

CT & MR ENTEROGRAPHY

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Introduction

- Historically, the small bowel has been a relative black box due to its inaccessibility to endoscopic evaluation
- Thus, conventional radiologic procedures (i.e. barium studies) were the only imaging methods providing morphologic evaluation of the small bowel

Introduction

- ⦿ Small bowel evaluation and imaging has undergone dramatic evolution over the last couple decades
- ⦿ Indeed, there has been great advances in endoscopic methods (i.e. double balloon endoscopy and video capsule endoscopy).
- ⦿ At the same time, there has been significant advancements in radiologic imaging
 - Primarily CT and MR

Barium Studies

Two types:

- ⦿ Small bowel enteroclysis (SBE)
- ⦿ Small bowel follow-through (SBFT)

Ultrasound

- Can evaluate bowel for mural thickening and hyperemia
- Real-time → can assess peristalsis
- Can evaluate extra-enteric disease including fistulas and abscesses

- Subtle mucosal changes can not be detected

Ultrasound

- Ileocecal region, sigmoid, ascending and descending colon are usually adequately visualized

Limitations:

- Proximal ileum and jejunum can be difficult to assess due to multiple overlying bowel loops and deep pelvic location
- Transverse colon is challenging because of its variable anatomy

COMPUTED TOMOGRAPHY (CT)



CT

- ⦿ Can be split up into two techniques
 - CT Enterography – patient drinks oral contrast
 - CT Enteroclysis – NJ tube placed fluoroscopically prior to CT and luminal contrast introduced via NJ tube
- Superior distension achieved with Enteroclysis; the convenience, efficiency, and superior patient experience achieved with Enterography makes it the preferred technique

CT Enterography

Technique:

- ⦿ Patient drinks a large volume of fluids for optimal small bowel distension
 - ⦿ (1.5 – 2 L over 1 hour prior to exam)
- ⦿ Neutral or low-density oral contrast mixture used
 - ⦿ Provides optimal mucosal assessment
- ⦿ +/- Anti-peristaltic agent given prior to scanning
 - i.e. buscopan
- ⦿ IV contrast given for bowel wall enhancement and assessment of extra-enteric abnormalities

CT

- Routine CT still useful in certain scenarios such as:
 - Acute small bowel obstruction
 - Abscess
 - Fistulae
 - Toxic megacolon
 - Local and metastatic tumour spread

CT Enterography

⦿ Pros

- Scan time < 1 min
- Greater spatial resolution
- Less expensive than MRI
- Can evaluate spectrum of small bowel pathologies in a single study
 - i.e. IBD, GI bleeding, celiac disease, small bowel tumors

CT Enterography

⦿ Cons

- Poor toleration
 - High volume oral contrast
 - Oral contrast used often causes severe diarrhea
- Exposure to ionizing radiation (~ 6 mSv per study)
 - Pediatric patients
 - Multiple exams
- Limited in patients with renal dysfunction
 - eGFR < 30
 - Contrast-induced nephropathy (CIN)

Magnetic Resonance Imaging (MRI)



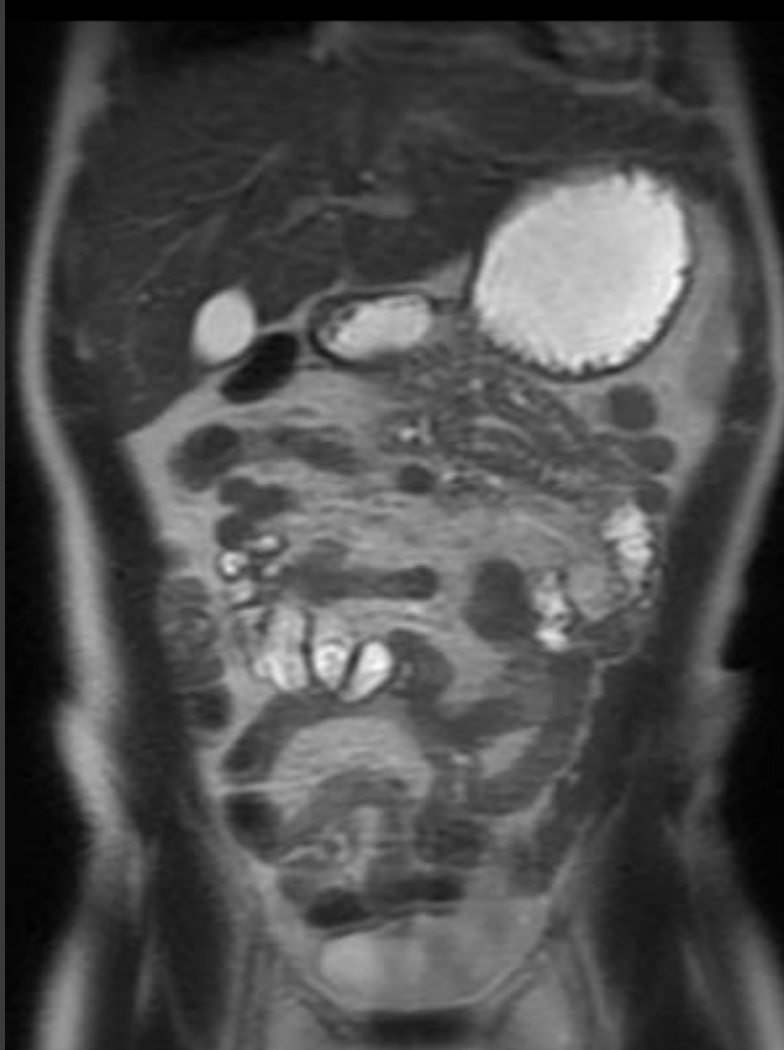
MR Enterography (MRE)

- ◎ Similar prep to CT Enterography
 - Requires large volume of oral contrast to distend the small bowel
 - 1.5 – 2 L over 1-2 hour
 - IV contrast to enhance mucosal abnormalities and extra-intestinal disease
 - Buscopan for anti-peristalsis

Distension, Distension, Distension

- ⦿ Adequate small bowel distension is crucial – main difficulty in our practice
- ⦿ We use methylcellulose and water mixture
 - Well-tolerated, however frequently suboptimal distension of jejunum
- ⦿ Polyethylene glycol solution (PEG)
 - Reported to have improved bowel distension
 - High complaint rate of diarrhea
- ⦿ VoLumen (commercially available low-density barium solution)
 - Better tolerated than PEG, with reported improved jejunal distension
 - \$\$\$

MRE



Suboptimal small bowel distension



Good small bowel distension

MRE

⦿ Advantages

- No ionizing radiation!
- Greater contrast resolution
- Multiple series performed over 30-45 minutes allows assessment of collapsed segments
 - Determine peristalsis vs spasm/stricture
- Ability to perform “MR fluoroscopy” to assess bowel peristalsis

MRE

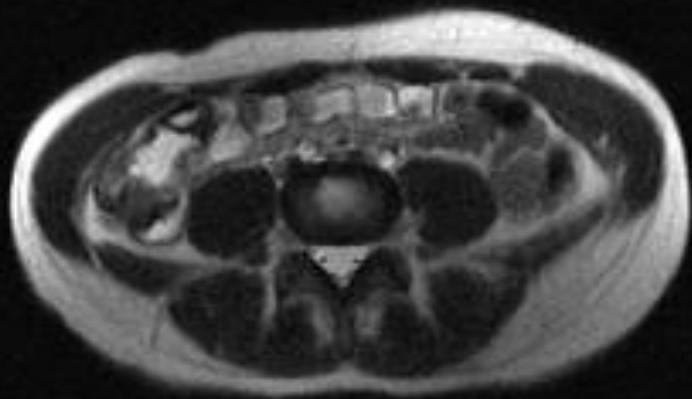
⦿ Disadvantages

- Insensitive to early mild mucosal disease
- More expensive than CT
- Less availability
- Exam time 30-45 minutes
- Requires greater patient compliance for breath-holding
- Claustrophobia
- Pacemakers & Implants are contraindicated
- Limited in patients with severe renal impairment
 - Nephrogenic systemic fibrosis (NSF)

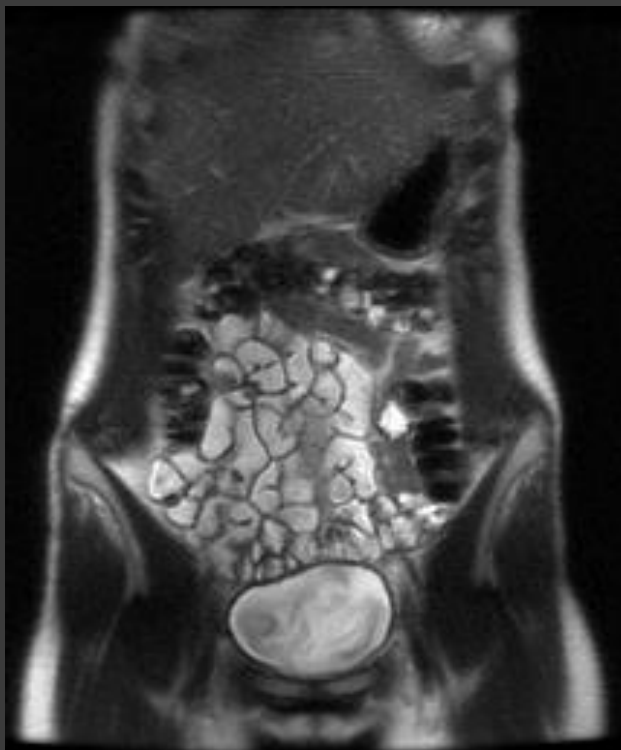
MRI sequences

- ⦿ Pre-contrast sequences
 - Ultrafast T2 sequences
 - Steady state free precession MRI (FIESTA)
 - Diffusion-weighted images (DWI)
- ⦿ Post IV contrast sequences
 - Coronal Dynamic post-contrast T1
 - Axial Delayed post-contrast T1
- ⦿ Total scan time ~ 30 minutes

