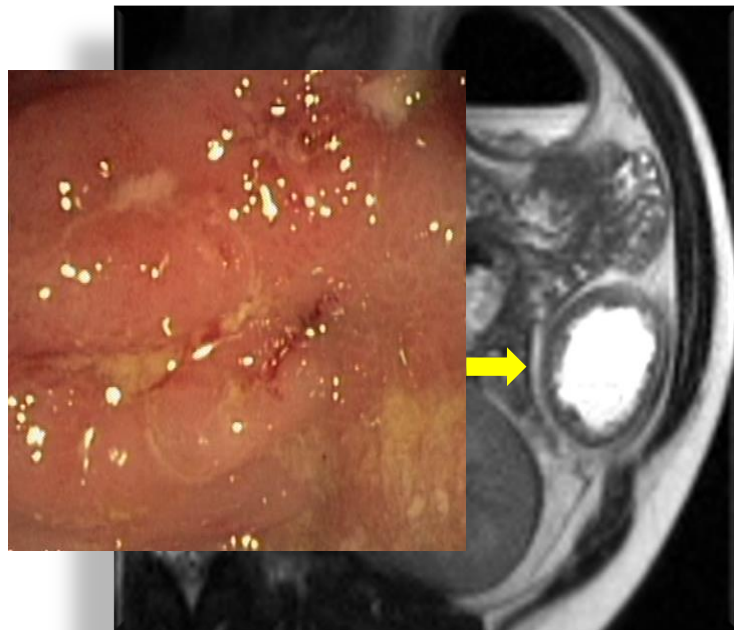


**Figure 2: Sensitivity and specificity of MRE and ultrasound for the extent and presence of small bowel and colonic disease against the consensus reference standard**

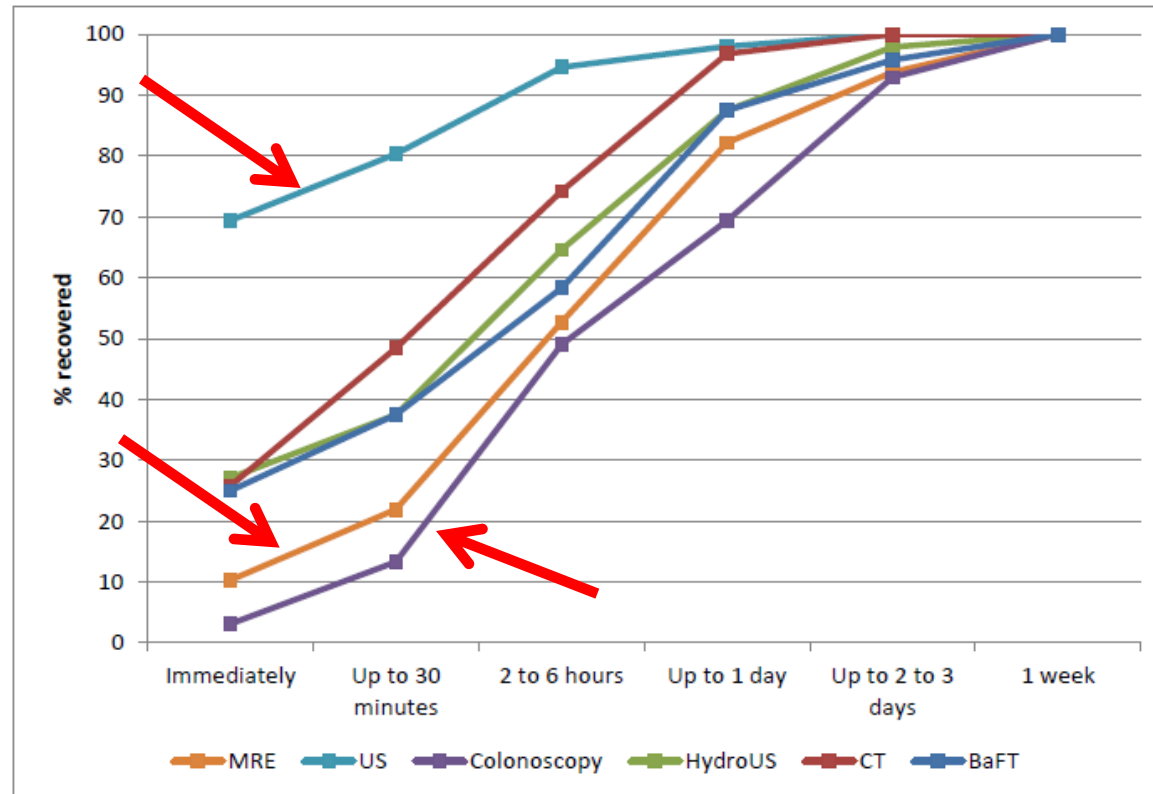
FN=false negative. FP=false positive. MRE=magnetic resonance enterography. TN=true negative. TP=true positive. Error bars represent 95% CI.



# Mucosal detail



# Recovery time



MRE recovery time  
 -significantly longer than US ( $p < 0.001$ )  
 -shorter than colonoscopy ( $p < 0.001$ ),

>1 day to recover  
 MRE - 26/146 (18%)

US - 3/147 (2%)

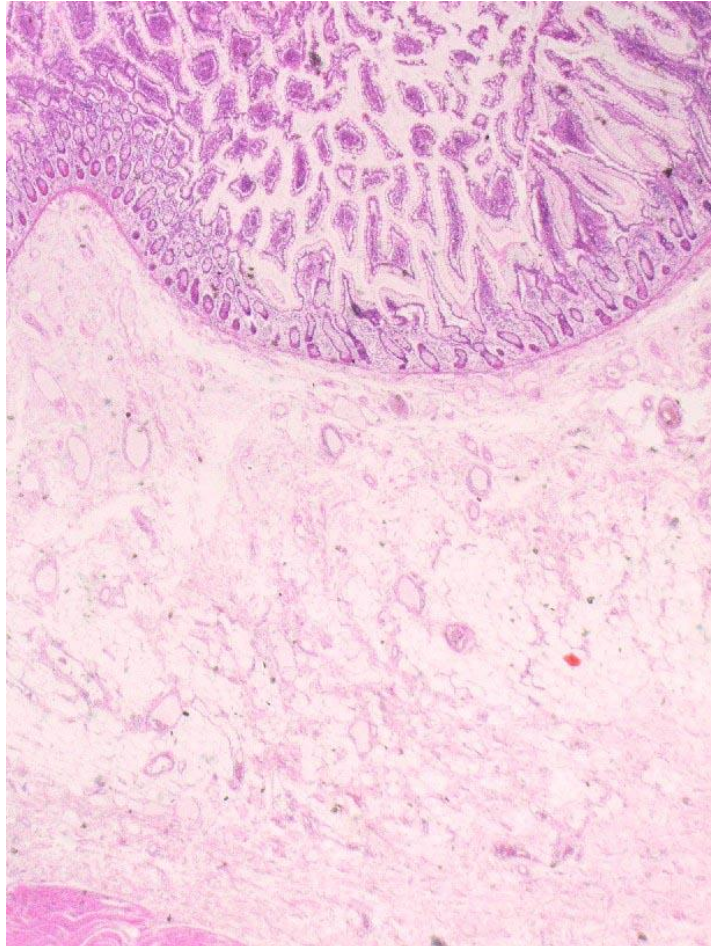
Colonoscopy - 30/98 (31%)

Worth warning patients!

