St Mark's (STM) Radiology Guide [A] (3.5th Edn., Feb 2024)

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Introduction
This guide has been written primarily as a resource for radiology trainees starting at St Mark's Hospital (STM), covering the essential components of gastrointestinal imaging including: terminology, abbreviations, acronyms, clinical concepts relevant to radiology, imaging, and logistics.

Practices will naturally differ between centres, though it is hoped this guide will help trainees engage with the specialist imaging and perspectives at STM, as well as provide the clinical context to facilitate conversations with colleagues.

The most up to date version can always be found at the following link (password is 'terminology'):
https://www.stmarksacademicinstitute.org.uk/resources/st-marks-radiology-guide-1st-edition-feb-2022/

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[A] The hospital is named for the Christian saint 'Mark the Evangelist', whose symbol is the winged lion, which itself has a complex origin.

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I. Terminology

1. SURGICAL

1.1. Rectal cancer Anatomy & Concepts [1]

Ties in with rectal cancer reporting (see imaging section)

Peritoneum - consists of two layers of mesothelium.
Parietal layer lines the inner surface of the abdomen and pelvis, whereas the visceral layer partly or fully invests/covers a number of abdominal organs (i.e. intraperitoneal) to varying degrees.
Other structures *behind* the peritoneum are retroperitoneal.

- See *Coffin A et al* [2] and also *Levy AD et al* [3]
- See *Tirkes T et al* for a more clinical review [4]

- Intraperitoneal:

- Structures: Most of the stomach, 1st part of the duodenum, small bowel, caecum and appendix, transverse colon, sigmoid colon and upper rectum.
    - Covered by *Serosa*, which is the same as the visceral peritoneum
    - These structures have a *mesentery*[B] and are relatively mobile.

- Retroperitoneal:

- Structures: Oesophagus, pylorus of stomach, 2nd-4th parts of duodenum, ascending colon, descending colon and anal canal.
    - Covered by *Adventitia*, which is connective tissue.
    - These structures are fixed and do not have a mesentery

Serosa (= visceral peritoneum)
Can be a confusing term, and often what people really mean is the peritoneum.

- Peritoneum invests (covers/encloses) various viscera within the abdomen and pelvis, but doesn't *fully* invest every structure
    - Intra-peritoneal structures are covered by *serosa* (which is mesothelium, i.e. visceral peritoneum). These structures have a mesentery and are relatively mobile.
    - Retro-peritoneal structures have an *adventitia*, which is connective tissue. These structures are fixed and do not have a mesentery.

Peritoneum in Colon cancer
The TNM system defines T4a when disease involves visceral peritoneum. Therefore, transmural disease (extending through the wall) remains T3 unless it actually reaches the peritoneum or involves other structure which would upstage to T4b disease
This is relevant for the retroperitoneal colon where posteriorly there is no visceral peritoneum

- The ascending colon and descending colon are partly peritonealised anteriorly
    - A tumour with posterior transmural disease will therefore remain T3
- The caecum, transverse colon, and sigmoid are almost entirely covered in peritoneum

Peritoneum in Rectal cancer

- Peritoneum covers the *anterior* surface of the upper rectum, but reflects away anteriorly at a point called the 'peritoneal reflection', which is visible as a 'V' shape axially where the left and right sides of peritoneum meet in the middle.
- The rectum below the peritoneal reflection is therefore not covered in peritoneum.

[B] A double fold of peritoneum which attaches intraperitoneal structures to the abdominal wall

- In a total mesorectal excision (see below) the surgeon does not resect the peritonealised anterior surface of the rectum
- Therefore, if you see tumour at this peritonealised aspect, it should be reported as disease involving the peritonealised surface rather than the mesorectal fascia (MRF). The importance is that this surface does not form part of the resection margin

Circumferential Resection Margin (CRM) [5]
Refers to the surgical dissection plane of a standard *total mesorectal excision* (TME) operation, mainly defined by the mesorectal fascia (MRF) which bounds the fatty tissue (mesorectum) directly surrounding the rectum, [C] except for the most distal part.

Additionally, for tumours involving the anal canal the CRM is also defined by the inter-sphincteric space.

On MRI: When disease lies 1-2 mm from the CRM it is 'threatened', and when < 1 mm it is 'involved'. A 1 mm cut off on MRI is 76% sensitive and 88% specific for an involved CRM.

- The use of 'threatened' can create ambiguity, and therefore some suggest this should not be used when reporting

When disease threatens or involves the *peritoneum*, this is not a 'threatened/involved CRM', as the peritoneum does not count as part of the resection margin.
However, this should be highlighted in the report so the surgeon is aware during the operation (reduces risk of tumour spillage, which is known to increase the risk of disease recurrence).

MRF and CRM are therefore <u>not</u> synonymous, as the former is anatomically defined whereas the latter is defined by the *actual* operative margins.

- MRF should therefore be used when reporting to reduce ambiguity

See *Santiago et al. (2020)* for an excellent introduction to rectal cancer MRI.

Total mesorectal excision (TME) [D]
Rectal cancer surgical procedure with curative intent. Essentially synonymous with a *Low Anterior Resection*.
Involves removal of the mesorectum (the rectum & mesorectum are contained within mesorectal fascia).
Forms the core part of several middle and low rectal surgeries which have several variations. A partial TME is performed for cancers in the upper third of the rectum.
TME is proven to prevent recurrence of disease. [E]

Dissection planes of the standard TME:

- Posteriorly: behind mesorectal fascia until reach pelvic floor, then over surface of levator and down towards the inter-sphincteric plane
  - Pre-sacral fascia is left behind
  - The rectosacral fascia has to be cut, as this 'anchors' the rectum

[C] MRF and CRM are often used synonymously, but are not quite the same. MRF is an anatomical structure, whereas CRM defines the intended surgical plane during the operation, which ideally should match the MRF.
[D] Pre-TME, rectal cancer recurrence rates were high (~40% vs ~5%) as the rectum was blunt dissected away from pelvis, leaving disease behind.
[E] Note that where the tumour is present *below the level of the levators*, the lateral margins of the tumour are inferior to the mesorectum, and therefore the benefits of TME do not apply as any disease will not be contained within the resected mesorectum. Hence an APE is also needed to remove disease fully.

- Anteriorly: from top of Denonvilliers' fascia[F] (from peritoneal attachment to rectum) to the pelvic floor
- Lateral: Along surface of MRF, keeping away from pelvic sidewall nerves

Depending on the extent of disease, a TME can be combined with a high anterior resection or an abdominoperineal resection as below.
Disease involving the anal canal will obviously require more than the standard TME to avoid leaving disease behind.

Disease extending *outside* the MRF
Can conceptualise this as an anterior compartment above and below the peritoneal reflection, a posterior compartment, and an infra-levator compartment.

Pelvic floor
The levator ani is the umbrella term for multiple muscles which form the pelvic floor, part of which dives down behind the rectum to become the puborectalis sling.[G]
In a standard TME the surgeon doesn't resect below this to avoid disrupting the sphincter complex, though this is required for disease involving the anal canal.

Rectal veins
These pass into the mesorectum, and drain cranially and represent a route by which disease may recur or spread outside the MRF / CRM.

- Inferior and lateral rectal veins: Important to assess where these veins drain to look for disease deposits and to highlight them in MDTs, as disease may lie outside of the standard TME resection. Radiotherapy may be used to reduce recurrence in these areas
- Superior rectal vein: main drainage (upper and middle portion). Assess for tumour spread (vascular disease) along this path

Where is the recto-sigmoid junction?
Radiologically it is pragmatically defined as the sigmoid 'take off', where the relatively fixed upper rectum turns acutely to pass anteriorly ('horizontal sweep'[H]) to become the more mobile sigmoid (intra-peritoneal) which receives its vascular supply via the fan-shaped sigmoid mesentery.

When describing tumours on MR, some radiologists prefer to give the distance of the tumour's caudal aspect from the anorectal junction instead of saying upper/mid/lower rectum to avoid any ambiguity.

[F] Denonvilliers' fascia = rectoprostatic fascia
[G] Puborectalis defines the top of the anal canal.
[H] Easiest to appreciate on sagittal images.

1.2. Colorectal Surgical Procedures, Anatomy, Concepts, & associated complex cancer procedures
(See also *MR of Rectal Cancer* section)

Core rectal cancer operations:
See Horvat et al. (2019) [6] for a good review with illustrations

a) Endoscopic & minimally invasive surgery
These can be used for early rectal cancer and polyps

Techniques:
- ESD: Endoscopic submucosal dissection
- EMR: Endoscopic mucosal resection
- TAMIS: Transanal Minimally Invasive Surgery
    - Represents a crossover between laparoscopic and TEM procedure, with similar indications to TEM
- TEM: Transanal *Endoscopic Microsurgery*
    - Select patients with early rectal cancers (cT1[I], < 3cm, within 8 cm of anal verge, < 30% of wall circumference)
    - Sphincters preserved

Utilisation of the above:
- No extension into submucosa: EMR / ESD
- At least 1 mm submucosa preserved: ESD or partial thickeness TEM
- Less than 1 mm submucosa and greater than 1 mm muscularis preserved: potentially eligible for TEM
- Less than 1 mm muscularis: Total mesorectal excision (TME) required

b) TME and Anterior Resection - the anal sphincter complex is left in situ
- Anterior resection - tumours not involving the sphincters
    - High anterior resection (also referred to as Partial Mesorectal Excision; PME) - used for rectosigmoid cancers, and can be used for upper third rectal tumours though a low anterior resection/TME may also be warranted.[J] Upper tumours don't necessarily require the more inferior dissection, hence 'partial' TME.
    - Low anterior resection (LAR)[K] (essentially synonymous with a TME procedure) - used for mid or low-rectal tumours
    - The tumour is resected and the remaining distal colon anastomosed to the residual rectum
- Ultra-Low Anterior Resection:
    - Needs a colo-anal anastomosis for very low rectal tumours (anastomosis < 3 cm from dentate line)
    - Sphincter can be sparred where tumour is *above* the ano-rectal junction

- Transanal Total Mesorectal Excision (TATME):
    - Relatively new technique utilised for patient with low rectal cancer

[I] cT1 = a T1 tumour on clinical assessment (see *Histology* section)
[J] TME often better if aggressive disease (signet cell) or extensive lymphovascular disease
[K] Risk of LARS (low anterior resection syndrome) - constellation of symptoms associated with this procedure

c) TME with variations of perineal resections ('extended TME procedures')

- Standard Abdominoperineal resection (APE/APER):
    - For tumours infiltrating the anal canal or levator ani and/or external sphincter, < 1 cm from anal verge or where resection would cause incontinence.
    - Sphincter complex resected, requiring permanent colostomy
- Extra-levator Abdominoperineal resection (ELAPE):
    - Indicated when tumour infiltrates intersphincteric plane and external sphincter and/or levator ani
    - A broader dissection of the sphincteric complex compared to standard APE, which might otherwise leave behind disease that extends more laterally
    - Sphincter complex resected, requiring a permanent colostomy
- Intersphincteric abdominoperineal resection:
    - Combined with low anterior resection. Can be considered where the *intersphincteric plane is not infiltrated* by tumour
    - Spares the external sphincter to retain the pelvic floor and avoid perineal herniation
    - In *selected* cases can be used to maintain faecal continence[7]

Managing peritoneal disease:

- CRS: Cytoreductive surgery - resection of peritoneal surface disease and metastases.
    - Often paired with HIPEC [8]
- HIPEC: Hyperthermic intraperitoneal chemotherapy - instillation of chemotherapy into the abdominal cavity (used at Basingstoke Hospital)
- EPIC: early postoperative intraperitoneal chemotherapy
- Defunctioning: to disconnect a portion of bowel, e.g. end colostomy with an oversewn rectal remnant ('stump') left *in situ* (which is therefore 'out of circuit').
    - Utilised in multiple contexts, including bulky obstructing rectal and colonic tumours

1.3. Other surgical techniques (mainly non-oncological)

1.3.1 Anal fistulae surgical approaches:

Summary from *Iqbal et al. (2021)* [9] (see also *MR Fistula*)

Surgical terminology:

- 'Laying open' of tract: superficial tracts which aren't related to the sphincters can be cut open and allowed to heal
- Rationalisation: very complex fistulae may be 'rationalised' to simplify them into more manageable tracts, with the aim of subsequent sphincter-preserving surgery
- Horseshoe: radial fluid collection which lies both sides of an internal opening

Seton: heavy suture or thin rubber drain placed along the fistula tract to allow it to continuing draining, though this alone will not resolve the tract. Options following this include:

- Removal of seton and hoping that the tract heals to resolution (since any abscess has been removed, discharge should have been minimised)
- Use of cutting seton: slowly tightened over weeks

Fistulotomy:

- 'Laying open' of a fistula tract. Standard approach for low perianal fistula
- All the sphincter muscle caudal to the tract is divided
- Usually reserved for inter-sphincteric and low trans-sphincteric fistulae given the potential functional impact from cut muscle
- Important to select the right patient group (good muscle quality)
- Reporting: Highlight all extensions and fluid collections to ensure treated fully

VAAFT

- Direct endoscopic visualisation of a fistula and electrocautery of the tract, with closure of the internal opening via semi-circular stapler, scope clip, mucosal flap, or simple suture
- Reporting: Tract size and internal opening size (< 5 mm) important in terms of predicating success in closure

FiLaC: Fistula laser Closing

- Insert a filament into the tract (maximum diameter 1.8 mm), which is then withdrawn as laser cauterises along the tract (a newer technique)
- The final 15 mm of the filament are rigid
- Reporting: Complex, branching tracts make FiLaC unsuitable, as do wider tracts with cavities
    - Tracts < 4-5 mm without complexity

LIFT: Ligation of inter-sphincteric fistula tract

- Aims to separate the tract from bowel
- The inter-sphincteric portion of the tract is excised and ligated to prevent bacteria from entering the tract
- Dissection and ligation of the tract's inter-sphincteric portion
- Reporting: Wide tract > 6 mm, oblique course rather than perpendicular through the inter-sphincteric space, or the presence of linear/horseshoe inter-sphincteric extensions make LIFT unsuitable
    - Also need healthy/intact sphincters in the region of LIFT
    - Internal opening shouldn't be too high, as risks injury

Anal fistula plug

- Gel plug used to occlude the tract, pulled through from internal to external opening. One end is fixed to the ano-rectal wall. Secured with a fistula
- Reporting: Important to describe branches and extensions, as these won't be addressed by the plug

Rectal advancement flap (RAF)

- Closes the internal opening. Involves excision of tissue around internal opening and mobilising a cranial flap, which is then brought down to the excision's lower border to cover the internal opening
- Remaining tract is either cored or curetted.
- Flaps can be mucosal, partial, or full thickness
    - Greater thickness reduces recurrence but with greater risk of impaired continence
- Reporting: Important to describe proctitis, high internal opening (more difficult approach)

Summary of fistula components and suitability of different procedures.

Fistula characteristics	Fistulotomy	VAAFT	FiLaC	Flap	LIFT	Anal fistula plug
High IS	May be suitable	May be suitable	May be suitable	May be suitable	Unsuitable	May be suitable
Low IS	Ideal	May be suitable	May be suitable	Unsuitable	Unsuitable	May be suitable
High TS	May be suitable	May be suitable	May be suitable	May be suitable	May be suitable	May be suitable
Low TS	Ideal	Ideal	Ideal	May be suitable	Ideal	May be suitable
Extrasphincteric	Unsuitable	May be suitable	May be suitable	May be suitable	Unsuitable	May be suitable
Suprasphincteric	Unsuitable	May be suitable	May be suitable	May be suitable	Unsuitable	May be suitable
Ischioanal extension	Ideal	May be suitable	Unsuitable	May be suitable	May be suitable	Unsuitable
IS horseshoe	May be suitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable
Supralevator extension	May be suitable	May be suitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable

IS, intersphincteric; TS, trans-sphincteric.

Summary of anatomical features that determine suitability of surgical procedures.

Procedure	Features
Fistulotomy	• Amount and integrity of sphincter remaining after division (cephalad to the tract) • Cephalad obliquity of fistula tract through intersphincteric space • Location of extensions and collections relative to primary tract
VAAFT	• Diameter and location of internal opening • Multiple angulated extensions and hairpin bends • Tract diameter
FiLaC	• Extensions • Sharp angulation of the tract • Length and diameter of the tract
LIFT	• Tract width and course through the intersphincteric space (oblique/perpendicular) • Intersphincteric horseshoes, extensions, or collections • Deep, wide internal opening • IAS defect in the caudad dissection zone • High internal opening close to anorectal junction
Anal fistula plug	• Extensions • Tract length • Trans-sphincteric fistulas • Location of internal opening
Rectal advancement flap	• Proctitis • Scarring from previous surgery • Previous sphincter injury • Diameter and location of internal opening

1.3.2 IBD and Polyposis surgical techniques:

- Colectomy variations:
  - Hemi: left or right colon removed with ileo-colic anastomosis
  - Subtotal: rectum and sigmoid left, with this remnant either oversewn and a stoma brought out upstream, or an ileo-sigmoid anastomosis formed
  - Total: removal of entire colon with rectum left
- Proctectomy: removal of the rectum
  - Proctocolectomy: removal of rectum and colon
  - (Pan)proctocolectomy (PPC): removal of anus, rectum, and colon

- RPC: Restorative proctocolectomy – removal of entire colon and rectum with ileo-anal pouch (see below), often used in ulcerative colitis.
- IRA: Ileo-rectal anastomosis - reserved for select ulcerative colitis/polyposis patients where the rectum is left *in situ*
  - IDSA: Ileo-distal sigmoid anastomosis
- IPAA [10]: Ileal pouch-anal anastomosis (most commonly a J-pouch). Used in ulcerative colitis and other conditions necessitating pan-proctocolectomy in order to avoid stoma by folding ileum into a pouch to form a 'neo-rectum' [L]
  - Morphology
    - Pre-pouch ileum (afferent limb) leads to the pouch inlet and pouch body (reservoir)
    - Pouch outlet is anastomosed to a short rectal cuff[M] of tissue, or directly to anal canal (efferent limb)
    - Pouches commonly have a blind-ending portion (internal pouch, pouch appendage)
      - Don't confuse the blind component with a contained leak - this contributes towards the *reservoir*
  - Pouchitis: most commonly 'secondary' (sepsis being the most common cause[N]). May also be 'primary idiopathic'
    - The rectal cuff can also become inflamed ('cuffitis')
    - Can be assessed on imaging, but pouchoscopy ± biopsy is more accurate
    - Patients may rarely develop a pouch cancer
  - Pouch adaptation: [11] [12]
    - The pouch can dilate with a volume of ~ 400 mL over time, though there is considerable variation in emptying
    - Pouch ileum adapts to its new function as a neorectum, and can develop deep clefts in the mucosa that mimic colonic folds (pseudovalves of Huston)
    - On imaging the prepouch ileum may dilate slightly, but significant dilatation of the pouch or prepouch ileum warrants consideration of hold-up / obstruction
- Abcarian colostomy: a defunctioning loop colostomy
- Kock pouch ('continent ileostomy'): Formed using ileum after a colostomy where the anus is removed, and therefore an IPAA isn't possible.

[L] Pouch failure: ~ 10% in 10 years. Note that PSC increases risk of failure as well as pouch cancers.

[M] Rectal cuff describes the remaining bit of rectum to which the ileal pouch is anastomosed.

[N] Sepsis particularly in the form of pre-sacral collection, which may improve with antibiotics or steroids. Important to identify as immunosuppression (especially biologics) can then lead to a significant deterioration

- Ileum acts as a reservoir with a portion connected to the skin to form a valve, which the patient can access using a catheter to empty.

1.3.3 Miscellaneous

- Other important surgical procedures & technique
See *Terrone et al. (2011)*[13] for a good review of the common major GI operations.

Colorectal, Hepatobiliary, and Upper GI

- ACE: Antegrade continence enema - appendix is connected to the skin so that enemas can be administered directly into the caecum for 'washout'. Commonly used in spina bifida where constipation is problematic
- Complete Mesocolic Excision (CME): Procedure for colonic cancers [14]
- Fundoplication:
    - Nissen: Stomach fundus wrapper fully around the gastro-oesophageal junction (full wrap)
    - Dor: Fundus wrapped only around anterior aspect of gastro-oesophageal junction (partial wrap)
    - Toupet: Fundus wrapped around posterior aspect of gastro-oesophageal junction (partial wrap)
- Hartmann's procedure: A rectosigmoid resection with an end colostomy brought out and the rectal (or sigmoid) remnant left behind and oversewn (defunctioned)
    - Often an emergency procedure to avoid a primary anastomosis (e.g. acute perforated diverticulitis, tumour perforation)
    - Depending on circumstances, bowel continuity can be reversed at a later date
- Single Incision Laparoscopic Surgery (SILS): For colorectal surgery. All the laparoscopic ports are introduced through a single incision (often umbilicus or site of planned stoma). Longer procedure times but improved hospital stays
- Transanal total mesenteric excision (TaTME): combined standard laparoscopy with transanal mesorectal excision
- Whipples (pancreaticoduodenectomy) [15]: removal of pancreatic head, duodenum, gallbladder, and bile ducts

Rectal prolapse and Anal operations

- Altemeier procedure: perineal rectosigmoidectomy[O]
    - Prolapsed rectum has a full-thickness circumferential incision, with the hernia then entered and the prolapsed 'delivered'. The mesentery is then serially ligated until no more bowel can be pulled down. The excess bowel is transected and then joined to the anal canal.
- Delorme's procedure: modification of perineal rectosigmoidectomy procedure for rectal prolapse.
    - The mucosa of prolapsed rectum is excised and the muscle layers pleated (i.e. like a concertina) and stitched
- Soave coloanal anastomosis (Soave procedure): utilised when rectal / pelvic dissection to form a conventional anastomosis would be difficult (e.g. radiation induced fibrosis).
    - Procedure originally described for Hirschsprung's disease, and still used by some surgeons for this.
    - Consists of a transrectal coloanal sleeve anastomosis in which the distal colon is 'delivered' through the rectal remnant ('tube within a tube'), and therefore avoids a potentially dangerous perirectal dissection[16]

[O] Summary of Altemeier and Delorme procedures: https://emedicine.medscape.com/article/2026460-treatment#d12

Urological

- Ureteroneocystostomy: reimplanation of the ureter into the urinary bladder, mainly relevant for us in the complex cancer setting. Several techniques exist:
    - Boari flap and ureteric reimplantation: the disease involving the distal ureter is resected and part of the bladder is folded into a tube which extends from the bladder to the ureteral orifice. The distal ureter then reimplanted here
    - Psoas hitch: can be utilised when the remaining ureter is too short to reach the bladder. The posterior bladder is therefore attached to the psoas muscle to reduce the gap needed to allow ureter reimplantation
- Mitrofanoff ('continent catheterisable channel'): Appendix or small bowel used to connect urinary bladder to the skin with valve, which can be intermittently catheterised to empty

Misc.

- Haemostatic surgical material:
    - Surgicel (cellulose mesh) & Gelfoam (gelatine sponge): appears faeculent on imaging (especially CT) and may be confused with collections.

- Examinations & investigations

- DRE: Digital rectal examination
- EUA: Examination under anaesthesia - not surgery *per se*, but conducted by the surgeon and often prior to/as part of a surgical procedure
- Flexi / Flexisig: Flexible sigmoidoscopy

- Complex ventral wall hernia repair

- See imaging section

1.4. Anatomy and other miscellaneous surgical terminology & concepts

Anatomical structures:

- CRM: Circumferential resection margin - the surgical plane used for a standard TME in which the mesorectum is excised.
- MRF: Mesorectal fascia - the fascial plane which contains the Mesorectum, and defines the CRM during surgery
    - CRM and MRF are *not* quite the same (surgical plane vs. an anatomical structure), though often used synonymously and interchangeably
- TI & NTI: Terminal ileum and neo-terminal ileum
    - A neo-terminal ileum is the same as an ileo-colic / ileo-colonic anastomosis
    - Occasionally in patients with extensive small bowel resections there will be a jejuno-colic anastomosis (don't call this NTI by accident)
- IGAP and SGAP: Inferior / Superior Gluteal Artery (perforators) - important to identify radiologically
    - Can be injured in complex pelvic surgery due to relative invisibility.
    - Flaps supplied by these vessels can also be used to reconstruct/cover the defect at time of a perineal resection
- PSW: Pelvic sidewall (usually in reference to lymph nodes or disease deposits)
- SLAM: The *Sacral Ligament and Muscle (complex)* - a specific term used at St Mark's to describe the sacrotuberous, sacrospinous and ischiococcygeus muscle and ligamentous complex, which are all closely related to each other. May be removed in complex cancer surgeries (see *complex cancer* section).

Intussusception

- Invagination of a proximal bowel (*intussusceptum*) into a more distal portion of bowel (*intussuscipiens*)

Bowel obstruction & hernias

- Closed loop obstruction: bowel obstruction with two distinct transitions / points of obstruction. Consequently the bowel between the two points is unable to decompress and is at high risk of perforation[17]
    - Examples include an adhesional band involving a loop of small bowel at two separate points, large bowel obstruction with a competent ileocaecal valve (colon unable to decompress into the small bowel), large bowel volvulus (by definition closed loop) or even the biliopancreatic limb of a Roux en Y where there is obstruction of the distal BP limb (since this is blinding ending proximally)
    - It is important to highlight this to the clinical team as these often necessitate prompt intervention to avoid perforation
- Hernia descriptions:
    - Hernia:
        - External: protrusion of tissue or organ/viscus beyond the wall of the cavity by which it is usually confined
        - Internal: protrusion of a viscus through a normal or abnormal peritoneal or mesenteric defect, remaining within the the peritoneal cavity
    - Incarcerated hernia: simply a hernia which cannot be 'reduced' (as in the hernial sac contents cannot be pushed back into a normal position clinically). This is <u>not</u> the same as a *strangulated* hernia
    - Strangulated hernia: herniated bowel with compromised perfusion (an incarcerated hernia may become strangulated)

- Internal hernia: protrusion of abdominal viscera through an opening within the confines of the peritoneal cavity (though note not all internal hernias are strictly intra-peritoneal) [18]

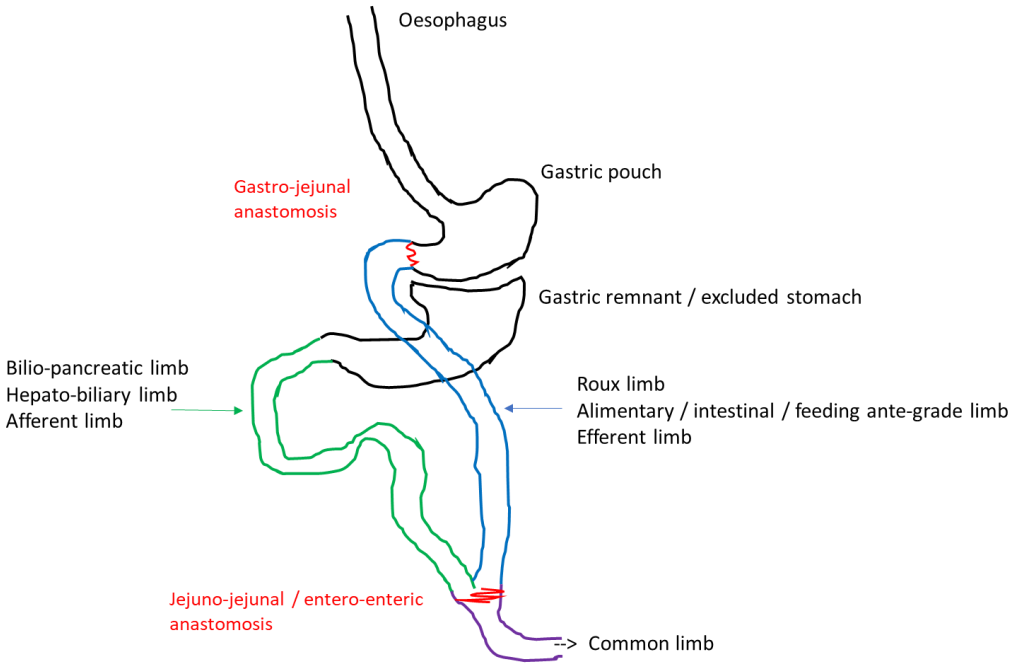
- Eponymous herniae

No., Term (alphabetical order), and Description
1 Amyand's - Appendix within the hernial sac
2 Barth's - Loops of the intestine between serosa of the abdominal wall and persistent vitelline duct
3 Béclard's - Femoral hernia through saphenous opening
4 Berger's - Hernia in pouch of Douglas (Cul-de-sac)
5 Bochdalek - Congenital posterolateral diaphragmatic hernia
6 Busoga - Direct inguinal hernia caused by narrow defect in conjoint tendon or transversalis fascia, common in Busoga area of Uganda, South Sudan, and Ghana
7 Cloquet's - Femoral hernia perforating the aponeurosis of the pectineus, lying therefore behind the femoral vessels
8 Cooper's - Femoral hernia with two hernial sacs (bi-ocular femoral hernia)
9 De Garengeot's - Appendix-containing incarcerated femoral hernia
10 Gibbon's - Hernia with hydrocele
11 Gruber's - Internal mesogastric hernia
12 Grynfeltt's - Hernia through Grynfeltt-Lesshaft triangle (superior lumbar triangle).
13 Hesselbach's - Hernia of a loop of the intestine through the cribriform fascia presenting lateral to femoral artery
14 Hey's - Encysted scrotal or oblique inguinal hernia covered by three coverings of the peritoneum
15 Holthouse's - Inguinal hernia that has turned outward into the groin
16 Krönlein's - Partially inguinal and partially pre-peritoneal hernia
17 Larrey's - Morgagni's hernia (alternative name)
18 Laugier's - Femoral hernia through gap in lacunar ligament, more medial in position and almost always strangulated
19 Lederhosen - Bilateral inguinal hernias connected across the abdomen by the terminal ileum whilst enveloped in suprapubic inferior abdominal wall bulge, like the front-flap found in the traditional costume "Lederhosen"
20 Littre's - Hernia with Meckel's diverticulum
21 Lumbar - Lumbar region hernias: (1) Petit's and (2) Grynfeltt's
22 Malgaigne's - Abdominal wall muscle protrusion during leg raise test
23 Maydl's - Hernia contains two loops of bowel arranged like a "W"
24 Morgagni - Retrosternal diaphragmatic hernia
25 Mery's - Perineal hernia protruding through pelvic floor muscles and fascia
26 Narath's - In congenital dislocation of the hip, hernia behind the femoral vessels
27 Pantaloon - Ipsilateral concurrent direct and indirect hernia, each sac protrudes on either side (Pantaloon legs) of the inferior epigastric vessels
28 Petersen's Herniation of the small bowel through mesenteric defect from the Roux limb (bariatric gastric bypass)
29 Petit's Hernia through inferior lumbar triangle (Petit's triangle)
30 Phantom - Localised muscle bulge after muscular paralysis
31 Richter's - Strangulated hernia involving one sidewall of the bowel
32 Rieux's - Protrusion of intensive into a pouch behind the caecum (retrocaecal)
33 Rokitansky's - Separation of muscular fibres of the bowel allow protrusion of a sac of the mucous membrane
34 Serofini's - Hernia behind the femoral vessels
35 Spigelian- Congenital or acquired defect in the spigelian fascia (transversus abdominis aponeurosis)
36 Treitz's - Hernia into spaces/folds of posterior parietal peritoneum adjacent to ligament of Treitz (para-duodenal hernia)
37 Velpeau's - Femoral hernia in front of the femoral vessels

Reproduced from: Awwad, A. Lederhosen Hernia: First Description and Literature Review. *SN Compr. Clin. Med*. 2, 788–791 (2020). https://doi.org/10.1007/s42399-020-00304-1

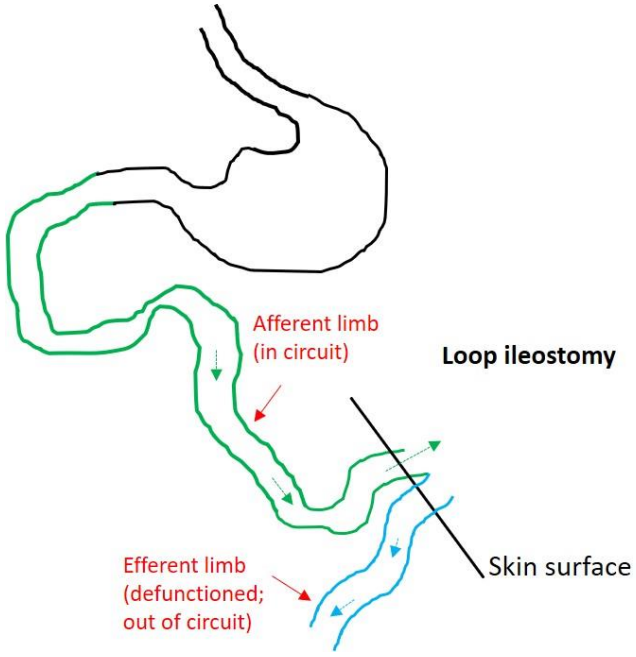
Terminology used with bowel & stomas

- Roux-en-y bypass: lots of differing names for the limbs, which can be confusing



  - Note: the common limb may also be called the '(common) efferent limb'
  - Anastomoses named in red

- Defunctioning stomas (e.g. loop ileostomy, loop colostomy)
  - A segment of bowel is brought to the skin surface, partly divided, and sutured to the skin surface. Easier to form (and also later reverse) than end stomas



        - Afferent limb: proximal (upstream segment) through which bowel contents is emptied into stoma bag.
        - Efferent limb: distal (downstream segment) which is 'out of circuit' and connects to the diverted downstream bowel.
    - Note that each of the two limbs of a defunctioning loop ileostomy will have its own orifice (both close together) at the skin surface, and both can be cannulated as part of a loop-o-gram study, depending on the clinical question.
    - Diversion colitis: [19] [20] inflammation of the out-of-circuit bowel after a defunctioning ileostomy or colostomy. Most patients are asymptomatic, and features disappear after restoring continuity (i.e. putting the bowel back in circuit).