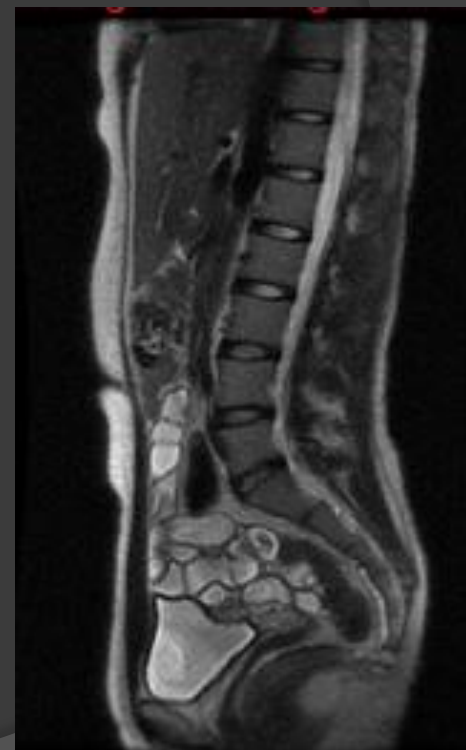
Multi-planar T2 Image



Axial

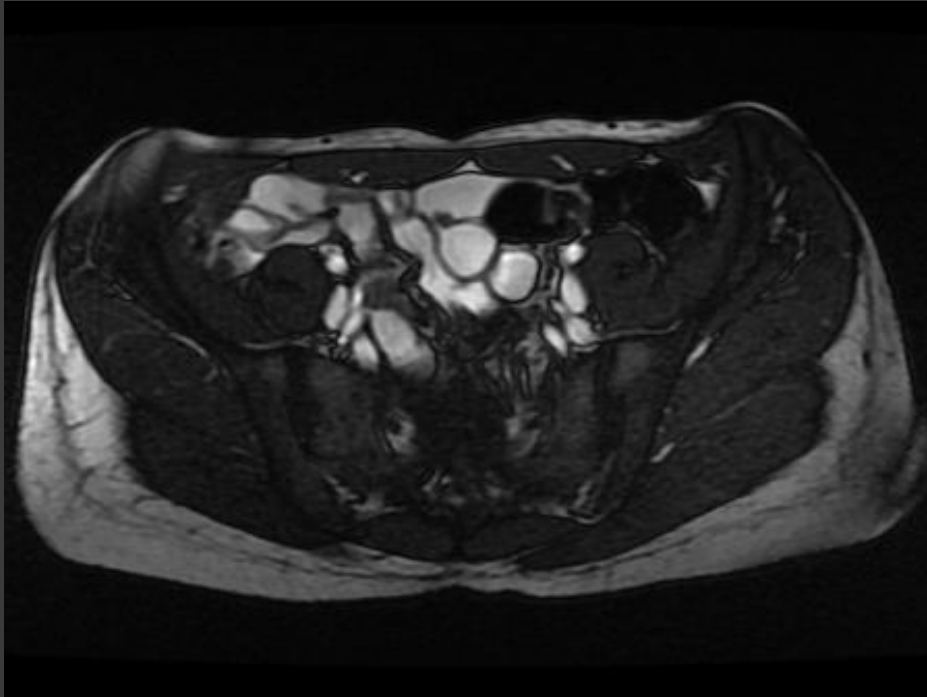


Coronal

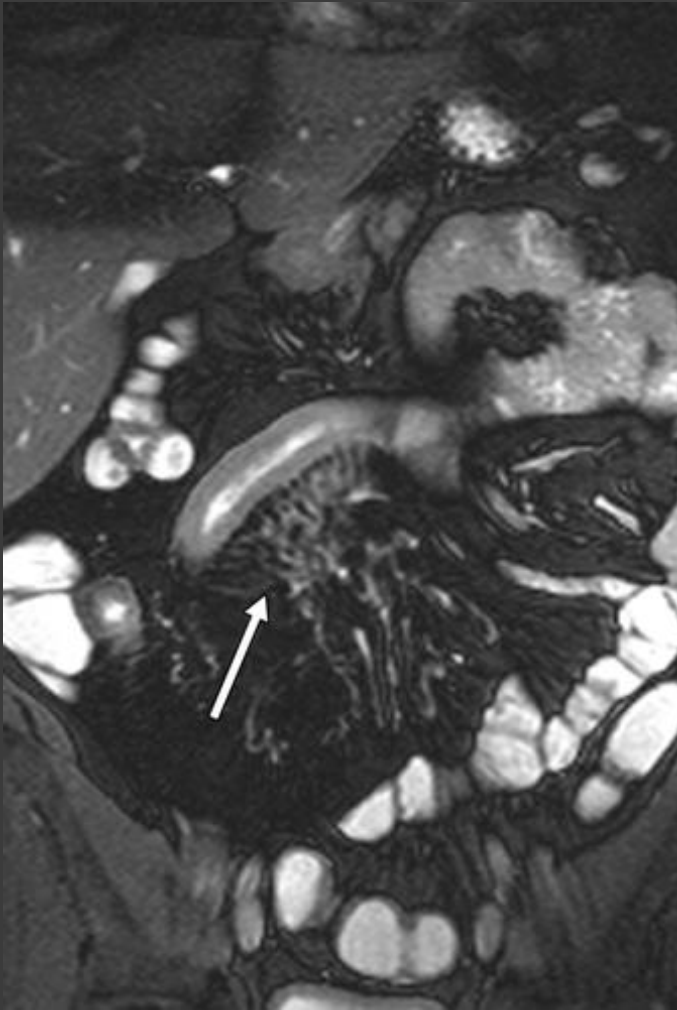


Sagittal

FIESTA

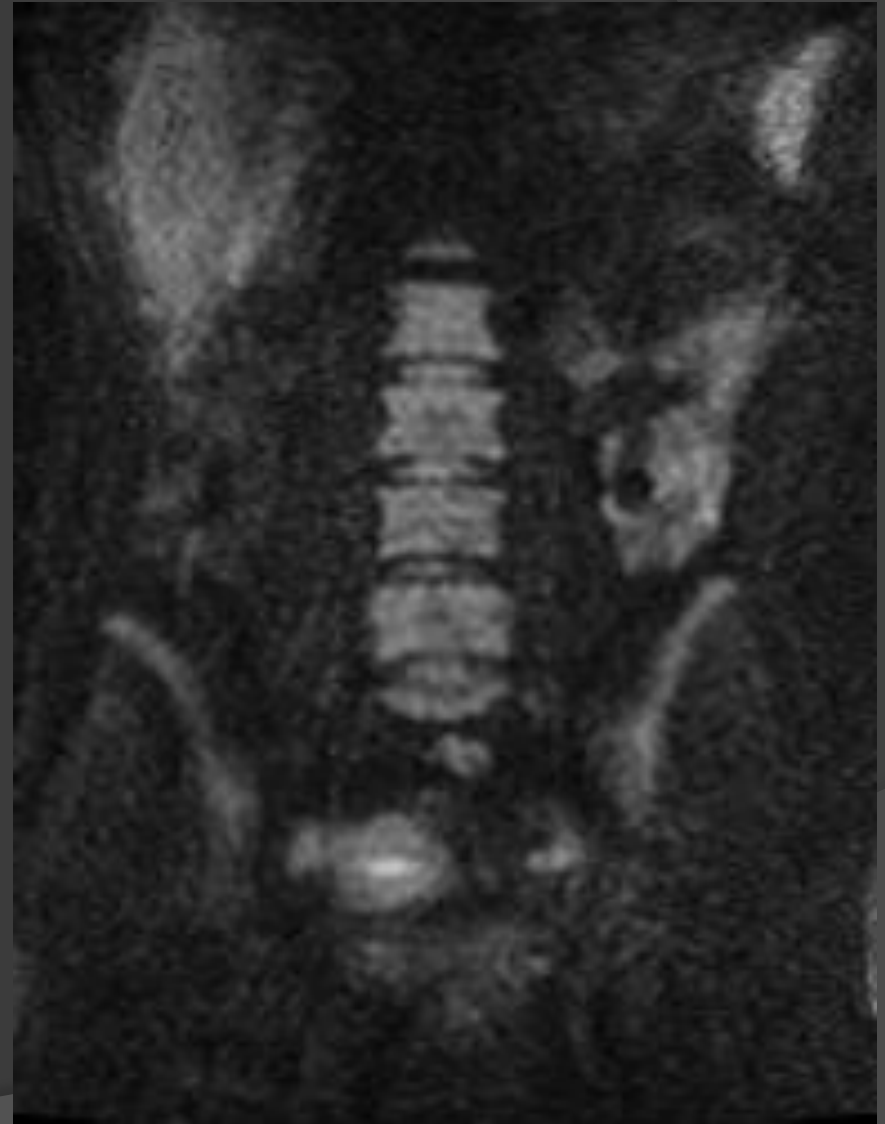
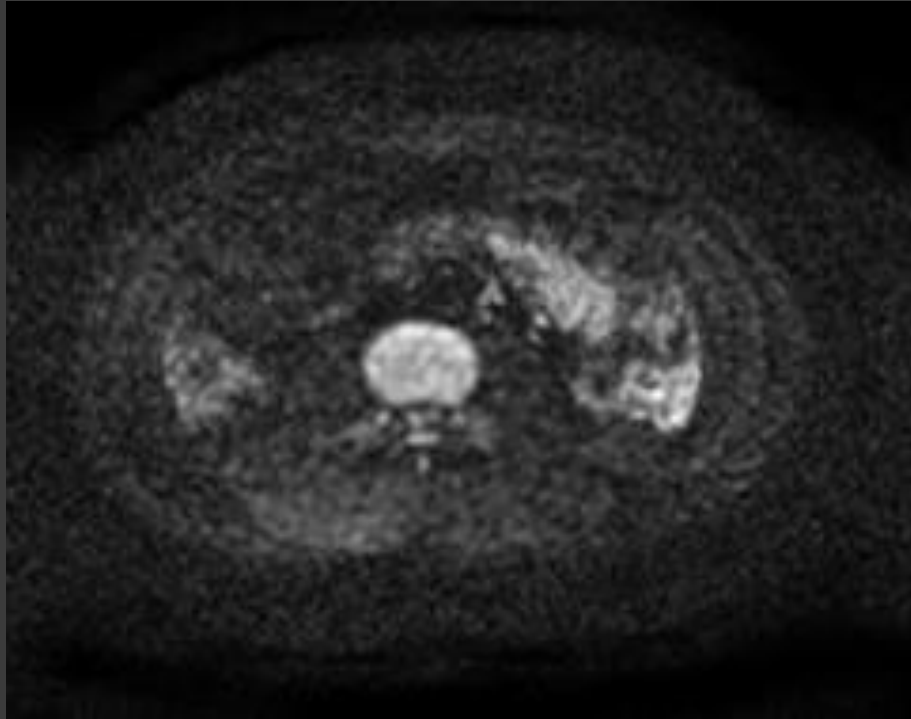


FIESTA

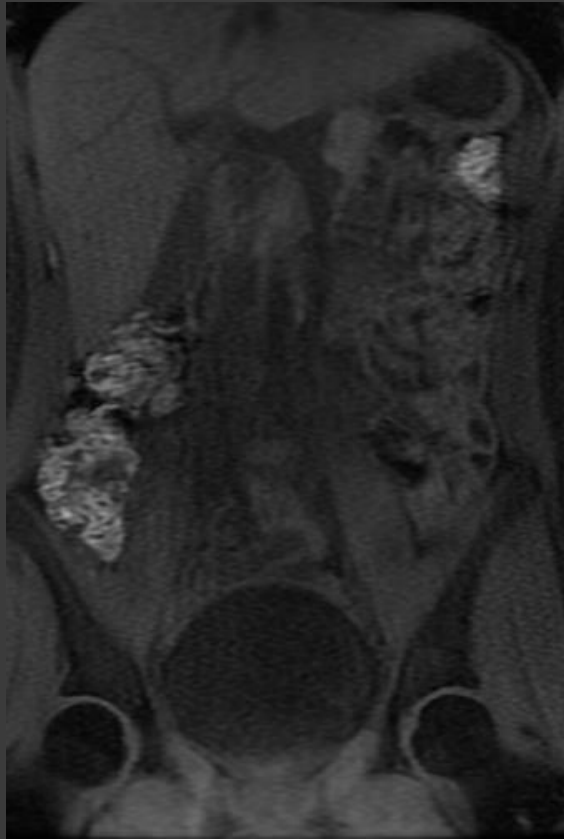


- Engorged mesenteric vessels surrounding inflamed distal ileum “comb sign”

DWI



Pre & Dynamic Post-Gad T1



CTE / MRE – Crohn's disease

- ① Detect active inflammatory SB disease and its complications at diagnosis
- ① Assess therapeutic response and mural healing
- ① Detect complications of disease and therapies

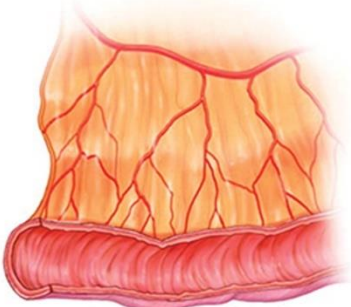
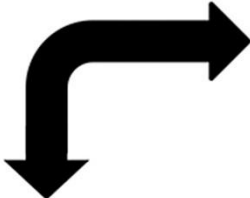
Phenotypes of Crohn's

- ◎ Spectrum / state of disease
 - No imaging signs of active inflammation
 - Active inflammatory small bowel Crohn's disease
 - Stricture Crohn's disease
 - Penetrating Crohn's disease
- ◎ Skip lesions can be in different disease states

Intestinal manifestations

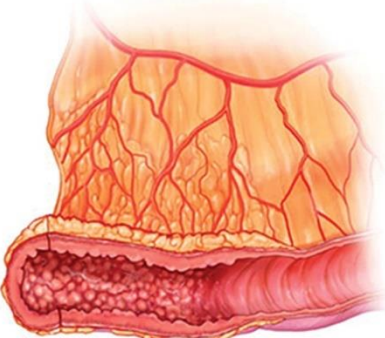
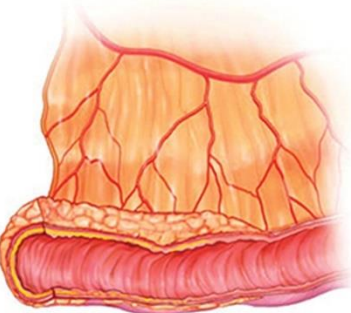
- Segmental mural hyperenhancement
- Mural thickening
- Intramural edema
- Stricture
- Ulcerations
- Sacculations
- Diminished motility