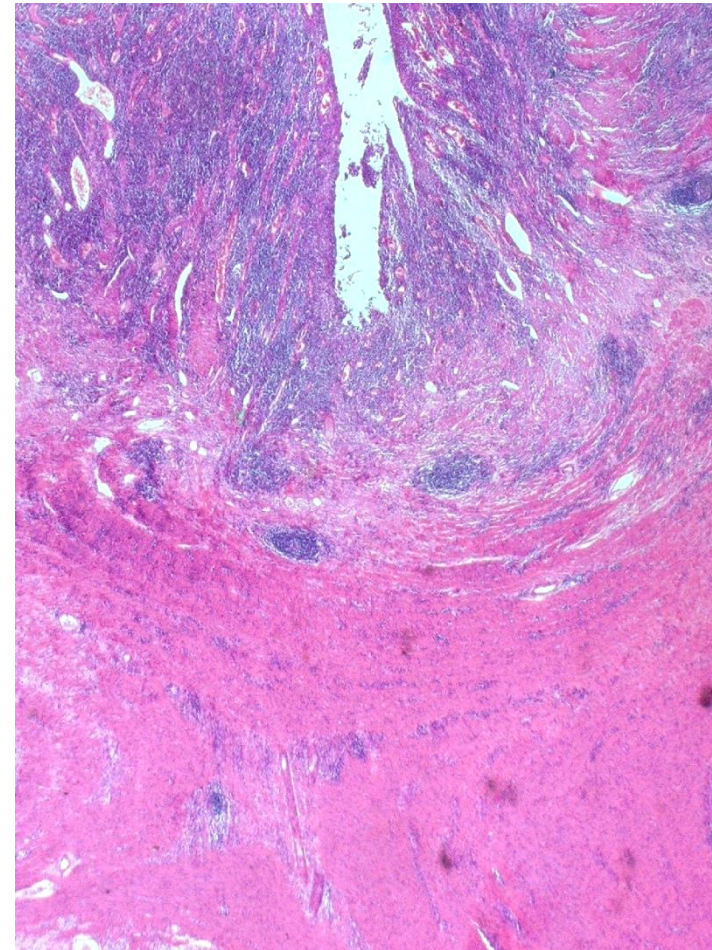
# Disease activity



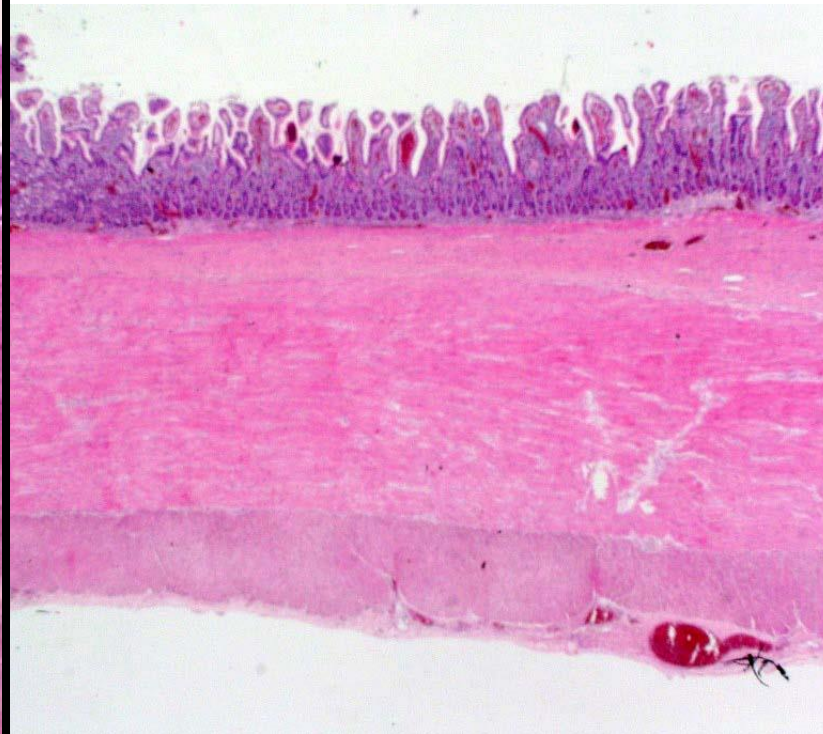
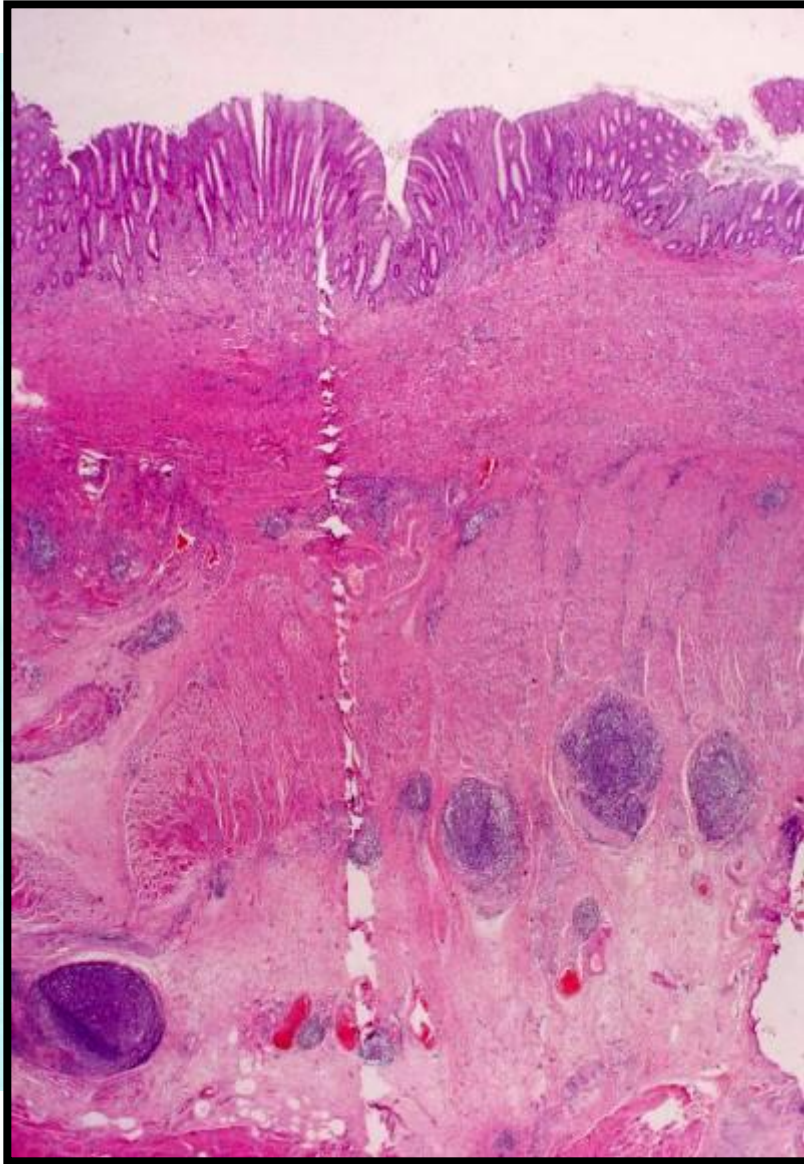
## Normal



## Abnormal

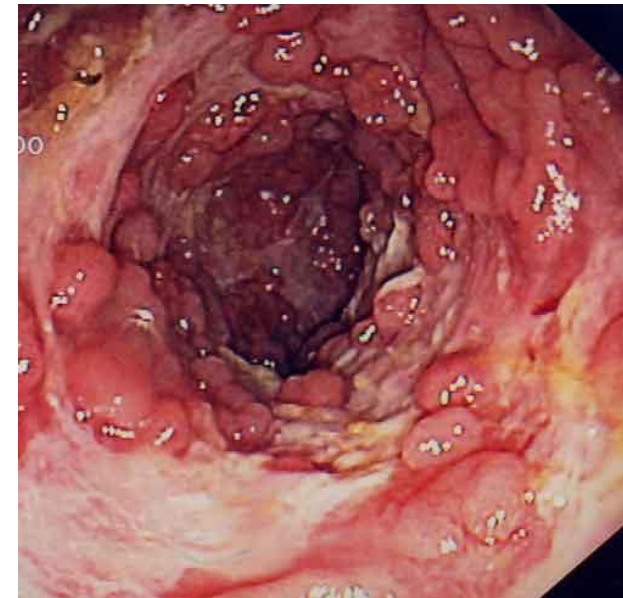
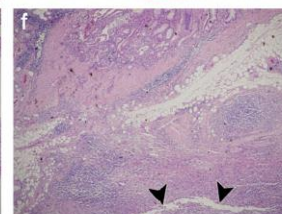
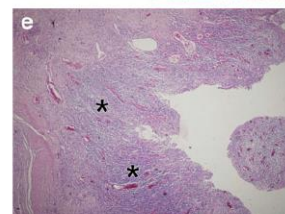
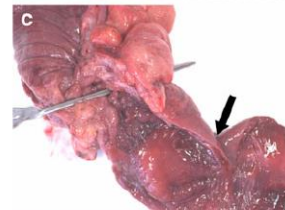
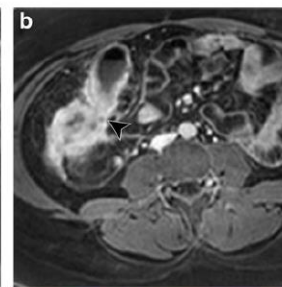
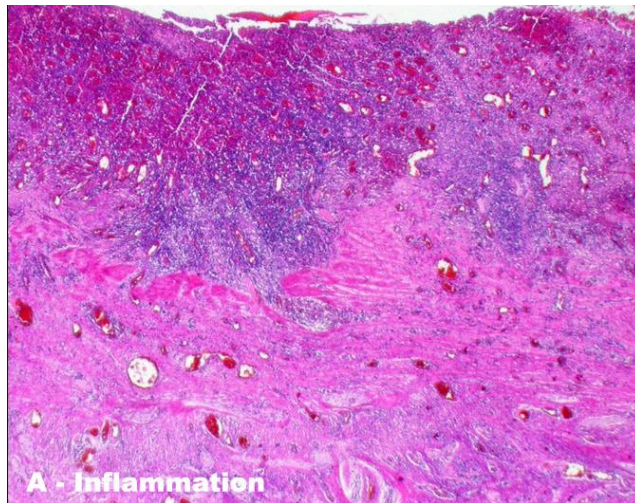
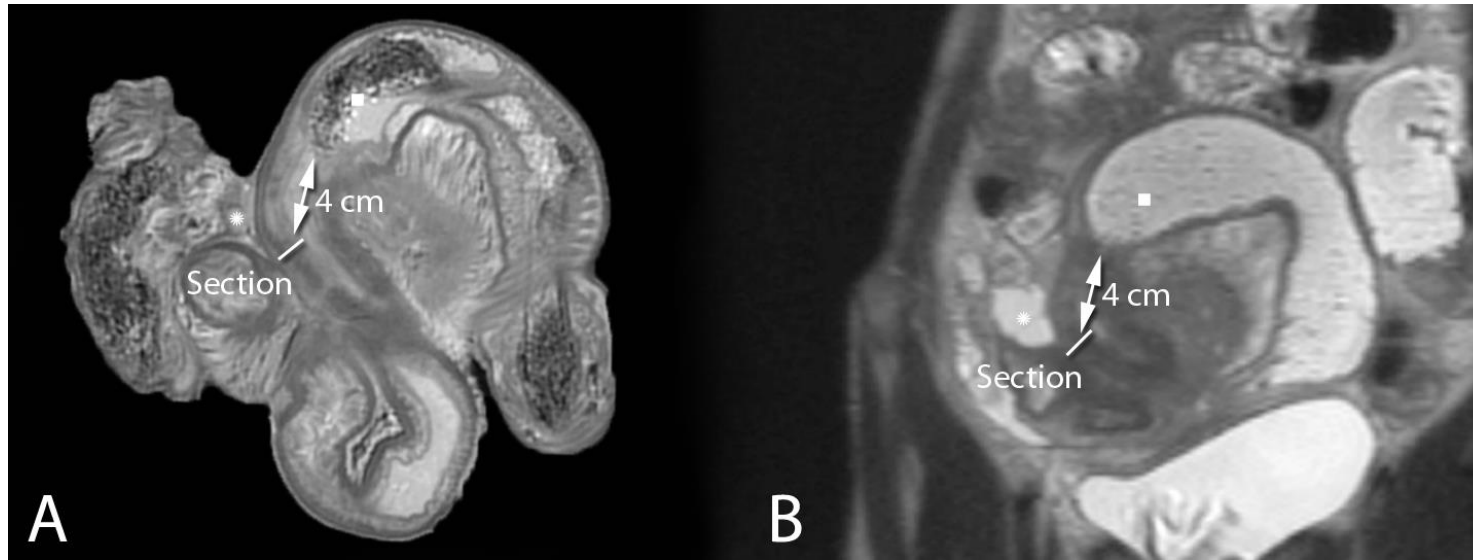