- An end stoma will generally have just one afferent limb, though there may be an oversewn rectal/sigmoid remnant left *in situ*
    - You may also see an out-of-circuit 'mucous fistula' formed, for example for a very distal obstructing cancer.

- A double-barrelled stoma (almost always a colostomy) has two *separate* cutaneous openings that are adjacent but distinct, unlike a loop stoma where a bowel segment is just partially divided.
    - Therefore, there is an *afferent* limb and a distal limb (sometimes also called a mucous fistula)
    - Note: In a loop colostomy, the *efferent* (defunctioned) limb is effectively the same as a mucous fistula, though this term is reserved for end or double-barrelled stomas

Blind ending bowel terminology

- Bypass / Bypassed: descriptor for bowel which has been *excluded* from normal gut circuit / intestinal flow
    - E.g. the excluded/remnant stomach, or the Bilio-pancreatic limb as in the Roux-en-y example above
- Blind <u>loop</u>: a segment of bowel that has been bypassed and is 'out of circuit'. Created *intentionally* during surgery
- Blind <u>pouch</u>: a shorter segment of bowel, often at the level of an anastomosis
    - Unlike a blind loop, a blind pouch is *not* created intentionally
    - Classically occurs with side-to-side (which invariably leaves a small blind end), but also in end-to-side anastomoses
    - Can lead to 'blind pouch syndrome' where the blind segment dilates abnormally and forms a pouch with resultant stasis and bacterial overgrowth
- Remnant (less correctly a 'stump'): an oversewn end of bowel which does not lead anywhere, e.g. rectosigmoid in a Hartman's procedure
    - 'Blind-ending' can also be used when describing these appearances

Types of bowel anastomosis [21]

Anastomosis type	Uses
End-to-end	Small bowel, colorectal
End-to-side	Colorectal
Side-to-side	Small bowel

Enterotomy = division of small bowel generally, which may be part of a resection, anastomosis, stoma formation, or occasionally inadvertent (e.g. operating on complex adhesions).

- For colorectal anastomoses *side-to-end* is often preferred over *end-to-end* if there is a size discrepancy between the two ends to be joined.
- Anastomoses may be handsewn (absorbable or non-absorbable which determines visibility on imaging) or stappled (easier, quicker).

It is important to know what anastomosis has been performed, as this will determine the expected appearances on imaging which may mimic/be confused with pathology, for example:

- An anastomotic leak in an end-to-end anastomosis may mimic the normal blind end of a normal end-to-side anastomosis on enteric contrast studies (CT + rectal contrast, or fluoroscopic contrast enema)
- Blind-ended remnant in an end-to-side anastomoses can develop its own complications, so should be carefully assessed as well, not just the anastomosis itself

IBD complications

- Cavities, fistulae, and sinuses [22]
    - Fistula: abnormal passage between two epithelised surfaces
        - For example, between two bowel segments, or from bowel to skin (external opening)
        - Epithelium lines hollow organs and surfaces exposed to the external environment
    - Sinus: A blind-ending tract, either from a skin or epithelial surface (including bowel) to a deep-seated focus of infection, a vestigial structure, to aberrant secreting tissue
        - For example, a blind-ending tract leading from a perianal internal opening, or small bowel Crohn's penetrating disease tract leading blindly into mesentery

Surgical drains

- Robinson drain: percutaneous, large bore, free drainage (non-vacuumed). Commonly left in the abdomen at the end of an operation
- Corrugated (Yates) drain: percutaneous, small bore, with lots of perforations/small holes along its length (hence 'corrugated). Often used for perineal wounds
- Endo-Sponge: inserted rectally to treat anastomotic leaks (vacuum drain)
- Pigtail drain: generic name for percutaneous drain which forms a coiled tip. Commonly inserted via interventional radiology for post-surgical collections

2. HISTOLOGY

2.1. TNM staging considerations [P]

TNM precursors: c = clinical; r = radiological; p = pathological;
and also … y = following neo-adjuvant chemotherapy [Q]

- For example, a tumour's stage can be expressed radiologically or histologically as T3 N2 M0 V2

- Nodes (x/y) = x nodes involved by disease out of y total nodes present in the surgical resection specimen
    - Documented as e.g. N0 (0/25), to mean 0 involved nodes out of 25 in the resected specimen

- Resection margins: important for deciding on further treatment
    - R0: microscopically margin-negative resection, in which no microscopic or gross macroscopic tumour remains in the primary tumour bed
    - R1: removal of all macroscopic disease, but microscopic margins are positive for tumour
    - R2: gross residual disease with gross residual tumour that was not resected (primary tumour, regional nodes, and macroscopic margin involvement)

- Vascular invasion:
    - V0: no evidence of vascular invasion
    - V1: microscopic vascular invasion (a *pathological* diagnosis)
    - V2: macroscopic vascular invasion (can be a radiological or pathological diagnosis)
    - Use either V0 or V2 used when giving a radiological staging (since radiology cannot appreciate microscopic V1).

- Lymphatic invasion: L0 or L1
- Perineural invasion: Pn0 or Pn1

Other histopathological terminology

- 'Donut': describes the *en bloc*[R] resection of the rectum and mesorectal fat as part of a total mesorectal excision
    - A TME procedure creates a tube-like specimen provided to the pathology team, which is cut into transverse donut-like rings as part of the assessment by the Histopathologist
- Kudo Classification:
    - Tumour infiltration into the upper third (sm1), middle third (sm2), or lower third (sm3) of the submucosal (sm) layer in surgically resected specimens
    - High resolution MRI can delineate the depth of invasion in early rectal cancers, and the patient may therefore be able to undergo minimally invasive surgery rather than a full TME procedure.

Neoplastic Disease Spread:

- EMVI and LVI: Extramural vascular invasion and Lymphovascular invasion

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[P] TNM: Tumour Node Metastases system. Globally recognised for staging mainly solid cancers.
[Q] For example: **yp**T1 N1 V2 would be a *pathology-based* TNM staging *after* chemotherapy.
[R] To surgically remove as one intact specimen, rather than in pieces.

    - Disease involving draining veins or lymph nodes/lymphatics; represents an independent poor prognosticator
    - May be difficult to distinguish between vascular and lymphatic disease, and so LVI may be a more accurate term than EMVI when there isn't the classical expanded tubular vein appearance seen in EMVI. [S] 'Disease deposit' is often used as synonymous term.
- Transmural spread: disease that extends directly outwards from / across the bowel wall
- Extramural disease: any disease which is outside the bowel wall (e.g. EMVI, deposits)
- PCI: Peritoneal Carcinomatosis Index - scoring system for describing the extent of peritoneal disease, which can be applied radiologically (and also surgically) – See Imaging section

[S] EMVI: Extramural vascular invasion - tumour expanding vein and intermediate signal replacing normal flow void (can be seen on MRI as well as CT).

2.2. Histological findings & Immunohistochemistry

- Immunohistochemistry: histological technique to determine expressed 'markers' in cancer cells. Helps classify tumour origin, aggressiveness, and potential treatment options.
- Adequate quantities and quality of tissue biopsy are needed to run these tests.[T]
    - This is dependent on core biopsy size and the overall number of samples.
- Tests can be run at a later stage *if* there is sufficient remaining material
    - Tissue from surgery or biopsy can be fixed in paraffin to create 'tissue blocks'. These can be stored and requested for transfer between histology departments (i.e. from another hospital) for a specialist opinion.
    - Looking at another hospital's slides, or just having access to their written reports are more limited alternatives for reviewing histology performed elsewhere

Tumour markers should be interpreted in the context of the cancer and other histological findings (hence the importance of the Histopathologist and their experience at meetings). The below is a basic overview of frequently encountered markers (see also 'tumour markers' in the *Oncology* section):

- Neuroendocrine tumours (NET)
    - CD56: Small cell cancers
    - Chromogranin: protein secreted by NETs
    - Synaptophysin: glycoprotein that is an integral part of the neuroendocrine secretory granule membrane
    - (Ki-67 index: the mitotic rate of neuroendocrine cells)
- CDX2: intestine-specific transcription factor, expressed in the nuclei of epithelial cells throughout the intestine, from duodenum to rectum
- CK20: gastric and intestinal mucosa
    - CK7: Seen in ovary, lung, and breast but not GI tract. Hence often used with CK20 to distinguish ovary, lung, and breast cancers from colorectal
- CTNNB1: positive marker in 90% of sporadic desmoids

- MSI and MMR: Mismatch repair and Microsatellite instability
    - MMR deficient colorectal cancer has a more favourable prognosis
    - Identifies patients who may benefit from immunotherapy
    - We generally undertest. Can test retrospectively from histopathological specimens
- RAS / RAF status: specific molecular pathway gene variation[U] that can be detected
    - Relevant as predicts response to novel agents in colorectal cancer
    - No RAS variation patients: benefit from anti-epithelial growth factor antibodies (e.g. Cetuximab)

[T] Note that fine needle aspiration (FNA) samples only allow more limited cytological analysis.
[U] 'Pathological gene variation' is preferred to gene 'mutation'.

2.3. Cancers of Unknown Primary (CUP)

Covered by the Upper GI MDT at Northwick Park. CUP often relies on the expertise and guidance of Histopathologists in attempting to determine the primary cancer.

- CUP = Evidence of clear metastatic disease (often peritoneal or nodal) but where a primary origin cannot be clearly identified
    - Some cancers (e.g. primary peritoneal malignancy) may mimic CUP
- Immunohistochemistry can help, but markers are not always specific and may only be able to suggest a range of cancer origins (e.g. breast or upper GI origin).
- Tumour markers can be used, but must be interpreted with caution (see 'tumour markers' in *Oncology* section)
- Poorly differentiated tumours may require re-sampling
    - The normal architecture of tissue is so heavily disrupted that it impairs histological assessment
- Radiologists can also suggest targets for biopsy (e.g. areas of peritoneal caking, the most abnormal looking nodes, liver metastases)
    - Identify safest, easiest, and largest targets that are most likely to yield diagnostic, non-necrotic tissue
    - CT-PET can guide where exact to biopsy a lesion, to ensure sampling of avid (actively dividing cells) tissue rather than the often non-diagnostic necrotic component

3. CLINICAL & MEDICAL

3.1. Medical conditions and their related terminology

3.1.1 Malignant:

- CRC: Colorectal cancer
- NET: Neuroendocrine tumour
    - Also note extrapulmonary small cell cancers (EPSCC): rare, also found in GI tract
    - Poor prognosis and similar natural history / treatments to pulmonary small cell cancer

3.1.2 IBD: Inflammatory bowel disease

- CrD/CD: Crohn's disease
    - Disease can be thought of as:
        - Inflammatory (non-stricturing & non-penetrating)
        - Luminal narrowing (no functional obstruction) & Stricturing (stenosing; luminal narrowing + functional obstruction)
        - Fistulating (penetrating)
- UC: Ulcerative colitis
- ECF: Entero-cutaneous fistula [V]
- SI: Small intestine

Extra-intestinal manifestations of IBD: numerous,[23] but some of the important and/or radiologically detectable include …

- Enteropathic spondyloarthropathies (particularly sacroiliitis[W])
- Osteopenia (insufficiency fractures of spine and sacrum) & Avascular necrosis
- Hepatic steatosis
- Primary sclerosing cholangitis (PSC, especially in Crohn's Disease)
- Thrombosis (portal vein, superior mesenteric vein, pulmonary emboli, deep vein thrombosis)
- Vulval Crohn's disease (differentiate from perianal fistulous disease)[24]

Short bowel syndrome: Clinical syndrome of malabsorption following resections of small bowel [25]

- Normal length of small intestine is extremely variable (related to height amongst other factors). Ranges from 630 - 1510 cm.[26]
- Short bowel is defined as < 200 cm small bowel *in continuity*,[X] though note that shorter lengths combined with large bowel may be sufficient to avoid symptoms.
    - < 50 cm is very likely to produce symptoms.

- IF: Intestinal failure - commonly due to short gut from multiple / extensive small bowel resections. However *Intestinal Rehab* is used as a more accurate term[Y]
    - IFU / IRU: Intestinal failure/rehab unit
    - TPN: Total parenteral nutrition – either external via tunnelled catheter, fully implanted catheter (with injectable port), or peripherally inserted catheter

[V] ECF may be used as an all-encompassing term for small and large bowel cutaneous fistulae (e.g. colo-cutaneous fistula). It is important for radiologists to report fistulae accurately as this has implications for surgical planning and intestinal failure management.
[W] Avoid confusing with *Osteitis condensans ilii* (benign).
[X] Out-of-circuit small bowel won't contribute to the patient's absorption, so make sure you differentiate in- and out-of-circuit small bowel when asked for small bowel length.
[Y] 'Failure' implies nothing further can be done for short bowel patients, and hence 'rehabilitation' is a more helpful and accurate term.

- HPN: Home parenteral nutrition

3.1.3 Hereditary Polyposis syndromes (benign, but with malignant potential): [27]

a) Adenomatous

- FAP: Familial adenomatous polyposis
  - Autosomal dominant (APC gene in 85%), manifesting as very large number of adenomatous colorectal polyps.
  - Cancer invariably occurs by the 4th decade without prophylactic surgery
  - Extracolonic:
    - *Desmoid tumours*: these can make surgery difficult if they involve abdominal wall (incisions), or tether bowel. Most commonly small bowel mesentery and abdominal wall (see below)
    - Gastric and duodenal adenomas and neoplasm
- Gardner's:
  - Variant of FAP
  - Extracolonic cancers: osteomas (skull), thyroid, epidermoid cysts, fibromas, desmoid
- Turcot syndrome:
  - Variant of FAP
  - Fewer polyps but associated with paediatric brain tumours (medulloblastoma, ependymomas, glioma)

b) Hamartomatous

- Peutz-Jeghers
  - Polyps throughout the GI tract, but most commonly small bowel (obstruction, intussusception, rectal bleeding)
  - Increased incidence of GI, breast, and pancreatic cancers
- Juvenile polyposis
  - 'Juvenile' refers to the histopathology of polyps rather than age of onset
  - Mainly right-sided colonic polyps
  - Increased risk of cancer (including gastro-duodenal)

c) Other

- HNPCC: Hereditary non-polyposis colorectal cancer (Lynch syndrome)
  - Autosomal dominant
  - Non-polyposis: Cancers can arise even when there are relatively few polyps (though these patients can also have polyposis, hence HNPCC
  - Associated with endometrial, ovarian, gastric, HPB, and small bowel cancers
- SPP: Serrated polyposis syndrome [Z]
  - Serrated adenomas

3.1.4 Desmoid disease: [28]

- Look for solid lesions and increased attenuation within the mesentery.
  - Can tether bowel, cause obstruction, and even fistulae.
  - Important to describe, especially if an operation is planned, as this can help the surgeon plan their approach.

[Z] Note that serrated polyps are important to recognise as they don't necessarily follow the standard adenoma-adenocarcinoma sequence of standard polyps.

- Can be difficult to differentiate from disease recurrence (peritoneal disease in particular), and the diagnosis is often made based on: clinical presentation, 'oncological trajectory',[AA] and imaging
    - Both can be avid on CT-PET
    - Biopsy can cause desmoids to grow (as can surgery), and a desmoplastic-like response can be seen in recurrent neoplastic disease, which can be confused for desmoid
- Most desmoid are *sporadic*, with only 10% having FAP
- Biopsy and testing for CTNNB1 (performed at sarcoma centres) - positive marker in 90% of sporadic desmoids

3.1.5 Defecation-related and Pelvic floor

- OD: Obstructive defecation - conditions that result in impaired rectal evacuation.
    - Include: pelvic dyssynergy (anismus), rectocele, enterocele, pelvic organ prolapse, rectal intussusception, rectal mucosal prolapse, and full rectal prolapse
    - Note: the *obstructive* defecatory conditions listed above do not necessarily cause a physical obstruction to evacuation (for example a rectocele may empty well during a proctogram study). However when reporting proctograms it is helpful to describe whether abnormalities do physically obstruct evacuation.
    - See also *defecating proctogram* which goes into greater detail on OD conditions
- ARP: Anorectal Physiology - specialist department investigating patients with problem defecating (see also obstructive defecation)
    - It is worth visiting the department to see the work that they do.
    - See *Carrington et al. (2018)* [29] for a useful review of ARP
- BFB: Biofeedback - behavioural therapy utilising bowel and muscle retraining for patients with non-surgically correctable cause of defecation or who have not responded to other treatments
- EAUS: Endoanal ultrasound
- FI: Faecal incontinence
- OASI / OASIS: Obstetric Anal Sphincter Injuries
    - 1st degree: Perineal skin injury only
    - 2nd degree: Perineal muscle injury, but not involving anal sphincter
    - 3rd degree:
        - 3a: < 50% of external anal sphincter
        - 3b: > 50% of external anal sphincter
        - 3c: Injury to both external and internal anal sphincters
    - 4th: Anal sphincter injury also involving anal epithelium
- PF: Pelvic floor

3.1.6 Other conditions and their terminology:

- BAD: Bile acid diarrhoea - malabsorption of bile salts results in chronic diarrhoea. Patients dramatically improve on starting chelation
- SIBO: Small intestinal bacterial overgrowth (syndrome), which can have variable clinical severity. More commonly seen following bowel surgery or in conditions of the gut
- SRUS: Solitary rectal ulcer syndrome - rare benign syndrome with constipation, rectal bleeding, and ulcers (not always present).
    - Recurrent mucosal intussusception is thought to be associated with SRUS, and is an indication for proctogram

[AA] How is the patient doing otherwise? Any other sites of confirmed disease recurrence. Tumour markers elevated?

- Vascular rings (aortic) and slings (pulmonary artery): rare, but may result in dysphagia. Congenital vascular encirclement (either partial or complete)
    - Dysphagia lusoria: specifically secondary to an aberrant right subclavian artery
    - Effect of rings & slings on oesophagus and trachea:
        - Posterior oesophageal indentation: double arch, right arch with an aberrant left subclavian artery, or left arch with an aberrant right subclavian artery
        - Anterior oesophageal and posterior tracheal indentation: pulmonary slings
        - Bilateral indentation: double aortic arch.
        - Right indentation: right arch or a double arch with left atresia.
        - Left indentation: double arch with a right arch atresia or circumflex aortic arch with right ductus
    - See *Etesami M et al.* for a full review of vascular ring and slings[30]

3.2. Management of IBD (an overview) [31]

Crohn's and Ulcerative colitis may represent different manifestations of the same overall disease process, as they do not seem to manifest together in the same patient.

Patients with apparent UC who have colectomy may subsequently develop CrD.

- Ulceration within an ileo-anal pouch raise this possibility

3.2.1 Treatment options in CrD:

Aim is to induce and maintain remission, as a definitive cure is not currently available

- Medical: [BB]
    - Steroids: not intended for long-term use, though patients can fail to taper / reduce doses without symptoms recurring
    - Antibiotics: treating infectious complications
    - Aminosalicylate (5-ASA) (e.g. Pentasa)
    - Azathioprine and Methotrexate: may be used in active CrD where there is failure of 1st line treatment or tapering of steroids
    - Biologics (anti-TNF) (e.g. Adalimumab, Infliximab): effective at reducing and maintaining remission, though should be avoided in undrained sepsis and carefully considered post-malignancy (due to their immunosuppressive effect)
- Nutritional:
    - Elemental diets are effective (especially for children) but unpalatable
- Endoscopic: [32]
    - Strictureplasty / stricturoplasty
    - Endoscopic balloon dilatation (EBD)

- Surgical:
    - Resection of diseased bowel: extensive resection risks short gut / intestinal failure
    - Diverting stomas are effective for treating distal inflammation in recalcitrant / refractory disease
    - Surgery is common (75% within 20 years of diagnosis) and an important part of management, but is not curative. Patients will frequently need further surgery
    - Indications: intra-abdominal inflammatory masses, fistula not responding to medical management, fibrotic stricture with obstruction, toxic megacolon, haemorrhage, cancer

[BB] Top down vs. bottom up strategies: respectively relate to either using maximal treatment straight away, or gradually escalating treatment until achieve remission (similar to the 'analgesic ladder' concept). Treatment paradigm has shifted more towards a top down approach more recently.

Endoscopic treatment of Crohn's Disease		
	Candidate lesion	**Avoid**
Stricture	Mainly fibrotic Short (< 4 cm) Benign Single or multiple, but straight bowel lumen Stricture far from fistula orifice of the proximal bowel (> 5cm)*	Mainly inflammatory Long (> 4 cm) Malignant Angulated stricture / multiple stricture with angulated lumen; associated abscess Stricture near fistula orifice of proximal bowel (< 5 cm)
Fistula	Single, long fistula tract	Complex, branched fistula, short fistula tract
* If the stricture is less than 5 cm from a fistula opening or associated with concurrent abscess, endoscopic dilation should not be attempted because it may cause bowel perforation by disrupting the fistula tract		
From Chen M et al (2015)		

3.2.2 Treatment options in UC:

- Medical
  - Steroids: reduces severity of acute episodes
  - Aminosalicylate (5-ASA) e.g. Pentasa - significantly reduce relapse rates
  - Antibiotics: treating infectious complications
  - Azathioprine and Methotrexate: added in chronic active disease for their steroid sparring effect and to help maintain remission
  - Biologics (anti-TNF) e.g. Adalimumab, Infliximab: role somewhat less clear
- Surgery: Generally either total colectomy + end ileostomy or ileo-anal pouch
  - Acute attacks not responding to medical therapy
  - Complications of acute attack (perforation, megacolon)
  - Chronic continuous disease
  - Dysplasia / cancer

3.3. Endoscopy and related

3.3.1 Endoscopic techniques for assessing lesions

- WLE: White light endoscopy - conventional light source used during optical endoscopy
- NBI: Narrow band imaging - alters the normal red-green-blue filters of the white light source via a filter so that narrower wavelengths (blue and green) predominate, and hence gives better relative visualisation of surface mucosa for assessing microvascularity and 'pit patterns'.[33]
- CHR: Chromoendoscopy - dye sprayed onto lesions or more diffusely (in screening). Allows greater detection and characterisation of lesions beyond standard white light endoscopy.
- CLE: Confocal (laser) endomicroscopy: technique allows significant (x 1000) magnification during endoscopy to improve visual diagnosis.[34]

3.3.2 Endoscopic interventions

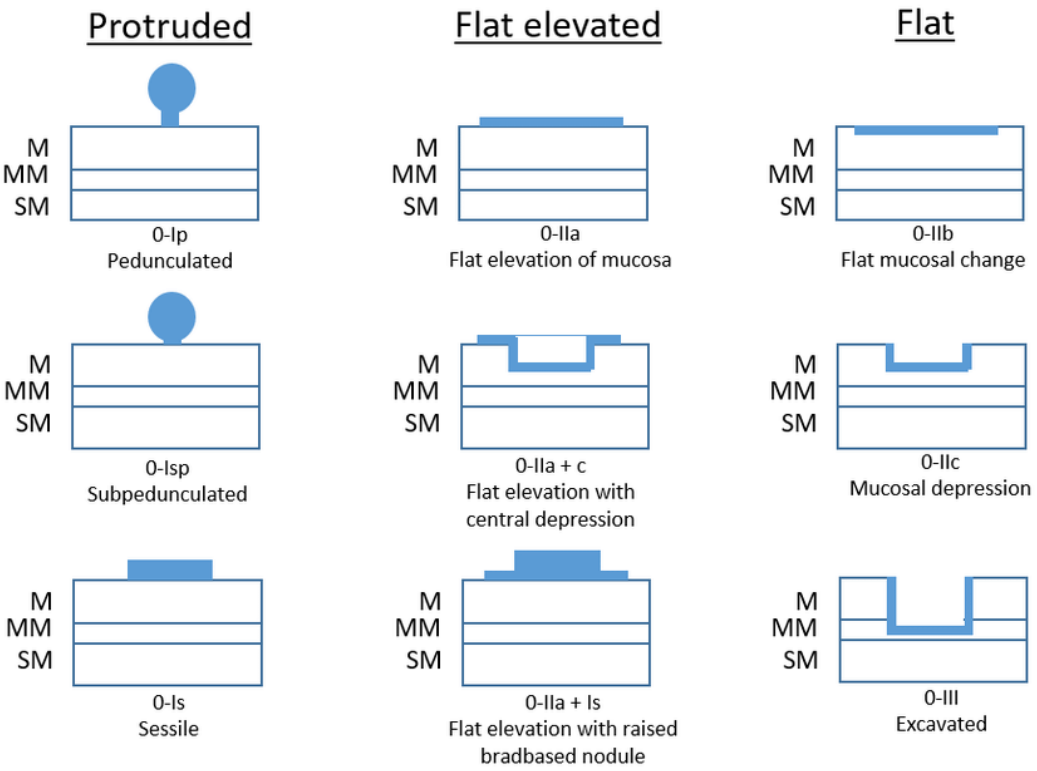
- DBE: Double balloon endoscopy - technique allowing assessment of the small bowel using balloons to advance the scope. Used to 'trawl' the small bowel for polyps in polyposis syndromes
    - When reporting studies helpful to comment on which end will be an easier approach for a lesion (i.e. via colonoscopy or OGD)
- EMR: Endoscopic mucosal resection of polyps / suspicious lesions. May not be feasible for all (e.g. if near appendiceal orifice)
- ESD: Endoscopic submucosal dissection
- Submucosal lift: endoscopic technique to determine if a lesion is submucosal. Inject saline below lesion, and if submucosal the lesion will generally lift up, but if it has invaded beyond submucosa it will remain tethered down (anchored by its 'roots').
    - If MRI is performed after this procedure, diffuse oedema at the site can be seen which can complicate interpretation. These superficial lesions may be extremely difficult to appreciate even if a submucosal lift hasn't been performed
- Tattooing: of bowel mucosal during endoscopy, which can be used as a permanent visual marker for future use
    - This marks both the inner and outer aspect of bowel, so surgeons can identify diseased segments identified during an earlier endoscopy, even during laparoscopy, and ensures the correct segment is resected
    - Example would be when a polyp is removed and turns out to be malignant. Tattoo means that the segment is appreciable later for resection

3.3.1 Misc

- VCE: Video Capsule Endoscopy
    - The patient will usually undergo a patency capsule CT in advance. This involves swallowing a dissolvable capsule of the same size as the actual video endoscopy capsule followed by a CT to ensure that this won't cause obstruction

3.3.3 Terminology & Classifications

- HGD and LGD: High and Low grade dysplasia respectively
- Kudo Criteria: Classification of Colorectal Crypt Architecture on endoscopy (grades I-V) for colorectal neoplasms [35]
- Paris classification: used for endoscopic polyp evaluation to classify the morphology of mucosal lesions



[M = Mucosa, MM = Muscularis mucosa, SM = Submucosa]
Image from *Bernal J et al. (2017)* [36]

- Polyps:
  - TA: Tubo-adenoma
  - TVA: Tubo-villous adenoma
  - LST: Lateral spreading tumour
    - Non-polypoid lesions at least 10 mm in diameter with lateral growth
    - *Granular* (G-LST) and *Flat* (F-LST) types

3.4. Enteric support devices

- Nasogastric tube (NGT): blind insertion with plain film to confirm position
- Naso-jejunal tube (NJT): inserted under fluoroscopy

- PEG: Percutaneous endoscopic gastrostomy
  - Venting PEG is used as a long-term means of decompressing the stomach. This may be combined with a jejunal tube for feeding (together called a PEG-J, with a gastric and jejunal port - important to identify correctly during contrast studies)
- RIG: Radiologically inserted gastrotomy
  - Inserted under fluoroscopy instead of via endoscopy (Interventional Radiology)

- PEJ: Percutaneous endoscopic jejunostomy
  - Feeding tube inserted into the jejunum
- Surgical jejunostomy ('surgical jej'): more invasive, though can be done laparoscopically

- PEGJ/'PEG-J': Percutaneous endoscopic gastro-jejunostomy.
  - Combination

3.5. Miscellaneous

- CUP: Cancer of Unknown Primary
  - There is a dedicated MDT, though all efforts should be made to exclude an obvious primary prior to referral
- EEN: Exclusive enteral nutrition
- EUS: Endoscopic ultrasound - generally to assess ampullary and pancreatic lesions
- UGI & LGI: Upper and Lower gastrointestinal
- Krukenberg tumours: metastatic deposits to the ovaries, most commonly seen in GI primaries and often bilateral. Endometriosis may mimic these
- Medena catheter: fine catheter used by patients to assist in emptying of ileo-anal pouch

Clinical fitness grading scores: Important for deciding on the appropriateness of further investigation, and whether a patient is likely to tolerate/manage the bowel preparation used in CT-colonography

- ASA: American Society of Anaesthesiologists Physical status
  - Patient's fitness graded from 1 (normal healthy patient) to 5 (not expected to survive without an operation). Grade 6 also exists (brain death) [cc]
- PS: Performance status (WHO grades) - clinical fitness of the patient

WHO Performance Status [37]
0: able to carry out all normal activity without restriction
1: restricted in strenuous activity but ambulatory and able to carry out light work
2: ambulatory and capable of all self-care but unable to carry out any work activities; up and about more than 50% of waking hours
3: symptomatic and in a chair or in bed for greater than 50% of the day, but not bedridden
4: completely disabled; cannot carry out any self-care; totally confined to bed or chair

[cc] https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system

- Clinical Frailty Scale: Judgement-based tool to assess frailty ranging from 1 (very fit) to 9 (terminally ill).