Active Inflammatory Crohn's Disease

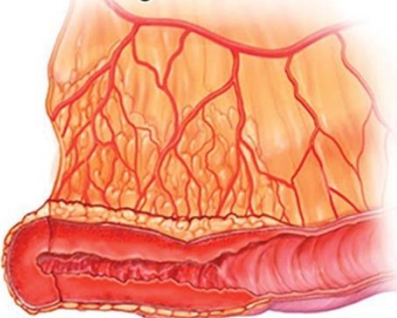


No imaging signs of inflammation

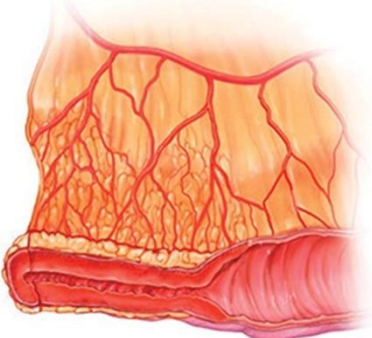
- Normal
- Inactive/quiescent disease



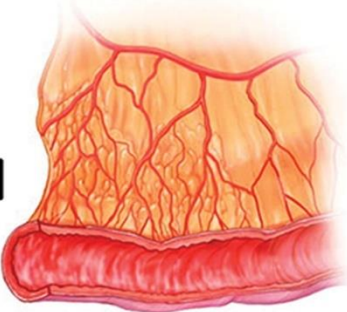
Without luminal narrowing



Narrowing without upstream dilation



Stricture development
(unequivocal upstream dilation)



Non-specific inflammation



Penetrating complications



Intra-abdominal manifestations

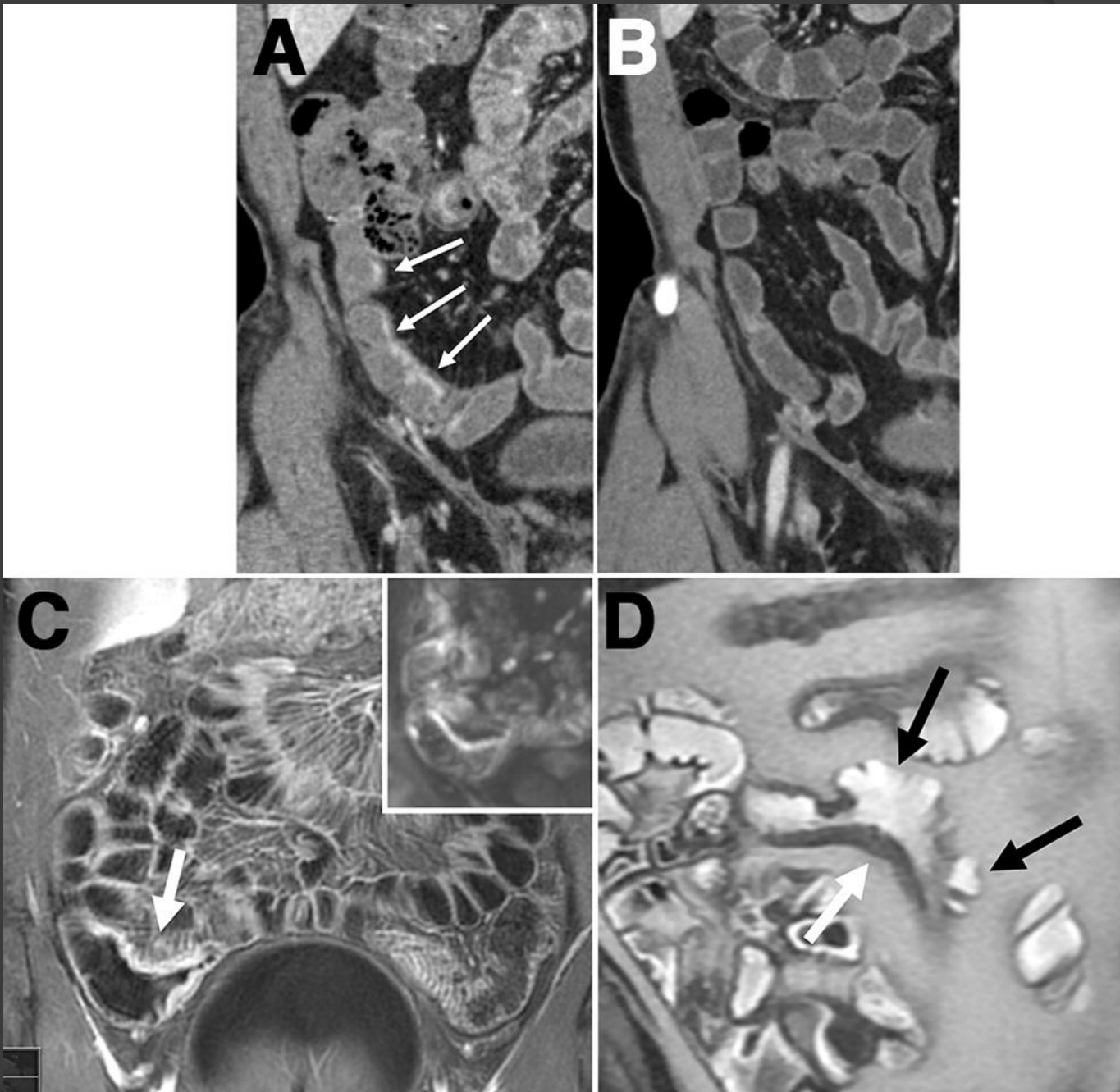
- ⦿ Fistula
- ⦿ Inflammatory mass
- ⦿ Abscess
- ⦿ Peri-enteric edema / inflammation
- ⦿ Engorged vasa recta
- ⦿ Fibrofatty proliferation
- ⦿ Mesenteric venous thrombosis / occlusion
- ⦿ Lymphadenopathy

Extra-intestinal manifestations

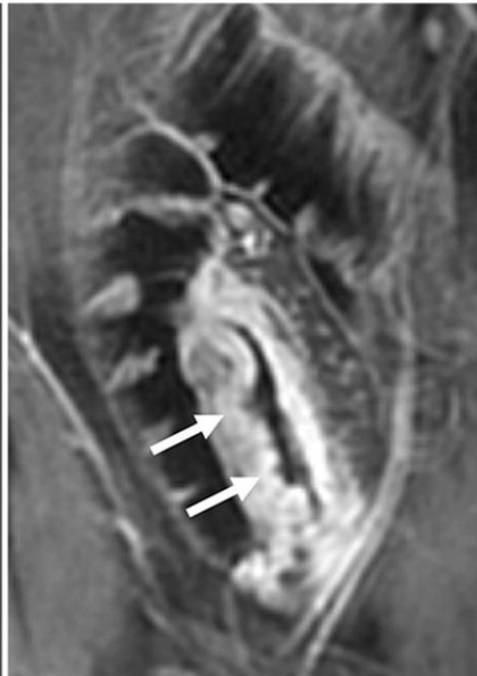
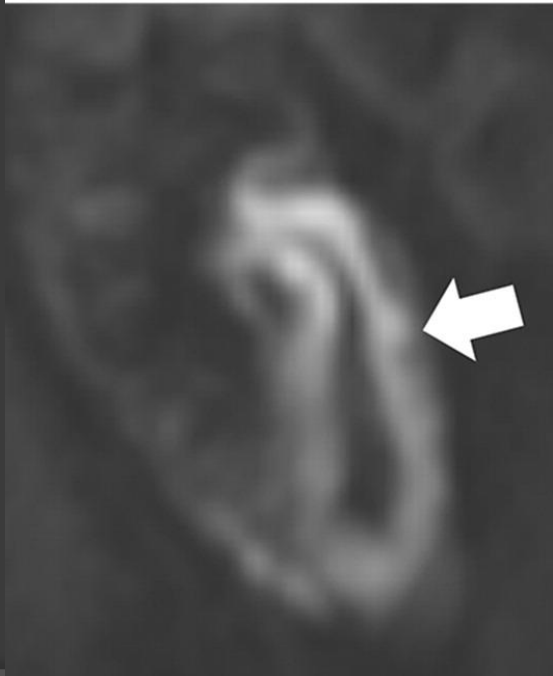
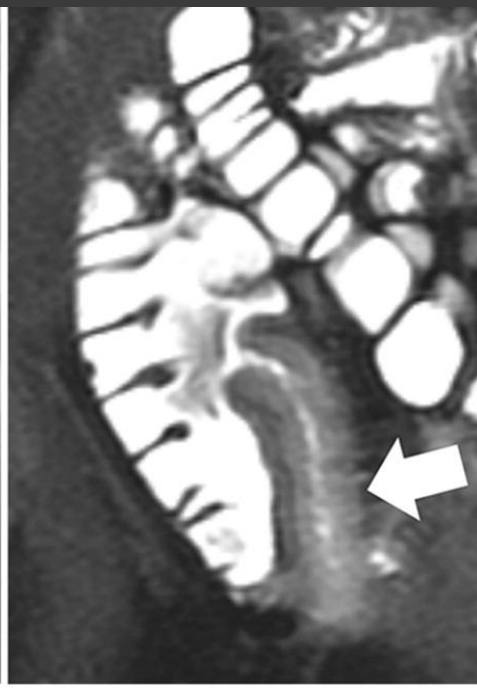
- 50% of IBD patients have EIM
- Sacroiliitis
- PSC (primary sclerosing cholangitis)
- AVN (avascular necrosis)
- Pancreatitis
- Nephrolithiasis and cholelithiasis

Active inflammatory disease

- Mural thickening
- Intramural edema
- Mural hyperenhancement
- Engorged vasa recta
- Peri-enteric edema / inflammation

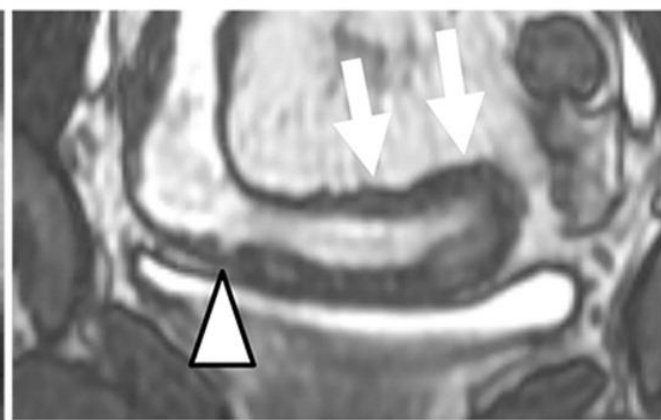
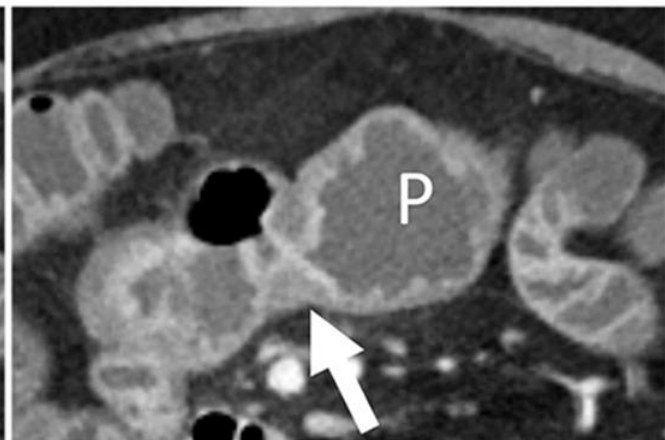
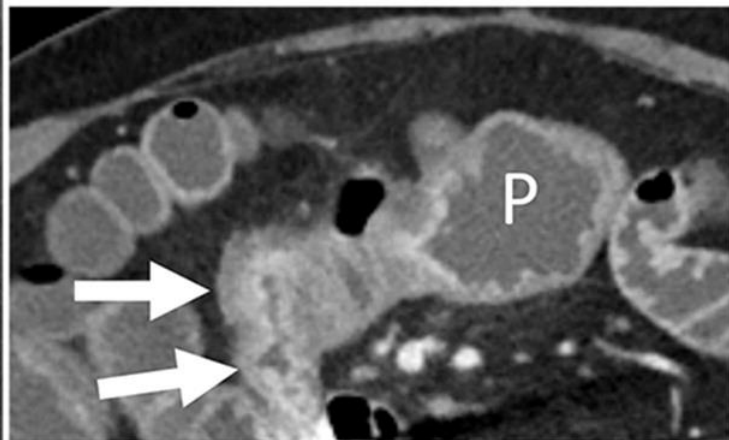