# Selection site location



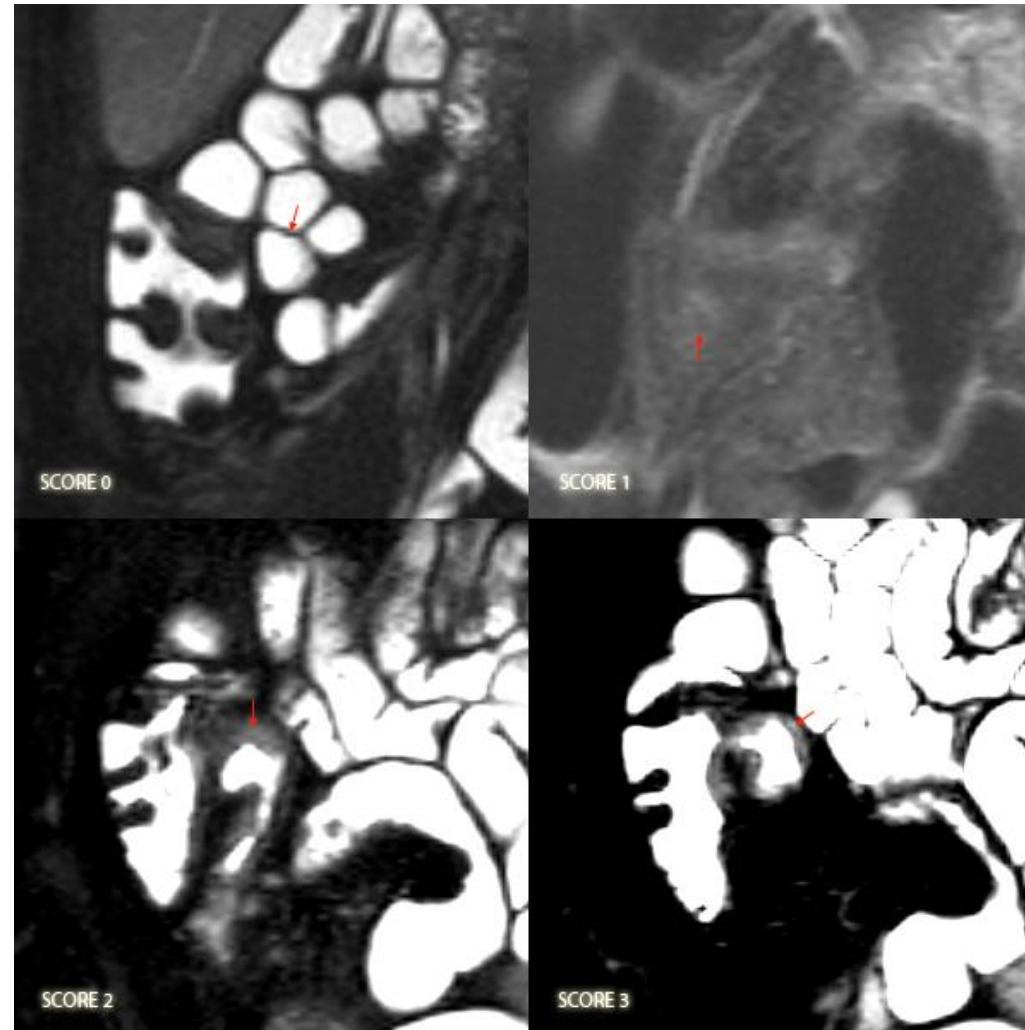
# Activity assessment – imaging features

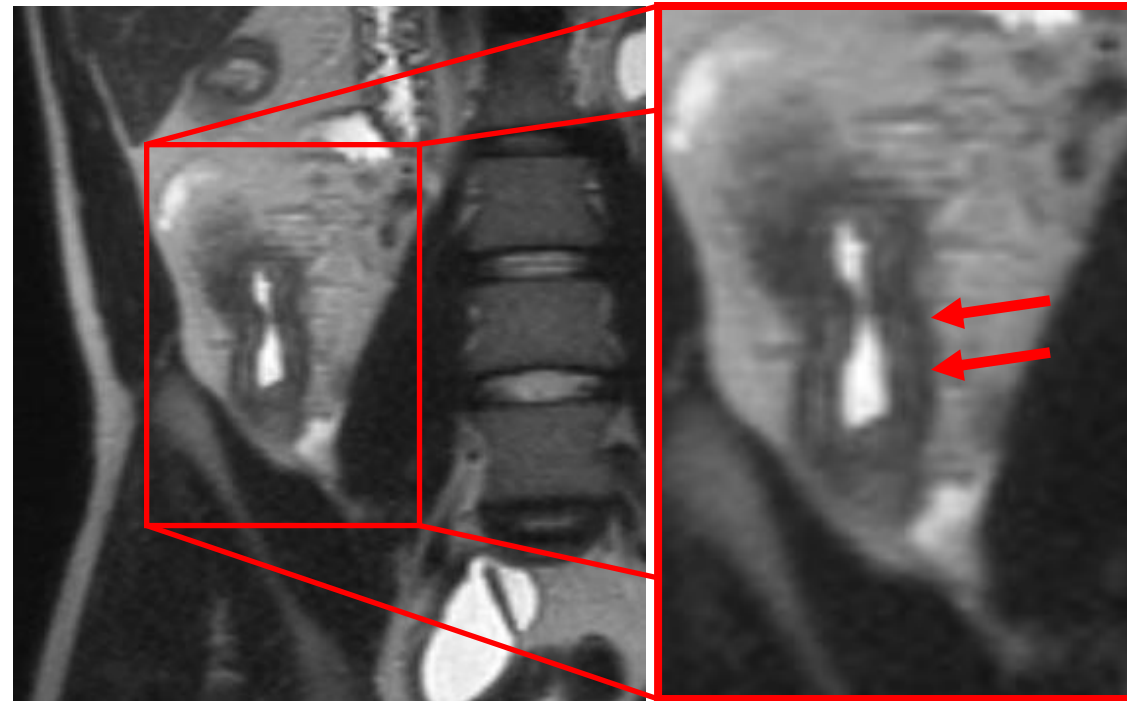
| MRI Feature                   | Reference   | Reference Standard  |
|-------------------------------|---|---|
| Wall thickness                | Zappa et al. [40]   | Histologic examination of surgical specimen               |
|                               | Rimola et al. [39]  | CDEIS   |
|                               | Steward et al. [53]                                       | Surgical and endoscopic biopsy and histologic examination |
|                               | Lasocki et al. [75]                                       | Surgical and endoscopic biopsy and histologic examination |
|                               | Ziech et al. [35]   | Histologic examination of surgical specimen               |
|                               | Koh et al. [76]   | Colonoscopy and surgical findings                         |
|                               | Gourtsoyiannis et al. [77]                                | CDAI  |
|                               | Florie et al. [34]  | CDAI and Van Hees activity index                          |
| Mural T2 signal intensity     | Maccioni et al. [38]                                      | CDAI, CRP, ESR  |
|                               | Taylor et al. [37]  | Histologic examination of surgical specimen               |
|                               | Steward et al. [53]                                       | Surgical and endoscopic biopsy and histologic examination |
|                               | Rimola et al. [39]  | CDEIS   |
| Perimural T2 signal intensity | Zappa et al. [40]   | Histologic examination of surgical specimen               |
|                               | Maccioni et al. [38]                                      | CRP, ESR  |
| Steward et al. [53]           | Surgical and endoscopic biopsy and histologic examination |   |
|                               | T1 enhancement  | Rimola et al. [39]  |
| Taylor et al. [37]            |   | Histologic examination of surgical specimen               |
| Steward et al. [53]           |   | Surgical and endoscopic biopsy and histologic examination |
| Zappa et al. [40]             |   | Histologic examination of surgical specimen               |
| Ziech et al. [36]             |   | CDEIS   |
| Florie et al. [34]            |   | CDAI and Van Hees activity index                          |
| Enhancement pattern           |   | Steward et al. [53]                                       |
|                               | Zappa et al. [40]   | Histologic examination of surgical specimen               |
|                               | Koh et al. [76]   | Colonoscopic and surgical findings                        |
| Comb sign                     | Zappa et al. [40]   | Histologic examination of surgical specimen               |
| Lymph nodes                   | Rimola et al. [39]  | CDEIS   |
|                               | Gourtsoyiannis et al. [77]                                | CDAI  |

- Wall thickness
- T2 high signal (on FS)
- Perimural T2 high signal
- Contrast enhancement
- Layered enhancement
- Comb sign
- Lymph node enlargement