- CRT: Chemo-radiotherapy
- RT: Radiotherapy
    - Cyberknife: a more accurate method of delivering RT in which the radiation beam is repositioned during each treatment. Allows larger treatment fractions to be delivered (see 'Oncology' section below)

- BCSP / BCS: English bowel cancer screening (program)
- FIT: Faecal immunochemical test
    - 150 mcg/g conveys … 1/3 risk of bowel cancer (NHS threshold)
    - 10 mcg/g conveys … risk of 1/10 (GP threshold for CTC referral)
    - High FIT without an obvious cancer: Most common differential would be IBD or high-risk adenomas[38]
- PEI: Pancreatic exocrine insufficiency
- STT: Straight to test - abnormal FIT leading straight to CT-colon or endoscopy
- IDA: Iron deficiency anaemia
- W&W: Watch and wait
- 2WW / 2WR: Two week wait / rule cancer referral. A GP request for an urgent evaluation of symptoms that may be due to cancer

4. ONCOLOGY [39]

Medical oncologist (MRCP qualifications) and Clinical oncologist (MRCP and FRCR qualifications) are Physicians treating cancer who can be thought of as existing along a spectrum, utilising differing quantities of systemic treatment and radiotherapy in their practice. The distinction between the two can be complex. [DD]

4.1. Radiotherapy (RT)

The aim is to utilise the most appropriate combination of:

a) treatments ('fractions')
b) overall duration of treatment
c) and total dose administered over the treatment duration

… in order to effectively treat disease whilst minimising short and long-term side effects / complications to healthy tissues.

- Treatment regimens can be briefly summarised by describing total dose and number of individual treatments e.g., *55 Gy in 20 fractions = 55 Gy/20#*

Treatment goals:

- Radical: curative intent
- Palliative: disease control for symptom relief
    - Giving RT too early may prevent the patient from having later RT where symptomatic disease control would be more useful. Treatment timing is therefore important and considered early

External beam radiotherapy covers various methods of delivering radiotherapy using ionising radiation delivered externally, for example via via SBRT (stereotactic body radiotherapy) which allows precise doses with minimisation of irradiation of healthy tissues.
Intraoperative radiotherapy may sometimes also be used.

4.2. Chemotherapy

Treatments

- Neoadjuvant: given prior to surgical resection to downstage disease
    - Disease may shrink down and 'retreat' away from involved/threatened structures (e.g. an involved posterior prostate in rectal cancers), but note that unless there is a complete response (CR) to treatment (see *RECIST* below) there is likely to be at least some residual disease. This must be considered in planning the extent of surgery to avoid leaving disease behind (i.e. correlate with pre-treatment imaging)
- Adjuvant: given following surgical management
- Palliative: focus on symptom relief

[DD] https://www.rcr.ac.uk/medical-and-clinical-oncology-are-we-more-or-less-same

4.3. Interventional Oncology

- RFA: Radiofrequency ablation for tumours
    - Can be used to control sites of disease (typically liver and lung)
    - Important to consider timing as metastases may no longer be visible on imaging after starting chemotherapy.
- Liver RFA:
    - Generally used for lesions < 3 cm
    - Lesion must be away from capsule and major vessels. The latter is to avoid 'heat sink' effect (i.e. when treating a lesion near a large vessel, the heat is taken away by the vessel therefore reducing the size of the thermal ablation zone).

4.4. Tumour Markers [40]

Biochemical markers which are associated with underlying malignancies. They are generally not specific, and so should be used cautiously. They may also be raised in benign disease.

Their main roles are:

1. Helping to suggest the most likely primary cancer in cases of unknown primary
2. Monitoring of disease response / recurrence (e.g. an upwards trend in CEA is useful to monitor for colorectal recurrence)
3. Prognosis and predicting response to specific treatments
4. As part of scoring systems to determine risk of malignancy (e.g. CA-125 for ovarian lesions)

Some common markers (with summary of their *commonest* associated malignancy):
From Lab Tests Online [41]

- AFP: liver (hepatocellular carcinoma but also e.g. cirrhosis, hepatitis), and also testis
- CEA: colorectal
- CA 12-5: ovarian
- CA 19-9: pancreatic
- hCG: placental (e.g. choriocarcinoma)
- HER-2: breast cancer ['positive' patients may benefit from *Herceptin*]
- SMRP: mesothelioma
- PSA: prostate
- Thyroglobulin: thyroid
- Calcitonin: thyroid

4.5. Treatment Response in cancer

Response evaluation criteria in solid tumours (RECIST)

- Radiological system to formally comment on disease response to treatment
- Describes responses as:
    - Improving disease: complete response (CR) or partial response (PR)
    - Stable
    - Progressive
- Take care using terms like 'progressive' or stable' outside of a formal RECIST report, as to Oncologists they carry very specific meanings and thus implications for treatment [42]
    - Note also that treatment can alter the appearances of disease

- Metastases may increase in size when treated (actually a marker of good response), and sclerotic bone lesions can suddenly 'appear' (representing an osteoblastic treatment response to bone disease that was previously not visible to CT [EE])

[EE] The full extent of metastases to bone are often not appreciable on CT. Treated disease becomes sclerotic and hence suddenly 'appears' on the post-treatment CT.

II. Radiology Resources & Logistics

5. IMAGING

Sections:

5.0 Abdominal Reporting Concepts
5.1 Fluoroscopy & Radiography
5.2 Ultrasound
5.3 CT
5.4 MRI

5.0. Abdominal Reporting Concepts

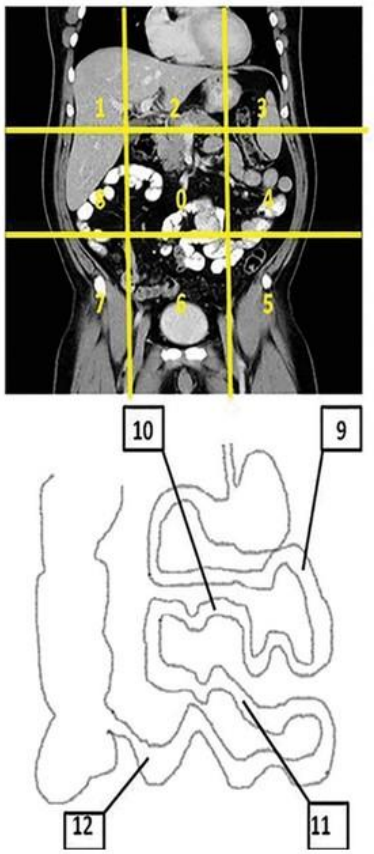
A. Describing Orientation in Imaging

- Upstream & Downstream (for proximal and distal respectively): avoids confusion as some endoscopists may consider proximal to be anal verge (from their perspective)
- Proximal & Distal: use with caution in structures like pancreas as there may be varying interpretation as to which 'end' you are referring to[43]
    - Up- and downstream are also useful for the biliary system (e.g. downstream pancreatic duct rather than proximal/distal), and also in venous drainage[FF]
    - However, some radiologists would say you need to specify a reference point when using this terminology (i.e. downstream *from* something else)
- Use of clockface: only used in the axial (or axial oblique) image plane, where 12 o'clock is anterior and 6 o'clock is posterior
    - Can refer to anterior, posterior, cranial and caudal margins when the bowel is in a non-axial orientation
- Cranial (sometimes cephalic/cephalad) and Caudal: towards head and towards 'tail' respectively. These are embryological terms and strictly shouldn't really be used outside of this context. They are however useful terms for orientation generally and are routinely used by both clinicians and radiologists
- Ventral and dorsal: towards the front (anterior) and back (posterior) respectively
- Antero-lateral/medial and Postero-lateral/medial
    - Similarly antero-inferior/superior and postero-inferior/superior

B. Peritoneal Carcinomatosis Index - *Aherne et al. (2017)* [44]

Used for defining the extent of intra-abdominal peritoneal disease. This can be used when deciding on which patients may be suitable for further treatment such as Cytoreductive surgery and HIPEC.

[FF] Proximal and distal when applied to a vein refers to its direction of flow. E.g. the proximal internal jugular vein is towards the head and distal is towards the heart. Hence up- and downstream or cranial/caudal can avoid confusion.



CT PCI Calculation

Score	Size
LS0	No visible tumour
LS1	<0.5cm
LS2	<5cm
LS3	>5cm or caking

	Region	Score
0	Central	
1	Right Upper	
2	Epigastrium	
3	Left Upper	
4	Left Flank	
5	Left Lower	
6	Pelvis	
7	Right Lower	
8	Right Flank	
9	Upper Jejunum	
10	Lower Jejunum	
11	Upper Ileum	
12	Lower Ileum	
	Total	

LS-0: no disease
LS-1: tumour deposits smaller than 0.5 cm in diameter
LS-2: tumour deposits 0.5–5 cm in diameter
LS-3: tumour deposits greater than 5 cm in diameter, or confluent disease/caking

The PCI score is then calculated by adding together the scores for each region of the abdomen and pelvis (PCI score from 0 - 39).

C. Contrast in Abdominal Radiology

- The American College of Radiology (ACR) produces a helpful and detailed manual on contrast agents [45]
- Oral contrast considerations [46]

- Luminal contrast use in CT

Negative density (air) and Neutral density (fluid) provide innate contrast, especially in bowel obstruction.
Positive contrast can be introduced using diluted iodinated contrast medium (or less commonly dilute barium).

- Take care to consider if a scan should be delayed in cases where the patient has been given undiluted contrast recently (usually Gastrografin on the ward for abdominal films to prognosticate in small bowel obstruction) to reduce the risk of a non-diagnostic CT due to streak artefact.
- A plain radiograph (± delay) to assess how much contrast remains and its density may be helpful before progressing to a CT.

Regimens vary between radiologists and institutions, but a 1:10 dilution[GG] (~ 10%) is generally effective for most indications.

- This regimen prevents excessive dilution of contrast within small bowel, which may be fluid-filled due to secretion in small bowel obstruction

Main indications:

- Demonstrate anastomotic leaks, help identify bowel course (in complex abdomens or post-operative patient), to demonstrate transition points in obstruction (often not needed as fluid and air provide innate contrast), intestinal mapping, and to delineate suspected enterocutaneous fistulae
- Luminal contrast make commenting on bowel enhancement more difficult, so should probably be avoided if there is a specific question regarding bowel ischaemia

Water Soluble Luminal contrast use in CT		
Indication	**Protocol ***	**Notes**
Oesophagus (e.g. perforation)	- First cup (~ 200 mL) 5 minutes before scan. - Second cup drunk prone on scanner table. Patient to turn over several times before scanning supine (as able). Note: Contrast orally, **not** via nasogastric tube (NGT).	NGT should be clamped. *Consider* an unenhanced control CT first (not routine). Turning, as much as patient mobility allows (be pragmatic).
Gastric anastomosis and proximal small bowel	250-500 mL taken over 30 minutes. Scan at 30 minutes.	*Consider* an unenhanced control CT first.
Small bowel †	250-1000 mL taken over 45 - 60 minutes. Scan at 90 - 120 minutes. Consider shortening times with small bowel stomas & short bowel lengths (scanning at 45-60 mins or when stoma producing good volume of effluent), or increasing time delay before scanning in ileus	More than 500 mL is usually impractical. 250-500 mL helps reduce risk of patient vomiting contrast and should usually be sufficient.
Large bowel	1000 mL taken over 60 minutes. Scan after 2 - 4 hrs.	Variable results. If the scan is for a *distal* colonic / rectal anastomosis, rectal contrast will probably be more successful and diagnostic.
Rectum or left sided colon (anastomosis assessment) ‡	Depends on height of anastomosis: [47] - Low (rectum to sigmoid) ~ 100-300 mL - High (to splenic flexure) ~ 300-500 mL Injected via 12 Fr rectal catheter. Catheter balloon: generally avoid inflating if recent anastomosis.	*Consider* need for a low dose pre-contrast CT to define anastomosis level if no recent imaging. Consider a repeat topogram after injecting contrast to see

[GG] 1:10 = 1 part contrast to 10 parts water, e.g. 30 mL contrast added to 300 mL water. Make this clear when protocoling CTs to avoid confusion.

	The volumes may seem high, but the purpose is to ensure good distention of bowel to maximise the chance of demonstrating a convincing anastomotic defect. Volumes can be adjusted depending on the anastomosis level. Use of topograms to demonstrate how far contrast has passed can also help rationalise the volume injected.	if contrast has passed beyond level of anastomosis (though it can be hard to appreciate the contrast).
* General dilution of around 1:10, e.g., 50 mL Omnipaque 350 in 500 mL of water. Gastromiro is an alternative but less palatable. Gastrografin is also less palatable, stimulates more diarrhoea, and is unsafe if aspirated.[48] † Note that there is a set dilute small bowel Gastrografin protocol available on Soliton RIS available for the 'CT abdomen and pelvis with IV and oral contrast' study code. ‡ Unless specified, the radiographers will use a rectal contrast regimen of: 3 mL Gastrografin diluted in 60 mL of water (volume may therefore be insufficient for higher anastomoses)		

Regimen to be used should be *clearly* documented on the vetted CT, e.g.

- "50 mL of Omnipaque 350 diluted in 500 mL of water. Patient to have 250-550 mL over 1 hour (orally or via nasogastric tube, volume as tolerated) and scan at 90 minutes."

D. Grading hepatic steatosis at imaging

A summary of *Starekova et al (2021)*[49]

Ultrasound:

- Subjective assessment on B-mode imaging
    - Mild: slight increase in liver reflectivity
    - Moderate: moderately increased liver echogenicity (convincingly brighter compared to the right kidney), slightly impaired visibility of diaphragm and the portal vein wall
    - Severe: significantly increased reflectivity of the liver, poor visualisation of diaphragm and portal vein, beam attenuation resulting in poor visualisation of the deeper right lobe
- Moderately good, but subjective and operator / machine dependant. May also fail in obese patients or those with ascites
- New Ultrasound derived fat fraction techniques have been shown to correlate reasonably well with MRI

CT:

- Can be graded using average Hounsfield values with superior results on unenhanced CT. Can be confounded by beam hardening and increased BMI amongst other factors
- Unenhanced CT:
    - Normal: 64 HU
    - Moderate steatosis: 42 HU
    - A value of 48 HU is highly specific for moderate-to-severe steatosis
- Contrast enhanced CT: less accurate, and should using be attempted in portal venous phase
    - Compare liver and splenic HU values
    - A liver-spleen attenuation difference of -19 HU has been reported as the optimal cut-off for at least 30% steatosis (i.e. liver lower density than spleen)

MRI:

- Proton derived fat fraction (PDFF)
    - Several techniques which make use of chemical shift principle to separate water and fat protons in voxels
    - This allows the proportion of fat within the liver to be expressed as a simple % and correlates well with histology, though is also susceptible to confounders
    - Proton derived fat fraction: Fat / (water + fat)
- Clinically meaningful thresholds for steatosis have not yet been unanimously defined, therefore the authors of this paper suggest:
    - Mild: 5-15%
    - Moderate: 15-25%
    - Severe: > 25%
- Similar thresholds can probably also be justified for Siemens' US derived fat fraction technology, since this has been validated against MRI

E. Imaging the Complex Abdomen

Active bowel disease, repeated operations, and complications all contribute to the complex abdomen. Some patients may be relatively asymptomatic, whereas other will suffer a significant impact to their quality of life with risk of further complications.

The radiologist can add significantly to the surgeon's management plan when deciding on the feasibility of abdominal wall repair, treating ongoing bowel disease, and restoring intestinal continuity.

Surgeons will usually have three main questions for radiology:

- Degree of abdominal wall compromise: herniae, muscle separation and volume loss, safe sites to enter the abdomen
- Intra-abdominal complications and problems: fistulae, collections, adhesions,
- Intestinal mapping: what has been removed, what still remains, what is in- and out-of-circuit, length of remaining bowel, fistulae, quality/function of remaining bowel (e.g. bowel lumen patency/compliance)

i. Abdominal wall defects: [50]

Ventral abdominal wall hernia refers to those arising at the anterolateral abdominal wall. Complex hernias are often defined as those > 10 cm in transverse width.
Repair can be high risk (especially as these are more common in patients who are obese), but they also result in significantly impaired quality of life.

Imaging Techniques:

- Contrast enhanced CT most commonly used ± oral contrast (if there are also questions regarding intestinal anatomy and fistulae)

What to report:

- Hernia:
    - Position: involving the linea alba = midline, otherwise described as 'lateral'
    - Size of hernia abdominal defect:
    - Size of hernia sac in 3 planes: use multiplanar reformats to ensure this is representative
    - Contents of sac: length of bowel if possible and evidence of adhesions

    - Distance of cranial and caudal margins of sac from the xiphisternum and pubis respectively (if midline)
- Complications such as collections
- Loss of domain calculations:
    - How much peritoneal volume is contained within the hernia and needs to be returned into the abdominal cavity. Used to calculate the difficulty of repairing the hernia. Save multiplanar formatted images of the measurements as a reference for others.
    - *Hernia sac volume (HSV) = L x W x H x 0.52*
        - Measure using coronal and sagittal to give the most accurate measurement
    - *Abdominal cavity volume (ACV) = L x W x H x 0.52*
        - Measure the abdominal cavity: anteroposteriorly (anterior vertebral body to anterior abdominal wall) and transverse, and craniocaudal from diaphragm to pubis
        - *Extrapolate position of anterior abdominal wall if needed*
    - *Total peritoneal volume (TPV) = HSV + ACV*
    - *Loss of domain = HSV/TPV; greater than 20% implies difficult closure*
- Rectus diastasis (separation)
    - Separation of the rectus abdominis muscles. No defect in the widened linea alba, but abdominal fat and bowel may protrude anteriorly between the separated muscles
    - Considered diastasis if the gap between the medial aspects of the rectus muscles measures > 2 cm
    - May coexist with herniae, and also increases the risk of hernia recurrence.

Types of abdominal wall repair:

- Onlay: mesh anterior to rectus sheath and/or external oblique
    - Superficial wound infections
- Inlay: mesh between separated rectus muscles
    - Can become detached laterally
- Sublay (retro-rectus): mesh posteriorly to rectus muscle but anterior to its posterior fascia
- Underlay (pre-peritoneal): mesh between the peritoneum and the transversalis fascia
    - Can become detached laterally
- Intraperitoneal: mesh beneath the peritoneum
    - Encourages small bowel adhesions, fistulation, and perforation (as small bowel is in direct contact with mesh)
- Transversus abdominis release (TAR): technique where the posterior abdominal wall musculature is used to create a retromuscular plane. Combined with mesh

ii. Enterocutaneous fistulae and collections

The main complications seen in this context, which can be assessed in a number of ways.

Imaging techniques:

- CT abdomen & pelvis with oral contrast: has largely replaced fluoroscopic fistulograms, as it provides better anatomical localisation of fistulae and is much easier for both patient and radiologist. A sufficient time delay is needed to ensure contrast reaches the suspect area(s)
- Fluoroscopy:
    - Loopograms can assess bowel (typically small bowel) both up and downstream of a stoma to look for fistulae to the abdominal wall.

- Likewise a water contrast enema may help delineate if an entero-colic fistula is present.
- Fistulograms may still have a role in select patients

iii. Intestinal mapping

Imaging techniques:

- CT abdomen & pelvis ± oral contrast: contrast is mainly useful when assessing for fistula, or where it is difficult to delineate bowel in a cachectic patient or following sequalae of operations/sepsis
- FL Loopograms can assess bowel (typically small bowel) both up and downstream of a stoma. Length and patency are the main questions. Does the bowel distend normally with no strictures or fistulae, i.e. any problems that would prevent distal limb feeding or restoration of continuity?
- FL enema: mainly used to assess defunctioned colon (may include a colo-colic anastomosis check) or a blind-ending recto-sigmoid remnant. Checking patency, evidence of strictures, normal bowel compliance / distensibility

Common examinations performed at STM, along with extra notes and useful references

5.1. Fluoroscopy (FL) & Radiography	
Study	**Notes**
Colonic Transit studies	Abdominal film after ingesting radiopaque markers. See the protocol sheet outside STM fluoroscopy room (and below).
Contrast enema	Rectal / colonic anastomotic patency and integrity. Healing following know perforation or anastomotic leak.
Swallow and Meals	Swallows: assess for dysmotility, pouches etc. and occasional leaks for post-op patients Meals: uncommon, but may be appropriate for patients who cannot undergo gastroscopy. Can assess duodenum and duodenojejunal flexure for malrotation and outlet obstruction.
Small bowel follow-through	Dysmotility, features of obstruction (dilatation), angulated and tethered bowel in adhesions.
Loopogram [51]	To assess bowel up/downstream of a loop stoma: strictures or obstruction (that might prevent stoma reversal or cause problems after continuity has been restored), assessing potential for distal feeding, bowel mapping [HH]
Tubogram	Checking PEG / PEJ location and tube patency. Occasionally also cholecystostomy drains (Omnipaque 240 is a better contrast for this, as it is less likely to obscure filling defects due to ductal calculi).
Defecating proctogram [52] [53] [54]	Rectal barium paste (+ oral barium to opacify small bowel in female patients). Ask patient to evacuate whilst taking cine loops to assess for obstructive conditions. Determines if patient will benefit from pelvic floor physiotherapy/biofeedback or surgical treatment.
Pouchogram	Defecating *or* enema variants depending on whether assessing pouch function, or leak/anatomy (see also IPAA).
Fistulogram [55]	Selective canulation of enterocutaneous fistulae and injection of water soluble contrast to assess the anatomy or condition of downstream bowel.
Note: Undiluted gadolinium (Dotarem) *can* be used for loopograms and enemas where there is iodinated contrast allergy, though this is very expensive which limits maximum practical volume	

[HH] Bowel mapping refers to working out what bowel is left, its length, and (to a degree) its condition.

5.1.1 Colonic Transit studies

Indication:
To assess patients with suspected delayed gut transit. Usually patients will describe symptoms of 'constipation' (which is a somewhat subjective diagnosis) and infrequent bowel opening, often with abdominal discomfort as a result.
Although these are called 'colonic transit studies', these studies cannot distinguish between small and large bowel as the cause of delayed transit.

Protocol:
Note: transit study protocols will vary in other institutions and depend on the specific marker manufacturer used.

Patient ingests specific gelatine capsules at home on set days, each containing 10 Polyurethane markers containing 40% barium sulphate (patient takes two of each type). These will show up on XR imaging.

Protocol for colonic transit study		
Day 1	20 markers	Spheres or Cubes
Day 2	20 markers	Rods
Day 3	20 markers	Rings
Day 6	Abdominal radiograph taken for interpretation	

The patient then attends the department for an outpatient abdominal radiograph.
The markers are counted by the reporting radiologist. More than the designated number in any marker group constitutes delayed whole gut transit.

Day 6 radiograph - retained markers to define slow transit		
Day 1 markers	> 4	Spheres or Cubes
Day 2 markers	> 6	Rods
Day 3 markers	> 12	Rings

Reporting:
Describe how many of each of the markers are present and their main distribution within the colon (if possible). For example: "There are 7 day one, 6 day two, and 5 day 3 markers on this day six radiograph".

Note that despite being called a *colonic* transit study, it cannot truly differentiate between delayed small bowel and large bowel transit, and hence it is more accurate to describe delay in *whole gut transit*.

5.1.2. Contrast enema:

Indication:
Generally to check the *patency and integrity* (i.e. strictures and leaks) of a colonic or colo-anal anastomosis, often requested prior to stoma reversal.
Sometimes this test will also be done as part of 'bowel mapping' for patients referred to STM from elsewhere with unclear anatomy.
Other infrequent indications include assessing for healing of prior complicated diverticulitis.

Procedure:

- Foley catheter (16Fr usually) inserted anally
    - For patients who have been defunctioned with a stoma, inserting the catheter may sometimes be quite uncomfortable, but is rarely not tolerated
- Depending on the height of the anastomosis, the catheter should not be advanced too far
    - Avoid going above anastomosis as may opacify this key area of interest more poorly.
    - Whether you inflate the balloon will depend on anastomosis height. Practice sometimes differs between Radiologists and depends on specific clinical scenarios.
    - Inflating the balloon represents a balance between ensuring a good seal and maximising chance that you'll see a leak (as you don't want to cover the point of leak with the balloon).
    - Consider deflating the balloon and taking images as part of your study.
    - You can use tape to further secure the tube or in lieu of inflating the balloon

- Take full exposure 'control' images before starting. You may struggle to see the anastomotic sutures depending on the anastomosis type
    - Correlate with any cross-sectional imaging which may show you the anastomosis, or at least the expected level of anastomosis based on the prior tumour's site if only pre-operative imaging available.(remember to search by DOB for *imported* imaging)
- A dilute mixture of water and Omnipaque is instilled via a gravity fed enema bag by releasing a small sliding clamp across tubing leading to the rectal catheter.
    - Hand injection is also possible, but more time consuming
- Start in the left lateral position and screen dynamically as contrast flows into and through the rectum
    - Look for extra-luminal leak or areas of possible narrowing (can you subsequently capture the possible narrowed segments 'opening up' to prove they're not strictures?)
    - Full exposures can be used (45° obliques, as well as use of cranio-caudal tube angulation) to interrogate areas in more detail
    - Screen in frontal projection (like an abdominal radiograph) to demonstrate that contrast flows upstream towards the stoma (or as proximal as you can follow it)
- If you are having difficulty opacifying the rectum well (e.g. contrast is just passing straight into the more distal colon) try utilising the 'control of contrast speed' suggestions below

Control of contrast speed [II]

- Release the enema bag tubing's clamp halfway for slightly slower contrast flow
- Lower the height of the contrast-filled bag to slow flow rate
- You can also tilt the head of the bed up at the start of the procedure (warn the patient) to reduce contrast flow through the rectum

Post-procedure

- Keep the rectal tube in and place the enema contrast bag at floor level to try and drain as much contrast back out (use the yellow clinical waste box for the bag). Try straightening and bending the tube to improve emptying
- Sometimes contrast will have filled the patient's stoma bag
- Warn the patient that they should sit on the toilet for a bit after the test, as some residual contrast will likely come out rectally (which they may not be expecting)

[II] Contrast can rapidly pass the (usually low/distal) colonic point you want to assess, so it can be helpful to reduce contrast flow (at least initially) to better opacify the area of interest.

5.1.3. Small bowel follow-through:

Indication:
To assess small bowel motility, strictures, adhesions, and fine mucosal detail.

Procedure:

- Patient has 10 ml oral metoclopramide if normal / slow transit
- Barium dilution depends on case type…
    - Non-complex cases / strictures / bowel mapping:
        - 1 pot EZ-Paque diluted up to 65% line [JJ]
        - Split into 2 cups, which are then topped up with water
        - Second cup given as needed
    - When specifically assessing primarily for fine mucosal detail
        - 1 can of Baritop 100, which is split between two cups, each of which is then topped up with water
        - Second cup given as needed

Patient drinks the first cup of barium. Screen at ~ 15 minutes to assess progress.
You can give the second cup when the stomach and proximal small bowel is 'empty' of barium. Ideally you want to time barium ingestion so this second bolus (when combined with the first) creates a continuous 'column' of good opacification throughout the small bowel

- Depending on transit you can bring the patient back every 15-30 mins to screen and assess progress
- You do not need to take full exposures early on unless there are abnormalities for assessment.
    - Screening alone gives useful information on motility/features of obstruction. Save exposures for when better detail is needed to assess specific abnormalities (e.g. terminal ileum)
- Aim for contrast to reach caecum, with use of manual compression here to separate small bowel loops to assess the terminal ileum (though for some indications this will be less important)

The FL machine has a built-in paddle for compression of small bowel to help separate loops.

- Be mindful of how much pressure you're applying and patient discomfort
- Small radiolucent footballs are also available for the patient to lie on whilst prone, where the patient's own weight acts to separate the loops.
- Note that deep pelvic loops can be difficult to separate as the bony pelvis gets in the way

Key parts of the examination:

Looking for adhesions:

- Screening whilst patient is left/right lateral decubitus, collimated to just look at anterior abdominal wall for free movement of small bowel.

Taking exposures:

- Ask the patient to take a breath and hold when screening or taking exposures to optimise quality.

[JJ] EZ-Paque comes in plastic containers containing dry barium. Container has lines on the side showing how much water needs to be added to create a specific dilution (e.g. a 65% dilatation).

- Exposure use should be limited in younger patients, and generally used only when greater image quality is needed.

Look for …

- Motility: contrast see-sawing back and forth with poor progression
- Overall transit time of contrast: great variation, but sometimes progression will be unequivocally slow
    - Normal small bowel transit time to caecum is < 2 hours
- Adhesions: areas where small bowel is kinked or tethered together and doesn't separate.
    - Is small bowel dilated upstream of this point? Does contrast progress poorly beyond the point of abnormality?
- Irregularity of small bowel (especially terminal ileum)
- Contrast where it shouldn't be: has contrast opacified e.g. colon relatively early to suggest fistulation?

5.1.4. Defecating Fluoroscopic Proctogram (sometimes called defecography):

Indication:
Difficulty with defecation and suspect 'obstructive defecatory' conditions.

Pre-procedure:
Speak to the patient, explaining the procedure and potentially exploring the exact symptoms more if needed.

Ask the patient if they have any techniques they use to help evacuation [KK]

- Remember that patients may not volunteer information unless directly asked
    - Anal digitation: either to manually evacuate or to straighten / open the anal canal to allow evacuation to start
    - Vaginal or perineal digitation: may correlate with an anterior rectocele. Pressure applied anteriorly can reduce the effect a rectocele has on normal evacuation
    - Sitting forwards / changing position and excessive straining
- You can provide the patient with gloves and ask if they're happy to demonstrate what they normally do whilst screening. Provides additional useful information for the anorectal physiology team when they see the patient

- Female patients: Oral barium suspension drunk ~ 30 mins before to opacify small bowel
    - To look for enteroceles, which represents small bowel prolapsing into the recto-uterine space (hence not applicable in male patients)
- 100 mL of porridge & barium paste injected rectally. Tell the patient to 'hold onto' the paste until you give the instruction to evacuate
    - Some patients may have marked incontinence to the paste, so just ask them to do their best retaining paste (being sensitive as some patients can find this embarrassing). This itself is diagnostic information.

[KK] Can be helpful to ask this before starting the test, and then ask if the patient is willing to demonstrate if their initial evacuation is poor. Can ask such as: "Some people find they have to sit in a specific position, insert a finger, or push with their hand to help with going to the toilet. Is there anything similar you have to do to help with emptying?"

Image acquisition:

- Patient sits on the commode. Warn them this may move slightly (depending on the type of machine being used)
- Take a full dose exposure control image or low-dose single image in younger patients (useful to compare pre- and post-evacuation)
    - Also in female patients: make sure your control image demonstrates small bowel loops have been opacified by oral barium

- The patient is then asked to evacuate the paste whilst sitting on commode as images are acquired:
    - Low magnification is normally adequate for all images and reduces dose
    - Generally do serial full exposures at 1 frame/second[LL] for the first attempt at evacuation (equates to 20 frames before automatically stopping), and can then use conventional low dose screening to capture any further information.
    - *However* in younger patients strongly consider screening alone (at 3.75 fps) ± *limited* run(s) of serial full exposures (at 1 fps) towards the end of defecation if you think there may be subtle intussusception [MM]
- Patient expected to <u>evacuate ~ 60% of paste in 20 seconds</u> (subjective measurement)
    - Further standard screening acquired at 3.75 fps
    - Ano-rectal junction descent of < 2 cm from the pubococcygeal line (roughly equivalent to the horizontal line on the image where the patient sits) is generally within normal for pelvic floor descent

Common pathologies:

- Pelvic floor weakness: The ano-rectal junction (ARJ) may be low-lying at rest: suggestive of pelvic floor weakness. It should descend < 3.5 cm on defecating (judged from the level of the ischial tuberosity (i.e. from the visible horizontal line visible on images where the patient sits). [56]
    - ARJ may be initially normal at rest, but then descends markedly on evacuation, suggesting weakness only on an increase in intraabdominal pressure
    - If the ARJ is already very low-lying at rest then you may see minimal further descent
- Rectocele: bulging of the rectal wall anteriorly or posteriorly. Can 'trap' stool and prevent effective evacuation as evacuatory force pushing from above forces stool/paste into the reservoir-like rectocele rather than down into the anal canal. An anterior bulge < 2 cm is considered with normal limits.
    - Subjective grading: 2-4 cm mild, 4-6 cm moderate, > 6 cm large
- Enterocele: small bowel descending to cause obstruction, either into the rectovaginal recess, or the posterior peritoneal recess.
    - This is why female patients are given barium to drink before the test to show the position of small bowel, otherwise it is difficult to appreciate an enterocele
- Rectal intussusception and rectal prolapse: abnormal descent of the rectal mucosa into the anal canal, which may physically obstruct evacuation.
    - A spectrum from recto-anal (internal) intussusception to full prolapse of the rectum externally.
    - Descent of mucosa below anal verge is defined as prolapse.