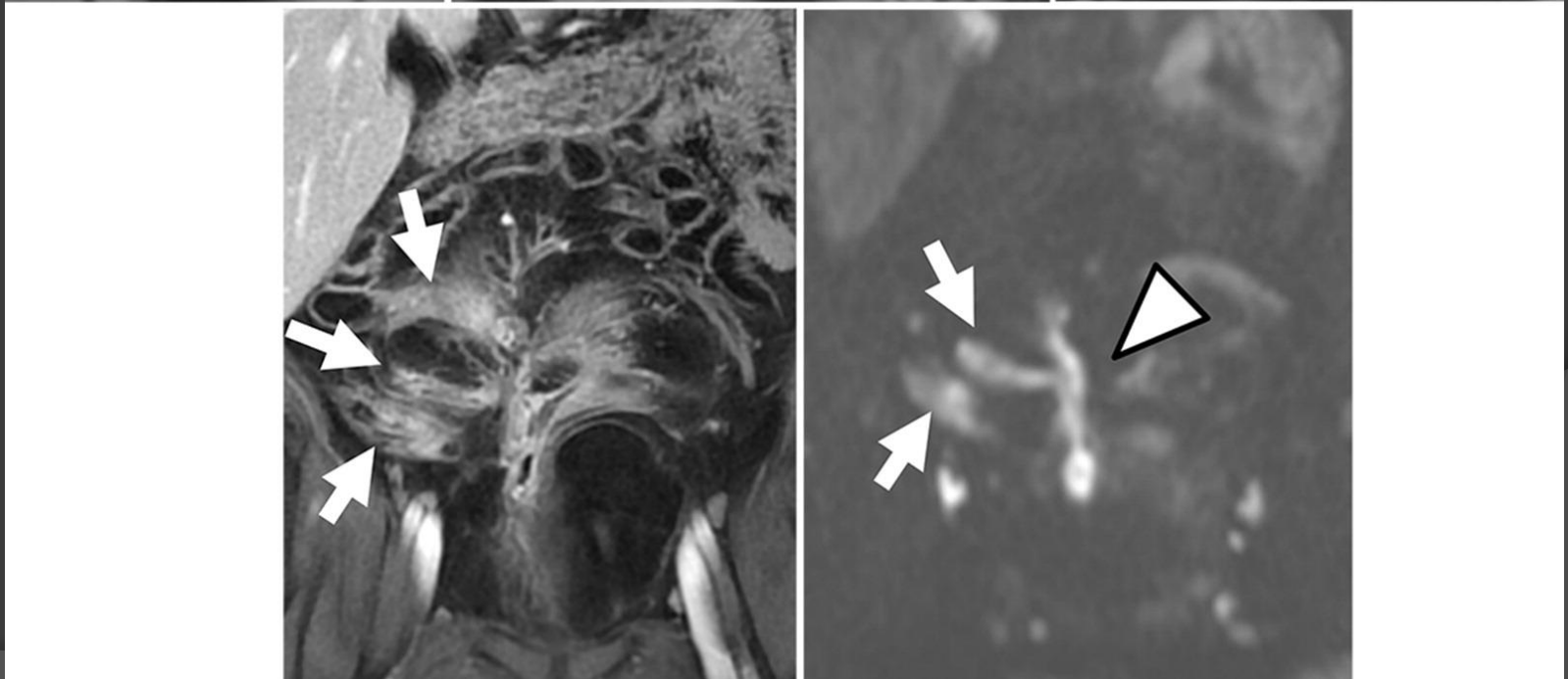
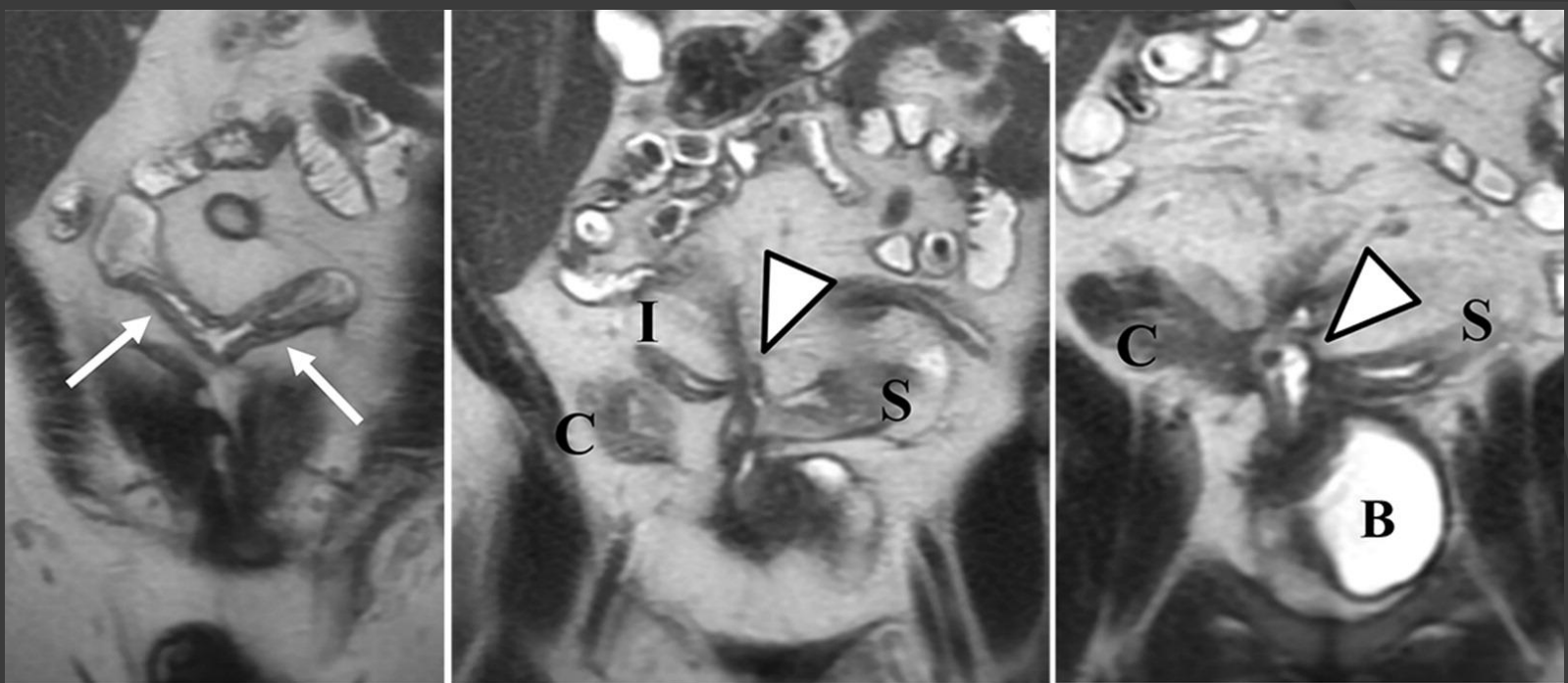
Stricture disease

- ⦿ Mural thickening and luminal narrowing
 - Without upstream dilatation
 - Probable stricture
 - With upstream dilatation
 - If moderate to severe, then small bowel obstruction
- ⦿ Inflammatory or fibrotic strictures
 - Most are mixed in nature
 - Difficult to distinguish on imaging



Penetrating disease

- ⦿ Penetrating disease occurs with active disease and strictures
- ⦿ Fistula
 - Simple fistula
 - Complex fistulas
 - Sinus tract
 - Perianal fistula
- ⦿ Inflammatory mass (aka phlegmon)
- ⦿ Abscess



Structured template reporting

- ◎ Common language / nomenclature
 - Standardizes care
 - Improves outcomes
- ◎ 2018 SAR consensus statement
 - Bruining et al. Radiology: March 2018
 - Suggested Reporting Template adapted from Baker et al.

MRE or CTE with intravenous contrast

Appropriate entries for patient history, CT technique, oral and intravenous contrast media, other medications, and radiation dose as per institutional guidelines.

Comparison:

Findings:

Disease location (stomach, duodenum, jejunum, mid or distal ileum, terminal ileum, colon, rectum, anus)

Number of diseased segments

Type(s) of disease (if all segments have similar findings then report once; if one or more segments are different then report each separately)

Inflammation

Describe imaging findings of inflammation (hyperenhancement, enhancement pattern, bowel wall thickening, intramural edema, ulcerations, restricted diffusion)

Describe location, length and severity (see Table 1), and describe stability or increase or decrease compared to prior studies

Other mesenteric findings (eg, mesenteric vein thrombosis, perienteric edema, comb sign, fibrofatty proliferation)

Stricture

State if imaging findings of inflammation is/are present

Describe location and length

Describe degree of upstream dilation (mild <4 cm, moderate to severe ≥4 cm)

Penetrating complications: describe sinus tract, fistula, inflammatory mass, abscess, or perforation

Site

Complexity

Relationship to inflamed bowel or stricture

Perianal disease

Site

Complexity/classification

Associated abscess: presence or absence

Response to therapy

Compare to earlier exams to describe resolution or exacerbation of inflammatory findings

Extra-intestinal findings: sacroiliitis, AVN, PSC, cholelithiasis, nephrolithiasis,

Other complications or unrelated findings, eg, chronic mesenteric vein occlusion

Impressions (add modifiers as shown in Table 4):

Inflammation statement: If inflammation is present, specify location and length, estimate severity or change

Nonspecific small bowel inflammation

Active inflammatory small bowel Crohn's disease (± luminal narrowing)

Crohn's disease with no imaging signs of active inflammation

No imaging signs of small bowel inflammation

Stricture statement

Stricture with signs of active inflammation, specify length of stricture and degree of proximal obstruction

Stricture without signs of active inflammation, specify length and degree of proximal obstruction

Penetrating statement: describe type of fistula, simple or complex, and other penetration, and association with strictures and enteric inflammation

Perianal fistula (if present)

± Other complications

Impression - Inflammation

- ⦿ Nonspecific small bowel inflammation
- ⦿ Active inflammatory small bowel Crohn's disease
 - Without luminal narrowing
 - With luminal narrowing
- ⦿ Crohn's disease with no imaging signs of active inflammation
 - Known prior active inflammatory Crohn's disease with residual radiologic findings
 - AKA "Quiescent" or "inactive" disease
- ⦿ No imaging signs of active inflammation

Impression - Stricture

◎ Stricture

- With imaging findings of active inflammation
- Without imaging findings of active inflammation

Impression - Penetrating

- ◎ Penetrating Crohn's disease
 - In addition to Inflammation and/or Stricture
 - Describe the complication of penetration

Other complications (if present)

- Perianal fistula
- Extra-intestinal manifestations

Pathology on CT Enterography



- Mucosal hypervascularity
- Mural stratification
- Mesenteric hypervascularity and inflammatory changes

“comb sign”

→ Crohn's disease



Patient with Crohn's disease

- Long segment of TI thickening
- Mucosal hyperenhancement
- Mural stratification
- Proximal dilation consistent with obstruction