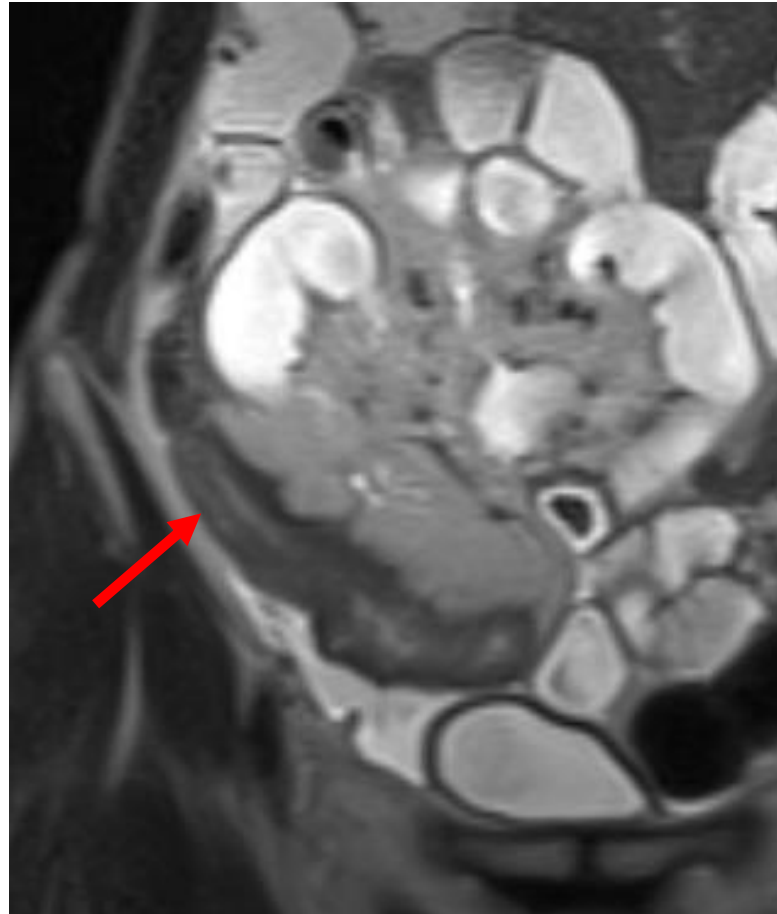
## Activity assessment – T2 “grey” not black



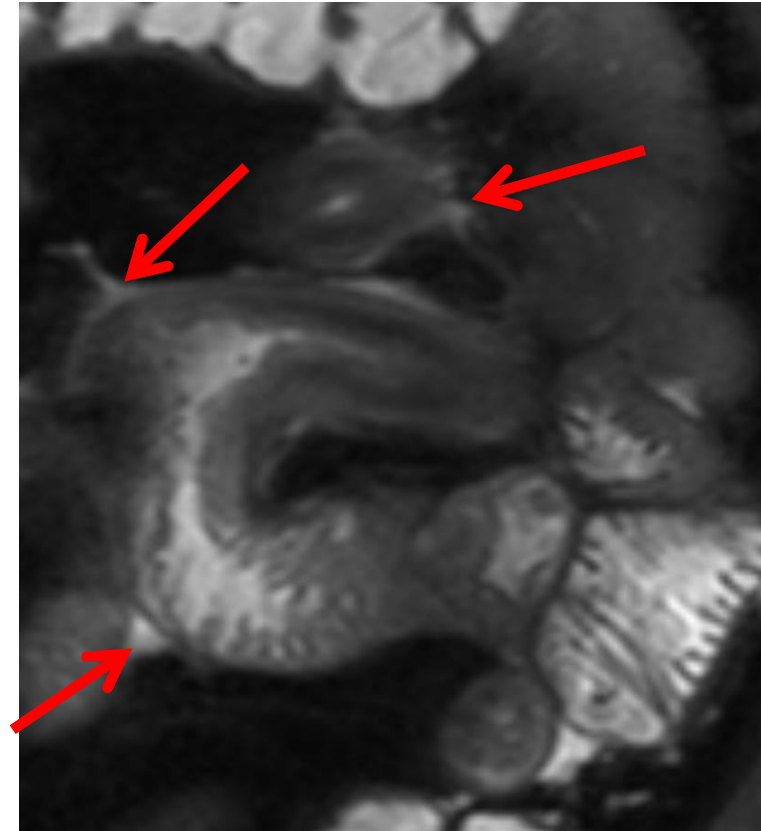
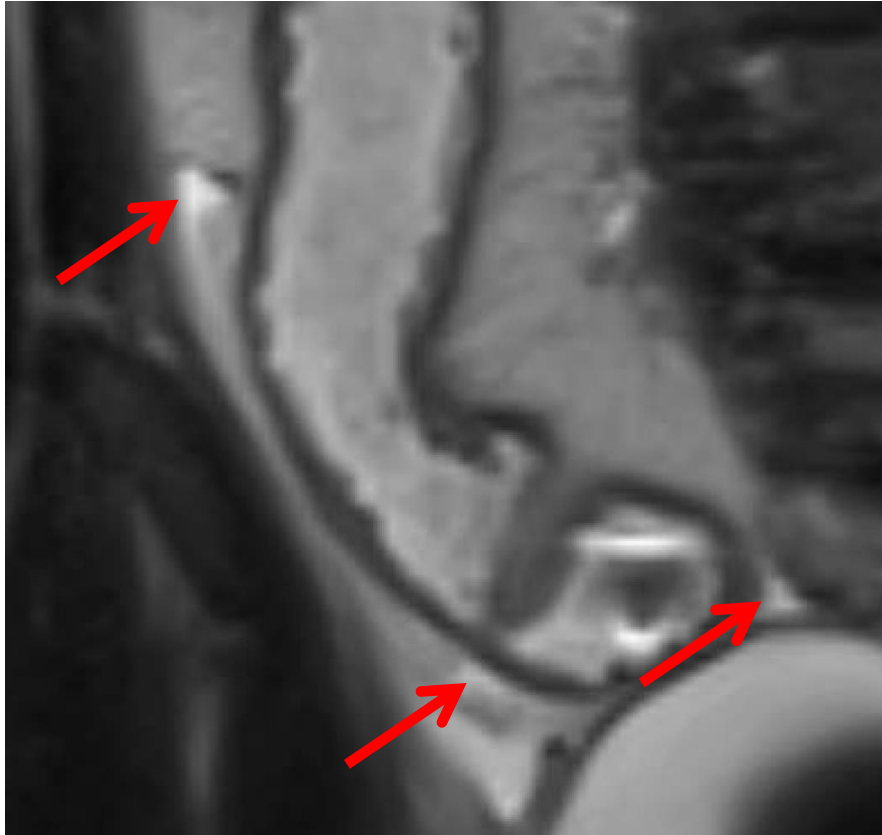




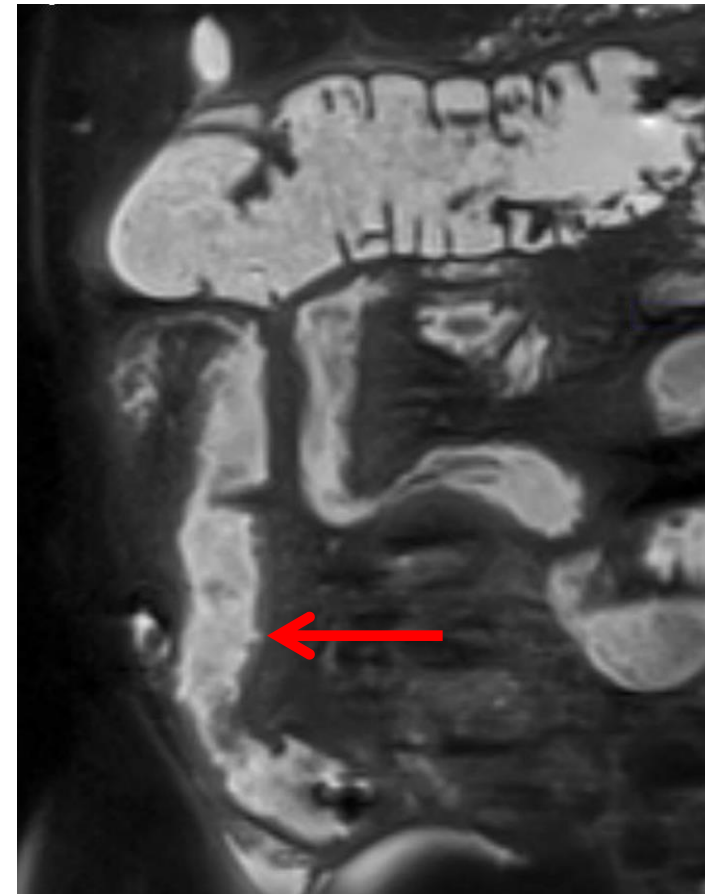
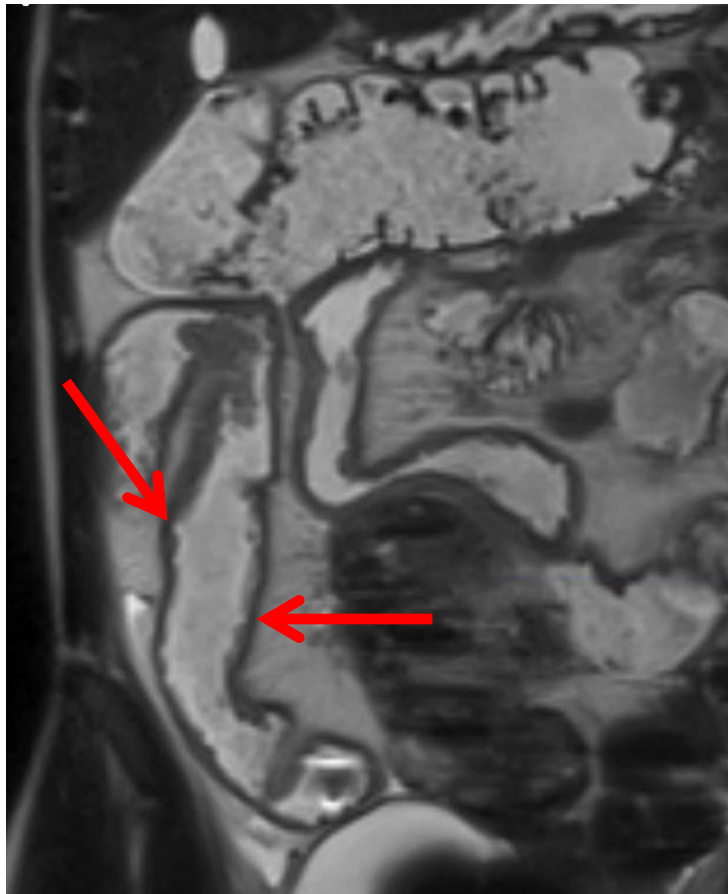