[LL] Don't forget to change the machine setting from spot (single exposure) to serial exposures at 1 fps <u>before</u> asking the patient to evacuate.

[MM] Radiation dose is obviously more significant in younger patients. Full exposures often do not add a huge amount of extra diagnostic information over screening, especially where anismus is suspected.

        - Rectal prolapse can be graded as 'high' or 'low' take off, describing the point at which the rectum begins to abnormally descend (high therefore being more severe)
- Anismus (dyssynergy): functional disorder of prolonged and/or incomplete evacuation. Discoordination of the evacuatory process.
    - Can be seen as failure of puborectalis to relax, anal canal not opening, and a see-sawing of the rectum as the patient attempts to evacuate
- Perineal ballooning: bulging of the perineum several centimetres below the bony outlet of the pelvis during straining

Important to describe how these pathologies actually affect evacuation (e.g. does the rectocele empty fully or 'trap' barium, or does the intussusception prevent effective emptying?)

5.1.5. Loopogram:

Indication:

The exact procedure will rely on the clinical question.

- Assessing the upstream limb of the stoma:
    - Problems with stoma: any stenoses or adhesions?
- Assessing the downstream limb of the stoma
    - Defunctioned small bowel of any cause (e.g. previous Crohn's flare): condition of the downstream small bowel. Could the patient's stoma be safely reversed? Any fistulae?
    - Potentially for distal feeding: Sometimes the downstream limb will be cannulated and enteral feeding used. Any strictures or obstruction which would prevent this working?
    - Defunctioned ileoanal pouch: Is the small bowel downstream of the stoma in good enough condition to reverse the stoma and put the pouch back 'in circuit'?
- Upstream and/or downstream limbs of stoma:
    - Bowel mapping: Confirming what length of bowel is left and its quality

Key questions to answer: strictures, adhesions, features of obstruction, extraluminal contrast leak, fistulous tracts.

Procedure:

For a defunctioned ileostomy loopogram:

- First check the patient has spare stoma bags
    - May need a bag change if bag is very full before starting, and also a clean bag at the end
- Cut a linear or cross-shaped hole in the stoma bag's clear plastic window to reach the stoma itself (depending on how easy it is to visualise the stoma)
    - Clean the area with gauze swabs so you can see the stoma orifices. You may also need suction (possibly several times) to remove stoma output if this obscures your view

- Identify the two distinct orifices and work out which limb you need to assess:
    - Afferent leads upstream/retrograde (to the 'in-circuit' bowel)
        - Should produce effulent (check with patient which is the 'active' orifice)
    - Efferent leads downstream/antegrade (to the 'out-of-circuit' or defunctioned bowel)
        - Often subtle. May need to gently explore to find the small orifice

- Once you've worked out which limb you need (most often efferent limb):
    - Cannulate with a Foley (16Fr usually produces good seal, though a 14Fr or even 12Fr may be required), and advance ~ 5-10 cm gently
    - If the catheter does not advance easily then try flattening it out and gently advancing horizontally at different angles. It should be obvious when you're going in the right direction, as the tube will advance smoothly.
    - Do not let go as the tube may slip back
    - Inflate catheter balloon gently as tolerated (often no more than 6 mL), and pull back to check seal
    - Inject undiluted Omnipaque 350 via a bladder syringe whilst screening in frontal projection, saving still images sequentially so you can follow the progress
- Full exposures can be used with frontal as well as 45 degree left and right obliques to better delineate small bowel and also allow calibrated measurements of bowel length
    - Save cine loops to demonstrate peristalsis or motility issues
- Depending on anatomy and the clinical question aim to reach: the ileocaecal valve & caecum, ileo-colic anastomosis & proximal colon, or ileo-anal pouch.
    - If you can't opacify the limb fully then you *may* also need to do a conventional retrograde enema so that you can assess the full length of bowel
    - If assessing a pouch, look for 'compliance' (does the pouch fill/distend properly or does its volume stay fixed?) and for any points of narrowing (are they seen to 'open', or do they stay fixed suggesting stricture?)
- Once done, cover the hole in the stoma bag with a square piece of 'sleek' tape (avoiding sticking it to the stoma itself).
    - This just needs to create a seal so the patient can change their stoma bag outside

5.1.6. Pouchogram:

Indication:
Type of study depends on the history and question…

a) Defecating pouchogram: for patients with deterioration in pouch function (prolonged and difficult emptying etc.)

- Injection of 100 mL of barium Baritop 100 liquid (2 x 50 mL syringes), then 50 mL of barium paste rectally
    - Essentially the same as a defecating proctogram, though these are harder to interpret as a less common study with post-surgical anatomy. Also less consensus on what constitutes 'normal' in this group
    - Furthermore most studies will almost certainly demonstrate a degree of abnormality

b) Pouchogram enema: concern regarding pouch leak

- Essentially the same as a water-soluble contrast enema
    - See the water soluble contrast enema section above, as there is a lot of overlap with technique
- Leaks may be very subtle, often at the level of anastomosis and most often posterior. Correlation with prior cross-sectional imaging can be very helpful
- Indication:
    - Contrast leak: often at the pouch-anal anastomosis and posterior
    - Pouch morphology and distention: any kinking or tethering?
    - Upstream small bowel: dilatation to suggest obstruction?

5.1.7 Fistulogram:

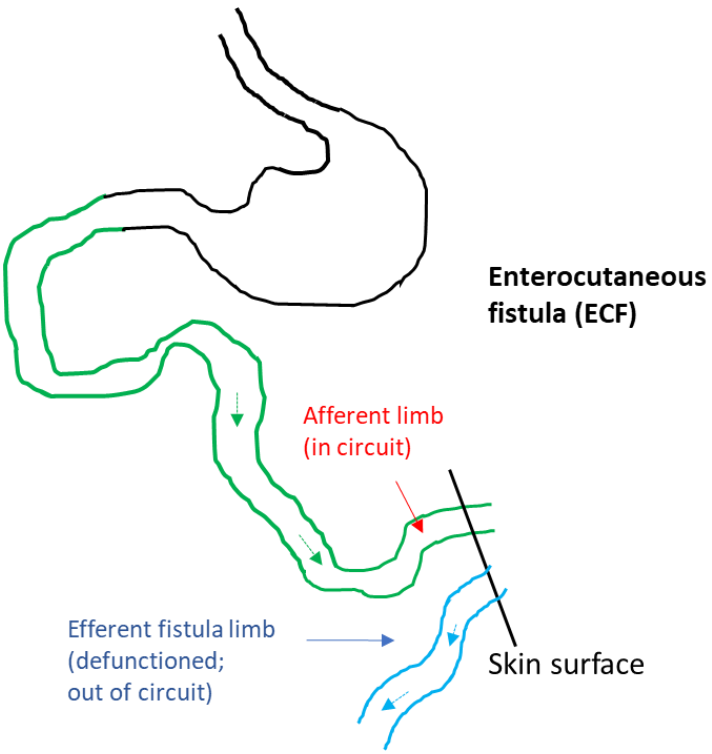
Indication:
Generally utilised for the assessment of enterocutaneous fistulae, potentially multiple for the same patient.

- See loopogram above, as there are many similarities with technique

Background:
Enterocutaneous fistulae (ECF) may arise due to many clinical scenarios including Crohn's disease, complications related to previous interventions (including radiotherapy), and malignancy.
The complexity can vary in terms of the number of small bowel loops involved, output volume, and the degree of intestinal impairment.

Note that enterocutaneous fistula may sometimes be used as a synonym for any bowel fistula, and a patient labelled with ECF may in fact have a colocutaneous fistula.

- This may arise due to 'relaxed' (and strictly incorrect) use of terminology or where the anatomy is so complex that this is understandable
- A fistula may of course involve both small and large bowel, as well as other structures (e.g. bladder and vagina), and it is important to convey this to the treating team



Preparation:

- Make sure to review any prior cross-sectional imaging to form an impression of the underlying anatomy (anything available on searching under the patient's DOB?)
- Confirm which external openings the team would like to be evaluated
    - Sometimes the question will be broader, e.g. "can you please confirm if these external openings communicate to small bowel , and if so which ones?"
- Speak to the patient: they will often be able to tell you where the openings are and which are active

    - The anatomy is often much like a defunctioning loop stoma: 'active' opening (the upstream / afferent limb) and 'inactive' (leading to downstream / efferent small bowel)
- Gain access to the fistula
    - Often covered with a large stoma bag or wound management device. As per loopogram (see above) carefully cut a cross in the clear plastic
    - Check spare bag available and also tape to cover the stoma bag defect at the end of your study
- Confirm the openings and which you need to cannulate
    - You may need to improve the lighting to see small efferent openings. Look for peristalsis and gently probe the area
    - Sometimes entire tubular segments of small bowel will be externalised rather than just an external opening

Procedure:

- Cannulate the opening:
    - Use jelly and the largest possible Foley catheter, at least a 10 Fr ideally
    - The smallest is 8 Fr, but this is quite 'bendy' and doesn't have much rigidity
    - Do not use needles or rigid catheters (risk of creating a false passage). A fistula which can be successfully cannulated should be accessible with a Foley catheter
- How do I actually insert the Foley? The tube doesn't seem to want to go in.
    - Gently probe around the opening and try advancing the Foley gently.
    - You may need to advance at a relatively flat or steep angle, so try different angles of approach around the entire circumference of the opening
    - Do not force the Foley. If you are in the right place you should be able to advance without significant resistance. You may however feel the tube being pushed back, so it is useful to have tape ready to stick the tube down
    - Once in place inflate the catheter balloon with a few mL of water to hold in place
- Begin hand injecting water soluble contrast (e.g. Omnipaque) whilst screening
    - There should be minimal resistance, though this will partly reflect the catheter size. Firm pressure may be needed, but be gentle for the initial injection until you have a 'feel' for how the contrast is progressing
- Take low dose cine loops and save the useful ones that show contrast progressing
    - Saving single images rather than loops is also reasonable, as long as the gaps in between aren't too great since you want to be able to estimate the bowel length which becomes harder with limited information and overlapping bowel loops
    - At least a few dynamic cine loops should be saved, as these demonstrate bowel motility and how contrast progresses. Selective loops can help document adhesions, strictures, and distortion
    - Full dose exposures may be appropriate, but be mindful of accumulated dose and patient age. Ask yourself what the exposure is going to provide over low dose screening. The main use is in clarifying an abnormality
    - Most images will be acquired with the patient supine, but turning the patient for oblique or even lateral projections can be helpful to separate overlying loops. A lateral view can help demonstrate adhesions at the anterior abdominal wall

5.2. Ultrasound	
Study	**Notes**
Endoanal [57] [58] [59] [60]	Assessment of incontinence and obstetric sphincter injury
Endorectal ± biopsy	Staging or further assessment of rectal lesions (can differentiate T1-T2 cancers seen on MRI and assess suitability for endoluminal resection)
Elastography (liver) [61]	Shear wave elastography to assess for fibrosis in the context of viral hepatitis, alcoholic liver disease, NAFLD/NASH. See also above: 'Imaging of hepatic steatosis'
Small bowel (SBUS) [62]	IBD (more established for use in Crohn's than Ulcerative colitis). Very useful for follow-up of known disease, in children, and those who cannot tolerate CT/MR or bowel prep. SBUS should not be thought of as an inferior examination to MRI or CT, and is a powerful tool when used by well-trained operators.
Contrast enhanced ultrasound (CEUS) [63] [64]	Microbubble intravenous contrast, licensed for use in hepatobiliary and renal pathology, but can also be used off label. From the GI perspective it is mainly used to characterise incidental focal liver lesions, as an alternative action where CT/MR are not feasible, or as a tie-breaker test when there remains diagnostic uncertainty.

5.2.1. Endoanal US (EAUS):[NN]

A. Technical Aspects of Image Acquisition

i) Equipment:
Transducers come in several forms:

- a mechanical sector model where the crystal rotates 360 degrees to create a radial transverse image
- a linear array transducer which forms a coronal or sagittal image (including obliques), depending on how tit is rotated
- a radial electronic array

All types of transducer can create 3D images, either by the crystal physically moving inside the transducer housing (taking multiple axial images), the transducer being withdrawn during image capture (again taking multiple axial images), or by the linear transducer rotating (reconstructs the 3D image from coronal/sagittal planes).
Regardless of the method, the resultant 3D images are the same.

ii) Preparation: Patient position and consent

- Explain the procedure will involve inserting an ultrasound probe into the anal canal, and they may feel some buzzing/vibration which is how the probe takes pictures, and that you will be gradually withdrawing the probe
- Confirm the patient does not have a latex allergy

[NN] Any reference by Clive Bartram is a useful resource given his extensive work on EAUS.
The 'Handbook of endoanal ultrasound' is available at the NPH John Squire library [shelf: WI600 BAR]

- Latex free probe covers can be used instead. These can be a bit more fiddly to use, but do not alter the image quality assuming they are used correctly

- Positioning:
  - Prone: for female patients (unless not feasible). Easier to keep transducer centred at 12 o'clock and creates less distortion of anal canal than a decubitus position
  - Left decubitus far more comfortable for pregnant patients, patients with stomas, or when lying prone is not feasible or comfortable. May be the preferred position by some operators for male patients.
- The distal aspect of the trasnducer should be covered with ultrasound gel and a probe cover applied.
  - Aim for an even circumferential coating of gel without large blobs of gel in order to minimise air bubbles and improve contact.
  - This will minimise reverberation artefacts from air between the probe and probe cover.
  - Gel is then applied to the probe cover externally

iii) Holding the probe, scanning technique, and obtaining images:

- STM currently uses a *BK Specto* machine. Make sure machine is set to the Endoanal setting.
- Aim to acquire images that match the orientation of an MRI (i.e. anterior canal would be 12 o'clock on the screen)
- The marker on the probe (a vertical line |) represents the anterior 12 o'clock position when scanning. This should therefore point towards the *floor* when scanning patients in the *prone* position so that 12 o'clock is shown at the top of the screen. [OO]
  - Ensure depth scale set to 2.5 cm (can use greater depths for problem solving, e.g. to assess the extent of an abscess)
- Gently insert the probe ~ 4 cm to reach the anorectal junction
  - If you have the probe active during this time you can watch on the screen for landmarks to make sure you do not 'overshoot' the puborectalis muscle into the rectum – easily done in patients with a short anal canal
  - You can tell you are at the level of the rectum as you will get artefact due to loss of probe contact with the bowel wall
- Acquiring images:
  - Start by obtaining 2D images from the level of the sling-like puborectalis muscle
  - There are 3 essential levels where images need to be obtained:
    - Upper canal at the level of puborectalis
    - Mid canal where both the internal and external sphincters should be seen at complete rings. This is also the level where the internal sphincter thickness should be measured at 3 or 9 o'clock position
    - Lower canal: Just below the internal sphincter, where only the subcutaneous external sphincter is seen
  - Once these have been taken, return to the level of puborectalis and obtain a 3D 'cube' volume as below
    - Note: if the patient is tolerating the examination poorly, start by taking the 3D image rather than 2D images, as this may be all you can feasibly get

Acquiring 3D 'cube' images (can be conceptualised similarly to a thin slice CT volume)

- Hold the transducer steady at the level of puborectalis and press the 3D button and 'acquire'

[OO] If scanning in the lithotomy position (e.g. in theatre) then the line should point upwards towards the ceiling.

- The rotating crystal then gradually moves down inside the probe housing (away from the patient) to acquire sequential axial images.
    - These are then reconstructed into a cubic volume which can be further manipulated on the US machine
- Keep the transducer as still as possible whilst it acquires the volume. It can be stopped early, e.g. if short anal canal
    - The cube data can be reviewed and manipulated (sectioned and reformatted) on the machine
        - Can be helpful to create coronal and sagittal images with length measurements
    - The cube is *not* sent to PACS, but the raw axial images are, which will appear as a scrollable stack of ~800 images
    - Separate software can also be used to manipulate the cubic data, e.g. in MDTs when not at the BK ultrasound machine

B. Anatomy and Interpretation of images

i) Anal canal anatomy and gender differences

- Anal canal length:
    - Measured from the level of puborectalis to the caudal margin of the subcutaneous external sphincter
    - The anal canal is longer in males than females
    - Puborectalis length is the same, but occupies a greater proportion of the canal length

- External anal sphincter (EAS):
    - In men the EAS is cylindrical and occupies the whole canal
        - An anatomical pane of fat is appreciable between the EAS and the transverse perinei muscles
    - In women the EAS is appears deficient ventrally within the upper canal (an incomplete ring), with a physiological gap extending from puborectalis to the EAS in the middle canal level. [65]
        - Moving the probe distally shows the lateral aspects of the EAS coming together anteriorly to form a complete ring, just below the superficial transverse perinei muscles which are seen in the 11 and 1 o'clock positions (mid canal level)
        - The length of this gap varies, and should not be mistaken for a sphincter injury
        - In women, EAS fibres fuse with the transverse perinei and there is no anatomical plane (unlike in males)
    - Differentiating the anatomical gap from an EAS injury
        - An anatomical gap is seen as low reflectivity with smooth, regular margins
        - A sphincter defect is seen as mixed reflectivity with irregular margins

- Internal anal sphincter (IAS)
    - Effectively the same between men and women
    - Thickness measurements should be taken at mid canal level (3 and 9 o'clock positions)

Normal ranges for internal sphincter thickness

Width directly correlates with age but *not* with other factors • < 55 yo: 1-2.5 mm normal • > 55 yo: 2.5-3.5 mm normal • 70 yo: up to 4.5 mm may be normal, but > 4 mm is often taken as abnormal in any age
See Williams A et al. (2000)

ii) Sonographic appearances of the anal canal

Like the rest of the gastrointestinal tract, the anal canal is made up of distinct stratified layers of differing reflectivity. From inner to outer:

1. Interface between transducer and mucosal surface (hyperechoic)
2. Subepithelial tissue (moderately reflective)
3. Internal anal sphincter [IAS] (hypoechoic); smooth muscle
    a. Superiorly it merges with the rectal circular muscle
    b. Does not appear entirely uniform
    c. Becomes more echogenic with age
4. Longitudinal muscle (moderately echogenic); smooth muscle
    a. Variable thickness and conspicuity
    b. Joins with the levator ani into the intersphincteric plane to form the conjoined longitudinal layer, which extends to the perineal skin
5. External anal sphincter [EAS] (echogenic and striated pattern); skeletal muscle. Has 3 parts, and importantly differs in females where the EAS' ring is incomplete anteriorly within the upper canal (see above):
    a. Deep part: is integrated with the sling-like puborectalis.
    Anterior fibres joining the deep transverse perinei.
    (Puborectalis merge with the levator ani cranially and fixes the anal canal to the inner aspect of the pelvis.)
    b. Superficial: Broad attachment to the coccyx posteriorly via the anococcygeal ligament.
    Merges anteriorly with the superficial transverse perinei.
    c. Subcutaneous: Lies below the termination of the IAS

C. Pathology Assessment

Pathological processes can generally be split into the following groups

1. Internal sphincter:

- Too thin or echogenic
    - Primary degeneration: sphincter intact but generally thinned
        - Considerable variation in the sphincter with age
        - Suspect when it measures < 2 mm in a patient > 50 years old
- Too thick
    - Solitary rectal ulcer syndrome, recurrent straining or prolapse: sphincter 3.5-4.5 mm
    - Can be asymmetrical
    - > 4 mm should be considered abnormal, regardless of age
- Deficient:

- Following trauma (obstetric, sphincterotomy, haemorrhoidectomy etc.). May see a wide 'gaping' defect with retraction and bunching of the sphincter [PP]
- Note that obstetric injury can uncommonly result in an isolated internal sphincter injury (mechanism thought to be due to high pressures)

2. External sphincter:

- Obstetric trauma (OASIS; *Obstetric anal sphincter injuries*)
  - Most commonly seen at the level of the perineal body
  - Trauma suggested by asymmetry at the formation of the anterior ring, which may also involve the internal sphincter
- Grading of injuries:
  - 1st degree: Perineal skin injury only (may need suture repair)
  - 2nd degree: Perineal muscle injury, but not involving anal sphincter (usually needs suture repair)
  - 3rd degree: subdivided (all need surgical repair)
    - 3a: < 50% of external anal sphincter
    - 3b: > 50% of external anal sphincter
    - 3c: Injury to both external and internal anal sphincters
  - 4th degree: as 3c, but also involves anal mucosa (surgical repair)

- Can be far harder to delineate, and the 3D images can be very helpful for this, as scrolling though the axial images 'dynamically' makes it easier to appreciate abnormalities
  - If there is a clear internal sphincter injury in suspected obstetric injury, then it is likely there will also be a corresponding external sphincter injury in a similar distribution

- Assessing and quantifying the size of defects:

- The sphincters can be divided up like a clockface when viewed axially and described in terms of 'hours' of defect, so each hour = 30 degrees
  - Scarring < 30° is *generally* less likely to be of clinical significance
  - For example, a tear extending from 11-2 o'clock is a tear of 90°
  - Measuring in degrees on PACS: use the circle annotation tool and create a circle the same size as the transducer/anal canal on the image. The centre of ROI circle will have a dot, and from here you can use the angle tool to measure the extent of scarring / defect accurately

- Measuring the anal canal and sphincters[66]:

- Measurements can be made after manipulating the cube 'volume' on the BK ultrasound machine
- Start by looking at the 'axial' images …
  - Trim the cube's cranial aspect to begin at the level of the puborectalis to define the upper limit of the anal canal
  - Trim the cube's caudal aspect to where the hyperechoic subcutaneous portion of the external sphincter ends
  - Rotate the cube to give a 'sagittal' equivalent view, and then scroll through the side of the cube to give a sagittal cutaway.
- Anal canal length derived by: measuring the sagittal cranial to caudal length (from puborectalis to caudal aspect of the subcutaneous external sphincter

[PP] Internal sphincter can be thought of as a taut rubber band. When cut it will retract and bunch up, usually posteriorly since most injuries are anterior

- Internal sphincter length derived by: Measuring from the cranial aspect (puborectalis) to the caudal aspect of the hypoechoic internal sphincter

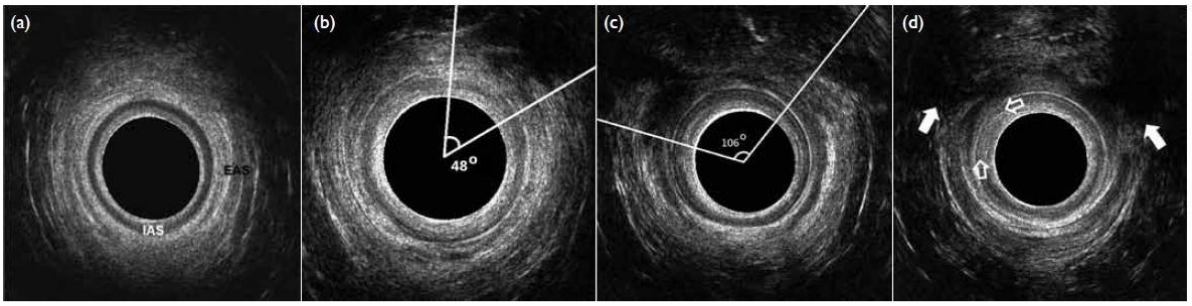


FIG. (a) Endoanal ultrasound of a 34-year-old woman after normal vaginal delivery. She was asymptomatic of anal incontinence. There was a complete hypoechoic ring (IAS) and mixed echogenic ring (EAS), signifying intact IAS and EAS with no OASIS. (b) Endoanal ultrasound of a 34-year-old woman after vacuum extraction. She was asymptomatic of anal incontinence. There was a hypoechoic defect of 48 degrees in the EAS involving less than half of the thickness of the EAS, indicating an occult partial-thickness EAS injury. The IAS was intact. (c) Endoanal ultrasound of a 29-year-old woman after vacuum extraction. She was diagnosed with a third degree (grade 3a) tear with repair done after delivery. A hypoechoic area in the EAS was present from 9 to 2 o'clock region (106 degrees) spanning the full thickness of the EAS; while the IAS was intact. She did not have symptoms of anal incontinence. (d) Endoanal ultrasound of a 30-year-old woman after normal vaginal delivery with occult anal sphincter injury. There was a hypoechogenic area at 10 to 2 o'clock region (between solid arrows) involving full thickness of the EAS and a discontinuity in the hypoechoic ring which was the IAS at 9 to 11 o'clock (between arrow outlines), signifying both EAS and IAS injury. She was asymptomatic of anal incontinence
Abbreviations: EAS = external anal sphincter; IAS = internal anal sphincter; OASIS = obstetric anal sphincter injury

Examples of progressively severe sphincter injuries - Image and text from *S P K Kwok et al (2019)*[67]

5.2.2. Liver US Elastography (pSWE / pulse shear wave elastography):

St Mark's currently performs elastography with Siemens ultrasound Point shear wave elastography (pSWE), making use of acoustic radiation force impulses (ARFI)

- A full liver US is usually conducted along with abdomen & pelvis, though may not be needed if there has been a good quality recent US Liver.[QQ]
    - Make sure to save some views of the liver edge utilising a medium frequency linear transducer for higher resolution (assessing wavy / nodular edge)
    - Avoid calling the liver 'cirrhotic' without additional clinical information, as this is a histological diagnosis rather than a sonographic finding. If there is documented biopsy proven cirrhosis then it is more correct to describe as 'B-mode appearances consistent with known cirrhosis', otherwise can describe as 'features consistent with chronic liver disease'
    - That said, elastography readings elevated into the Metavir F4 range do correlate to advanced fibrosis and histologically proven fibrosis in the correct clinical context
        - Remember than inflammation may raise values, so it is important to try and perform elastography in a non-acute setting

- Check that the patient is correctly fasted.
    - A collapsed gallbladder should be a reminder to specifically ask the patient when they last ate or drank
    - Elastography readings may be elevated in the non-fasted state
- Patient positioned with right arm above head and supine or slight 30° left decubitus to increase intercostal acoustic window
    - At least 10 good measurements (i.e. not invalid X.XX readings or artificially high due to rib shadowing artefact) during quiet breath hold,[RR] 2 cm below capsule with ROI marker away from vessels / bile ducts, and perpendicular to capsule
    - However breath holds are probably not as important with modern machines. Taking readings during gentle breathing may make it harder to obtain a reading, but those that you do obtain are comparable to those taken during a breath hold. [68]

- How good are my readings for this patient? Are they adequate?

Adequacy criteria for Siemens ARFI:

- Taking at least 10 readings is good practice
- You can also sample additional liver sites (change the machine setting to 'site 2' and then take another 10 readings from a different area) if there is doubt about the readings.
- Taking additional readings when fibrosis is suspected can be helpful to ensure a good data set, since elevated readings will inherently give a wider standard deviation
    - Note: Updated versions of the Siemens US machines are able to record up to 15 elastography readings from a single large 'region of interest', rather than taking multiple individual readings (auto point shear wave elastography)
    - They can also provide an 'Ultrasound Derived Fat Fraction' to objectively grade hepatic steatosis (< 5% is normal)
- The *Median* result is used for grading fibrosis

[QQ] The B-mode appearances of the liver are important clues to underlying chronic liver disease, for example liver reflectivity + echotexture, contour irregularity, and ascites.
Likewise pulse wave/spectral assessment of the portal vein, portosystemic shunts, and splenomegaly can suggest portal hypertension, which is an important clinical finding and often underreported on imaging.
That said, unlikely that there will have been significant interval change if the last US was within 6 months.

[RR] Explain to the patient this is different from taking a deep breath in, and you just want them to stop breathing when you ask. You can usually take 3-4 readings from one breath hold, but be mindful that long breath holds can be uncomfortable, particularly for patients with coexisting respiratory conditions.

- The IQR/median value is used to determine adequacy of results:
    - Using the C51 transducer: < 0.30 kPa (0.15 m/s)
    - Using the auto pSWE with DAX transducer: < 0.60 kPa (0.3 m/s)

- Template report for reporting Elastography studies:
    - Type 'elastlite' then press F8 to insert the template

Suggested Technique	Comments
Fasting for 4–6 hours	The normal liver is very compliant, so a nonfasting patient with a normal liver will likely have normal elastography findings. However, the fibrotic liver is less compliant and in the nonfasting state can have falsely increased elastography values. Six hours of fasting is likely longer than necessary but corresponds to what we typically ask for when scanning the gallbladder. Four hours is likely sufficient.
Specific positioning	Supine or slight (30°) left lateral decubitus position
Right arm elevated above the head	Improves intercostal access
Shallow breath hold	The patient only needs to hold his or her breath for a few seconds; it may be helpful to practice the breath hold with the patient prior to initiating elastography; obtaining a measurement in deep inspiration or with a Valsalva maneuver can give inaccurate measurements
ROI placement in the right lobe of liver (typically segment VII or VIII) about 2 cm beneath the Glisson capsule, perpendicular to the liver capsule	Use intercostal transducer placement; avoid reverberation artifacts; avoid increased subcapsular stiffness (1.5 cm); the transducer-specified lens focus is typically about 4–5 cm below the transducer, thus best measurements are in this region; maintain the ARFI pulse perpendicular to the liver capsule; find a location with best B-mode image without shadowing
ROI placement to avoid large liver vessels and/or bile ducts and rib shadows	The ROI actually extends 1 cm above and below the in-plane ROI, so check the liver in these areas prior to initiating the elastography measurement for large vessels and focal lesions
Acquisition of measurements	Ten measurements obtained in the same location

Causes of unreliable readings:

- Operator technique and incorrect sampling
- Technical factors: beam attenuation for example, which may require changing transducer frequency
- Patient factors: obesity and poor views when sampling (poor B-mode views mean likely poor elastography results)
- Sampling error: fibrosis may not be homogenous within the liver
- Coexisting liver disease: acute inflammation or steatosis in particular

NAFLD score, Fibroscan, and Elastography score:

- Relation between Fibroscan and Elastrography:

TE (Transient Elastography) - *Fibroscan* is a proprietary technology using non-invasive *mechanical* shear waves through the liver to calculate liver stiffness as an approximation for liver fibrosis

- Readings are given from F0-F4 (from kPa readings) to grade the severity of liver disease
    - Non-guided (unlike an ultrasound elastography which allows image guidance), and generally used by Gastroenterologists in the clinic setting
    - Not suitable for patients with raised BMI or ascites
    - Cannot perform a conventional US examination

Shear wave elastography - Describes the general technique of utilising *sound waves* to calculate liver stiffness and derive fibrosis. The exact technique depends on the individual vendor, but ARFI (acoustic radiation force impulse) is the most studied.

- Readings are given as velocity (m/s) and elasticity (kPa)
    - Comes as an 'extra' on conventional ultrasound machines
    - Multiple implications with varying degrees of literature, including liver, thyroid, and even small bowel in Crohn's (assessing stricture fibrosis)

Readings between Fibroscan and US Elastography are comparable (see the elastlite template we use, which shows equivalents and how they relate to the Metavir fibrosis score).