- Submucosal fat deposition in longstanding Crohn's disease



Complications of Crohn's disease

- Ileal-ileal fistula
- Abscess

Two Pts with GI Bleeding



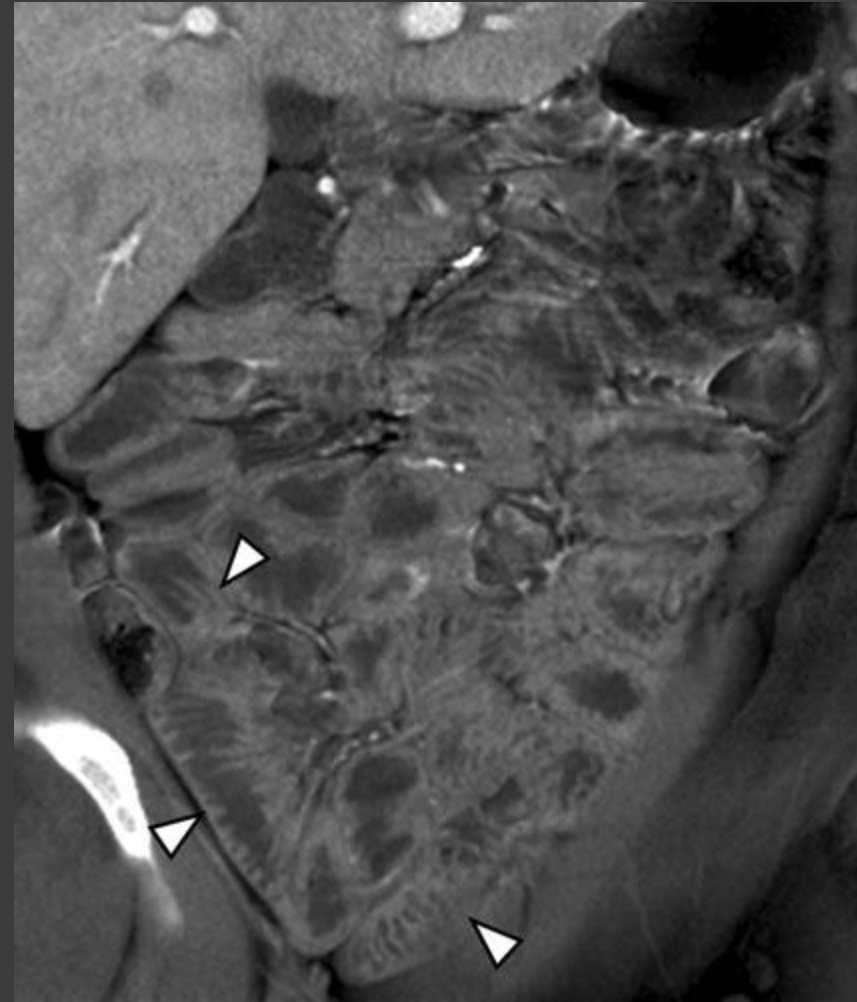
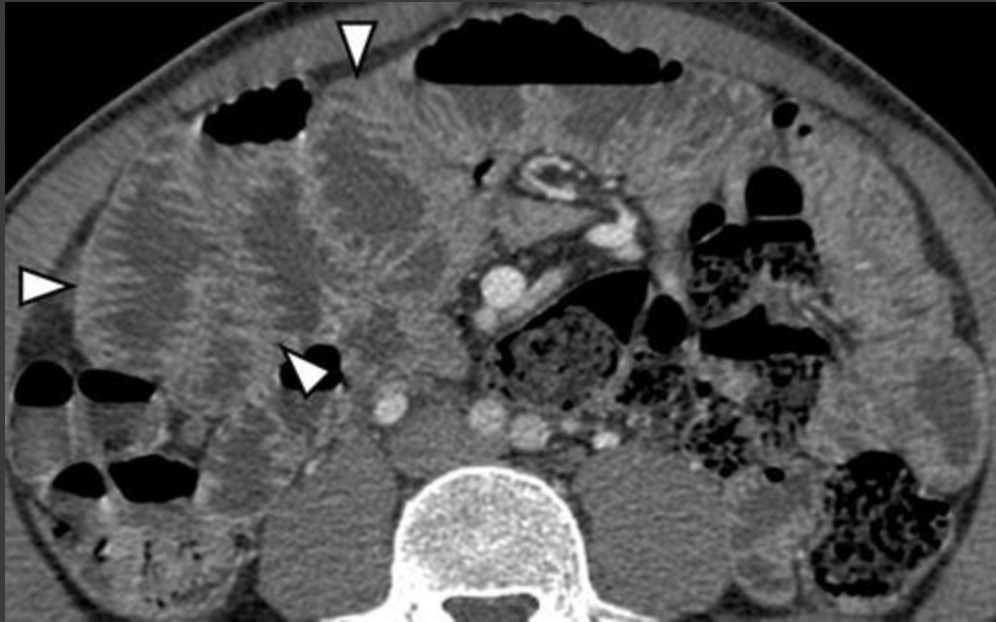
- Small area of enhancement along colonic wall
→ Angiodysplasia



- Ileal outpouching → Meckel diverticulum



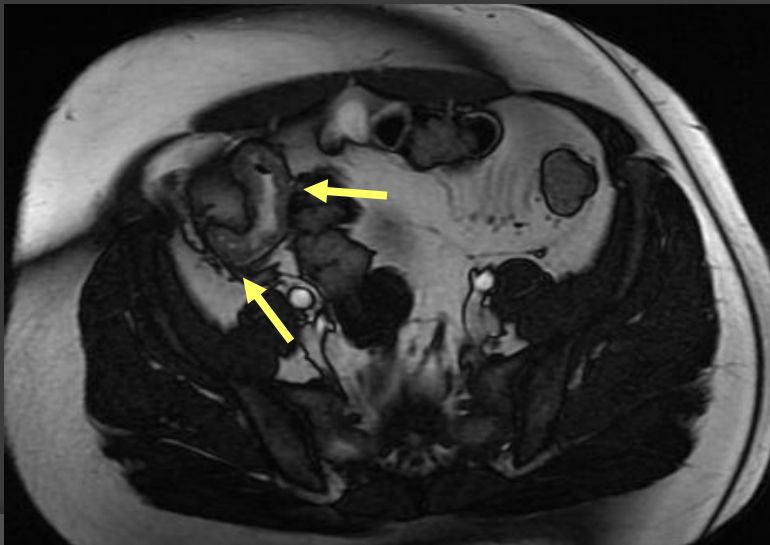
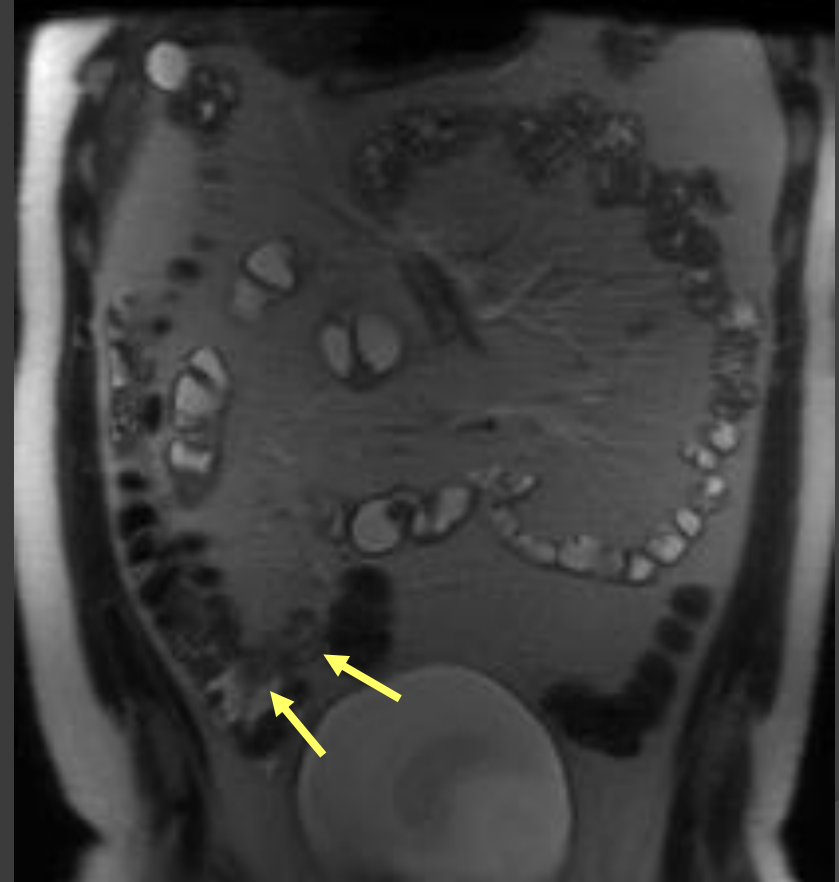
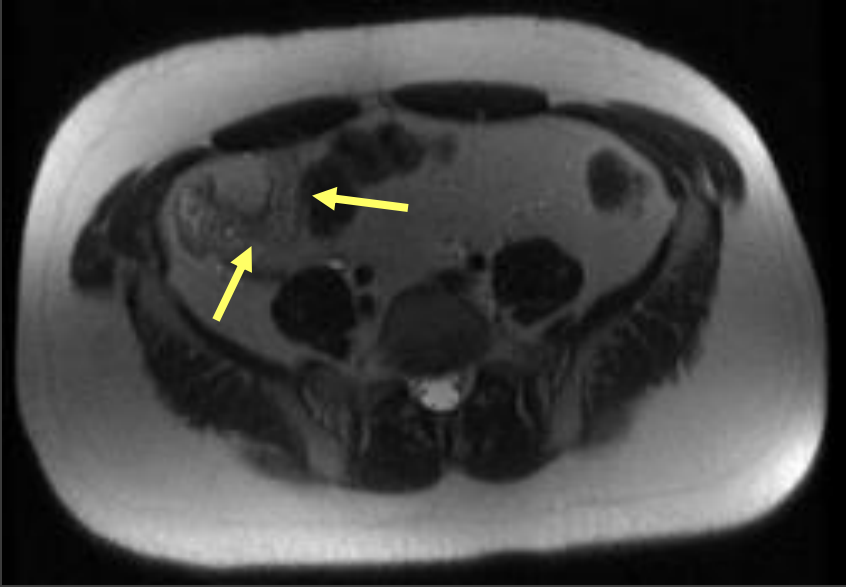
- Mesenteric mass with a spiculated margin
 - Enhancing lesion in the distal ileum
- Carcinoid



- Reversal of fold patterns with jejunization of the ileal mucosa
→ Celiac disease

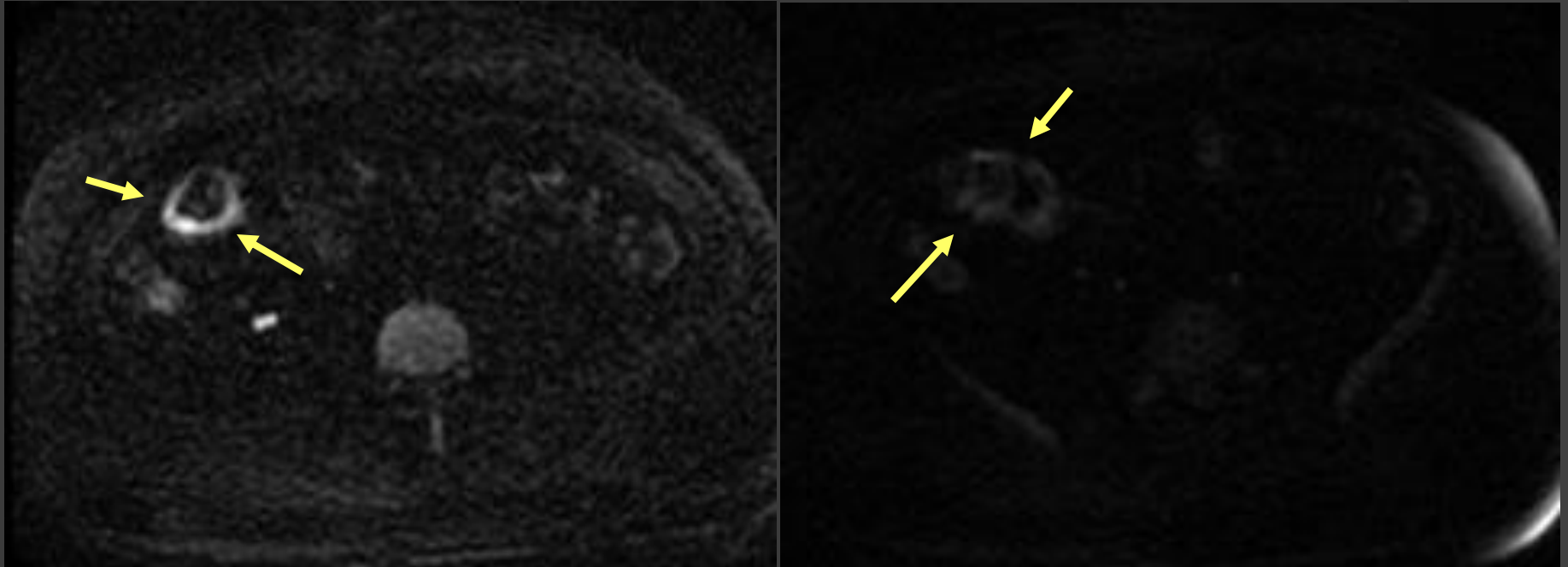
Pathology on MR Enterography

Case 1 – Crohn's disease



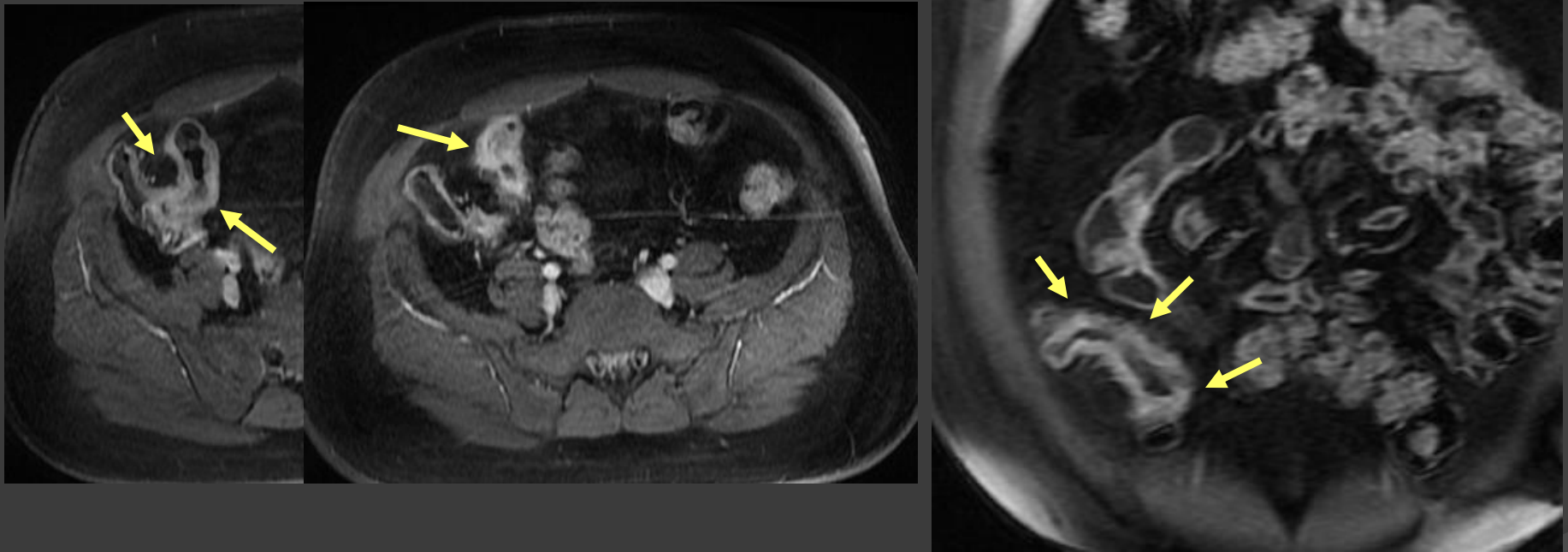
- Long-segment thickening of the terminal ileum