## Activity assessment – perimural fluid



## Activity assessment – ulceration





# MRI activity scores: Radiologist grading

## CDMI

| Mural features               | 0      | 1                             | 2                              | 3                           |
|------------------------------|--------|-------------------------------|--------------------------------|-----------------------------|
| Mural thickness              | <3mm   | >3-5mm                        | >5-7mm                         | >7mm                        |
| Mural T2 signal (oedema)     | Normal | Minor increase                | Moderate increase              | Large increase              |
| Perimural T2 signal          | Normal | Increased signal but no fluid | Small ( $\leq 2$ mm) fluid rim | Large ( $> 2$ mm) fluid rim |
| Contrast enhancement: amount | Normal | Minor increase                | Moderate increase              | Large increase              |

**London score:**  $1.79 + (1.34 \times \text{mural thickness}) + 0.94 \times \text{mural T2 signal}$

**sMaRIA:**  $1 \times \text{mural thickness} > 3\text{mm} + (1 \times \text{edema}) + (1 \times \text{fat stranding}) + (2 \times \text{ulcers})$

## Activity assessment – key aspects

- Currently popular activity scores (sMaRIA, MEGS, London score etc) are converging on:
  - **Wall thickness >3mm**
  - **Mural oedema (“grey not black”)**
  - **Perimural fluid/ stranding**
  - **+/- Ulceration**

## Functional sequences

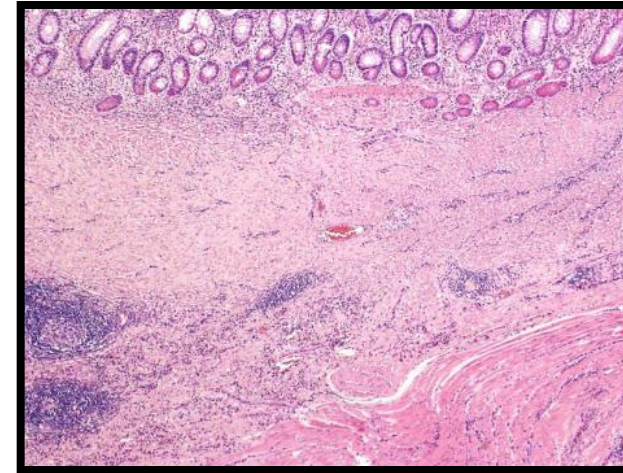
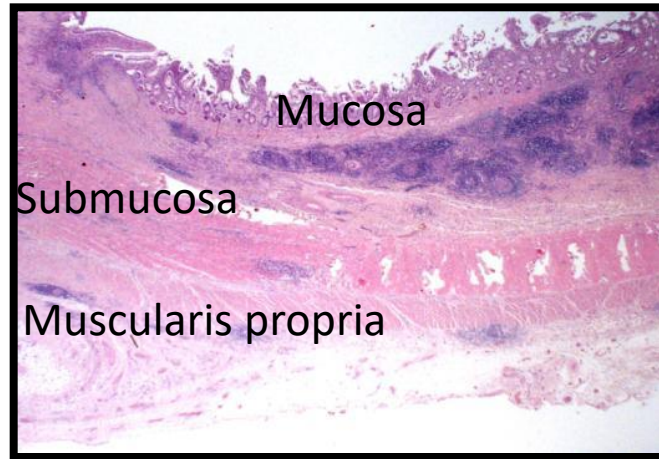
-DWI

-Motility

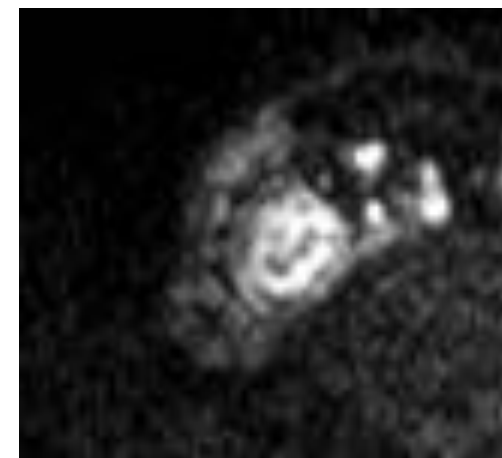
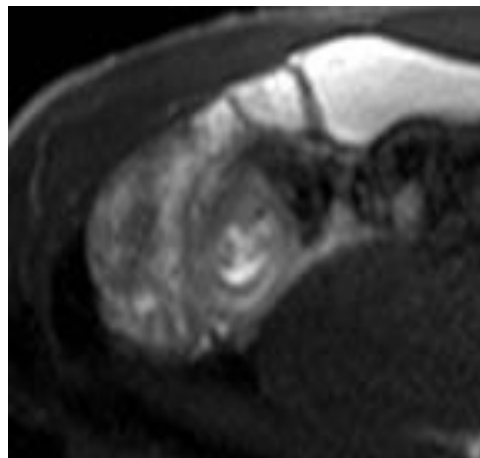
## Why is DWI abnormal in IBD

- Cellular infiltrate (acute and chronic)
- Oedema
- Crypt abscess
- Increased microvessel density
- Changes in mural perfusion
- Fibrosis

# Histo correlation-activity



Thickened muscularis mucosae and expanded submucosa (fibrosis)



# Diffusion-weighted MR Enterography for Evaluating Crohn's Disease: How Does It Add Diagnostically to Conventional MR Enterography?

*Kyung-Jo Kim, MD,\* Yedaun Lee, MD,<sup>†</sup> Seong Ho Park, MD,<sup>‡</sup> Bo-Kyeong Kang, MD,<sup>‡</sup> Nieuun Seo, MD,<sup>‡</sup> Suk-Kyun Yang, MD,\* Byong Duk Ye, MD,\* Sang Hyoung Park, MD,\* So Yeon Kim, MD,<sup>‡</sup> Seunghee Baek, PhD,<sup>§</sup> and Hyun Kwon Ha, MD<sup>‡</sup>*

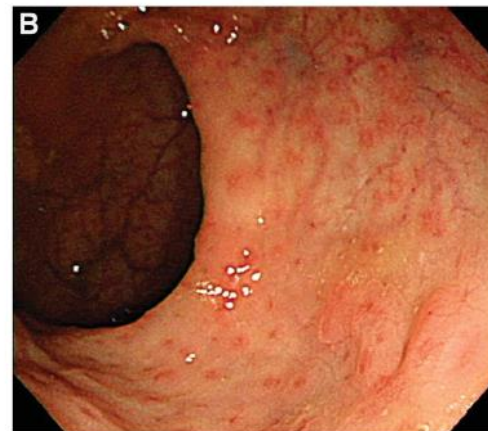
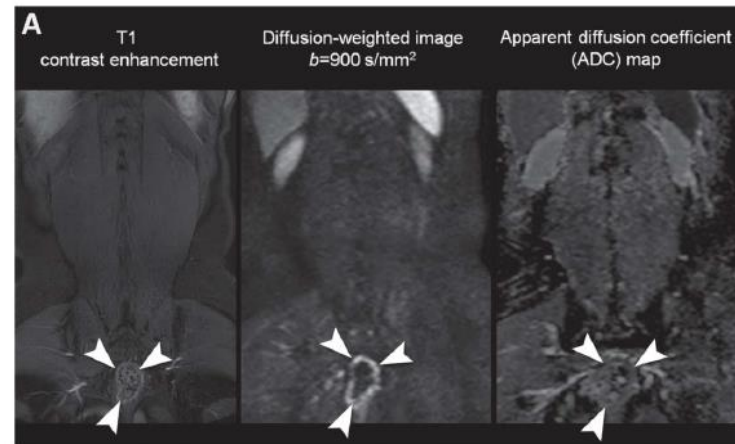
| Endoscopic Findings                     | Aphthae, Erythema, or Edema Only (n = 34) | Superficial Ulcers (n = 26) | Deep Ulcers (n = 32) | All (n = 92) |
|---|---|-----------------------------|----------------------|--------------|
| Active inflammation on conventional MRE | 18 (6/34)                                 | 77 (20/26)                  | 97 (31/32)           | 62 (57/92)   |
| Active inflammation on DWI              | 53 (18/34)                                | 73 (19/26)                  | 94 (30/32)           | 73 (67/92)   |

Data are percentages with the number of bowel segments provided in the parentheses.