- NAFLD score: [69]
    - Non-invasive score derived from multiple variables which predicts risk of advanced cirrhosis, reducing the need for biopsy.
    - Patients with a reading < -1.455 are unlikely to have advanced cirrhosis (negative predictive value of ~90%)

The clinical NAFLD score has been correlated to readings from Fibroscan and forms part of out referral criteria for elastography requests

NAFLD fibrosis score	**Correlated fibrosis severity on Fibroscan**
< -1.455	F0-F2
-1.455 to 0.675	Indeterminate score / fibrosis
> 0.675	F3-F4

How does point Shear Wave Elastography (pSWE) work? [70]
ARFI (acoustic radiation force impulse) is used to distort tissue

- These impulses are short duration sound pulses travelling along the main US beam.

As the main beam interacts with tissues, *shear waves* are created perpendicular to this and cause transient displacement of tissue (dependent on how 'elastic' the tissue is).

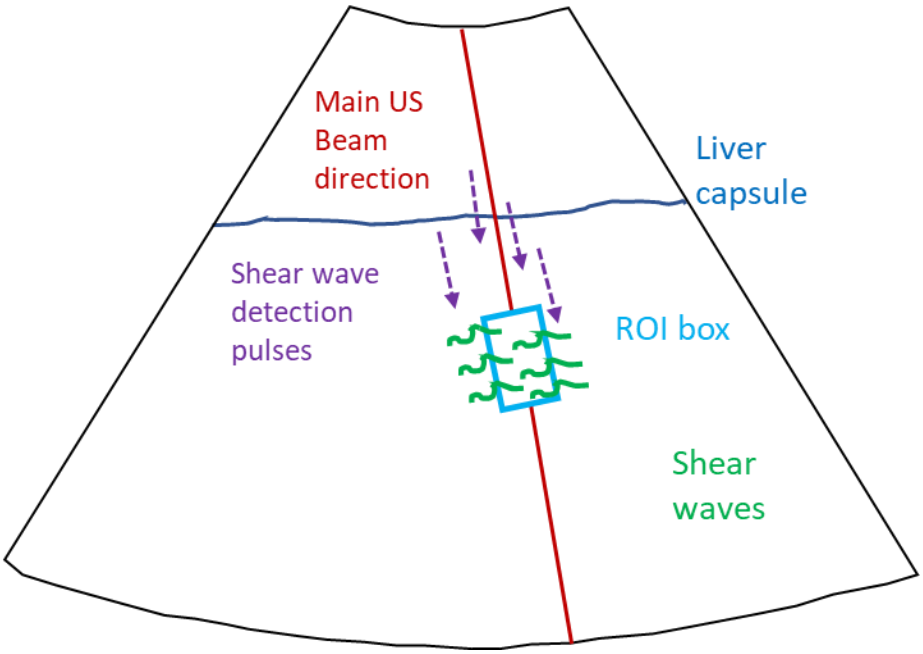
- When a *shearing force* is exerted on an elastic medium shear waves are generated.
    - These are *secondary waves* that propagate in the transverse plane (i.e. perpendicular) to the main *shearing* force direction
    - In ultrasound the acoustic impulses act as the main shearing force to generate the shear waves.

The shear waves are tracked within a region of interest (ROI) using sound waves parallel to the main beam, and an estimate of their speed of propagation is derived.

- Shear waves can only travel a short distance before being attenuated, which is why only a small ROI box is used to collect information about the tissue response (shear wave velocity).

Shear wave velocity (SWV) is mathematically proportional to the 'shear modulus' (a measure of how stiff / elastic a given material is).

- Sound travels faster in a stiffer / less elastic medium, such as a fibrotic liver.
- SWV therefore can be used to grade the severity of liver fibrosis.


Main US
Beam
direction
Liver
capsule
Shear wave
detection
pulses
ROI box
Shear
waves

Radiology referral guidelines for Elastography to LNWUH *(correct as of this STM guide version)*
Referrals from Hepatology, Gastroenterology and Infectious Disease only

New diagnoses/referrals
Hepatitis B and C
Autoimmune Hepatitis
Fatty liver

- Needs existing imaging at LNWUH showing fatty liver
- Needs NAFLD fibrosis score > -1.455 (filters out those who are unlikely to have fibrosis)

Other diagnoses

- US liver to have been done already
- Deranged LFTs over 3 months
- Liver screen done

Surveillance
Hepatitis B

- On treatment, 3 yearly interval elastography
- 2 years at discretion of consultant with rationale documented on request

Hepatitis C

- 1 year after treatment
- If no fibrosis, discharge
- If fibrosis, consider biopsy, otherwise 3 yearly interval elastography

Fatty liver

- If initial elastography abnormal, consider biopsy vs 3 year interval elastography
- If initial elastography normal, not further elastography indicated unless repeat NAFLD fibrosis score becomes abnormal.

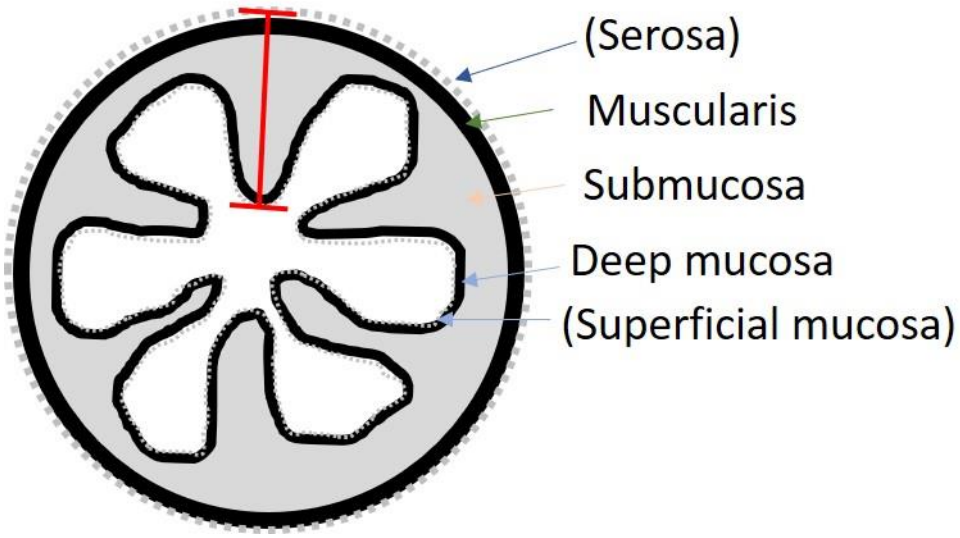
Autoimmune Hepatitis

- At Consultant discretion, but 2-3 year interval as a guide

Other diagnoses

- Only if significant deterioration

5.2.3. Small bowel US:



Bowel wall visible as 5 alternating distinct hyper- and hypo-echoic layers.
Note that a similar pattern is present in all bowel such as oesophagus, stomach, small bowel, and colon. This is characteristic mural stratification is sometimes referred to as 'bowel/gut signature'.

Note: The bracketed layers in diagram are not always visible as distinct layers at US.
Transverse single wall measurement represented by the red line (normal < 3 mm)

- 3 mm is fairly universally taken as a sensible threshold for calling abnormal small bowel
- This may however vary depending on degree of peristalsis and distention, as well as how exactly the measurement is taken
- Genuine wall thickening should be fairly circumferential and remain fixed and reproducible throughout an examination

i. Technique:

Start by finding the right colon and the caecum using a combination of longitudinal and transverse scanning. From here you can identify the terminal ileum. Trace small bowel upstream as far as possible. [71]

- Some operators may start by locating the stomach and the transverse colon, and from here confirming the position of the right and left colon (i.e. has there been previous colectomy to alter the anatomy?)
- The terminal ileum can be challenging to locate, and use of any prior cross-sectional imaging can help improve confidence as to it's location:
    -
- The remaining small bowel can be assessed utilising a 'mowing the lawn' approach to ensure that as much of the bowel is reviewed as possible
    - Graded compression is used to move bowel gas and also maximise chance of visualising bowel in the dorsal abdomen

Specifically tracing and evaluating the rest of the remaining colon is useful for a few reasons:

- Firstly, colon may show evidence of disease (be it Crohn's or ulcerative colitis)
- It can also be confused with diseased small bowel, so confirming where colon lies can improve overall confidence in the remaining examination

- The rectum can be hard to see:
    - Make use of a curvilinear transducer, and consider asking the patient to empty their bladder
- The splenic flexure can likewise be difficult:
    - Try using a posterior intercostal approach as if you were looking for the spleen, and the splenic flexure can usually be found. Try asking the patient to take a breath in

Use a mixture of probes:

- Curvilinear 2-5 MHz: overall assessment of the bowel
- Linear medium and high frequency: more focused assessment of the bowel wall thickness
    - A transducer with a frequency > 5 mHz is needed for accurate bowel wall measurement. This is usually a linear transducer with a frequency of ~ 9 mHz
- A mixture of transducers and frequencies should be used to ensure a good balance between accurate measurement and sufficient depth penetration
    - Most of the examination can be conducted with a medium frequency range transducer, with a high frequency transducer used for focused evaluation of segments
    - The curvilinear can be used to find the rectum and look at small bowel loops diving deep into the pelvis

ii. Intestinal Assessment

Comment on:

- Length and position of disease (small and large bowel)
- Mural thickening measurement
- Mesenteric fat:
    - Fat hypertrophy and fat wrapping (near circumferential fat hypertrophy)
- Colour Doppler signal:
    - Increased vascularity allows some functional comment on disease activity
    - Likely active disease if bowel wall thickening is also present
- Degree of peristalsis
    - Reduced in disease (active and chronic)
- Obvious upstream small bowel dilatation suggesting an obstructive element
    - Speak to the patient: do they get obstructive symptoms and if so when? Where do they get pain and does it correlate to the area(s) of disease?
- Change from previous studies
    - See below, but in short check if they are on any treatment
    - Do they meet threshold for treatment response, or have things worsened?
    - Can be difficult if no prior SBUS for comparison, but make use of any prior CT/MR, and try and provide comment (without over-reading the images)

Features of disease:

- Bowel wall
    - Total wall thickness: correlates to acute inflammation (more so than chronic inflammation and fibrosis)
    - Mucosa thickness: correlates to active inflammation
    - Submucosa:
        - Clarity: ill-defined = active inflammation
        - Strictures with relatively preserved mural stratification are more likely fibrotic than inflammatory [72]

        - May see areas of low reflectivity interruption of the normally fairly homogenously bright wall
        - Penetrating ulcers are appreciable as gas within the undermined bowel wall
    - Thickened = chronic inflammation
    - ↑ reflectivity = chronic (fat infiltration)
    - ↓ reflectivity / heterogenous = active inflammation
  - Muscularis thickness (hyperplasia): correlates to fibrosis
- Mesenteric fat: reflects transmural disease (not fibrosis)
  - Different appearances of mesenteric fat correspond to differing disease activity
  - The extent of fat hypertrophy is greater in active disease
  - ↑ reflectivity = active inflammation
  - ↓ reflectivity or heterogenous = chronic
- Colour / Power Doppler: increased vascularity reflecting active inflammation

See also:

- ***Bhatnagar et al (2021)***,[73] in particular the pictorial guide within the supplementary materials
- **Nishida et al (2023)**, [74] detailed guide to bowel ultrasound with detailed images

Strictures: Inflammatory or Fibrotic? [75] [76]

This a frequent question from clinicians, since it determines whether the patient is likely to benefit from medical treatment.
Fibrotic disease may require endoscopic dilatation or surgical resection.

Unfortunately both may coexist, and imaging mainly relies on the absence of inflammatory features in an abnormal bowel segment to suggest predominantly fibrotic disease.

- B-mode: Low of mural stratification suggests predominantly inflammatory disease
- Colour / Power Doppler: vascularity thought to be increased with active inflammation, but Doppler alone is not that helpful in differentiation (better combined with B-mode findings)
- Contrast enhancement: published studies and meta analyses show that enhancement certainly seems to correlates with active inflammation [77]
  - Authors have made use of quantification to differentiate between fibrosis and inflammation specifically, though data has been conflicting
  - This is therefore still very much an evolving area
- Elastography: shows some promising results, but still a work in progress

Assessing IBD Treatment Response with ultrasound (per the IBUS Group) [78]

Response = has there been a convincing treatment response

- Used to guide treatment escalation

Transmural remission/healing = normalisation of the bowel wall

- This is used a treatment target as it has prognostic significance: associated with a reduction in hospitalisation, relapse, and surgery[79]

General considerations

UC treatment response generally shorter than CrD, in particular bowel wall thickness.

- This may be explained by CrD being a transmural rather than just mucosal process.

Normal bowel wall thickness:

- Small bowel: 3 mm

- Colon: 4-5 mm

A1. Treatment response and assessment in Crohn's

- Treatment response defined as:
  - Reduction in bowel wall thickness of *> 25%* or
  - *> 2 mm* or
  - *> 1 mm and a reduction in colour doppler signal by one grade (Limberg score)*[SS]
- Time to assess:
  - At 14 ± 2 weeks after treatment initiation (regardless of type)
  - Some patients may benefit from much earlier assessment at 4-8 weeks
- Ideal bowel US response assessment intervals following treatment initiation, escalation, or change are at:
  - Baseline, 14 ± 2 weeks, and between 26-52 weeks (depending on clinical assessment, symptoms, and calprotectin)

A2. Transmural remission in Crohn's

- Transmural remission defined as:
  - *Bowel wall thickness ≤3 mm with normal / 0 colour Doppler signal (Limberg score)*
    - BWT < 3 mm gives a sensitivity of 89% and specificity of 96% in detecting inflammation, and remains the best marker
    - BWT correlates well with endoscopic response, and almost perfectly agrees with MR-E
- Time to assess: Between 26-52 weeks from treatment initiation, regardless of treatment
  - May occur already at week 12, but with increasing likelihood up to 1 year (and maybe even 2 years)

A3. Other Sonographic features related to response and remission in Crohn's

- Bowel wall stratification
  - More mixed data on how this correlates to treatment
- Inflammatory fat
  - Maintained presence may reflect chronic disease

Both important, but seen as contributory and not included in the current definitions

B1. Treatment response and assessment in Ulcerative Colitis

- Treatment response defined as:
  - Reduction in bowel wall thickness of > 25% or > 2 mm or > 1 mm and a reduction in colour doppler signal by one grade (Limberg score)
- Time to assess:
  - At 14 ± 2 weeks after treatment initiation (regardless of type)
  - Some patients may benefit from much earlier assessment at 4-8 weeks
- Ideal bowel US response assessment intervals following treatment initiation, escalation, or change are at:
  - Baseline, 14 ± 2 weeks, and between 26-52 weeks (depending on clinical assessment, symptoms, and calprotectin)

B2. Transmural remission in Ulcerative Colitis

Transmural remission defined as:

[SS] Limberg score: Subjective visual score for the extent of colour doppler signal.

- Defined as: Bowel wall thickness ≤3 mm with normal / 0 colour Doppler signal (Limberg score)
    - Sigmoid colon may have enlarged muscularis, so 4 mm taken as upper limit of normal in some patients
    -
- Time to assess: Between 14 ± 2 weeks from treatment initiation, regardless of treatment
    - May occur already at week 4, but with increasing likelihood up to 12 weeks (and maybe even 1 year)

B3. Other Sonographic features related to response and remission in Ulcerative Colitis

- Bowel wall stratification, inflammatory fat, and presence of haustrations all improve, but seen as contributory due to lack of data

5.2.4. Contrast Enhanced Ultrasound (CEUS):

European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) have produced detailed and useful recommendations on the use of CEUS in hepatic and non-hepatic applications.

Contrast enhanced ultrasound (CEUS) utilises ultrasound contrast agents (UCAs), which oscillate when placed within an ultrasound beam (i.e. when they are insonated). A form of subtraction imaging can be used to cancel out the linear body tissue response echoes from the non-linear / harmonic echoes returned by the microbubbles.
A low mechanical index (MI) imaging mode must be used to reduce bubble destruction.

Microbubbles are a similar size to red blood cells and therefore act as a true intravascular contrast agent (i.e. they stay confined to vessels and do leak into the interstitial compartments like iodine and gadolinium-based contrasts).

SonoVue for example consists of sulphur hexafluoride-encased microbubbles measuring ~ 5 µm. Bubbles last around 15 minutes, though studies typically last 5-6 minutes. This is the main agent used in the UK.
Microbubble contrasts with a hepatobiliary / Kupffer cell phase also exist, but are less widely used (e.g. Sonazoid).

CEUS is a well-established technique but has been somewhat underutilised in the UK compared to the rest of Europe. Not all clinicians are familiar with its uses, and so it can be helpful to actively suggest CEUS and educate colleagues regarding referrals or when converting CT/MR to CEUS.

- Advantages of CEUS include:
  - High resolution and dynamic information (compare to CT and MRI where only specific points in time are obtained)
  - Favourable allergy / adverse reaction profile (see below)
  - Respiratory excretion: therefore safe for use in renal failure
  - Alternative for patients who cannot tolerate MRI or have incompatible device etc.
  - Avoidance of ionising radiation
  - Cost effective
  - Shortens the from study time to actionable report for clinician when compared to CT and MRI

- Disadvantages include:
  - Not ideal when there are multiple lesions that need characterisation (e.g. liver), where CT/MR will probably be technically easier
  - May not be feasible to image some lesions (inaccessible or difficult to keep in the field of view)
  - Patients may still require staging imaging (that said, many liver lesions are benign and can be definitively characterised at CEUS)
    - Local staging can also be performed with CEUS though
  - Creates some logistical challenges, as needs a person to scan, and another to inject the contrast (difficult to do alone)

- Safety of Ultrasound Contrast Agents
  - Favourable allergy profile: a very large retrospective study involving 463,434 patients reported an overall incidence of adverse events as 0.034%,[80] specifically:
    - Non-serious: 0.033% (mild 0.014%, moderate 0.015%, and severe 0.004%)
    - Serious: 0.001%

    - Onset of symptoms within 30 minutes for 91% of cases
- Ask patients directly about sulphur and polyethylene glycol (PEG) allergies
    - Suitable if allergy to iodinated and gadolinium contrast (no cross reaction)

- Cardiac contraindications (somewhat controversial)
    - Critically ill patients (heart failure, angina, acute coronary syndrome etc.): The FDA[TT] issued a product warning that US contrast agents increase the risk of adverse reactions
    - Intra-cardiac right-to-left shunts are cited as a contraindication due to the theoretical risk of cerebral ischaemia
    - Pulmonary hypertension: theoretical risk of microbubbles occluding microvasculature leading to haemodynamic compromise
    - However, there is only weak or indeed no evidence to justify withholding US contrast agents from patients based on these risk,[81] though it is true that patients with serious cardiac conditions will be less able to compensate should they have a serious adverse reaction. Therefore a risk-benefit analysis (as for all patients) should be undertaken when considering use of UCAs in cardiac disease

- Indications:
SonoVue is licensed for use in characterising focal liver and renal lesions, but is also used off label for various other indications.
In the context of GI imaging it is mainly used for characterisation of incidentally detected focal liver lesions, where other tests (CT, MR, CT-PET) have failed to characterise a lesion, or further examinations (or contrast agents) are contraindicated/not feasible.

- Performing CEUS:

a) Explain procedure and obtain consent, asking about allergies and contraindications
- Allergy to components of SonoVue (PEG, sulphur)
- Serious cardiac disease: right-to-left cardiac shunts, severe pulmonary artery hypertension, uncontrolled serious hypertension (see above)

b) Assess the lesion on B-mode and locate the best place to image
- A longitudinal plane is the easiest way to keep the lesion 'in plane' at all times whilst the patient is breathing, though I find many patients can breath hold for close to a minute if needed
    - Decide on a suitable transducer. A medium frequency linear transducer can be very helpful, but will require a higher contrast dose due to the associated increased bubble destruction
- Use of breathing instructions may be needed throughout study for lesions with a high position or within the spleen
    - Practice these in advance with the patient to check you can obtain diagnostic images
- Note: Generally it is not advisable to perform a contrast study if the lesion cannot be appreciated on conventional B-mode US (though there are some exceptions, such as percutaneous biopsy for lesions not visible on conventional US)

c) The patient should be cannulated
- Ideally pink cannula in a large left arm antecubital vein

[TT] Food and Drug Administration (United States)

    - A blue cannula can be used but leads to higher bubble destruction on injection. That said, gentle injection into a large vein is adequate.
    - The right arm can also be used, but is more awkward during the injection procedure
- Attach a 3-way tap to the cannula (or alternatively can use the 2-way port that comes with some cannulas, making sure to use keep the tap turned/closed to avoid accidentally giving contrast too early
    - Note: Many 3-way taps can be turned in 45° increments, which closes off *all* ports, which can be very helpful to avoid accidentally injecting contrast or flush

d) Prepare the contrast agent [UU]

- SonoVue is the main agent used in the UK:
    - The premade syringe of 5 mL 0.9% saline is added to the vial of SonoVue powder, shaken for 10 seconds to create the microbubbles, and the required dose of reconstituted contrast drawn up for use
    - The dose required for studies varies, depending on the indication
        - See below for more detail on dosage
    - Attach contrast syringe to the 3-way tap heading in line with the cannula direction (prevents bubble destruction on injecting) [see diagram below]
    - Attach a 10 mL 0.9% saline flush to the side port of the 3-way tap

e) Start the low MI contrast mode (dual screen with low MI B-mode and the sepia-tinted [VV]contrast image displayed together on the screen)

- Make sure your B-mode image is optimised first
- Optimise the contrast image:
    - Turn down the contrast image gain (*not the B-mode gain*[WW]*)* so that only reflective tissue interfaces are visible on the screen
    - Consider decreasing the contrast frequency if greater depth penetration is needed, or changing to a very low frequency transducer[XX]
    - Increase depth: this is a balance between the lesion appearing too small on the screen against the lessened bubble destruction
    - Ensure the focal point lies deep to the region of interest to minimise bubble destruction at this point (can mimic washout)
- Start the timer at the same time as a colleague injects the desired contrast dose over a few seconds and then applies flush (5-10 mL)

f) Imaging in Contrast Mode

- Record a cine loop of the first 0-60 seconds
    - Check your machine settings in advance! Is the clip length set to 60 seconds?
    - It will take ~ 10 seconds for bubbles to arrive (potentially longer if impaired cardiac function)
    - Do not adjust settings such as gain or frequency once the study has started, as this can significantly affect interpretation due to inconsistency in between images

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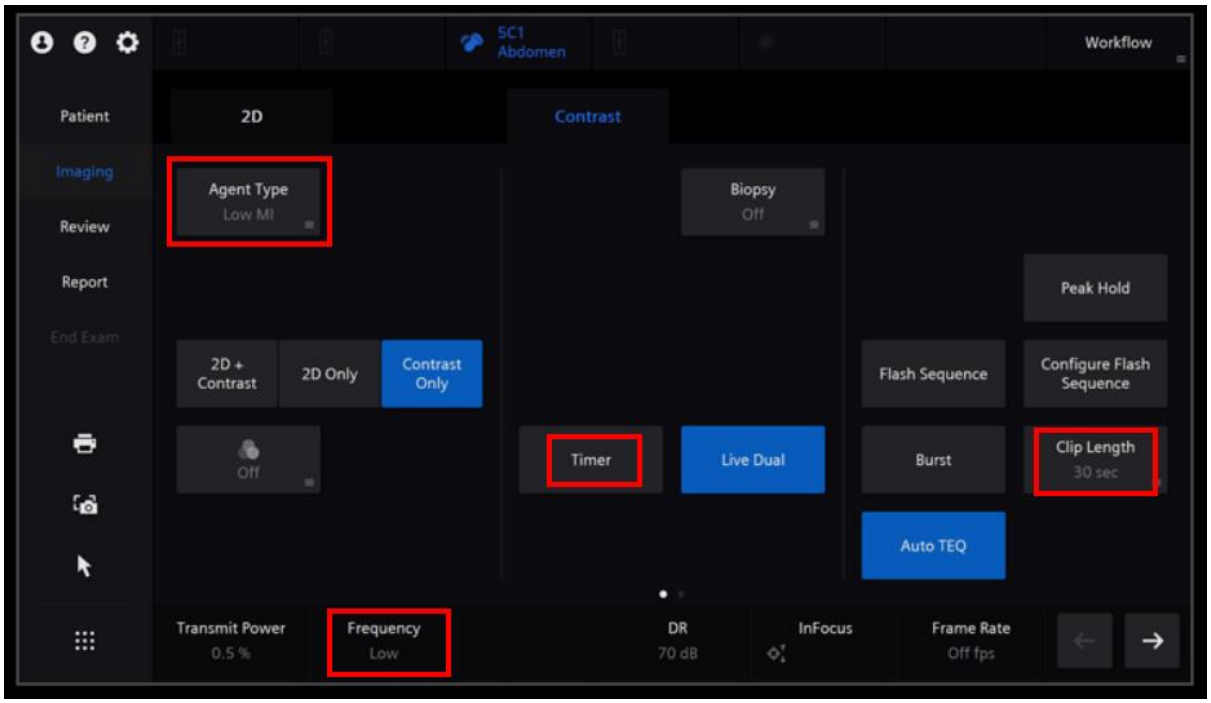
[UU] Thomas Jefferson University have a useful page with videos showing the preparation injection of ultrasound contrast agents: https://www.jefferson.edu/academics/colleges-schools-institutes/skmc/departments/radiology/jurei/ceus-resources.html

[VV] The subtracted contrast image is often sepia/orange tinted, but some machines may use a greyscale.

[WW] Remember that B-mode and Contrast image gain are controlled independently. Make sure you know how to correctly alter these settings.

[XX] A lower frequency improves penetration and reduces bubble resolution, but reduces image resolution.

- After 60 seconds freeze your image and un-freeze to take intermittent images / short cine loops every 30 seconds (i.e. at 1.5 mins, 2 mins, 2.5 mins etc.)
    - ! Freezing the image in between prevents bubble destruction and 'pseudo-washout'[YY]
- Images can be reviewed later to look for specific diagnostic patterns of enhancement



Example of Siemens Accuson Sequoia US machine contrast mode touch screen

- Key settings are highlighted in red

[YY] Contrast pools within lesions such as haemangiomata and is only slowly replenished. Excessive insonation destroys bubble contrast within the lesion, mimicking washout.
Likewise bubbles can be noticeably 'burnt off' in the near field (superficial part of image).

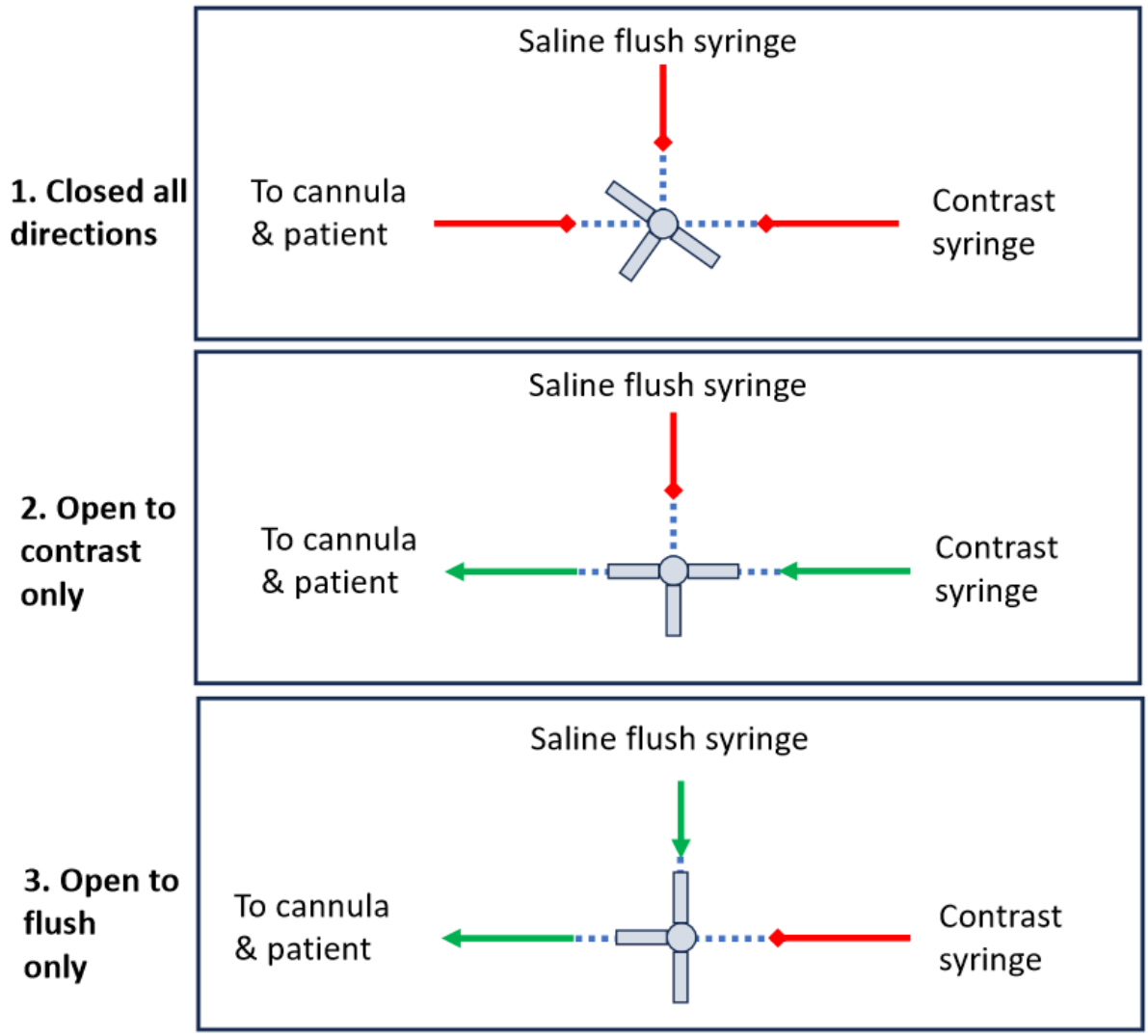


Diagram of a 3 way tap and injection set-up

- Note: turning the tap to any of the four 45° directions will close the tap to all directions (not just the position shown in image 1)

- Contrast Dosage and Phases

These differ depending on what is being assessed and are given below as the time following injection of contrast (by convention).

Note that the phases are not defined as rigidly as in MRI and CT since imaging is dynamic.

Liver – 2.4 mL (4.8 mL with medium frequency transducer)

- Arterial: 10-35 sec
- Portal venous: 30-120 sec
- Late: > 120 sec

Spleen – 1.2-2.4 mL (higher doses needed with medium frequency transducer)

- Arterial: 10-25 sec
- Portal venous: 30-120 sec

- Late: > 120 sec

Gallbladder – 1.2-2.4 mL (4.8 mL with medium frequency transducer)
- Arterial: 0-30 sec
- Venous: 30-180 sec

Kidney – 1.2 mL

Small parts (e.g. testes, thyroid) – 4.8 mL with medium frequency transducer

Endocavitary (e.g. tubograms) – 0.1 mL of SonoVue diluted in 20 mL of saline

Contrast Ultrasound for LI-RADS

LI-RADS (Liver Imaging Reporting & Data System) was created to standardize the reporting and data collection of CT and MR imaging for hepatocellular carcinoma (HCC).[82]

Originally devised for CT and MRI, a version for CEUS was first introduced in 2016 (see *essential resources* below).

The probability for HCC in the CEUS LI-RADS categories were given in this retrospective study by Terzi et al. [83]
- CEUS LR-M: this category carries a very high likelihood of malignancy, but is not specific for the type
    - HCC: 6/15 (40%)
    - H-ChC: 2/15 (13%)
    - ICC: 7/15 (47%)
    - [HCC 42% and other cancers 56% - data summarised in this webinar by Kono, Y (2024)[84]]
- CEUS LR-4:
    - HCC: 90/102 (88%)
- CEUS LR-5:
    - HCC: 149/152 (98%)
    - H-ChC: 1/152 (1%)

HCC = Hepatocellular carcinoma
H-ChC = Hepatocholangiocarcinoma
ICC = Intrahepatic cholangiocarcinoma

CEUS for local liver lesion staging is not as well established as for other lesions, but as data and use increases so will general acceptance.

a) When should LI-RADS be used?