Case 1 – Crohn's disease



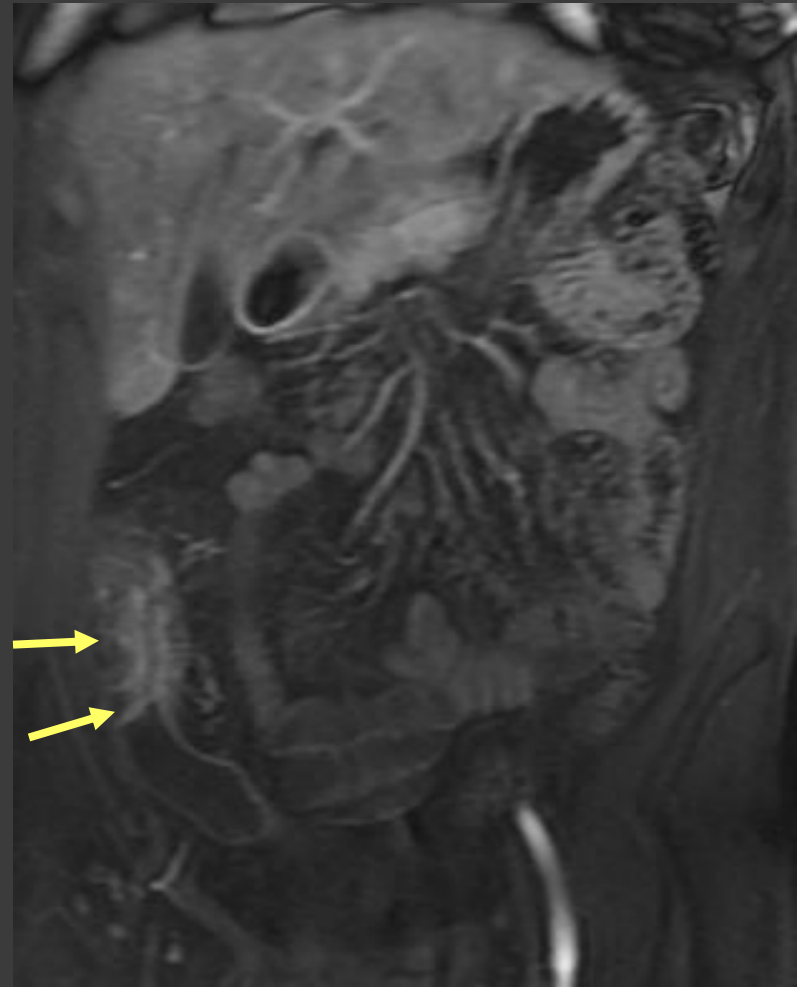
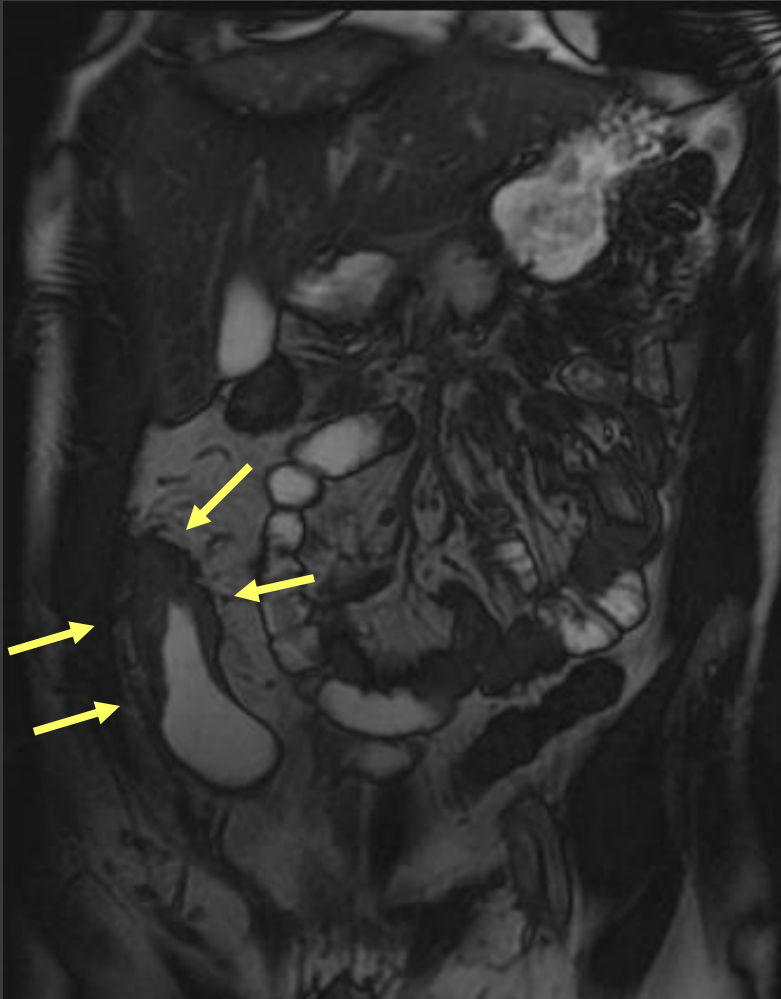
- Terminal ileum also demonstrates diffusion restriction

Case 1 – Crohn's disease



- Transmural enhancement of the terminal ileum

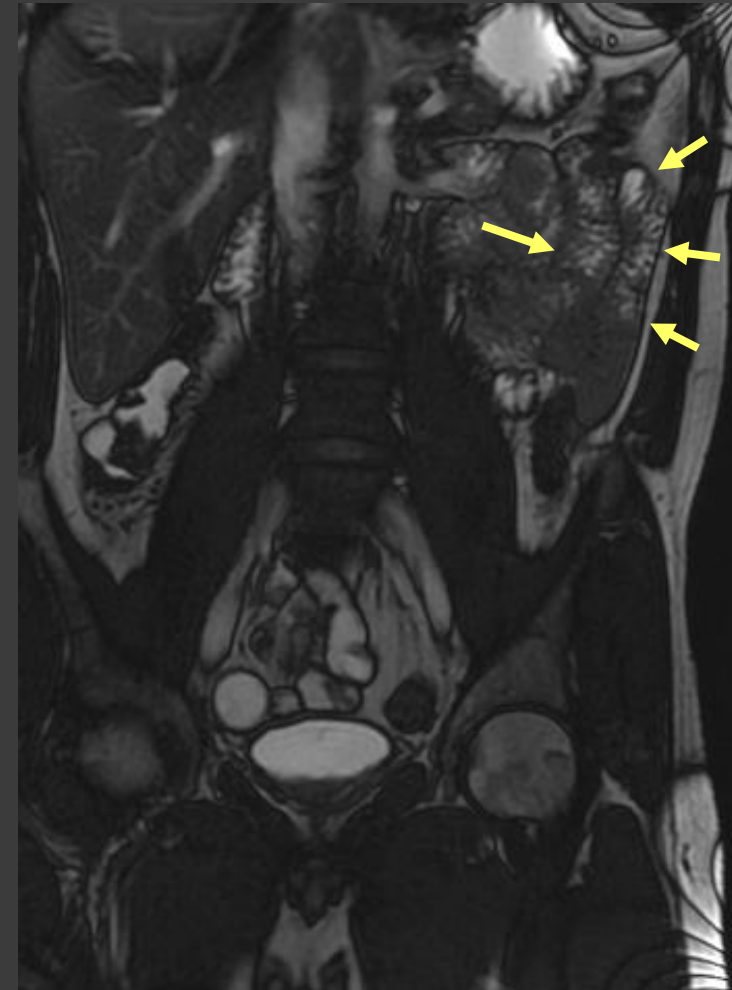
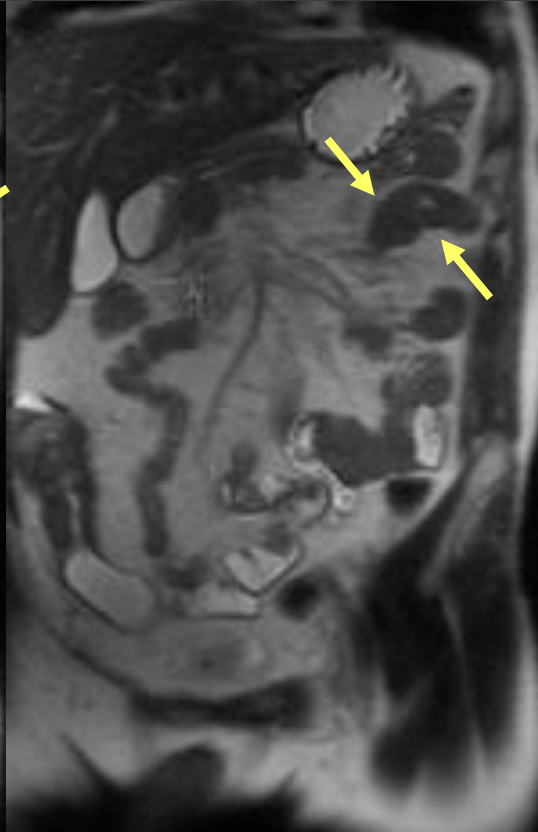
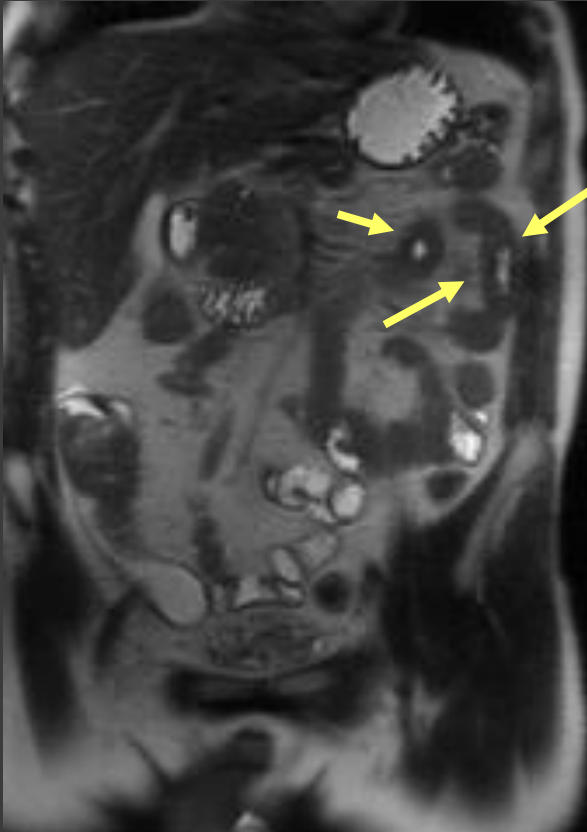
Case 2 – Crohn's disease