44 CD patients underwent MRI and colonoscopy  
 Matched MRE and colonoscopy for TI, right colon and rectum

## Sensitivity for colonoscopy abnormality

# FN conventional MRE



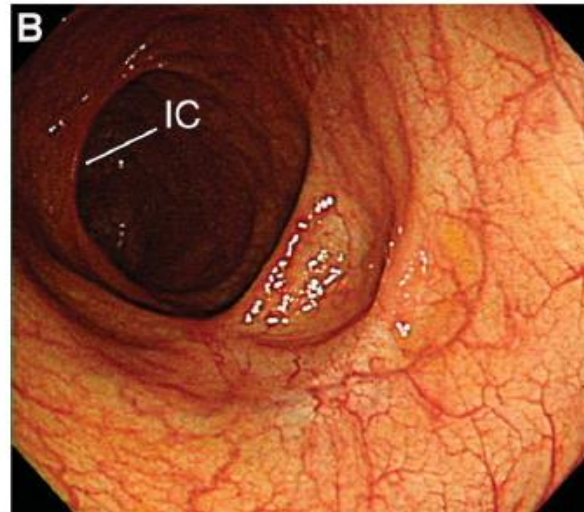
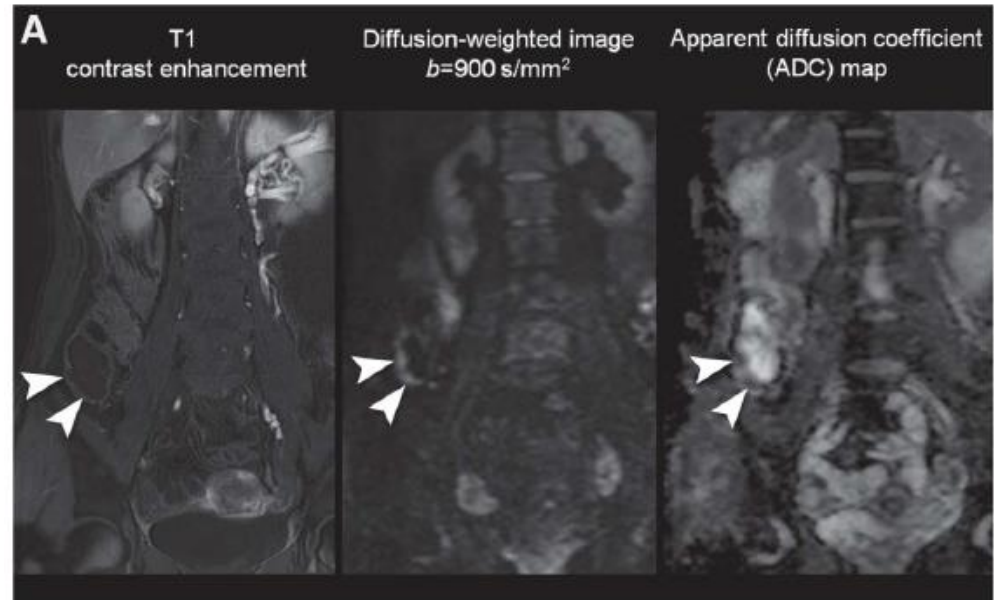


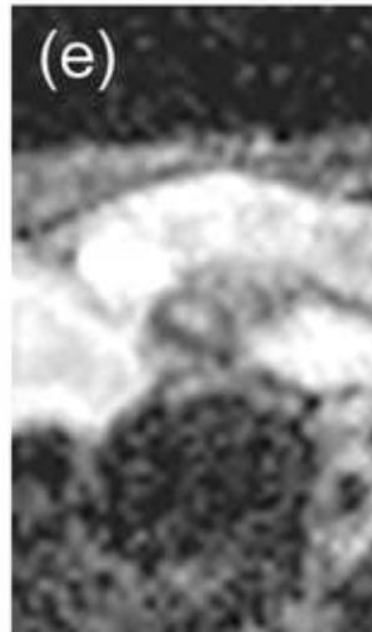
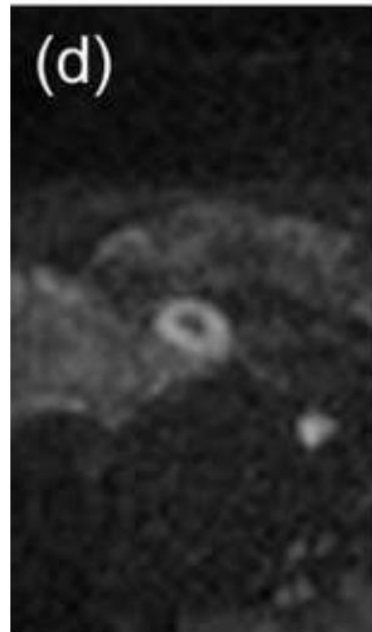
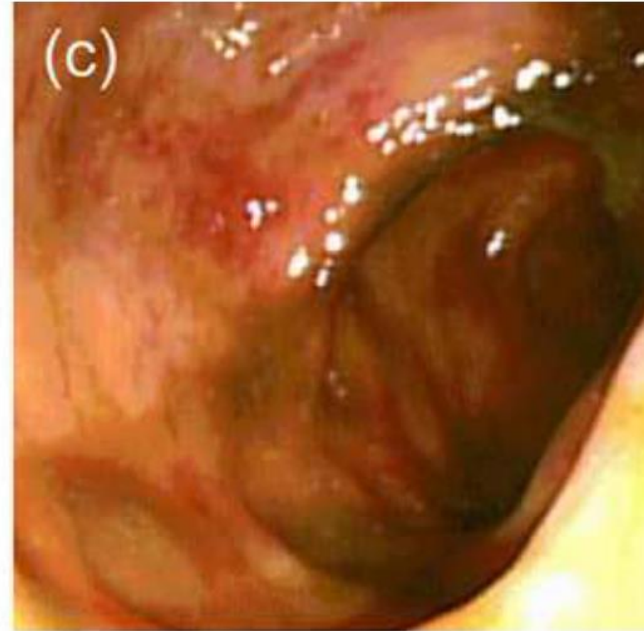
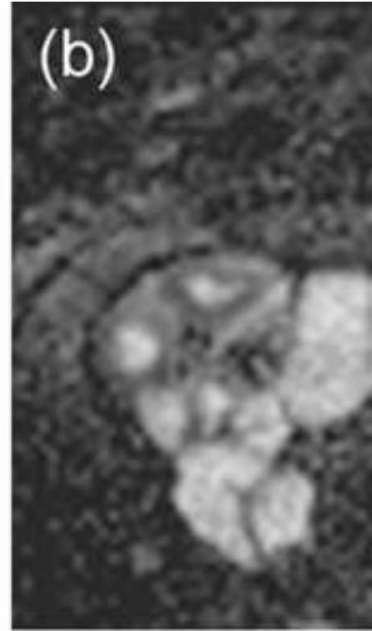
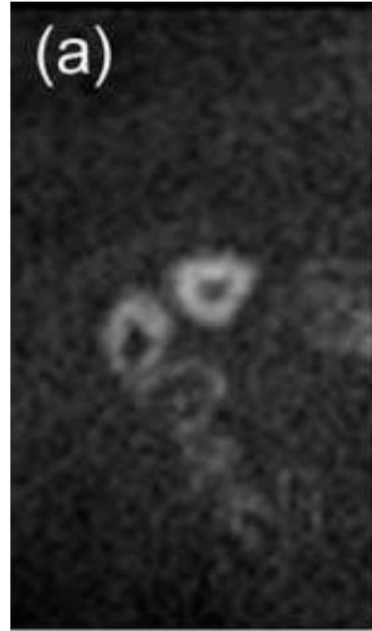
# Specificity for colonoscopy abnormality

|   | Sensitivity         |                       |                           | Specificity |                     |                       |                           |          |
|---|---------------------|-----------------------|---------------------------|-------------|---------------------|-----------------------|---------------------------|----------|
|   | Conventional<br>MRE | Combined<br>MRE + DWI | Conventional<br>MRE + DWI | <i>P</i>    | Conventional<br>MRE | Combined<br>MRE + DWI | Conventional<br>MRE + DWI | <i>P</i> |
| All types of bowel inflammation <sup>a</sup>    | 62 (57/92)          | 83 (76/92)            |                           | 0.001       | 94 (33/35)          | 60 (21/35)            |                           | <0.001   |
| Subgroups according to<br>inflammatory severity |                     |                       |                           |             |                     |                       |                           |          |
| Deep ulcers                                     | 97 (31/32)          | 97 (31/32)            |                           | 1           | NA                  |                       |                           |          |
| Overt (deep or superficial) ulcers              | 88 (51/58)          | 95 (55/58)            |                           | 0.171       | NA                  |                       |                           |          |
| Aphthae, erythema, or edema only                | 18 (6/34)           | 62 (21/34)            |                           | <0.001      | NA                  |                       |                           |          |
| Subgroups according to bowel<br>location        |                     |                       |                           |             |                     |                       |                           |          |
| Terminal ileum                                  | 91 (31/34)          | 94 (32/34)            |                           | 0.650       | 86 (6/7)            | 71 (5/7)              |                           | 0.560    |
| → Colorectum                                    | 45 (26/58)          | 76 (44/58)            |                           | <0.001      | 96 (27/28)          | 57 (16/28)            |                           | 0.003    |

Data are percentages with the number of bowel segments provided in the parentheses.  
<sup>a</sup>Includes overt (deep or superficial) ulcers and less severe lesions such as aphthae, erythema, or edema.  
 NA, not applicable.