Only in the following to maintain high specificity for HCC.
All the below must be applied to adult patients (> 18 year old):
- Confirmed cirrhosis: via biopsy or good quality US Elastography
    - Certain causes of cirrhosis are however excluded: congenial hepatic fibrosis or vascular causes (e.g. cardiac, Budd-Chiari)
- Chronic hepatitis B
- Current or prior hepatocellular carcinoma

Note that if US imaging is very suggestive of cirrhosis you can perform elastography at the same time to see if they fall into the cirrhotic range to allow use of LI-RADS.
Alternatively, you can give a conditional LI-RADS classification, for example: "Should the patient be confirmed to have cirrhosis this observation would be classified as CEUS LR-4."

b) Enhancement and washout descriptions

- *Arterial phase hyperenhancement (APHE) defined as:*
  - Relative hyper-enhancement[ZZ] during arterial phase (~10-35 seconds)
  - Not peripheral discontinuous globular pattern (which implies benign haemangioma)
  - Not rim enhancement (which implies malignancy in general)
    - This is classified as CEUS LR-M

- *Washout defined as:*
Visually assessed reduction in lesion enhancement (partly or entirely) over time compared to background liver during arteria or later phases.
  - Significance of washout is that it reflects blood volume relative to background liver
  - All liver neoplasms (primary or metastatic) have a lower blood volume than background liver, and so will show washout
  - Washout is therefore a feature of malignancy generally
  - Cholangiocarcinoma and metastases typically show earlier and more marked washout compared to hepatocellular carcinoma, and this can be used to suggest a diagnosis

CEUS requires further characterisation for *onset* and *degree* (unlike CT/MR where washout is either present or not present):
- Onset
  - Early: < 60 seconds
  - Late: ≥ 60 seconds
- Degree:
  - Mild: lesion less enhancing than background liver, but still shows enhancement
  - Marked: lesion virtually devoid of enhancement, appearing as a 'punched out' black perfusion defect by 2 minutes following contrast injection

		Washout Onset	
		Early (< 60s)	***Late (≥ 60 s)***
Washout Degree	***Marked***	Typical of cholangiocarcinoma & metastases [LR-M]	Suggests malignancy in general (not specific) [LR-M]
	Mild	Suggests malignancy in general (not specific) [LR-M]	Typical of HCC and HCC precursor nodules [LR-3-5]

The lesion shows mild washout initially and then washes out completely to look black. Is it mild or marked?
This depends on the time after contrast injection at which the washout becomes marked.
- If the washout becomes marked at or <u>before</u> 2 minutes, characterise as marked.
- If the washout becomes marked only <u>after</u> 2 minutes, characterise as mild.

[ZZ] Lesion enhancement unequivocally brighter than background liver (either entirely or part) during arterial phase

- If unsure, characterise as marked (to prevent false CEUS LR-5 categorization for non-HCC malignancies with borderline marked washout)

Essential Resources for Contrast Ultrasound

Courses & Webinars

- King's College run an excellent CEUS course aimed at new practitioners
- EFSUMB run regular free webinars which are archived on their website[85]

EFSUMB guidelines on when and how to use CEUS:

- Guidelines and Good Clinical Practice Recommendations for Contrast Enhanced Ultrasound (CEUS) in the Liver – Update 2020 – WFUMB in Cooperation with EFSUMB, AFSUMB, AIUM, and FLAUS [86]
- The EFSUMB Guidelines and Recommendations for the Clinical Practice of Contrast-Enhanced Ultrasound (CEUS) in Non-Hepatic Applications (long version) [87]

Artifacts and Technical Aspects

- Artifacts and Technical Considerations at Contrast-enhanced US [88]
  - It is important to understand the specific artifacts that are introduced with CEUS and pulse inversion imaging and this is an excellent summary

LI-RADS for Contrast Ultrasound

- LI-RADS conventional US surveillance of patients at high risk of hepatocellular carcinoma
  - This is not CEUS, but should be read in conjunction with the CEUS LI-RADS algorithm, as the two are complementary
- Core CEUS LI-RADS algorithm document [89]

International Contrast Ultrasound Society[90]

- Collection of resources, including educational webinars

<u>Addressing Common Criticism of Contrast Ultrasound</u>

"CEUS is time consuming and it's far easier to just do a CT or MRI"

- Yes, CEUS is more time consuming for the radiologist. However it saves radiographer time and also improves CT/MRI capacity
  - Many liver lesions are benign, so cross-section slots can be saved for the suspected cancers etc.
- CEUS also improves pathways as the time from scan to report is much less
  - CEUS can be reported at the same time, whereas CT/MRI often has a waiting time due to high cross-sectional imaging demand.
  - If CEUS is available the same day that an incidental liver lesion is detected on a conventional ultrasound then this can significantly improve the speed of patient management, immediately triaging to either benign and discharge, or neoplastic and further management

"But I could still just do a CT/MRI"

- What about patients who cannot have a CT or MRI due to:
  - MR incompatible medical devices, contrast allergy, renal failure, claustrophobia etc.?
- Or where CT/MR has not been able to answer the question?
- Consider also the cost implications:

- CEUS use saves money over CT and MRI, and has been recommended by NICE for use in focal liver lesions [91] [92]

"I've never heard of CEUS before. Is it reliable?"

- There is plenty of evidence validating the use of CEUS, as well as guidelines for its use (e.g. EFSUMB). Many centres in the UK are using it successfully.
- CEUS is utilised far more in the rest of Europe and China suggesting we need to be using it far more, just like for bowel ultrasound.

5.3. Computed Tomography

Study	Notes
CT-Enterography [93]	Patient drinks ~ 1.5 L of neutral density contrast to distend the small bowel, with enteric phase IV contrast (~ 45 seconds)
CT-Colonography [94]	Insufflation of colon following faecal tagging bowel preparation (Gastrografin) - see below
CT patency capsule check	Patient ingests a radiopaque capsule and a low dose CT is acquired for position. Capsule will dissolve with time. Where is the capsule? Has it reached the colon, or is it stuck at terminal ileum or even oesophagus etc. If the capsule is not visible on the Topogram it has presumably been passed and a CT may not be necessary, but check not stuck in oesophagus (I've seen this once before).
CT Abdomen-pelvis	Consider positive oral contrast in the post-operative complex cancer patient or for intestinal mapping (particularly in suspected fistula). May also be asked for an 'excretory phase' to check for ureteric leak (generally guided by clinical concern rather than done routinely), often in patients who've had an ileal conduit.
General oncology staging and surveillance CT-CAP	Pleural / portal venous phase CT generally, looking for sites of disease at staging, or evidence of disease recurrence and/or metastases.
CT-PET	F-fluorodeoxyglucose (FDG) PET/CT. Fuses unenhanced low dose CT with quantified measurement of tissue metabolism utilising radioactively labelled glucose, providing a degree of functional information.

5.3.1. CT-Enterography (CT-E):

Patient drinks ~1-1.5 L of fluid mixed with mannitol 1 hr prior to the scan in order to give a neutral density contrast to improve bowel distension through osmotic effect. [AAA]

- IV contrast administered in enteric phase (around 45 sec, where both portal vein and mesenteric arteries enhance)
    - The scan is noticeably 'brighter' overall and will require some re-windowing to read
    - Mixing artefact may also be present in portal and superior mesenteric veins

Mainly used in the assessment of Crohn's disease.

- Preferrable to MRI when: MRI would not be tolerated, motion artefact likely to be a problem, higher spatial resolution required
- Should be avoided in younger patients where possible

Assessment for luminal narrowing, true strictures (should be associated upstream dilatation to suggest functional obstruction), hyper-enhancement (to suggest active inflammation), and upstream dilatation to suggest functional obstruction / hold-up.

- Inflammatory bowel disease: Where are the segments of disease (small and large bowel), what lengths, the degree of mural thickening and hyper-enhancement

[AAA] Note enterolysis techniques also exist where fluid is infused into the bowel via an enteric tube, rather than the patient just drinking neutral density contrast prior to the study. These are less commonly done as they are invasive and even more uncomfortable (and time consuming) for patients, but give superior proximal small bowel distention.

    - Can use terminal ileum and duodenojejunal flexure as reference points
    - Features of obstruction or holdup?
    - Features of disease chronicity? Look at old scans
    - Disease activity (active inflammation): hyperenhancement, mural thickening, perienteric and mysentery stranding and fluid, increased mesenteric vasculature (comb sign), and changes from old scans
        - Fibrosis is inferred if a stricture is present but without features of active inflammation
    - Complications: penetrating / fistulating disease, collections (describe involved structures and where tracts go)

- Other uses for CT-E
    - Small bowel luminal polyps (note that due to radiation, paediatric PJS tends to be investigated with MR-E instead)
    - Mesenteric masses: is there an associated small bowel lesion (hyper-enhancing) to suggest a neuroendocrine tumour? There may be associated prominent vessels.
    - Note on enteric phase: gives information in an arterial and portal venous phase, therefore important to review vasculature, and bear in mind that incidental lesions in e.g. liver may be difficult to definitively characterise. Images will often appear generally bright and require re-windowing

5.3.2. CTC / CT-C: CT colonography: [BBB]

A modified CT of the abdomen and pelvis specifically to evaluate the colon. This allows detection of colonic polyps and cancers, as well as extracolonic findings which could be responsible for the patient's symptoms.

The term 'virtual colonoscopy' should be avoided as it is not entirely accurate, given the numerous differences between this and a conventional optical colonoscopy.

The patient must undergo bowel preparation similarly to a conventional colonoscopy (though we do occasionally do 'prepless' studies which have a far lower lesion detection rate).
Gastrografin is generally used alone due to its osmotic laxative effect secondary to a high osmolality, but additional laxatives are sometimes added for select patients (see below).

Patient preparation:

- Unprepared ('prepless') study: air insufflation of the colon only.
    - Very limited study which can only realistically exclude large protuberant (> 1 cm) lesions and cancers.
    - This *may* be appropriate for some patients but is not routine practice
    - A conventional CT is often pragmatically offered to the referring clinician instead, which will demonstrate large lesions (as well as extra-colonic pathology)
- Laxative only (e.g. Picolax)
    - Limited as no faecal tagging, but may be appropriate for patients with e.g. iodinated contrast allergy
    - Smaller lesions may not be appreciable, or cannot be called with confidence
- Standard preparation

[BBB] CTC (CT-colon) may be confused with Cardiac CT (hence the problem with context-dependant abbreviations)

    - Most patients have 2 x 50 mL of Gastrografin the day before, which tags faecal material and acts as osmotic laxative to prepare bowel
    - Patients who have had failed preparation before (on CTC or endoscopy) may also have picosulphate (e.g. Picolax) as additional catharsis
- Half preparation
    - Care needs to be taken in patients who are frail or have poor renal function (eGFR). A half dose Gastrografin regimen (2 x 25 mL) may be more appropriate.

- ± IV contrast: used for *specific* indications (e.g. anaemia) where extra-colonic pathology is more likely to be present
- Note: that a reported allergy to iodinated contrast prevents the patient from having oral Gastrografin bowel prep (as this is also an iodinated contrast)

Procedure:
On the day of the procedure the colon is insufflated and distended via a rectal catheter and tagging of faecal material with oral contrast media.

Scans are acquired in Supine and Prone (or a decubitus if not possible) ± other side decubitus

- Generally 2 or 3 views total, depending on degree of colonic distention achieved
    - Hence patient must be reasonably mobile
- Radiographers will review the images during the scan, assessing the colon for suspicious lesions
    - They will also scan the chest if a suspicious colonic lesion is seen (to save calling patient back to complete staging)

Reporting:
Scans are read by reviewing both the 2-dimensional images as well as a endoluminal view

- A volume rendered 3D model of colon is reconstructed from the volumetric data and can be navigated (a 'fly-through' read of the colon)
    - This 'endoluminal view' means polyps stay on the screen longer which increases their conspicuity over a standard 2D view

Patient position in CT-colon to improve distention	
Poor distention of …	**Improved by positioning patient …**
Right colon	Left lateral decubitus (LLD)
Sigmoid / descending colon	Right lateral decubitus (RLD)
Rectosigmoid junction	Prone
Air rises to fill the under-distended segment	

When might a CT-C <u>not</u> be appropriate?

- Possible issues with bowel prep: poor renal function (risk of dehydration), poor mobility (will they be able to manage the associated diarrhoea?
- Poor mobility: Can the patient turn on the table for at least prone & decubitus views?
- Poor compliance: Will the patient tolerate insufflation?

A standard CT abdomen & pelvis ± contrast may be more feasible and pragmatic in frail patients and will at least exclude a large obstructing tumour.

<u>5.3.3 CT-PET</u>:

The reporting of CT-PET is well beyond the remit of this guide, however it is useful to understand how this can be utilised in gastrointestinal radiology, as radiologists are frequently asked to review CT-PET during meetings, and reference to studies may be very helpful when reporting conventional cross-sectional imaging.

CT-PET combines conventional low dose CT cross-section with metabolic activity information derived from the detection of positrons emitted following the metabolism of radioactively labelled glucose. This metabolic activity is quantifiable, and is also provided as a visual graded grey scale and colour map data which can be fused with the CT images.

- Consequently anything that increases tissue metabolism has to potential to show increased avidity/uptake on the FDG component, and it is important to provide clear information and clinical context to the reporting radiographer, and when interpreting results in the MDT setting.

General limitations:

- MRI of the liver and breath hold CT-chest are still the optimum modalities when assessing for liver and lung disease respectively
- Mucinous disease has low tumour cellularity and therefore may not be avid on CT-PET
- Misregistration artefact between the CT and the FDG images can be seen (i.e. they don't 'line up' correctly) when images are fused.
    - Particularly a problem in the lungs as the FDG component is obtained with the patient free breathing rather than performing a breath hold as for conventional CT.
    - Bowel peristalsis and urinary bladder filling also
    - Cardiac motion artefact can hide lung nodules
- Scanning too early:
    - < 4 weeks after surgery and < 6 weeks after radiotherapy may show false positive
- Confusion with inflammatory processes
    - Hepatic abscesses can be problematic, especially in cholangiocarcinoma where biliary sepsis risk is higher. Often the patient will be septic clinically.
    - Infection / inflammation in the lungs mimicking avid metastases
- Synchronous primary tumours in bowel, lung, liver etc.

<u>Suspicious CT-PET findings</u>:

- Focal and nodular, well-defined, high avidity/uptake

<u>Use in colorectal cancer</u>:

a) Initial diagnosis – not routinely used

- Limited spatial resolution

b) Evaluating suspected recurrence with use prompted by:

- Equivocal or unclear findings detected on conventional imaging (CT & MRI) – differentiating post-surgical findings (fibrosis, haematoma, sequalae of anastomotic leak etc.) from genuine disease
    - Indeterminate pre-sacral mass is a specific indication for CT-PET (effectively the same as suspected recurrent disease)
    - Also useful for equivocal lymph nodes (active disease vs. reactive node)
- Rising tumour markers – serum CEA is used to monitor for colorectal disease recurrence, but has a false positive rate of 10-30%, and therefore CT-PET can be useful in problem solving (such as looking for occult disease not seen on conventional CT)

c) Metastatic disease:

- Assessing for the full extent of disease when deciding on additional surgery
    - Minimise risk of preforming highly morbid treatment which will not be curative

d) Response assessment

Accepted role in treatment response assessment

- Can show response to treatment, but not sufficiently accurate to determine a complete response

Response to targeted therapy

- Liver: radiofrequency ablation (RFA) and Selective internal radiation therapy (SIRT)

5.4. Magnetic Resonance Imaging	
Study	**Notes**
Dixon MRI techniques	A brief summary of Dixon MRI, which is increasing utilised.
MR-Enterography (MR small bowel) [95] [96] [97]	Oral neutral contrast administered with mannitol to distend small bowel, although jejunum (especially proximal) can be poorly distended. Buscopan given to reduce motion artefact from spasm / peristalsis. Cine loops not routine obtained at STM.
Rectal cancer [98] [99]	Buscopan given to reduce motion artefact. DWI / contrast enhanced sequences not routinely done at STM.
MRCP	Usual pathologies such as gallstones, but also less common entities such as primary sclerosing cholangitis (seen in IBD). See also the hepatobiliary radiology section.
MR Liver	Non-contrast (e.g. limited haemangioma assessment protocol), and dynamic contrast sequences (Dotarem or Primovist) - see also the hepatobiliary radiology section.
Complex cancer related scans (*See 'complex cancer'*)	Disease recurrence, cavities etc. May also include isotropic T2 images (SPACE sequences). [CCC]
Fistulae (perianal) [100]	STIR axial, coronal and sagittal acquisitions and standard T2 sagittal sequences obtained. Contrast can be administered for troubleshooting (e.g. differentiating fluid from fibrosis/scar).
Local assessment of a colonic tumour - suspected involvement of nearby structures	MR rarely used for colonic tumours, but can be helpful to determine if a tumour is involving nearby structures, e.g. abdominal wall, liver, duodenum. Protocol is the same as for rectal cancer, but with the small field of view sequences centred on the colonic tumour. A high resolution T2 SPACE can also be helpful
Appendix (paediatric) or 'acute abdominal MRI' protocols	Acute appendicitis may sometime be assessed with MRI. A protocol should be relatively abbreviated, such as: [101] • Axial & Coronal T2 (Single-shot turbo spin echo) • Axial & Coronal T2 FS (Single-shot turbo spin echo) [axial - lung bases to pubic symphysis; coronal - mid liver to pubis]

5.4.0 An Introduction to Dixon MRI sequences

All tissues contain protons, which can be excited by radiofrequency pulses with the returned signal used to derive MRI images. The exact timing and nature of pulses determines the specifics of image contrast and weighting.
Water and fat are the two main contributors to contrast in an image

- Water and fat molecules precess (spin) at different defined rates.
- Therefore, over time there will be points when the precession of both the water and fat molecules will either be the same where they overlap (in-phase) or different (out-of-phase)

A gradient echo pulse can be used to excite the protons:

[CCC] Siemens' name for a T2 fast turbo spin echo sequence: http://mriquestions.com/spacecubevista.html Contiguous (no gap between slices), high resolution, and isotropic allowing multiplanar reformat (MPR).

- The MRI machine can sample (listen) for signal from fat and water within each voxel at two defined time points in order to obtain both the in-phase (IP) and the out of phase / opposed phase (OOP) data - echo times 1 and 2)

IP and OOP data can therefore be efficiently acquired at nearly the same time, and then combined mathematically in various ways to produce 4 distinct sequences which have specific diagnostic utility. Note this can be used with a variety of weighting, but from a GI perspective you will mainly see this for T2 weighted images.

1. In-phase: water + fat
    - The 'standard' image, for example a conventional T2 weighted image

2. Out-of-phase: water - fat
    - As per the standard sequence, but where the *microscopic* fat signal has been suppressed, and so appears dark on the image
    - These images have a thick dark line at the fat/water interface between organs ('India ink artefact').
        - This is a chemical shift artefact seen in gradient echo OOP images, where the chosen TE (echo time) means that fat and water signal are opposed and so cancel each other out.
        - This is only seen in areas where there are relatively equal quantities of both fat and water so that the water and fat signal cancel each other out, hence this is seen at boundaries.

3. Fat only: IP - OOP
    - Used in musculoskeletal radiology – nicely shows fat-replacing neoplastic lesions in bone marrow for example (i.e. osseous metastases)
    - Can be used for fat quantification (mainly a research technique)

4. Water only: IP + OOP
    - Macroscopic fat suppression with fluid signal left behind

Examples of Dixon MRI in GI Radiology

- Liver MR: Signal loss ('drop out') between T1-weighted IP and OOP images can demonstrate steatosis
- Adrenal MR: again T1 weighted IP and OOP images can demonstrate fat with adrenal lesions, which forms the basis of adrenal nodule characterisation, since signal loss means microscopic fat and very likely a benign adenoma
- Perianal fistula MR: T2 weighted 'water only' images form the basis of perianal fistula imaging
    - Suppress all the bright fat and you leave behind the fluid-filled fistula tracts
    - Fat and fluid are both high signal on standard T2 weighted images, so this 'fluid sensitive' sequence makes it much easier to appreciate fluid signal tracts
- MR derived liver fat fraction:
    - The Dixon technique allows quantification of fat using the above Dixon, and hepatic steatosis given as a percentage
    - (Fat / Fat + Water) * 100%

Fat suppression techniques

There are several different means by which fat signal can be suppressed in MRI. The below is only a quick reminder:

- In- and out-of-phase: The OOP images suppress *microscopic* fat only, so for example mesenteric and subcutaneous fat retains high signal
- Fat suppression gradient pulse: Irregular fat suppression and slower than other techniques
- STIR: Uniform suppression using T1 properties. Insensitive to magnetic field inhomogeneities

Types of fat:

- Microscopic: steatosis, HCC, hepatic adenoma, post-chemo, adrenal adenoma
- Macroscopic: AML, hepatic lipoma, GCT, adrenal myelolipoma

5.4.1. MR-Enterography:

Mainly T2 weighted sequences with pre- and post-contrast fat-suppressed T1 (arterial and portal venous). Oral bowel prep returns high T2 signal and distends bowel to look for luminal narrowing present in disease.

- T2 sequences consist of
    - HASTE: better for wall thickness assessment
    - True FISP: thick black border at bowel-fat interfaces ('India ink' artefact). High resolution and fast to acquire
- Cine 'MR fluoroscopy' images occasionally, but not routinely used at STM

Similar to CT-enterography, though provides more information due to multiple sequences and superior soft tissue characterisation, including post-contrast in arterial and portal venous phases.

- MR Features in Crohn's Disease See *Radiology Assistant* for a good review

Crohn's disease can be thought of several groups:

- Inflammatory (non-stenosing, non-penetrating)
- Stenosing
- Fistulating (penetrating)
    - Transmural extra-enteric disease

Table 4. Recommended Radiology Report Impression Statements for Small Bowel Crohn Disease at CT Enterography and MR Enterography

Inflammation impression statements
No imaging signs of active inflammation
Nonspecific small bowel inflammation
Active inflammatory small bowel Crohn disease without luminal narrowing
Active inflammatory small bowel Crohn disease with luminal narrowing
Crohn disease with no imaging signs of active inflammation
Stricture impression statements
Stricture with imaging findings of active inflammation
Stricture without imaging findings of active inflammation
Penetrating Crohn disease impression statements
Sinus tract
Fistula
Inflammatory mass
Abscess
Free perforation
Perianal Crohn disease impression statements
Fistula
Abscess
Other complications impression statements
Femoral head avascular necrosis, sacroiliitis, primary sclerosing cholangitis, pancreatitis, mesenteric venous thrombosis or chronic mesenteric venous occlusion, neoplasm, cholelithiasis, or nephrolithiasis

Note.—Adapted, with permission, from references 7 and 8.

Table from Guglielmot et al. (2020)

- What is a stricture?

The definition varies depending on the perspective:

- Histopathologist: Stenosis due to mural thickening and consequent luminal narrowing
- Endoscopist: Unable to pass an *adult* scope
- Radiologist: several different definitions, but *from Guglielmot et al. (2020)*
    - Luminal narrowing = lumen narrowed by at least 50% (due to mural thickening)
    - Stricture = mural thickening + unequivocal upstream small bowel dilatation (> 3 cm)
        - Probable stricture = as stricture but without luminal upstream small bowel dilatation (< 3 cm), e.g. due to an associated fistula which then decompresses the upstream small bowel
    - Avoid using the term 'fibrostenotic' for stenotic disease - instead describe as e.g. 'stricture without imaging features of active inflammation'

- Disease type and activity

- Generally split into *inflammatory* and *fibrotic*, though in reality the two often coexist. Consequently it can be difficult to be definitive, but imaging features can help in suggesting that disease is predominantly one or the other.
    - No features of active inflammation in an abnormal segment suggests fibrotic disease
- Disease may be chronic but without active inflammation, chronic with active inflammation (active-on-chronic), or active without features of chronicity

- The disease features at imaging are split into bowel and extra-enteric below
- *Features suggesting 'chronicity' (i.e. Crohn's disease with no imaging features of active inflammation), marked as * below*
    - Appearances present on serial imaging may also suggest chronicity
    - Using terms like 'chronic' or 'quiescent' can be ambiguous unless qualified
    - It is clearer to describe features of Crohn's *with or without active inflammation*.

    - Chronicity itself is less helpful than disease activity generally, though can be useful to have idea for how long a patient has had Crohn's for

- Bowel features

a) Very useful and can be used for disease activity

- Mural thickening
    - The most sensitive feature for active inflammation
    - Disease preferentially affects the mesenteric border, giving rise to *asymmetrical* mural thickening. More severe disease can be *symmetrical* (circumferential), also involving the anti-mesenteric border
    - Disease can be *discontinuous* with 'skipped' segments of normal-appearing bowel in between, or *continuous*
        - When measuring lengths of discontinuous disease where there are very short lengths of normal bowel in between disease, this can be counted as one long segment of discontinuous disease
        - If the lengths of normal bowel in between disease are longer than a few centimetres, then it is worth detailing the normal/abnormal segment lengths individually [DDD]
    - May see evidence of bowel obstruction secondary to disease:
        - 'Functional small bowel obstruction' defined if upstream small bowel dilated > 3 cm
    - Multiple segments of functional and/or non-functional obstruction between segments of discontinuous disease can coexist. Look for dominant points of obstruction
- Mural T2 signal:
    - Increased T2 signal representing oedema suggests active disease
    - Fat deposition suggests chronicity.
    - Distinguish oedema from fat using the fat suppressed sequences: T2FS, DWI (effectively T2 FS images), or comparing HASTE/FISP images[EEE]
- Ulceration: only moderate or severe ulceration is appreciable on MR-E.
    - Only seen easily when there is also mural thickening
    - An ulcer is defined as undermining of the inner bowel wall which is then 'filled in' by luminal contents
    - Avoid confusing these with pseudo-sacculation[FFF] *

b) Useful for identifying sites of disease but less helpful for disease activity

- Enhancement: relative to mesenteric vascularity. May involve mucosa, submucosa / muscularis, and serosa
    - Suggests active disease
    - Note that contrast is not good at quantification of disease activity (including dynamic calculations), but useful for spotting sites of disease
    - Degree of enhancement and pattern
    - An asymmetrical enhancement pattern (with enhancement at the mesenteric side of the bowel) is specific to Crohn's

[DDD] Ask yourself: are the lengths of intervening normal bowel actually long enough to be worth preserving in a surgical resection? If not then it's probably better to think of this disease as effectively one long segment.
[EEE] Genuine fat on the HASTE T2 images will show corresponding black chemical shift artefact on FISP images.
[FFF] Disease generally affects the mesenteric border, with sacculation forming at the relatively sparred anti-mesenteric border. A sign of asymmetrical disease

    - A ‘layered’ enhancement pattern with a fibrotic or oedematous signal in the middle layer suggests more severe disease. A middle layer of fibrosis or fat suggests longstanding (‘chronic’) disease
- Diffusion weighted imaging (DWI)
    - Similar to contrast, helps in identifying sites of disease but even with the ADC map is not good for quantification of disease
    - The DWI images are effectively fat suppressed T2 images, so can be used to determine if mural fat deposition is present which suggests inactive / fibrotic disease
    - Pitfall: collapsed loops can give the impression of increased signal
    - The ADC map is less helpful, as mural low signal may simply reflect fat deposition
- Loss of normal haustration (colon)
- Impaired small bowel motility
    - If dynamic ‘MR fluoroscopy’ sequences. Less well-established technique

- Extra-enteric

a) Suggest active inflammation

- Increased mesenteric vascularity (‘comb sign’)
- Peri-enteric oedema:
- Mesenteric oedema - Fluid tracking along mesentery
- Mesenteric venous thrombosis
    - Usually close to areas of active disease

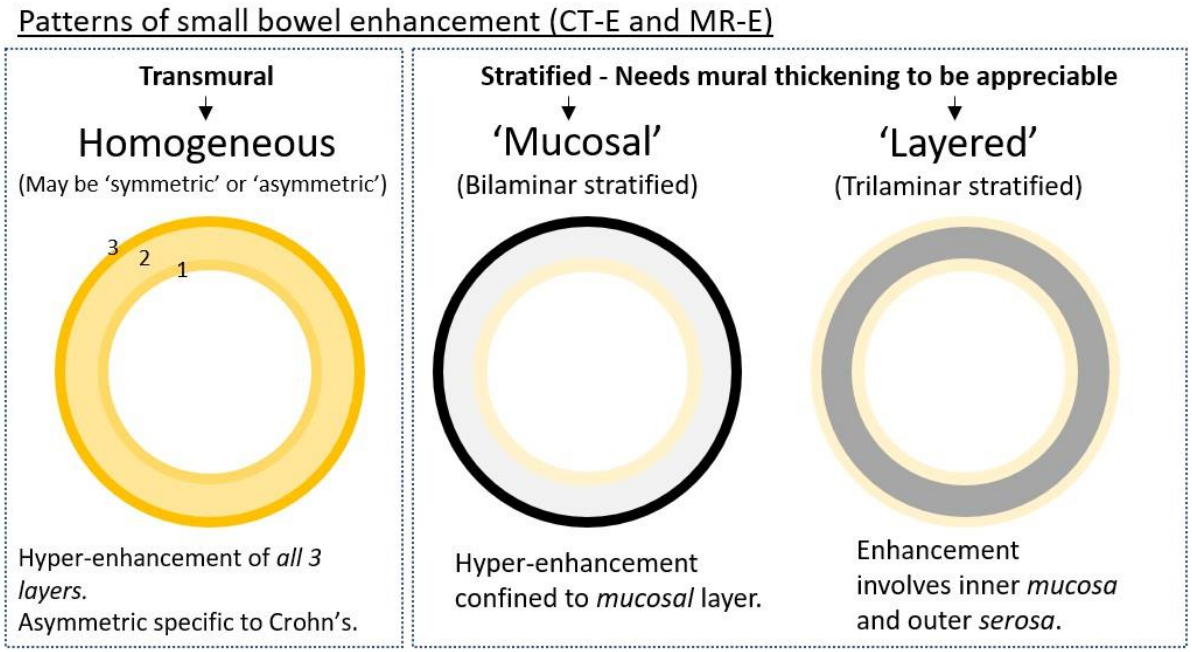
b) Suggests longer standing disease but also seen as part of active inflammation

- Fat hypertrophy (fat wrapping if circumferential)
    - Often asymmetrical, centred on mesenteric border.
    - Suggests more longstanding disease
    - Reflects transmural inflammation
- Lymph nodes
    - Often lie along vascular supply of involved segments of disease (‘reactive nodes’)

- Complicating features (due to penetrating transmural disease)

a) These frequently indicate active disease / inflammation

- Fistulae and sinuses
    - High signal T2 tracts that enhance avidly following contrast
- Abscess
- Inflammatory masses
    - Avoid using ‘phlegmon’, as this is somewhat ambiguous
- Free perforation



5.4.2 MR Rectum (cancer):

Relies on T2-weighted images.

See *Surgical* section for key concept relevant to rectal cancer.