- ◎ Active disease of the terminal ileum

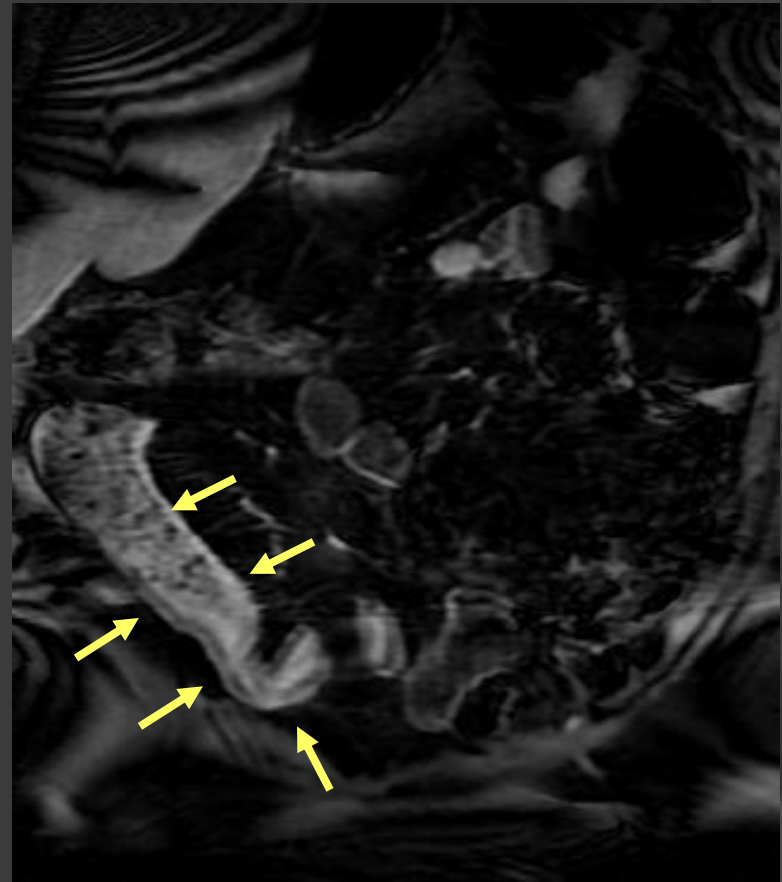
Case 2 – Crohn's disease

- ? Jejunal disease



- Just peristalsing bowel

Case 3

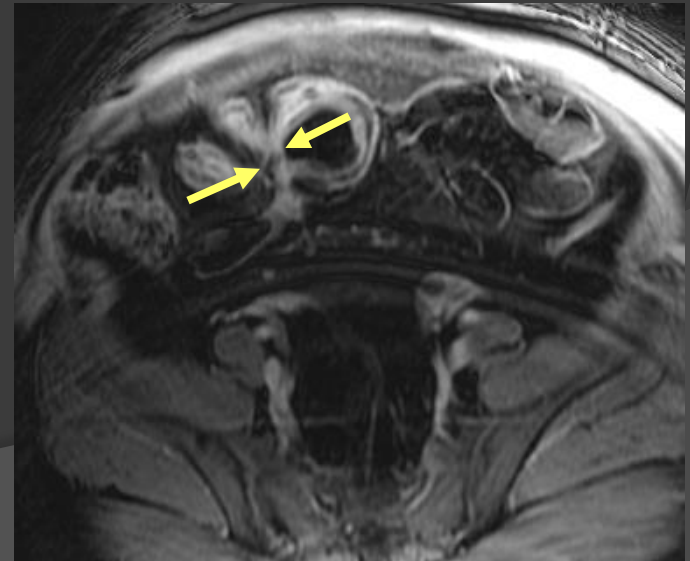
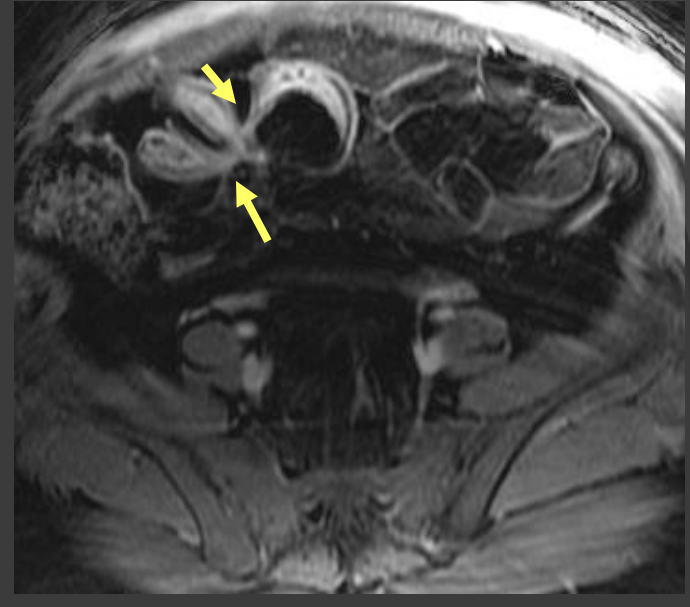


- ⦿ Disease of the terminal ileum with obstruction

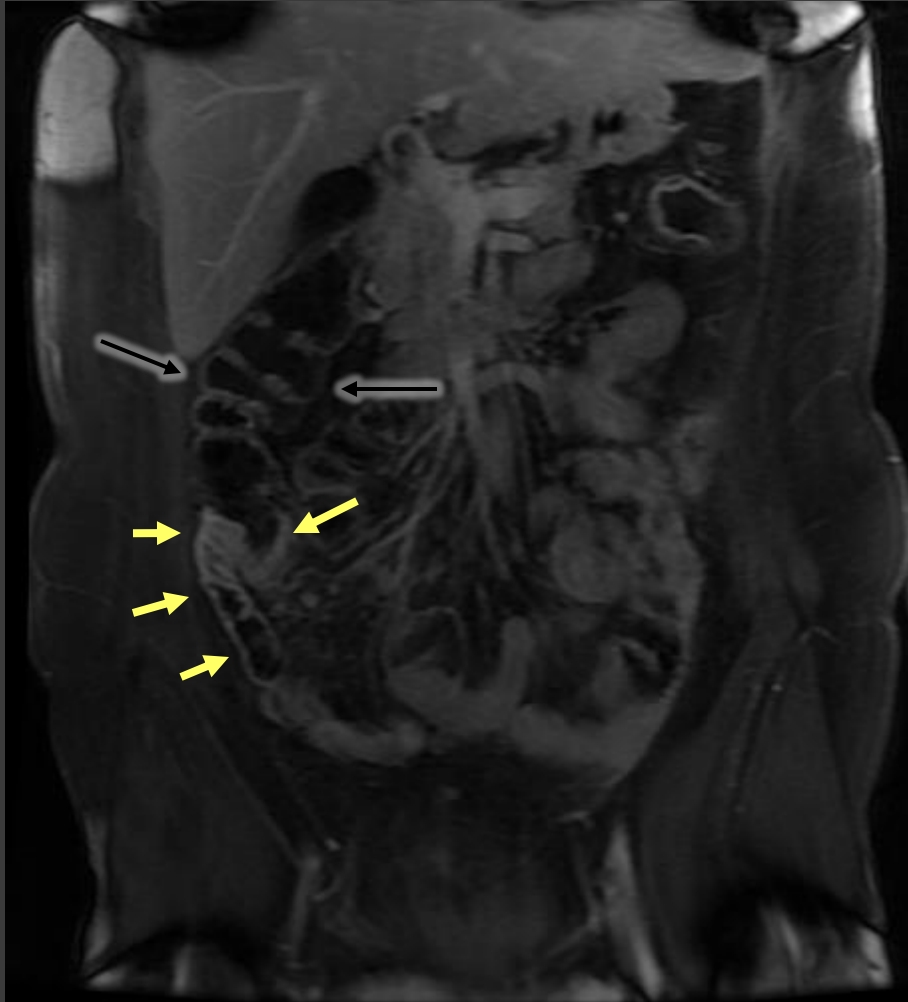
Case 3



- Long-segment disease of the TI
- Entero-enteric fistula

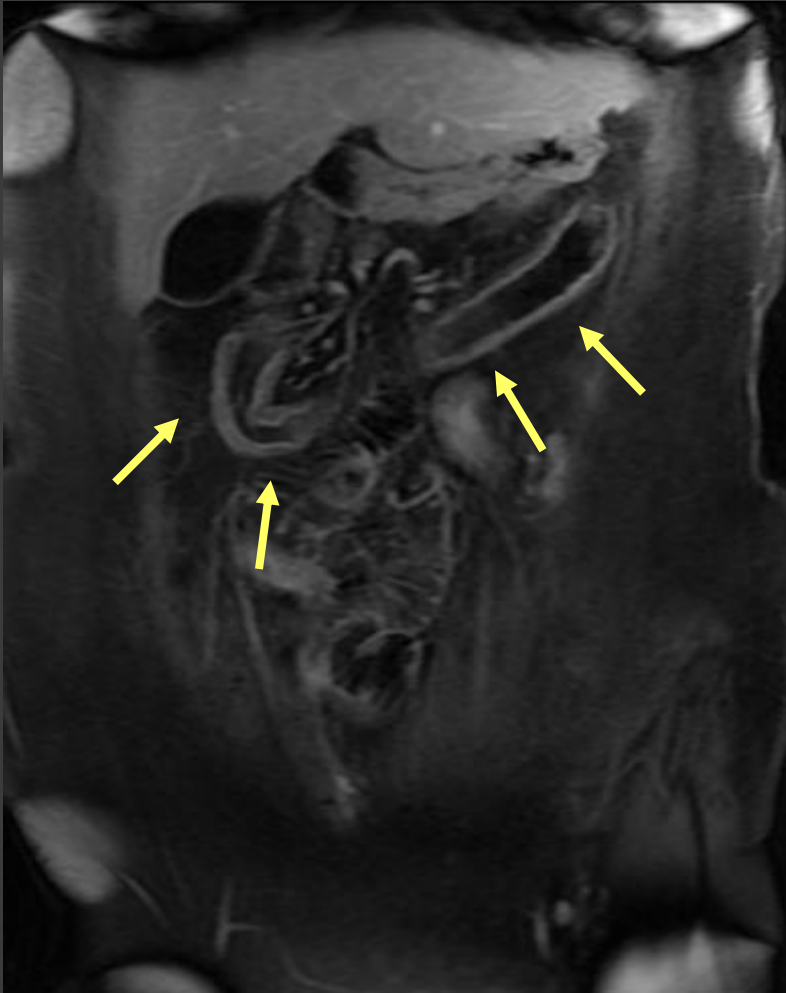


Case 4



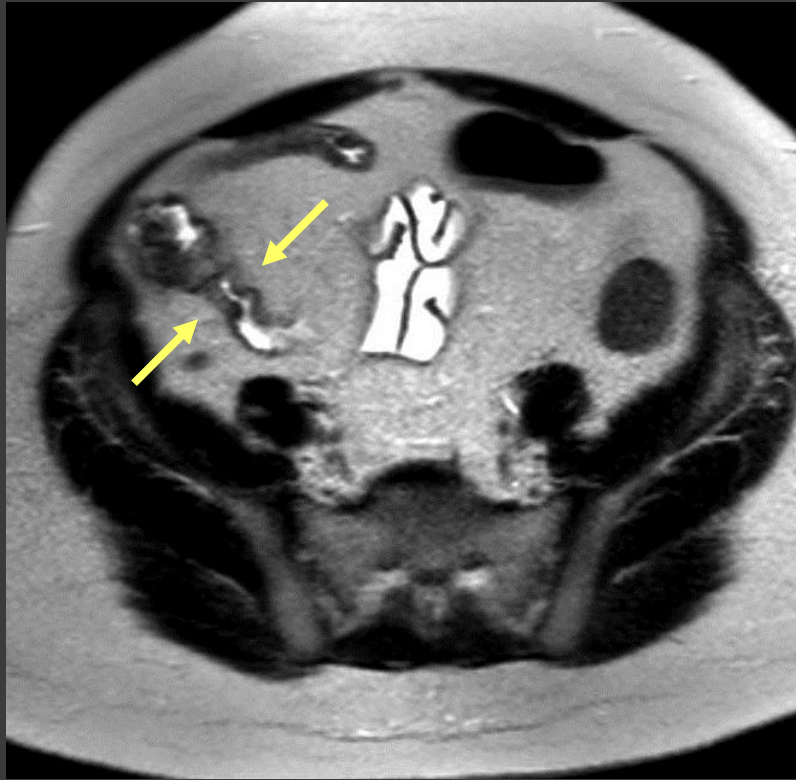
- Abnormal enhancement of the Terminal ileum and cecal pole
- Normal ascending colon