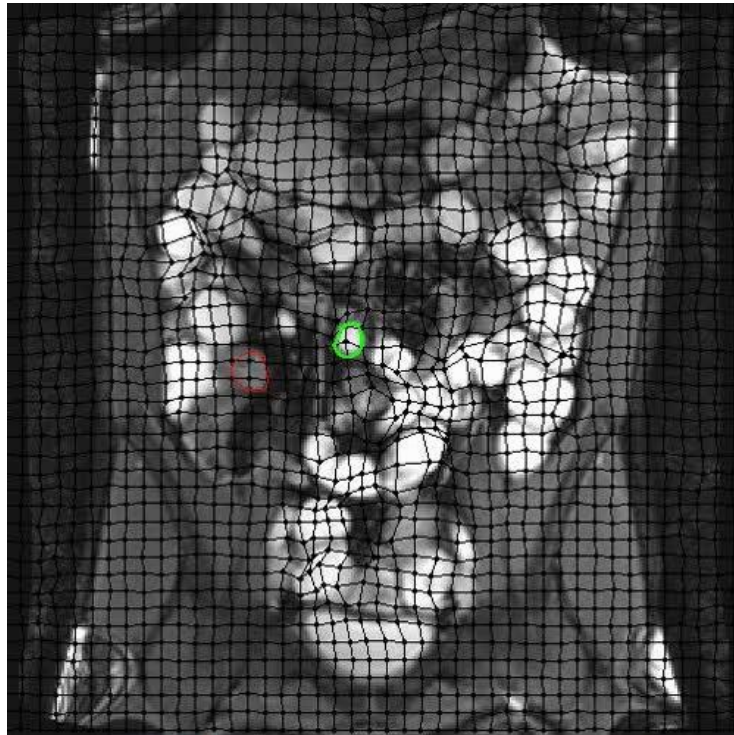
- FP DWI





# DWI

- DWI more sensitive than conventional MRI only especially for very early disease (in the colon)
- At the expense of a drop in specificity



Software quantitation of  
cine MRI motility  
increasingly available

# Quantified Terminal Ileal Motility during MR Enterography as a Biomarker of Crohn Disease Activity: Prospective Multi-Institution Study

*Alex Menys, PhD • Carl Puylaert, PhD • Charlotte E. Tutein Nolthenius, MD • Andrew A. Plumb, MBBS, PhD • Jesica Makanyanga, MBBS • Jeroen Tielbeek, MD, PhD • Doug Pendse, MBBS, MD • Lodewijk A. Brosens, MD • Manuel Rodriguez-Justo, MBBS • David Atkinson, PhD • Gauraang Bhatnagar, MBBS, PhD • Frans Vos, PhD • Jaap Stoker, MD • Stuart A. Taylor, MBBS, MD*

From the Centre for Medical Imaging, University College London, Charles Bell House, 43–45 Foley Street, 2nd Floor, London W1W 7TS, England (A.M., A.A.P., J.M., D.P., D.A., G.B., S.A.T.) and Department of Histopathology/Research Pathology, University College London Hospitals/University College London Cancer Institute, Royal Free Hospital, Rowland Hill Street, London NW3 2PF, England (C.E.T., J.T., D.P., L.A.B., M.R.J., D.A., G.B., S.A.T.)

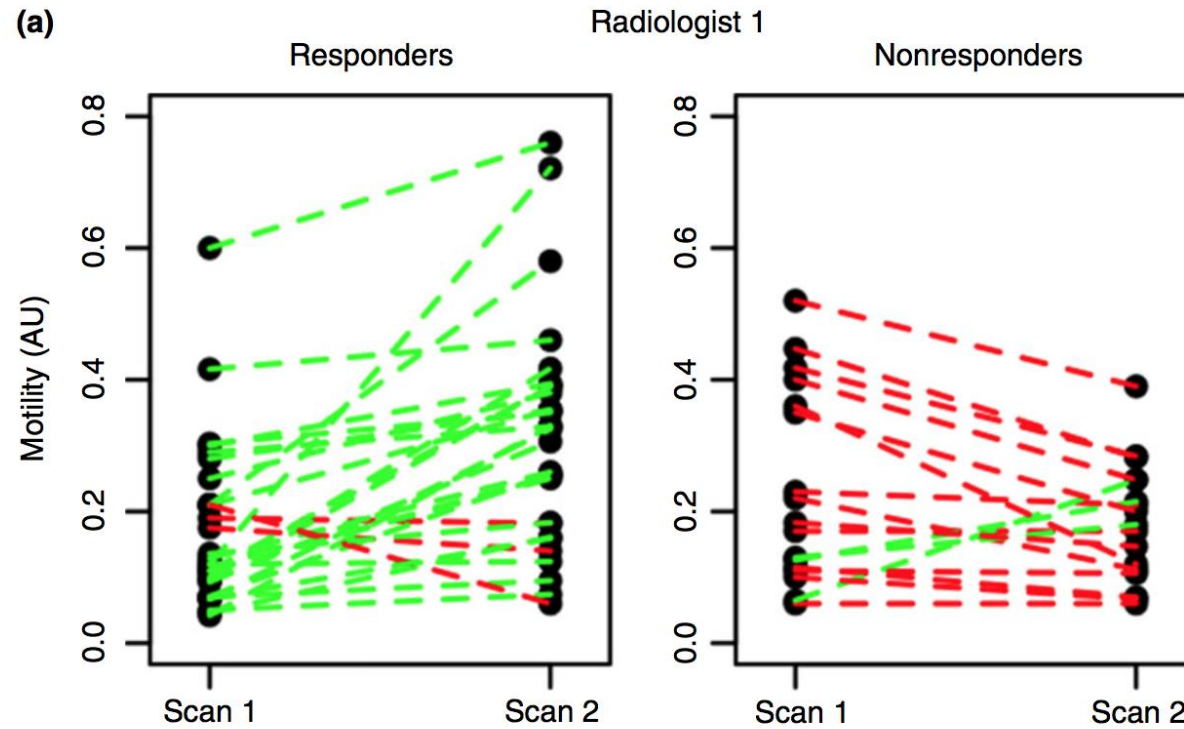
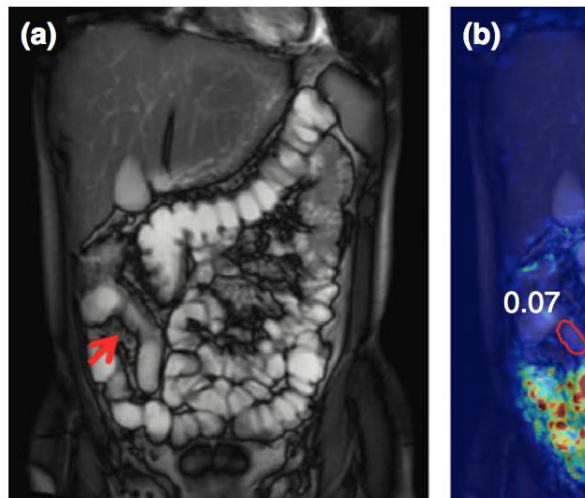
- 82 patients MRI and IC
- Motility had higher sensitivity for CDEIS  $\geq 4$  vs MaRIA (93 vs 78%) bit lower specificity (61 vs 81%)



# MOTILITY

AP&T Alimentary Pharmacology and Therapeutics

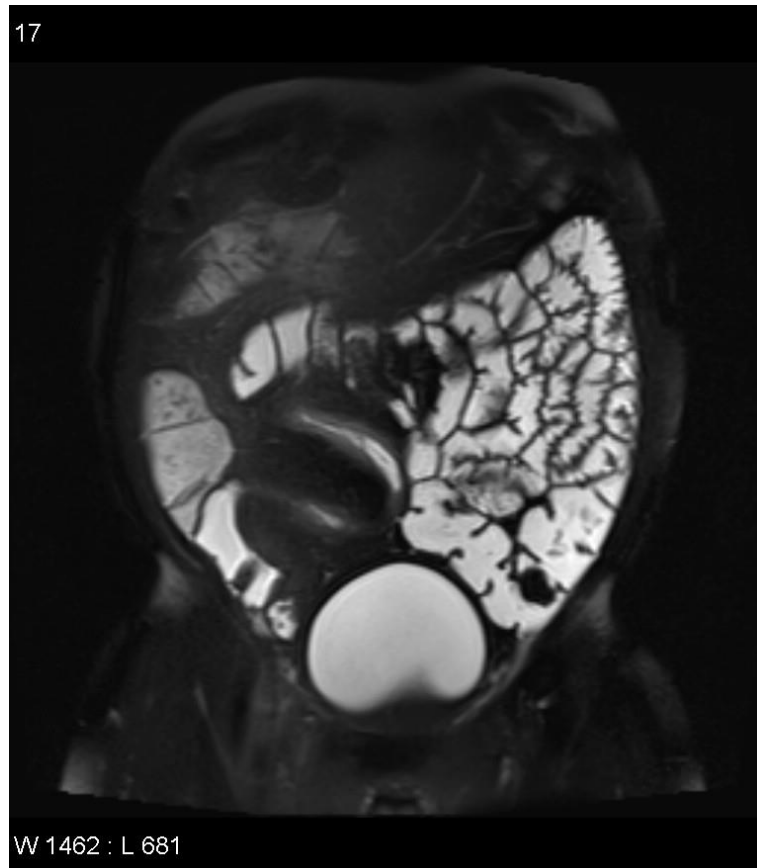
Magnetic resonance imaging is a sensitive marker of remission in Crohn's disease