Aim to describe

- Tumour
  - Morphology: annular / semi-annular (circumferential or incomplete ring), polypoid
    - Mucinous component (indicated by high T2 signal)
  - Length that the tumour extends over
  - How high the caudal (inferior) aspect of the mass lies above the anorectal junction, or if it actually involves the anal canal (see 'low rectal cancer staging' below)
    - Distance to anorectal junction is relevant in terms of what operation will be done
    - There is some ambiguity between where distal sigmoid / rectosigmoid / high rectum start & end. Sometimes better to simply give distances
    - Can also report distance between anal verge and caudal aspect of tumour, though this has less surgical importance. Can be a useful distance to correlate with endoscopy report to determine where a lesion should be on MR
  - Where the cranial / proximal tumour lies in relation to the peritoneal reflection
  - Transmural disease - where is it and what does it involve?
    - An intact low T2 signal muscularis suggests T1 or T2 disease at most (as per TNM staging)
      - Endorectal US can help distinguish T1 from T2 disease, though good quality high resolution T2-weighted imaging is still the best method
    - Disruption of the muscularis ± extension beyond means the tumour will be at least T3 disease
      - Low signal spiculation doesn't necessarily equate to transmural disease. A desmoplastic reaction may be seen at the tumour's invasive margin

- Circumferential resection margin (CRM): clear, threatened, or involved - can describe using clockface on axial images
    - Threatened = disease 1-2 mm from CRM; Involved = disease < 1 mm from margin
    - The CRM can be threatened/involved by direct transmural disease, but also by discrete disease deposits and suspicious nodes (in particular when the abnormal node's capsule has been lost)
        - If a suspicious node has well-defined capsule any internal disease may be contained, but an irregular node suggesting disease extension is important to comment on, as it may threaten/involve the CRM or other important structures

- Any discrete lymphovascular deposits or EMVI (generally along the venous drainage route cranially)
    - You can often see a discrete vessel in continuity with EMVI
    - EMVI may coalesce rather than being seen as a classical expanded tubular structure. 'Lymphovascular disease' can be helpful to describe these somewhat more ambiguous foci of disease

- Nodal disease: [102]
    - Can be very difficult to determine involved nodes on MRI
        - CT-PET increasingly used for problem solving, where extra sites of disease would meaningfully change management
    - Scrutinise the mesorectum for nodes, as well as the pelvic sidewall (PSW), and paraaortic levels for high disease (large field of view T2 images)
        - PSW nodes and those outside the pelvis should be highlighted, as these are not routinely resected in a TME, and may require a lateral dissection
    - Can define risk of node involvement based on the ESGAR consensus criteria as per *Beets-Tan RGH et al. (2018)*, though there is controversy as to the reliability.
        - Previously a clear distinction was not made between nodes and tumour deposits, and therefore the risk of nodal metastases is thought to have been inflated
        - More recent work shows that nodal metastases do not carry a worse prognosis, though tumour deposits do[103]

Table 4 Practical guidelines for nodal staging

Primary staging
Criteria for malignant node:
1. Short axis diameter ≥ 9 mm
2. Short axis diameter 5–8 mm AND ≥ 2 morphologically suspicious characteristics*
3. Short axis diameter < 5 mm AND 3 morphologically suspicous characteristics*
4. All mucinous lymph nodes (any size)
* Morphologically suspicious criteria:
Round shape
Irregular border
Heterogeneous signal
Restaging (after long course neoadjuvant treatment + downstaging interval)
All nodes with a short axis diameter < 5 mm should be considered benign
For nodes with a short axis diameter ≥ 5 mm no reliable criteria exist. As a practical guideline these nodes should be considered malignant.

What operation will the patient need?
This depends on what surgical planes are threatened

- See *Surgery* section for the types of operations and what surgical planes to consider

Clinical correlation when reporting

- "I can't appreciate the tumour they saw at endoscopy"
    - Look up the endoscopy report (see Logistics section; IT)
    - How big was the tumour, what was its morphology, how far was it from the anal verge?
    - Was it fully resected at the time (e.g. if a polyp)?
    - Do you have a CT-colon to compare with?
    - Could artefact be obscuring the lesion?
- When reporting do not necessarily assume a lesion is either benign or malignant.
    - If giving a provisional radiological staging you can say (for example): "If proven neoplastic at biopsy the provisional local radiological staging would be T2 N0 V0"
- Linear metal clip(s) in the rectum or colon (seen as metallic susceptibility artefact on MR)
    - These are Endoclips, which are placed after removing a polyp lesion endoscopically. They usually drop off a few weeks after being applied, but are relevant as they can create a non-diagnostic MRI scan.
    - If so, just recommend a repeat scan in a few weeks, by which time the clip will have usually fallen off. Can be a useful marker when looking for disease recurrence on a scan performed after a polyp has been resected
- Tumour that either extends from the rectum into the anal canal or vice vera
    - Important to try to differentiate anal from rectal cancer (surgical vs medical management)
    - Anal tumours tend to prolapse through anal verge and be centred on the anal canal
    - Ultimately biopsy should tell (rectal cancers are usually adenocarcinomas, and anal usually squamous, though mixed adeno-squamous cancers can be problematic)

TNM Staging Controversies in Rectal Cancer
Summary of some of the key points in this paper by *Lambregts et al (2022).* [104]

- Low rectal cancer staging
The primary tumour should first be defined by extent of invasion at the level of the rectum.
A description should be given for involvement of the anal canal itself.

- The internal sphincter and intersphincteric plane should not be taken into account with T-staging.
- Involvement of external sphincter, puborectalis, and/or levator ani (skeletal muscle) constitutes T4b disease
- Note that invasion into the internal sphincter or the intersphincteric space is important information but *does not change the overall T staging*, which is based off the rectal tumour.

An older system for describing involvement is given below. This is similar to the TNM system generally. [105]

mrLR1:

- Tumour confined to the bowel wall with intact muscularis

mrLR2:

- Tumour replaces/disrupts muscularis but not reaching the intersphinteric plane

mrLR3:

- Tumour invading the intersphincteric plane or lying within 1 mm of the levator muscle

mrLR4:

- Tumours invading the external anal sphincter and being within 1 mm and extending beyond the levator muscle ± invasion of adjacent structures

- Definition of T4b disease

Ambiguity as the TNM system does not clearly define 'structures' in its terminology.
The panel agreed that structures includes any structure (except peritoneum alone) and also compartments (such as obturator fat), so that invasion into a compartment constitutes T4b disease.

- MRF and CRM in reporting

MRF is anatomically defined, whereas CRM is defined by the operation.
Therefore when reporting, MRF should be preferred as this is reproducible. What constitutes the CRM may differ between different practitioners based on what they think the best operation would be, and also by the exact dissection planes during the operation.

- Limited data on MRF involvement by tumour-bearing structures which are not the primary tumour

For example, MRF contacted by an involved lymph node.

Involvement defined as:

- Primary tumour, an irregular lymph node, tumour deposit, or EMVI ≤1 mm from MRF.
- The use of 'threatened' (1-2 mm) should be avoided due to ambiguity

A smooth node at the MRF should not be taken to be involvement.

- See also nodal controversies below

- Difference between nodal metastases and tumour deposits

Previously a distinction was not made between the two, and therefore the risk was assumed to be the same.

More recent work shows that nodal metastases do not confer the risk they were assumed to, but tumour deposits and EMVI do. I.e. there are important prognostic differences.

More work is needed to determine if the two can be clearly and reproducibly defined so as to allow meaningful treatment stratification.
Fow now the panel suggest using the N category to document both involved nodes and tumour deposits/EMVI

- Lateral lymph nodes

Limited evidence on how involvement should be defined.
The panel agreed to adopt the pre-treatment size of < 7 mm as normal for obturator and internal iliac nodes.
Note that node morphology is not helpful in defining involvement.

5.4.3. Liver MRI:

(See also the Hepatobiliary section)

Three different protocols:

- Haemangioma assessment: limited non-contrast study
  - Assessment of lesion(s), often following detection on US, where it is strongly suspected these represent haemangiomas (echogenic, < 3 cm, no concerning medical history etc.)
  - Includes standard T2 and a more heavily T2 weighted sequences
- Extracellular contrast: Dotarem
  - Dotarem is generally better when the lesion(s) for characterisation have a wider differential
- Hepatobiliary contrast: Primovist
  - Primovist may struggle to characterise haemangiomas
  - Primovist also is associated with transient tachypnoea, rendering arterial phase images difficult to assess due to motion artefact

When to choose Primovist over Dotarem:

- High suspicion of metastases (e.g. liver lesions in colorectal cancer)
  - Metastases will remain hypo-intense
- Focal nodular hyperplasia (FNH) vs. Adenoma characterisation
- Suspected bile leaks
- (Note: Primovist is more expensive and has a higher rate of gadolinium deposition within the body compared to Dotarem, though the clinical significance of this phenomenon is presently unclear)

5.4.4 Anal Fistula MR:

See also the Fistula Surgeries section

Park's Classification:

1. Inter-sphincteric: commonest, path of least resistance
2. Trans-sphincteric: crosses external sphincter to reach skin surface
3. Supra-sphincteric: sepsis heads superiorly, over the puborectalis, through muscles of pelvic floor, and then inferiorly to an external opening
4. Extra-sphincteric: generally driven by problems in the rectum (cancer, IBD, iatrogenic), heading through pelvic floor (v.rare)

MR Anatomy:

- Anal canal: around 4 cm long [106]

- Upper: starts at the most cranial level of puborectalis
  - Here the sling of puborectalis and the external sphincter (deep part) are visible
- Mid: Where the external sphincter forms a complete ring
  - Superficial external sphincter, internal anal sphincter, perineal body, and the transverse perineii are visible here
- Lower: Level below which the internal sphincter terminates
  - Subcutaneous part of the external sphincter visible here

- Internal anal sphincter

- Continuation of the rectal circular muscle (i.e. continuation of rectum's muscularis propria)

- Its caudal margin terminates ~ 1-1.5 cm below the dentate line, and just above the caudal margin of the external anal sphincter

- Longitudinal muscle
  - Direct continuation of the longitudinal muscle of the rectum

- External sphincter formed of 3 layers (although there is some disagreement on this)
  - Puborectalis (part of the levator ani muscle complex[GGG])
  - External sphincter proper: deep, superficial, and subcutaneous components
    - The external sphincter 'rolls' inwards medially at its most caudal margin (forming the subcutaneous part)

- Intersphincteric plane
  - Contains longitudinal muscle (continuation of the rectum's distal circular muscle)

- Dentate line: not visible on MR but its position can be estimated
  - Coronally draw a line between puborectalis and anal margin. The dentate line lies around halfway between the two
- Inter-sphincteric groove (palpable surgical landmark)
  - Close to where the internal sphincter terminates

Aim to describe:

- Internal openings (defects in the anal canal, usually related to the fistula tract) and where they lie in anal canal (upper/mid/lower level, & clockface position)
  - Keyhole deformity / defect: Defect in the anal sphincter which causes it to deform from the normal round shape to an elongated/ovaloid shape
  - Horseshoe: Radial fluid forming either side of an internal opening (can be asymmetrical) in one of 3 planes:
    - Ischioanal fossa (extra-sphincteric), inter-sphincteric, or supralevator space
  - Hairpin bends: very sharp angulated bends (can complicate surgical intervention or make specific techniques impractical - see below)

- Where tracts pass (cranial, caudally, any divisions/ramifications/secondary extensions)
- Where tracts cross the external sphincter or puborectalis (clockface, if applicable)
- Any involvement of the levator, or any supralevator extension
- Fistulation to other structures, e.g. vagina

- Any collections
  - Note that fluid collections don't *necessarily* indicate sepsis, but this needs to be considered and at least described in the report
  - Are collections draining by a track with an opening? If not then they made need surgical intervention
  - It is important to carefully consider use of immunosuppression / biologics (IBD) when there is an undrained fluid collection which *may* represent a source of sepsis
  - Supralevator sepsis is concerning as can fistulate into vagina/bladder/rectum
- Any external openings (holes at skin surface where the track discharges from)

[GGG] Levator ani: consists of 3 muscles (puborectalis, pubococcygeus, and iliococcygeus) which are named for their attachments, forming a sheet of muscle representing the pelvic floor

Use of the clockface in description

May only be used in axial or axial-oblique images (any modality), as this correlates with the position as described during clinical assessment.

- 12 o'clock is anteriorly and 6 o'clock posteriorly
- If describing a large defect that spans several 'hours' it can be helpful to clearly state if you mean clockwise or anticlockwise to avoid confusion
    - E.g. "defect within the anal sphincter which extends from 3-6 clockwise"

Post-gadolinium sequences (not routine at STM):

- Helps differentiate between undrained sepsis and granulation tissue
    - Sepsis won't enhance
    - Subcutaneous tissue won't appear inflamed where there is granulation tissue
- Can be useful in 'complex' fistulae (usually defined as 1-2 prior interventions)

Malignant degeneration of longstanding fistula

- Tracts gets bigger and appear increasingly complex over time
- *Sudden* increase in volume of discharge
- Often present late, requiring abdominoperineal resection

6. LOGISTICS

6.1. IT Systems

Recommended programmes to gain access to whilst working at St Mark's.
Use the desktop IT helpdesk self-service icon on the desktop to request access where needed.

System	Accessed from	Uses
Cerner	Intranet 'clinical applications' and desktop	Introduced in Aug 2023 across the Trust as their electronic patient record system, replacing many of the pre-existing IT solutions
~~ICE~~ *	~~Intranet 'clinical applications'~~	~~Request & view imaging, blood, pathology~~
St Mark's CIS	Intranet 'clinical applications'	Early access to lower GI MDT list patients for discussion
Endoweb	Intranet 'clinical applications' [Ask colleagues for radiology's generic login]	Full endoscopy reports
Results	Intranet 'clinical applications'	Endoscopy reports, pathology
Below systems are set up via PACS Team, or do not require a specific login		
Soliton	Desktop	RIS
Sectra PACS (IDS7)	Desktop: opens from a browser (or alternatively via intranet)	PACS
Vitrea	Desktop icon on PACS reporting workstations	Cloud-based software used for reporting CT-Colons
* Functionality has been replaced by Cerner		

6.2. Preparation for MDTs

Where can I print lists?

- Printer access: use the IT self-service (available from the PC desktop) to request access to the 'follow me anywhere' printing (printer token).
- You collect a small sticker from IT (near physiotherapy, ask for directions) which you can apply to your ID badge to use with the printers throughout Northwick Park.

Some MDTs (e.g. LGI) have their own MDT worklist calendars on PACS that you can use (visible by all), or you can create your own 'static worklists' (visible only to you when you log in to PACS as yourself).

- Both allow you to have all the MDT patients in a list to quickly find them during meetings and are otherwise functionally similar

a) Lower GI

- Getting a head start on preparing each week

- This can be a busy MDT, and the formal list of patients is sent out on Wednesday afternoon
    - You can also use 'St Mark's CIS' to view the provisional, real-time list as patients are added by clinicians, so you can start preparing before formal lists are sent.
    - This is the same page the Cancer Coordinators use to create the formal Word document list that they later send out.
- The link for STM CIS is found on the Intranet homepage

- General advice:
  - When reviewing imaging remember to search under DOB on Sectra PACS (*not* Soliton)
    - Imported imaging is often under a separate record on Sectra, and even searching by name may not locate external imaging
  - Disabling the sync between PACS and RIS can be useful to stop the system 'jumping' between windows (a personal preference)
    - Open RIS *worklists*, and uncheck the box in the very bottom right of the screen
  - Always check for pulmonary emboli: occasionally incidentally picked up on portal venous phase CTs

- *Common questions and meeting scenarios (Lower LGI)*
  - CT-colon:
    - Is bowel preparation good enough to exclude more proximal / upstream lesions?
      - A more limited flexi-sigmoidoscopy instead of full colonoscopy could be performed if there's nothing more proximal
      - The planned operation may be changed if there's a suspicious polyp (or suggestion of polyposis syndrome) - e.g. hemicolectomy vs. a total colectomy
    - Confidence that a lesion is 'real'
    - Further imaging: If unenhanced or no CT chest, may therefore need full post-contrast CT-CAP for complete staging
  - MR Rectum
    - What operation is needed for curative resection (see operations section)?
      - Where is the tumour in relation to anorectal junction and is the anal sphincter involved?
      - Disease outside the MRF: pelvic sidewall nodes, deposits, suspicious nodes, EMVI (particularly extending cranially)
      - Specifically mention if the CRM is threatened or clear
    - Formal radiological staging: Local MR staging (and M-stage if CT-CAP has also been done)
  - MR Liver review:
    - Aim to clearly shows sites of metastatic disease and their segments, particularly if the clinical question is to review with a Hepatic Surgeon for treatment opinion
    - The portal venous phase images will usually be the best to show for the Hepatic Surgeon to orientate themself (shows venous and portal vessels clearly)
    - Question is generally whether the lesion is suitable for RFA / resection
  - CT imaging following colonoscopy where suspicious lesion detected:
    - Extent of disease
    - Is the endoscopically detected lesion visible, and can you provide TNM staging?
    - Further imaging: MR Liver if indeterminate lesion, or high risk (T3 and/or V2 disease)
  - Isolated review of CT-chest to complete staging
    - Is there metastatic disease, and what's the final radiological staging?
    - Do nodules look suspicious, or are they indeterminate
    - CT-PET may help for nodules at least 10 mm in size if there's still doubt. Follow-up CT in 3 months may also be helpful to assess for interval growth
  - Surveillance imaging:
    - Recurrent disease detected on a routine surveillance study in a patient with known treated cancer. Scan flagged for MDT discussion.
    - Where's the recurrence and its extent? This facilitates discussion as to what options are available surgically / medically to treat.

    - Is the suspected recurrence likely to be real?
        - Occasionally patients who are 5 years post-op will have a slight increase in a node, or a new area of soft tissue (? Deposit)
        - Local MR for further assessment may be helpful, or sometimes CT-PET for problem solving
- Endoscopically visible small bowel lesion / polyp
    - Often CT-E or MR-E: can you see an imaging correlate, and are there any further lesions (including associated mesenteric mass)?
    - What distance is the lesion from DJ flexure or terminal ileum (i.e. can it be reached with double balloon endoscopy)?
- Oncological response:
    - Comparison of imaging (e.g. two CT-CAP studies 6-months apart for a general overview of sites of disease and treatment response)
    - May be asked for a more focused review (e.g. comparing two MRI Liver studies)
    - Often external imaging without reports, and you may not have full history as to prior treatments (such as RFA to liver lesions or prior segment resections[HHH]), so caution needed when interpreting.
    - Look for previous radiology MDT documentation on Soliton to help, or EPRO clinic summaries / letters
- Incidental CT-PET avidity:
    - Does it correlate with other imaging, what might it represent, and how should it be investigated?
    - Example: avid rectal lesion which in hindsight is visible on previous CT. Possible rectal tumour - for DRE and flexisig in the first instance
- Post-operative histology cases:
    - Often don't need imaging reviewed, but wise to have looked at this in advance in case the MDT asks for a review following discussion of histology
    - Helpful to review the presenting scan too, especially if a question about surgical margins in retrospect
- Suspected pelvic retrorectal cyst review
    - Benign cysts should be homogenously high T2 signal without internal complexity or solid components
    - May require follow-up / surveillance, or potentially resection
    - Often an incidental finding
- Cases from other sources:
    - Example: Review of incidental lesion detected on MR Prostate (via Urology MDT)

b) Inflammatory Bowel Disease

Crohn's makes up the majority of cases (certainly the most complex scans).[107]

Split into Radiology (review of scans) and Dysplasia (review of histology) sections.

- Questions and clarification of scans often asked by clinicians

- Length of bowel involved:
    - Continuous or discontinuous disease, and how much normal bowel in between
- Disease activity
    - Mural thickening, mural oedema, and hyper-enhancement etc.
- Strictures and extent of upstream small bowel dilatation (i.e. evidence of obstruction)
    - Are all the strictures close together in a short segment that could be resected?

[HHH] Both can have very odd appearances with mixed T1/T2 signal from blood products and the ablation

    - Which stricture(s) are dominant, what length are they (may be amenable to strictureplasty). Discontinuous strictures that are separated by a lot of normal bowel cannot be resected without removing excessive bowel, or requiring many anastomoses.
- How much healthy / uninvolved bowel is left?
    - Bowel quality is important to mention when resection is being considered, as though the patient may not be left 'short'[III], the small bowel left behind may not be normal in terms of its function
    - Upstream uninvolved bowel may be somewhat thickened, representing 'adaption'. Normal bowel adapts to take on greater role to compensate for poor absorption of abnormal bowel.

- Any colonic disease?
- Are stomas / pre-stomal segments involved?
- Any extra-luminal complication?
    - Penetrating / fistulating disease: what is connected to what?
    - Intra-abdominal collections / inflammatory masses / fistulae
    - Undrained fluid may represent sepsis (risk when starting immunosuppressive biologics)
- Perianal fistula and undrained collections

- Extra-intestinal disease:
    - Primary sclerosing cholangitis, sacroiliitis / enteropathic arthropathy etc.
- Lymph nodes: commonly enlarged (reactive to inflammation), but important to remember CrD patients have an increased risk of malignancy, especially lymphoproliferative disorders [108]
    - Have the nodes changed, or are they disproportionate to the level of disease?

- How do I measure bowel length accurately?
- This can be very difficult and depends on: the degree of motion artefact, bowel distention, adhesions/fistulae (loops matted together).
    - Small bowel also varies in length considerably
    - It may be that you offer to have a look after the meeting and let the clinician know, rather than trying to rush a difficult measurement
- Measuring a ~ 5-10 cm segment and mentally summating these as you trace the bowel can be helpful
    - Easier to follow bowel and measure when it's all in plane (i.e. you can follow a long length of it on a single image)
    - Use a combination of axial and coronal if one plane is insufficient
- Often a general overview of saying a good length of normal small bowel remains is sufficient (> 50 or > 100 cm). Indeed, this may be all that it's possible to say on a given study if bowel is difficult to trace and poorly distended.

6.3. MDT Timetable

[III] 'Short' is sometimes used to describe patients with an overall short length of bowel remaining, or where a resection has / will leave the patient with short bowel.

Day		Meeting & Venue	Time & Frequency
Mon		General surgical [Teams] No preparation required. *ST2 trainee to attend as able*	13.00 Weekly
Tues		Benign Hepatobiliary [CMH conference room, BeCAD]	09.00 Weekly
		Complex Endometriosis MDT [Teams]	13:30 Once/month
Wed		IBD (~ 10 cases; can be complex with imported imaging) [Teams / CMH] Dysplasia cases (i.e. histology) generally discussed from 08:30. *Senior GI trainees to present and ST2 trainee to attend*	08.00 Weekly
		Pelvic Floor [Teams] Endoanal ultrasound and proctography imaging review with physiology.	12.00 Alternate weeks
		Benign Oesophageal & Swallows Meeting (ISOC) [Teams]	12.00
		Intestinal Failure and Nutrition [Teams]	09.00 Weekly
Thurs		Anal cancer [Teams] Linked with Imperial, with anal cancer cases presented at the end of their lower GI meeting.	~ 09.15 Alternate weeks
		Upper GI MDT [Teams] *ST2 GI trainee*	12:00
		Complex Abdominal Hernia XR Meeting [Teams]	Variable time Once/month
		Intestinal Mapping XR Meeting [Teams]	Variable time Once/month
		Complex cancer (~ 15-20 cases) [CMH 'Park Royale Suite] Rectal cancers requiring 'beyond TME' procedures. *Senior GI trainees*	Variable start in PM, ~ 14.00
Fri		St Mark's Grand Round [Teams]	07.30-08.15
		St Mark's XR meeting [CMH 'Park Royale Suite] Review of general GI imaging. Problem solving with complex imaging and cases that don't fit into the LGI meeting but where MDT discussion would be helpful. *GI trainees to attend*	08.15
		Lower GI MDT (~30 cases) [CMH 'Park Royale Suite] Final list sent out Thursday ~13:00, though may be late additions. Immediately after the XR meeting. *Senior GI trainees to present and ST2 trainee to attend (prior to UGI meeting preparation)*	09:00
[ ] Venue is almost exclusively via MS Teams, but physical venues also listed were applicable. * Exact time is decided in advance each month, but is very variable depending on clinician availability.			

6.4. Useful Sectra PACS Shortcuts

Image Manipulation:

- Multiplanar reformatting (MPR): Ctrl +M
  - Double click a quadrant to enlarge
  - You can MPR high resolution volumetric MRI sequences (such as the T2 SPACE)
  - Use Ctrl + A, C, or S to quickly change to axial, coronal, or sagittal respectively
- MPR and 3D volume render: Ctrl +T
- Rotate images:
  - Ctrl+ O: rotate by 90 degrees
  - Ctrl+ H: flip image left to right
- 'Slabs':
  - Ctrl and - : Opens the slab properties menu
  - Shift+ 1: 3 mm average (i.e. creating thicker slices)
  - Shift+ 2: 5 mm MIP
  - Shift+ 3: 10 mm MIP
  - Press - to turn slab on/off (don't use the Numpad -)
  - Hold Shift and rotate mouse wheel to increase/decrease slab thickness
- Sharpen image: Ctrl +E
- Zoom: Ctrl+ Mouse wheel

Measurements:

- Region of Interest (ROI) circle: R
  - Displays average Hounsfield units / CT-number
- Linear measuring calliper: M

Localising:

- Localiser (yellow line to represent the plane on other images): L
- Crosshair on & off (can be moved to make other images match the orientation): Alt +C
  - Holding Q will make the crosshair appear until you release

Flagging images

- Individual image slices on CT and MR, as well as individual images in a stack of US images can be 'flagged', which then lets you cycle through them quickly. Useful for MDTs or highlighting key images. Using the numpad keys specifically:
  - Flag an image with '/' and '*' to remove a flag. Flagged images will be marked with a small flag at the top of the screen
  - Use Page up and Page down to cycle through all the flagged images

Misc.

- Opening report window on PACS
  - Hover over the image window and press 'D' to open a small window with report
- Partitions - Divide a single window into varying increased partitions
  - Ctrl+1: 1 x 1
  - Ctrl+Shift+1: 1 x 1
  - Ctrl+Shift+2: 1 x 2
  - Ctrl+Shift+3: 1 x 3
  - Ctrl+2: 2 x 2
  - Ctrl+Shift+4: 2 x 2
  - Ctrl+Shift+6: 2 x 3
  - Ctrl+3: 3 x 3

    - Ctrl+Shift+9: 3 x 3
    - Ctrl+4: 4 x 4
- Linking two or more separate image stacks
    - Line the CTs up to equivalent slices
    - Then hover mouse over each window and press + (on Numpad)
    - Use - (on Numpad) to unlink

7. COMPLEX CANCER

7.1 Introduction to Complex Cancer

Definitions:

- Complex cancer: Rectal or anal cancer requiring surgeries *beyond total mesorectal excision*
    - Also includes management of recurrent or regrowth of disease
- Recurrence: Disease that has returned following a previous R0 (clear margins) resection
- Regrowth: Disease that has either now become apparent or increased in size following a non-R0 resection.

Meeting goals:

1. Describe extent of disease radiologically, and confidence that it fits into one of the following:

a) Local disease (including lymph nodes):

- Directly involved structures (direct invasion or encasement by disease, or < 1 mm clear plane between structure and disease)
- Threatened by active disease (structures contacted or within 1-2 mm)
- Nearby crucial structures clear of disease (e.g. ureters)

Interpretation may be complicated by prior chemo and/or radiotherapy, where an opinion on what represents inactive disease (post-treatment scar/fibrosis) vs. active disease may be difficult.

St Mark's favours description of the *maximum* extent of disease on imaging, even when radiologically there has been evidence of 'downstaging' following treatment.

- The rationale is that microscopic disease can persist at the disease margin after downstaging, risking R1 resection and subsequent recurrence if the more reassuring post-treatment imaging is used to plan the operative margins.
- Important to review the level of post-treatment (chemotherapy) 'scarring' and its distance from the anorectal junction
    - Relevant regarding where it's safe to create an anastomosis.

b) Metastatic disease (including lymph nodes)

- Extent and location
    1. CT-CAP
    2. CT-PET: still some uncertainty as to how best this should be used. Generally utilised for assessing suitability for further surgery. Examples of use - indeterminate findings on conventional CT, equivocal lymph nodes, skeletal disease, restaging disease, problem solving.
        - Note that mucinous disease may not be FDG avid due to low cellularity (i.e. not visible on PET).
        - Reduced sensitivity for lesions < 1cm in size
    3. MR Liver: most commonly with hepatobiliary contrast (e.g. Primovist) if high index of suspicion for metastatic disease
- Whether disease extent feasibly prevents a curative resection (i.e. would it be possible to gain control of the metastatic disease?)

2. What surgery would be required to achieve a curative (R0) resection

- An R0 resection is defined as having a > 1 mm clearance margin histologically
- Surgery needs to confidently remove all sites of disease (where feasible)

Surgery <u>feasibility</u>

- Expected morbidity/mortality related to planned surgery
- Patient fitness, acceptance of proposed surgery (which includes discussion of sexual function & fertility implications), and aftercare
- Ability to repair defects e.g. using flaps [109]

3. Surgical <u>options & alternatives</u> (both now and in future)

- Where surgery is not feasible: Symptom control surgeries e.g. defunctioning stomas, or requesting an oncology opinion for palliative radiotherapy and disease control
- Where disease has recurred *after* previous complex cancer surgery: any possibility of further surgery to gain control? Does for Oncological treatments?

The Surgical Roadmap:

A 'surgical roadmap' can be provided by the radiologist to aid planning surgery. A helpful mnemonic to make sure that all the relevant structures are considered used at St Mark's is 'BONVUE'.

B - bones:

- Sacrum and ischial spines, and occasionally also the pubic rami and pubic symphysis

O - organs:

- Will the patient need a partial or full pelvic exenteration?

N - nerves

- Sciatic nerve and its roots (mainly), though the femoral nerve is also considered (obturator nerve is not usually considered separately)

V - vessels

- Mainly the internal and external iliac vessels
- Excision proximal or distal to the superior gluteal artery is important for healing and flaps

U - urinary (ureters and bladder)

- Are the ureters involved and is there hydronephrosis? Will a Boari flap be needed? Is the prostate threatened or involved?
- Does disease lie close to the ureters, and would a stent be helpful to protect the ureters during the operation?

E - extra sites of disease

- Any additional sites of disease (liver, lungs). Evaluate all the available imaging.
- If there is further disease, have plans been made for disease control here also (e.g. wedge resection in liver and lung metastases)?

7.2 Anatomy & Surgical Techniques [110] [111]

Beyond Total Mesorectal Excision ('beyond TME') procedures:
Describes surgical techniques *beyond standard TME* operation for the treatment of complex cancer (including recurrent disease). These patients are seen in St Mark's Complex Cancer Clinic (CCC) and discussed at the dedicated complex cancer MDT.

A TME alone is *not* sufficient to fully remove disease that extends beyond the standard circumferential resection margin (CRM), and therefore operations will either involve a TME + additional procedures, or a TPE + additional procedures.

a) The core 'beyond TME' procedures:

- TPE: [JJJ] Total Pelvic Exenteration - curative intent; removal of all pelvic organs (necessitating formation of a stoma and an ileal conduit).
    - Omental fat is brought down to 'fill' the empty pelvis, and the perineal defect is replaced with a flap
    - Risk of subsequent:
        - Perineal hernia: Small bowel in particular may herniate into the 'empty' pelvis
        - The environment promotes adhesions and increases risk of small bowel obstruction episodes.