Case 4



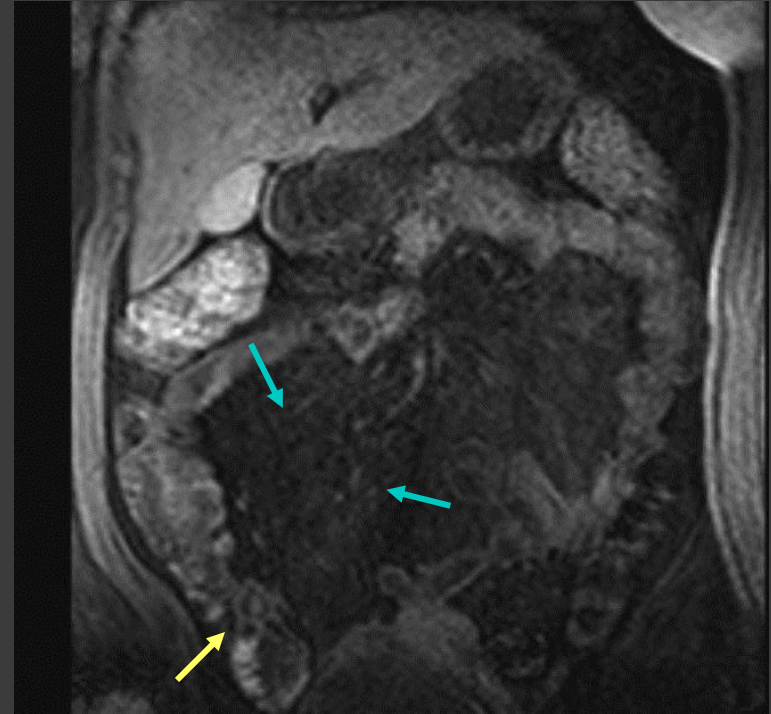
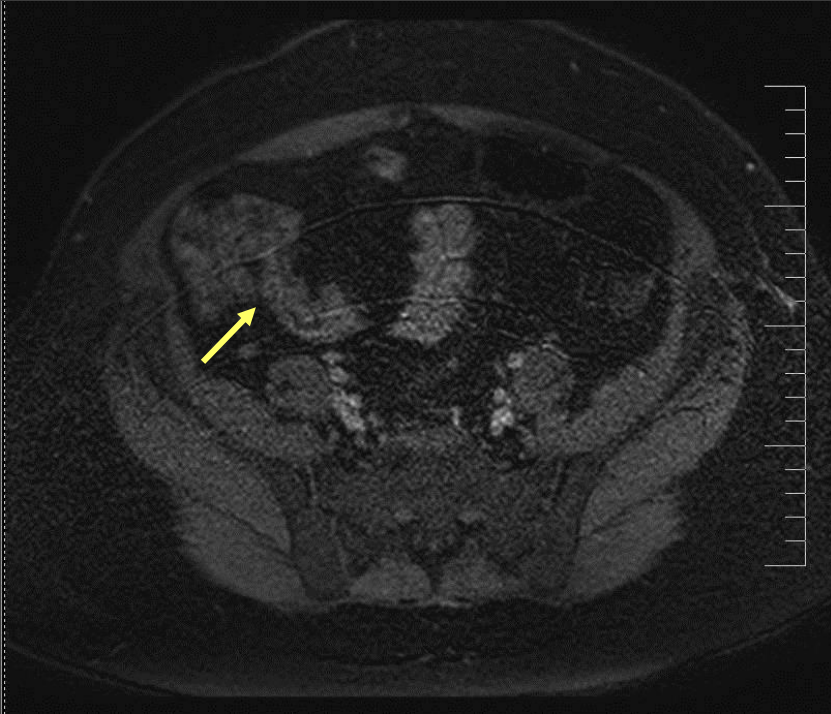
- ⦿ Skip disease of the transverse and descending colon

Case 5



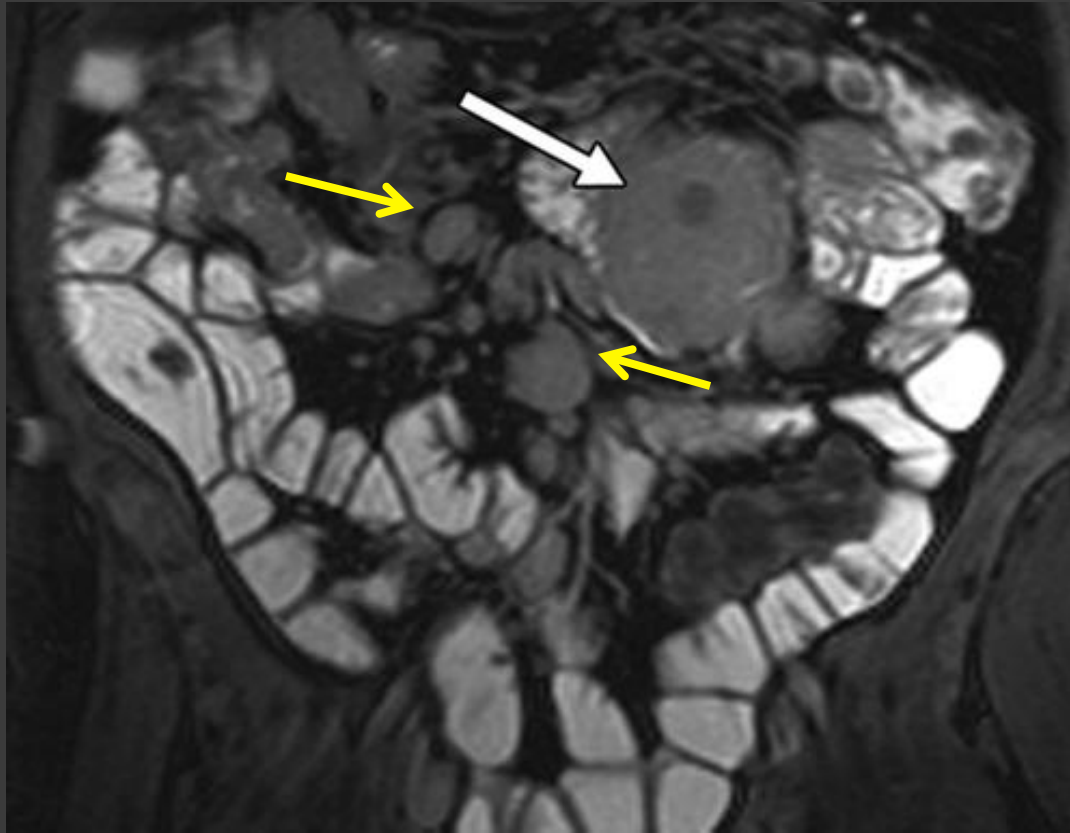
- Mild thickening and narrowing of the Terminal Ileum

Case 5



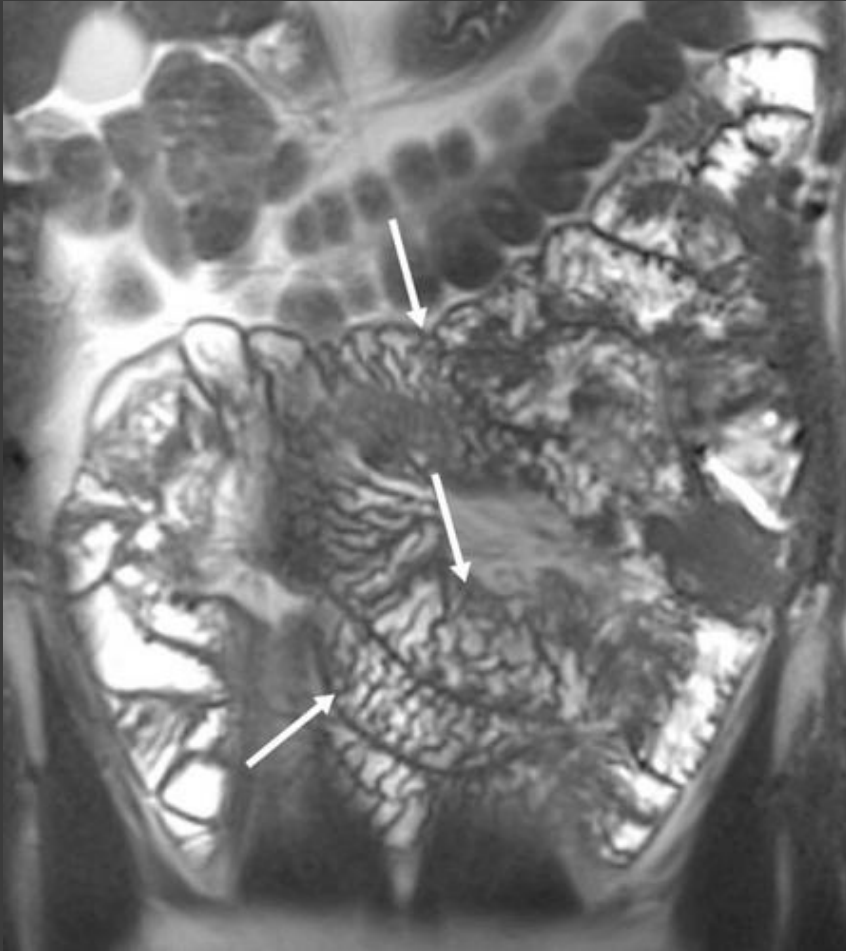
- No enhancement
- No mesenteric hyperemia or edema
- Fibrostenotic stricture, no active disease

Case 6



- Large mass arising from jejunum with adjacent lymphadenopathy
- Adenocarcinoma

Case 7



- ⦿ Reversal of fold pattern
 - Decreased number of jejunal folds
 - Increased number of ileal folds
- ⦿ Celiac Disease

What is the best radiologic study?

- ① CTE
- ① MRE

CTE vs MRE vs SBFT

- ◎ Lee et al (2009) - 30 consecutive pts
- ◎ CTE + MRE + SBFT
- ◎ Ileocolonoscopy reference standard

- ◎ Active small bowel CD
 - Accuracy: CT 87%, MR 87%, SBFT 76%
- ◎ Extraenteric complications (fistula, sinus tract, abscess)
 - Sensitivity: CT & MR 100%, SBFT 35%

CTE vs MRE

- ⦿ Siddiki et al (2008) - 30 consecutive pts
- ⦿ CTE + MRE
- ⦿ Ileocolonoscopy reference standard

- ⦿ Active small bowel CD
 - Sensitivity: CT 95%, MR 91%
 - Specificity: CT 89%, MR 67%

CTE vs MRE

- ⦿ MRE is an established technique with nearly equivalent accuracy to CTE
- ⦿ MRE may be more accurate at determining Inflammatory vs fibrotic strictures
- ⦿ The principle benefit of MRE is the ability to safely image patients without the use of ionizing radiation
 - Particularly relevant in young patients that will potentially undergo multiple imaging evaluations

CTE vs MRE

When is CTE Preferred?

- ⦿ Older patients (>35 years old)
- ⦿ Patients with non-specific symptoms
- ⦿ First study to rule out/in Crohn's disease
 - If CTE is negative, no need for MRE

Double-balloon Enteroscopy

- Excellent evaluation of superficial mucosal abnormalities
- Can obtain biopsies for histologic assessment
- Invasive
- Time consuming
- Limited availability

Video Capsule Endoscopy

- VCE is better at identifying mucosal abnormalities than radiologic modalities
 - Imaging is relatively limited at assessing early mucosal disease
- Limited by strictures
- Limited availability

Summary

- Currently, US, CT and MRI can be used for small bowel imaging, and are superior to conventional barium examinations
- Provide essential information about transmural and extramural involvement, and extra-enteric abnormalities
- Each imaging method has favourable and unfavourable features and often compliment one another
- Choice of which technique to be used depends on availability, safety, cost, patient tolerability, and diagnostic accuracy

References:

- [Amzallag-Bellenger E, et al. Effectiveness of MR Enterography for the Assessment of Small-bowel Diseases Beyond Crohn Disease. Radiographics. 2012;32:1423-1444.](#)
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	PROS	Cons
Conventional Radiology	<ul style="list-style-type: none"> - Good evaluation of mucosal disease - Well-tolerated - Readily available 	<ul style="list-style-type: none"> - Limited information of trans-mural and extra-intestinal abnormalities - Radiation (1-2 mSv)
Bowel Ultrasound	<ul style="list-style-type: none"> - Non-invasive, Safe - Good pt satisfaction - Good for small bowel and extra-intestinal disease 	<ul style="list-style-type: none"> - Operator dependent - Limited proximal bowel involvement - Limited in obesity
CT Enterography	<ul style="list-style-type: none"> - Fast - Great evaluation of intestinal and extra-intestinal disease - Can evaluate for multiple pathologies in a single study 	<ul style="list-style-type: none"> - Radiation (~6 mSv) - Large volume of oral contrast - Poor patient satisfaction – diarrhea - Limited in renal dysfunction
MR Enterography	<ul style="list-style-type: none"> - No radiation - Great evaluation of intestinal and extra-intestinal disease - May be better at assessing disease activity - Can evaluate peristalsis 	<ul style="list-style-type: none"> - Cost - Wait times - Long exam (30 – 45 mins) - Patient must be able to hold their breath - Claustrophobia - Large volume of oral contrast - Limited by pacemaker, implants - Limited in renal dysfunction