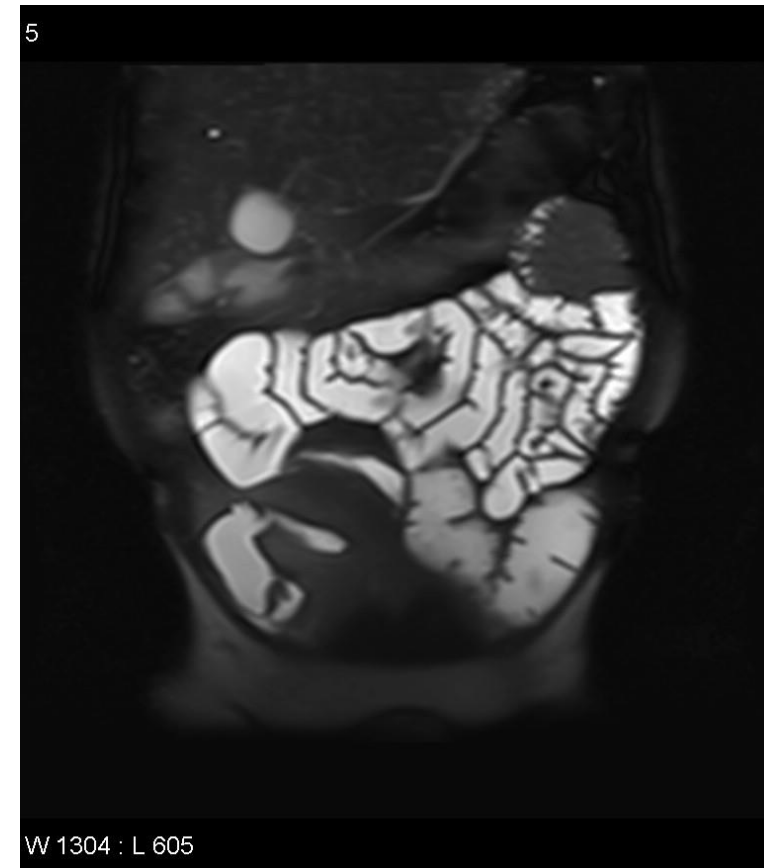
# Treatment response

# Single Shot Recovery Acquisition with Refocused Echoes (RARE)

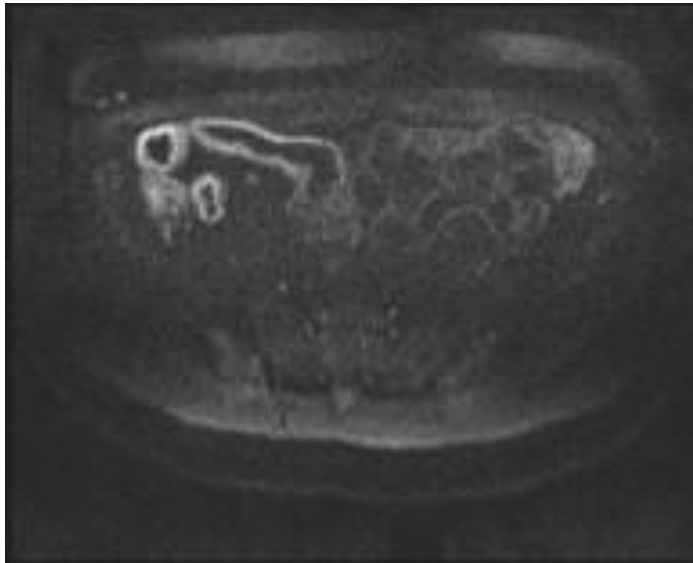
- Pre-treatment



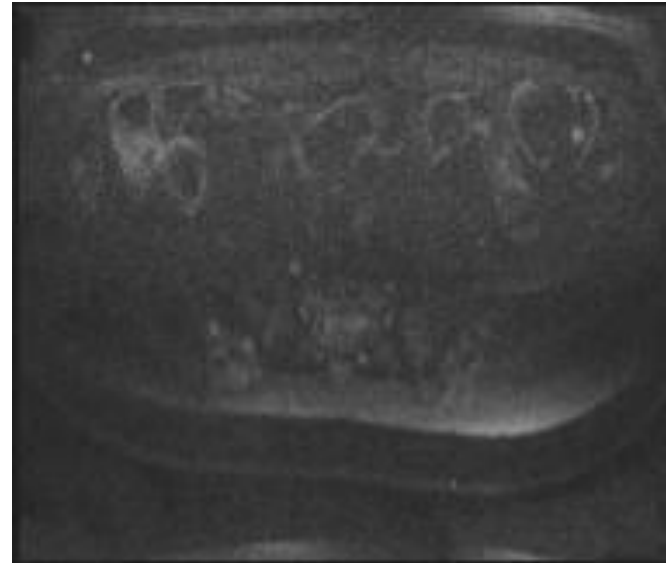
- Post treatment

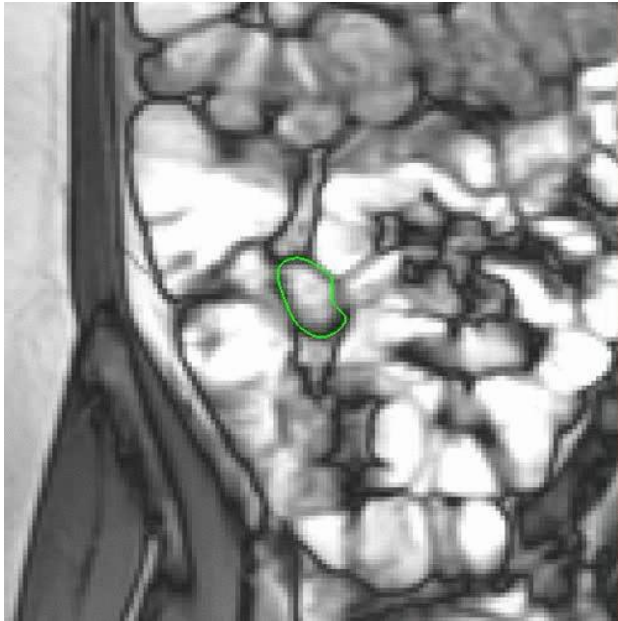


Pre-treatment

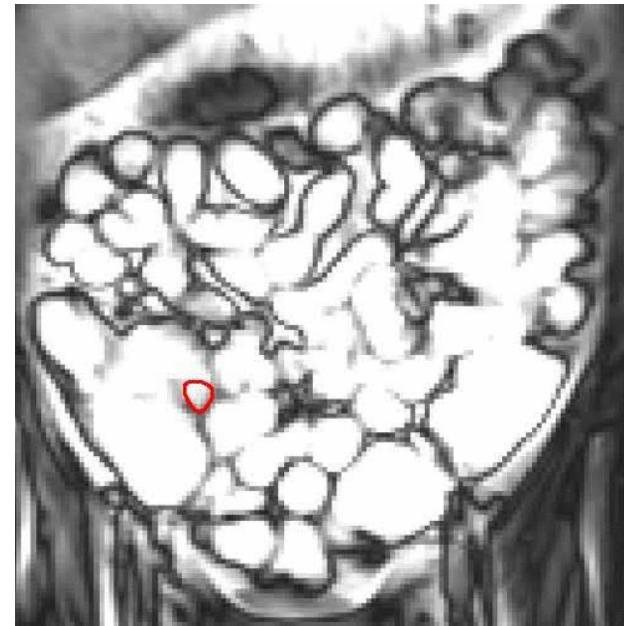


Post-treatment



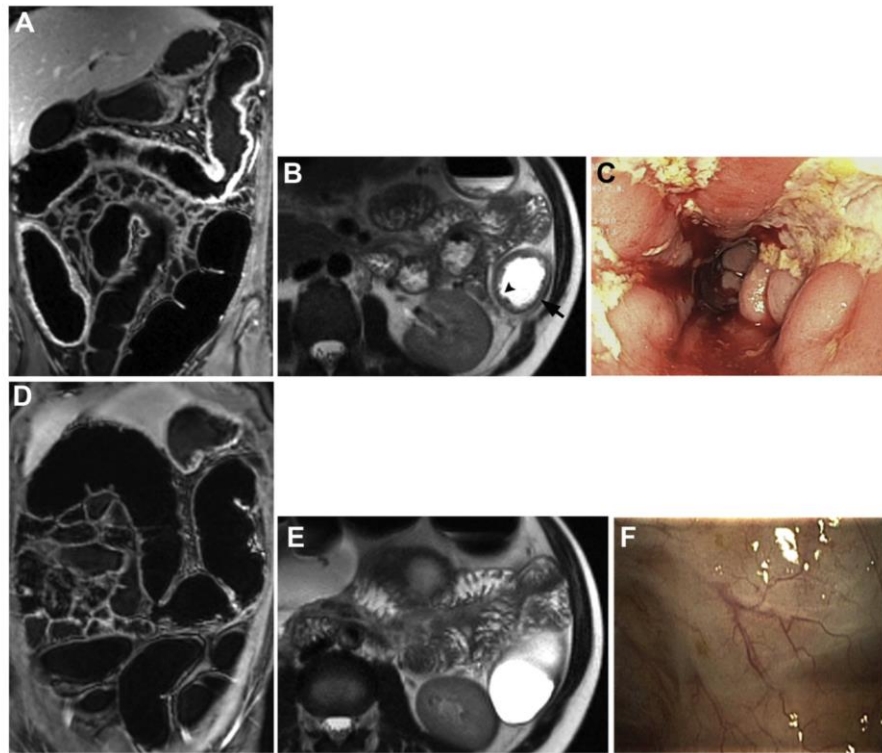


High motility



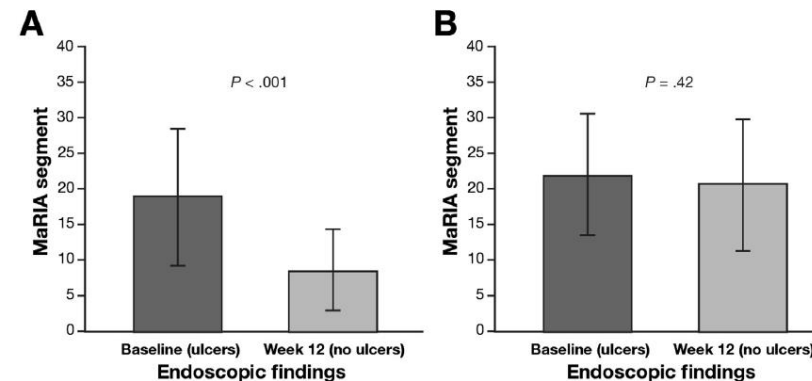
Low motility

# Imaging Activity scores improve in response to treatment



- Imaging remission
- Normalisation (or near normalisation) of MRE is ~equivalent to mucosal healing (90% overlap) **Transmural healing**

Ordás I et al . Accuracy of magnetic resonance enterography in assessing response to therapy and mucosal healing in patients with Crohn's disease. Gastroenterology. 2014 Feb;146(2):374-82





- MRE protocols are now established
- MRI has a role in disease
  - Detection
  - Activity assessment
  - Treatment follow up

# Thanks



- Jordi Rimola, Barcelona
- Andrew Plumb UCL
- Harbir Sidhu UCL
- Damian Tolan Leeds