- ELSiE: Extended Lateral Pelvic Sidewall Excision
    - Can either be a 'bony' resection (variable length of the ischial spines resected), or 'soft tissue' (where the SLAM[KKK] is released from its insertion at the ischial spine)
    - Curative intent; managing disease involving the pelvic sidewall, sciatic nerves, or extending through the sciatic notch

- Additional osseous resections including …
    - Sacrectomy (low or high): removal of entire levels of the sacrum *en bloc*[LLL]
    - Subcortical Sacrectomy and High Subcortical Sacrectomy (HiSS)

b) Related additional complex cancer procedures:
Note that many of these structures will be removed as part of a TPE by default, but may also be selectively removed in addition to a TME procedure

- BSO: Bilateral salpingo-oophorectomy
- Hysterectomy
- Vaginectomy
    - Important to know if neo-vagina reconstruction has taken place when reviewing scans
- Penile base resection
- Prostatic shave (for tumour contacting the prostate)
    - Denonvilliers' fascia (rectoprostatic fascia) separates the prostate and urinary bladder from the rectum

[JJJ] More limited anterior and posterior exenterations are also done, as well as supralevator TPE where anal canal is left in situ.
[KKK] SLAM: Sacral Ligament and Muscle (complex)
[LLL] Description for a resection which removes a structure or part of a structure as a single piece

- Removal of seminal vesicles
- Boari flap and ureteric reimplantation
- Omentectomy
- Colonic and small bowel stomas
- Ileal conduit: following cystectomy, a segment of ileum is used to fashion a dedicated short stoma to the abdominal wall, into which the ureters are connected
    - Having taken a length of small bowel for the conduit, there will also be an entero-enteric (ileal) anastomosis

Pelvic organs / viscera, Urological, & Reproductive			
Structure	**Relative to rectum**	**Specific Surgical technique**	**Notes**
		Common Viscera (male & female)	
Rectum (If not already removed)	N/A	Dependant on the extent of disease. See the '*rectal cancer surgeries*' section.	- Standard / Extra-levator Abdominoperineal resection + further 'beyond TME' resection(s) or - Total pelvic exenteration (sometimes posterior pelvic exenteration)
Urinary bladder	Anterior	Cystectomy (partial or total)	Consider partial if tumour abuts or invades dome of bladder. Post-op fluoroscopic cystogram to check for bladder injury may be requested.
Ureter(s)	Antero-lateral	Ureteric diversion / Ileal conduit. Ureterectomy ± re-implanation of the ureter (if disease at vesicoureteric junction)	May require pre-operative stenting if disease lies close to the ureters. Post-operatively: may receive request for a delayed/excretory phase CT (also sometimes called a CT IVU) to look for ureteric injury.[MMM]
Gonadal vessels	Antero-lateral		Fertility implications should be discussed with the patient
		Male	
Prostate (& urethra)	Anterior	Prostatic shave (threatened margin) Prostatectomy (invasion) often as part of TPE	Posterior surface of prostate can be 'shaved' away when tumour threatens margin.[NNN] Distance to urethra? In reality invasion of the

[MMM] Important to distinguish a ureteric injury from anastomotic leak. Can correlate with drain fluid Creatinine. Suspect leak if there are collections close to the ureter (especially if there has been specific ureteric surgery), if there are persistent collections increasing in size, and high drain fluid creatinine.

[NNN] Difficult surgically. No clears means by which to intra-operatively judge the distance between the posterior prostate and the urethra, thus the prostatic shave technique must be used with caution.

			prostate usually requires TPE as following neo-adjuvant therapy forming a urethral anastomosis after prostatectomy is complex with relatively high leak rates.
Seminal vesicle(s)	Anterior	Seminal vesiculectomies	
Penile base	Anterior	Penile bulb/base resection [112]	Surgery around this site can lead to penile metastases if disease recurs, due to the disruption of normal tissue planes. Important review area on subsequent MRIs (particularly sagittal).
Transverse perineal muscle (transverse perinei)	Anterior	Resection	Along with penile base
Female			
Uterus & Cervix	Anterior	Hysterectomy	
Ovaries & uterine tubes	Antero-lateral	(Bilateral) Salpingo-oophorectomy [BSO]	
Vagina	Anterior	Vaginectomy	Depending on extent of disease, it may be possible to do a posterior vaginectomy + reconstruction, or alternatively a total vaginectomy.
Table Notes			
· TPE (Total pelvic exenteration) will often be required for complex cancer where multiple pelvic structures are involved • More limited anterior (bladder & uterus) and posterior (uterus & rectum) pelvic exenterations also exist, and were originally devised for gynaecological cancers · Resection of many of the above structures will impact fertility and sexual function which therefore needs to be discussed during			

Pelvis (bony pelvis, side wall, musculature, neurovasculature)			
Structure	**Relative position**	**Surgical technique**	**Notes**
Pelvic Muscles & Ligaments (supporting structures)			
Levator plate & Puborectalis muscles	Pelvic floor	Resection defined by the main rectal cancer surgery (e.g. ELAPE or TPE)	Forms the pelvic floor. Puborectalis defines the upper anal cancer on imaging.
Obturator internus muscle	Lateral	Removal of overlying fascia or resection (partial or full thickness), depending on extent/depth of disease involvement. The depth of invasion is an important factor to describe.	Resectable (pelvic sidewall excision), though more difficult if sacroiliac joint or pubic disease (pelvic instability). Obturator nerve can be preserved if limited disease.
Piriformis muscle	Posterior		Resectable, though more difficult if acetabular disease. The medial piriformis is resectable via the abdomen, though the lateral component requires an ELSiE
Gluteal muscles	Posterior		
Sacral Ligaments and Muscles (SLAM) [1] [sometimes called the 'soft tissue SLAM' at STM]	Posterior		SLAM is a unique St Mark's term describing the sacrotuberous, sacrospinous and ischiococcygeus muscle and ligamentous complex, which are all closely related to each other.
Ischial spine [sometimes called the 'bony SLAM' at STM]	Posterior		Resectable, often as part of other procedures. (e.g ELSiE) Relatively contraindicated if there is metastatic disease. Useful surgical landmark. Disease lateral to the ischial spine should be highlighted when considering margins and feasibility.
The Pelvic Sidewall (PSW) [2]			
Pelvic sidewall (PSW) Lymph node resection ±	Postero-lateral	*Lymphadenectomy*	Resection of pathological nodes at the PSW. Lymphoceles may be seen on follow-up scans.
wider lateral margin to resect more lateral disease invasion / muscle involvement		*Extended Lateral Pelvic Sidewall Excision (ELSiE)* 113	Allows resection of disease within or contacting the PSW. Developed to counter the

		More extensive than lymphadenectomy: dissect off the piriformis and ischial spine with exposure of the sciatic nerve roots at the greater sciatic notch	poor prognosis associated with not resecting PSW disease. CT-PET may be used to identify involved PSW nodes outside the standard surgical resection.
Inguinal region	Peripheral	*Inguinal lymphadenectomy*	Important review area during scans. CT-PET highlights inguinal nodes, which are outside the standard surgical resection (even for a complex cancer procedure).
Bony Pelvis & Pelvic ring			
Sacrum	Posterior	*Sacrectomy* Complete removal of levels: - High (S1-S3) & - Low (S3-S5)	*Important to describe maximum height of disease (sacral promontory is a useful landmark for the surgeons [3]), and the depth of invasion.* <u>*Sacrectomy (full thickness)*</u> For disease directly invading the sacrum. A high resection carries greater morbidity (sacral nerves sacrificed), but a lower risk of recurrence. <u>*HiSS*:</u> [4] For disease involving the anterior cortex (< 10 mm). Curved osteotome used to take anterior sacral cortex. Reduced morbidity as maintain stability and nerve roots (cf. sacrectomy) without need for reconstruction. <u>*Subcortical Sacrectomy*</u> For disease at the presacral fascia. Less extensive than a HiSS.
		High Subcortical Sacrectomy (HiSS) [114]	
		Subcortical Sacrectomy	

Coccyx	Posterior	*Coccygectomy*	
Pubis	Anterior	*Resection of pubis*	
Neurovasculature (see also below)			
Individual lumbo-sacral nerve roots	Postero-lateral	*Nerve / nerve root resection* Important to recognise which nerve roots and nerves may need to be sacrificed for a curative resection, as this will guide informed consent on neurological morbidity. Requires discussion of morbidity with patient: mobility, pain, sexual function	Exit from neural foramina, before converging with other roots to form the named nerves.
Sciatic nerve (L4-S3)	Postero-lateral		Passes through Greater sciatic foramen. Sciatic nerve can be resected here. Excision will cause footdrop. Bilateral excision can cause significant morbidity.
Obturator nerve (L2-L4)	Antero-medially		Passes through obturator foramen.
Femoral nerve (L2-L4)	Antero-laterally		Travels laterally with femoral vessels.
Internal iliac artery	Postero-lateral	*Resection*	Can be resected, ideally *below* the origin ('take-off') of the superior gluteal artery to allow its preservation.[5]

Table Notes

[1] St Mark's refers to the SLAM, as surgically it is difficult to differentiate between the individual ligamentous structures as they blend into the levator ani.
Consists of 'bony SLAM' (ischial spine), and the 'soft tissue SLAM' (ligamentous component).
An ELSiE can involve a bony resection (variable length of ischial sine) and soft tissue component (ligamentous complex release from its insertion at the ischial spine) respectively.

[2] Pelvic sidewall = the posterolateral aspect of the pelvis, bounded laterally by the obturator internus, SLAM, and piriformis.

[3] Sacral promontory: useful intra-operative landmark for the surgeons, as anteriorly it is difficult to determine each distinct sacral level.
Extensive bony pelvic resection can create pelvic instability with associated morbidity.

[4] HiSS: Anterior central sacral column (limited laterally by the lateral aspect of the sacral foramina) is removed from the sacrum to a depth < 10 mm of cancellous bone.
Anterior sacrum removed *en bloc* along with invading tumour and anterior structures, preserving the posterior portion and alar of the sacrum.

[5] A flap supplied by superior gluteal artery can be used for reconstruction, and hence needs the SGA for perfusion. Therefore, it is important to report if iliac vessels need resection above or below the 'take-off' (origin) of the SGA.

Pelvic spaces, Fascia, and the Sciatic Foramina		
Structure / Space	**Anatomy**	**Notes**
Male: Recto-prostatic fascia (Denonvilliers')	A remnant of the recto-genital septum. Separates prostate & urinary bladder from rectum. Ascends to the seminal vesicle	Variable thicknesses on MRI, both visible below the peritoneal reflection. Appreciable separately from the much thinner and more anterior MRF.
Female: Recto-vaginal fascia / septum (fascia of Otto)	Separates vagina from rectum	
Presacral fascia & Rectosacral fascia (Waldeyer's fascia)	Presacral: Overlies the sacrum and fuses with the MRF at its postero-inferior margin. Rectosacral: Originates from the presacral parietal fascia at the S2-S4 level and fuses/becomes continuous with the posterior rectal visceral fascia (MRF)	During TME, the surgeon dissects between the MRF and presacral fascia (the interfacial plane).[115]
Retrorectal space	Between the *posterior aspect of the MRF* anteriorly and the *presacral fascia* posteriorly. The floor is formed by the presacral (parietal) fascia meeting the rectal visceral fascia (MRF), lying above the levator ani.	Space divided into superior and inferior by the rectosacral fascia. The superior part is continuous with the retroperitoneum.
Retro-pubic space (Space of Retzius)	Potential space between the pubic symphysis and urinary bladder	
Vesico-vaginal space		
Ischio-anal fossa [1]	Disease may directly extend into both.	Important to describe suspected disease deposits, as a wider margin may be taken by the surgeon to prevent a local recurrence. Note this includes sites of treated disease (especially if partial response to treatment).
Perineum		
Sciatic Foramina		
Greater sciatic foramen	Formed by the sacrotuberous and sacrospinous ligaments	Transmits piriformis… - Above: Superior gluteal neuro-vasculature - Below: Inferior gluteal neuro-

		vasculature, Pudendal nerve
Lesser sciatic foramen	Formed by the sacrotuberous ligament and the sacrospinous ligament	Transmits… - Obturator internus tendon - Internal pudendal neuro-vasculature - Nerve to obturator internus
Table Notes		
[1] Ischiorectal (cranial aspect) and ischioanal (caudal aspect) fossa are effectively the same space without a specific anatomical boundary, hence often just called the ischioanal fossa		

Pelvic nerves

The lumbosacral plexus represents the complex convergence of various nerve roots to form discrete nerves which provide motor and sensory innervation to the ipsilateral pelvis and lower limbs.

The plexus is formed from L1-S4 [OOO], and can be split into upper (L1-L4) and lower (L4-S4) parts. Lumbosacral Nerve roots exit via the neural foramina below their named vertebral body (e.g. L4 root arises below the L4 vertebral body [PPP]). The plexus is formed just laterally to where roots exit, mainly within the posterior psoas muscle.

Important pelvic nerves [116] [117]

Nerve	Roots	Motor / Sensory	Function
Lumbar plexus *			
Obturator	L2-L4	M, S	M: Supplies muscles of medial thigh (obturator externus and adductors) S: Medial thigh
Femoral	L2-L4	M, S	M: Anterior thigh muscles (Iliacus, pectineus, sartorius and quadriceps femoris) S: Anterior thigh & medial leg
Lumbosacral plexus †			
Sciatic	L4-S3	M, S	M: most hip lateral rotator and posterior thigh muscles, all muscles below knee S: Hip articular [1]; posterolateral leg, lateral and sole of foot
Superior gluteal	L4-S1	M	M: Gluteus medius & minimus
Nerve to quadratus femoris & inferior gemellus	L4-S1	M	M: Quadratus femoris & inferior gemellus
Inferior gluteal	L5-S2	M	M: Gluteus maximus
Nerve to obturator internus & superior gemellus	L5-S2	M	M: Obturator internus & superior gemellus
Nerve to piriformis	S1-S2	M	M: Piriformis
Posterior femoral cutaneous	S2-S3	S	S: Buttock and upper posteromedial thigh
Pudendal	S2-S4	M, S	M: Perineal muscles, external urethral and anal sphincters S: Genitalia (penis & clitoris)

Table Notes

[1] Articular nerves: sensory (including pain and proprioception)

* The femoral and obturator nerves are readily visible on MRI

† Likewise, the sciatic nerve is easily appreciated, as are other nerves to a varying degree

[OOO] L1 is often joined by T12.

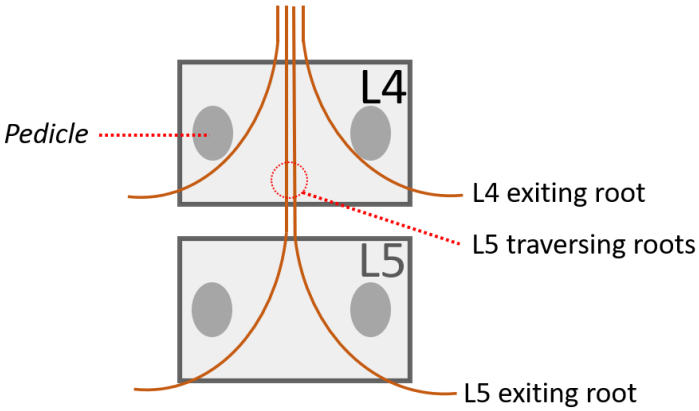
[PPP] Compare with cervical spine where the nerve root exits above its corresponding vertebral body.

Correctly identifying pelvic nerve roots

- Lumbar and Sacral nerves:

Traversing nerve root initially descends medially, then moves laterally to become the exiting nerve root at the neural foramen.

The exiting nerve root is named for the above vertebral body above.



- Landmarks for the pelvic nerves

- L5 & S1: separated by the superior gluteal artery (coronally)
- S2: passes through the piriformis muscle
- S2 & S3: separated by the inferior gluteal artery (coronally)
- S4 & S5: usually relatively easy to see low within the pelvis

8. HEPATOBILIARY

HPB Contents

Sections

8.1 Management options for oligometastatic colorectal cancer in the liver – an overview:
- 1.1 Anatomy & Surgery: Divisions of the liver and resections
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8.1. Management options for oligometastatic colorectal cancer in the liver – an overview

8.1.1 Surgical Resections

- Liver Anatomy & Resectional Terminology [118]

Divided into 'orders' via arterial supply (with identical biliary ramifications)

- 1st: right & left *hemi-liver*
  - Right & Left hemi-liver (divided by midplane of liver)
    - Supply: Right & left hepatic arteries
- 2nd: 4 *sections*
  - Rt anterior & posterior sections (divided by Right intersectional plane - no surface markings)
    - Supply: anterior & posterior segmental arteries
  - Lt medial & lateral sections (divided by left intersectional plane[QQQ])
    - Supply: medial & lateral segmental arteries
- 3rd: 8 *segments*
  - Segment IV: arbitrarily divided into IVa & IVb, as the vessel divisions prevent any clear further division.
  - Therefore Left medial section = Segment 4
  - Segment I (caudate) is distinct from hemi-livers
    - Supply: from both Rt & Lt hepatic arteries and portal veins.
    - Biliary: drainage into both Rt & Lt hepatic ducts

[QQQ] Umbilical fissure and line of attachment of the falciform ligament to the anterior liver surface

1st Order

Anatomical Term	Couinaud Segments	Term for Surgical Resection	Diagram (pertinent area is shaded)
Right Liver **OR** Hemiliver	Sg 5-8	Right Hepatectomy **OR** Right Hemihepatectomy	
Left Liver **OR** Hemiliver	Sg 2-4	Left Hepatectomy **OR** Left Hemihepatectomy	

2nd Order

Anatomical Term	Couinaud Segments	Term for Surgical Resection Add (-ectomy) to any of the anatomical terms	Diagram (pertinent area is shaded)
Right Anterior Section	Sg 5,8	Right anterior sectionectomy	
Right Posterior Section	Sg 6,7	Right posterior sectionectomy	
Left Medial Section	Sg 4	Left medial sectionectomy	
Left Lateral Section	Sg 2,3	Left lateral sectionectomy	

3rd Order

Anatomical Term	Couinaud Segments	Term for Surgical Resection	Diagram (pertinent area is shaded)
Segments 1-8	Any one of Sg 1-8	Segmentectomy (e.g. segmentectomy 6)	
2 contiguous segments	Any two of Sg 1-8 in continuity	Bisegmentectomy (e.g. bisegmentectomy 5,6)	

Imaged from *Strasberg SM, Phillips C (2013)*

a) Anatomical Resections

Resection of anatomical liver segment(s)

- Segmentectomy (resection of one segment)
- Sectionectomy (combination of adjacent segments e.g. left lateral – II/III)
- Right/left hepatectomy ± caudate resection [V-VIII/II-IV ± I]
- Extended right/left hepatectomy ± caudate resection [IV-VIII/II, III, IV, V, VIII ± I]
- Modified extended right hepatectomy [V-VIII + half of IV]

- Central resection [IV, V, VIII – leaving I-III & VI-VII]

b) Non-Anatomical Resections
A resection which does not conform to an anatomical segment

- Wedge resection – typically for metastases near the capsule, which are relatively easy to access, can be done laparoscopically

c) Combined Anatomical and Non-Anatomical Resections (typically for bilobar disease)
- Two stage hepatectomy (e.g. ALPPS – Associating Liver Partition and Portal vein ligation for Staged hepatectomy) [discussed in more detail later]

The primary colonic tumour can be resected synchronously with a liver metastasis ('case by case' basis).

In central liver resections involving the hepatic hilum a hepato-jejunostomy can be fashioned for biliary drainage.

- Resectability Assessment

Key considerations when assessing a patient's suitability for liver resection

a) Vascular assessment
- Portal vein – either the left or right <u>and</u> main portal veins must be free of disease
- Hepatic artery (see note below *) – either the left or right <u>and</u> main hepatic artery must be free of disease
- Hepatic veins – must be free of disease in the future liver remnant (FLR)[RRR]
- Involvement of the common hepatic artery or main portal vein precludes primary resection.

b) Disease assessment elsewhere
- Oligometastatic[SSS] disease in the lungs is <u>not</u> an absolute contraindication <u>if</u> lung disease can be resected/ablated
- Peritoneal disease generally an absolute contraindication to hepatic resection (unless low PCI, which can be considered on a case by case basis)
- Local nodal disease is *potentially* resectable

** A note on Hepatic Artery variants [119]*
- Important to alert the surgeon of variant anatomy prior to operating, as this may influence resectability.
    - For example, consider a case with central liver disease involving the proximal left portal vein and left hepatic artery, which also just involves the normal right hepatic artery, resection would not be possible.
    - However, in the same case with a replaced right hepatic artery (e.g. coming off the SMA), this may be clear of the central disease and so make a resection (left hepatectomy) possible.
- *Accessory* hepatic artery: arises from an anomalous origin (e.g. from SMA) and supplies a portion of the liver along with another artery.

[RRR] The future liver remnant is the portion of liver that will be left over *after* a hepatic resection
[SSS] Oligometastatic: limited systemic metastatic disease which has the potential for cure

- *Replaced* hepatic artery: arises from an anomalous origin and supplies a portion of the liver solely.

- Liver Volume Augmentation

In some cases, the future liver remnant (FLR) is not large enough to support normal function after a resection, and needs to be augmented prior to surgery. It is predominantly the left lobe that requires augmentation due to its naturally smaller volume.

Typically, the target is at least 20% volume (relative to pre-operative overall liver volume) in the otherwise healthy liver remnant, though this can increase to 40% in patients with underlying chronic liver disease/steatosis or who have been pre-treated with chemotherapy due to impaired function in these patients.[120]

Options include:

a) Endovascular

- Portal vein embolization (PVE)
- Hepatic vein embolization (HVE)

b) Surgical

- Two-stage hepatectomy (TSH) +/- Portal vein ligation (PVL)
- ALPPS (Associating Liver Partition and Portal vein ligation for Staged hepatectomy)

PVE and HVE are endovascular techniques where embolization material (e.g. coils, polyvinyl alcohol) or plugs (e.g. Amplatzer vascular plugs) are released into the vessel resulting in vessel occlusion.

- Both PVE and HVE can be performed in tandem (some centres prefer consecutive days) if significant volume augmentation is required to reach the threshold required post-operatively.
- PVE can increase FLR volume by 8-27%.[121] Hepatectomy is subsequently undertaken typically 6-8 weeks later.

- Two Stage Hepatectomy (TSH)

A two stage hepatectomy (TSH) is a technique for resection of bilobar liver metastases. The lobe with the lesser burden of metastases is cleared initially. The second stage is carried out 8 weeks later once the liver has had a chance to regenerate, and the lobe with residual disease is resected.

- PVL is often carried out at initial resection in a TSH. However, in patients undergoing single stage hepatectomy PVE is preferred as it is less invasive and does not result in adhesions, which can complicate subsequent surgery.

Associating Liver Partition and Portal vein ligation for Staged hepatectomy (ALPPS) is a relatively new variant on a two stage hepatectomy for bilobar disease, which induces hypertrophy of the FLR much more rapidly over 7-10 days.

- The first stage involves ligation of the portal vein and partition of the right and left lobes, which remain in situ. Any metastases in the FLR are also resected.
- In the second stage the remaining diseased liver (usually the right lobe) is excised.

Although advantages of ALPPS include rapid hypertrophy and high rates of R0 resection,[TTT] there are significant disadvantages including high rates of major complication and tumour recurrence.

[TTT] R0: a disease-free resection margin (see the Histology section for more detail)

- There is also a significant risk of post-operative liver insufficiency. Despite rapid increase in physical size of the FLR, its actual function takes longer to increase.
    - The risk of dysfunction can be further exacerbated if the remnant liver is not otherwise healthy (e.g. in the setting of pre-treatment with chemotherapy). [122]

8.1.2. Ablation Techniques

Ablation is performed with curative intent and is used in patients with unresectable disease or who are not surgically fit. There are two main techniques for metastatic liver disease [123]:

- Radiofrequency ablation (RFA)
- Microwave ablation (MWA)

RFA has been used for several decades, while MWA is a newer technique and performance data is catching up.

- Theoretical advantages of MWA over RFA include:
    - A larger ablation zone, less susceptibility to heat sink and faster ablation time.
- RFA is cheaper but slower (12 mins vs 3 mins).

These techniques can be performed intra-operatively under direct ultrasound visualisation to complement a resection or percutaneously, and are usually performed when there are a relatively small number of metastases. There are several considerations when assessing feasibility of ablation;

a) Size:

- Typically lesions up to 3 cm are amenable to ablation
    - Can consider overlapping ablation if larger (max 5 cm)

b) Location:

- Central lesions – increased risk of thermal central bile duct injury (resulting in strictures)
- Peripheral lesions – increased risk of intraperitoneal haemorrhage (capsular breach) and ablation of adjacent abdominal wall/viscera
- Proximity to large vessels – vascular injury/thrombosis is uncommon
    - Greatest challenge is the heat sink effect, which reduces the efficacy of ablation
- Proximity to gallbladder – risk of thermal injury to the gallbladder, cholecystitis or bile leak

c) Some lesions can be awkward to target:

- E.g. caudate lobe, high segment VIII where there is a risk of diaphragmatic injury and adhesions. These are considered on a case-by-case & risk-benefit basis.

d) Potential seeding risk from ablation

- Although the risk of this is low

Follow-up MRI is usually performed 6 weeks post ablation (assessing for incomplete ablation). Subsequent scans looking for local recurrence typically performed 3 monthly and then at increasing intervals.

- Post-ablation appearances on cross-sectional imaging

a) CT [124]

- Ablation zone appears as a non-enhancing low attenuation area at the site of the targeted lesion, which involutes gradually over time
    - Shape of the ablation zone may be irregular rather than rounded due to heat sink from adjacent large vessels
- May see:
    - thin rim of peripheral enhancement (hyperaemia following thermal injury)
    - central high attenuation areas (representing greater cellular disruption)

    - small gas bubbles related to the ablation (typically on immediate post-procedure scan), which generally resolve by subsequent scans
- Features of disease recurrence
    - New nodular enhancement at the periphery of the ablation zone

b) MRI [125]

- Ablation zone
    - Initially: High T1 signal, heterogeneous T2 signal initially (coagulative necrosis and blood/inflammatory products)
    - Then: develop more homogeneous high T1/low T2 signal
        - High T1 signal can persist for some time (> 9 months) but eventually decreases to become intermediate-low [126]
    - The ablation zone involutes over time
- Post-contrast (post-treatment appearances)
    - May initially see ill-defined peripheral enhancement like on CT due to thermal injury/inflammation
    - Often a thin-rim (1-2 mm, can go up to 5 mm), which usually fades with time

- Disease recurrence
    - Post-contrast: Can see irregular, nodular, thicker enhancement at the ablation margin
- Distinguishing recurrent disease from post-treatment
    - Low ADC values can be used
    - High DWI / low ADC suggests recurrent disease
    - High DWI / normal-high ADC suggests post-treatment

8.1.3. Chemotherapy & Radiotherapy

(See also the dedicated Oncology section)

a) SBRT (stereotactic beam radiotherapy)

This is an emerging treatment option for colorectal liver metastases in patients who are unsuitable for surgery or ablation.
Improvements in treatment planning software facilitate more tightly focussed treatment fields. [127]

- Historically, conventional radiotherapy delivering radiation to large areas of liver has been largely ineffective (unless for symptomatic relief) due to low tolerance of background liver to high dose radiation and associated increased risk of radiation-induced liver disease (RILD).

b) Chemotherapy

Neoadjuvant (pre-operative), adjuvant (post-operative), or palliative.

- This can be used to reduce the burden of hepatic disease prior to resection.

8.2. Hepatobiliary radiology related to St Mark's

8.2.1 Liver MRI

Three different protocols used at St Mark's:

a) Unenhanced:

- Assessment of lesion(s), often seen on US or CT, where it is strongly suspected that these represent haemangiomata
- Includes standard T1, T2 and a more heavily T2 weighted sequence (T2 weighted sequences with TE of 90 and 180) [128]
    - If a lesion is of high T2 signal on the TE90 scan, and appears the same on the TE180 scan, it is likely a cyst or haemangioma [uuu]
    - A loss of signal suggests an alternative pathology
- Generally, benign lesions including cysts and haemangiomata retain high T2 signal on heavily T2 weighted sequences compared to the standard T2 sequence while metastases/most other lesions lose signal

b) Extracellular contrast: Dotarem

- Dotarem is generally better as an initial gambit when the lesion(s) for characterisation have a wider differential

c) Hepatobiliary contrast: Primovist

- The Primovist (hepatobiliary) sequence is acquired with a 20 minute delay
    - At this time point there is uniform uptake of contrast by the hepatic parenchyma and excreted contrast can be seen in the biliary tree
- Low signal / no uptake in a lesion implies cells in that lesion are *different from normal hepatocytes*
- Primovist may struggle to characterise haemangiomata
- Primovist also is associated with *transient tachypnoea* and can render arterial phase images difficult to assess due to motion
- Colorectal cancer metastases:
    - The three best sequences for assessing CRC liver metastases are: T2 (intermediate), DWI (high) and Primovist (low)
    - CRC metastases classically demonstrate ring enhancement post contrast, though this is variable

- When to choose Primovist over Dotarem:

1. Suspected metastatic liver disease [low signal compared to liver on Primovist sequence]
2. Characterisation of FNH vs hepatic adenoma [FNH retains Primovist, adenoma classically does not]
3. Suspected bile leak [high signal blush/collection on Primovist sequence]

[uuu] A higher (i.e. longer TE) on a T2 weighted sequence accentuates the fluid components of a lesion, and therefore lesions that are more solid will show a relative loss of signal between TE90 and TE180 acquisitions.

8.2.2. Pancreatic Cystic Lesions

- Lesions

a) Common pancreatic cystic lesions:

- *IPMN* (main duct or side branch, can also have mixed type) [PD dilated with main duct IPMN, main duct IPMN also has greater malignant potential, though risk of malignant transformation is still relatively small]
- *Serous cystadenoma* ["grandmother" lesion, microcystic – cysts < 2cm, fibrous scar sometimes calcified, benign]
- *Mucinous cystadenoma* ["mother" lesion, unilocular, often in the tail, precursor to adenocarcinoma, smaller lesions < 3 cm less likely to harbour malignancy or high grade dysplasia, usually resected[129]]
- *Pseudocyst* [post pancreatitis, benign, no epithelial lining so not a true cyst, can become infected/fistulate with other structures]

b) Uncommon pancreatic cystic lesions:

- *NET* [can appear cystic but classically solid and arterially enhancing, may have calcification]
- *Solid pseudopapillary epithelial neoplasm (SPEN)* ["daughter" lesion, rare, low malignant potential, usually resected]

c) *Plus several other much rarer lesions*:

- Include: lymphoepithelial cysts and congenital cysts (not an exhaustive list)

- How to stratify risk of pancreatic cysts [130]

LOW RISK FEATURES	HIGH RISK FEATURES
Small (< 3 cm)	Large (> 3 cm)
Side branch	Main duct involvement
No nodules	Mural nodules
No PD dilatation	PD dilatation
Stable in size	Rapidly enlarging (> 5 mm/year)
	Symptomatic
	Obstructive jaundice

Absolute indications for surgery	Relative indications for surgery
Enhancing nodules > 5 mm	Cyst diameter > 40 mm
Main PD > 10 mm	Growth rate > 5mm/year
Positive cytology	Main PD 5-10 mm
Solid mass	Enhancing nodules < 5 mm
Jaundice	Raised CA 19.9
	New onset DM
	Pancreatitis

- Management of cystic pancreatic lesions

a) Surveillance (note that strategies vary between centres)

- for low risk lesions where there is no surgical indication or patients with significant comorbidities/short life expectancy
- pragmatically, if the patient is not fit for pancreatic resection the MDT can decide to stop surveillance

- a reasonable surveillance regime would involve 6 monthly MRI (or EUS) for first year after diagnosis, yearly thereafter
- post-surgical surveillance following removal of a side branch IPMN with high grade dysplasia or main duct IPMN typically involves 6 monthly MRI (or EUS) for the first 2 years and then yearly thereafter

b) Intervention

- surgical options include pancreaticoduodenectomy (Whipple's procedure), total pancreatectomy (for more diffuse disease) and distal pancreatectomy[131]
- a distal pancreatectomy usually includes a splenectomy as it is quicker and easier to remove *en bloc* (splenic preservation requires more extensive and time-consuming dissection)
- pancreaticoduodenectomy and total pancreatectomy are particularly big operations and the patient must be surgically fit with a surgical indication

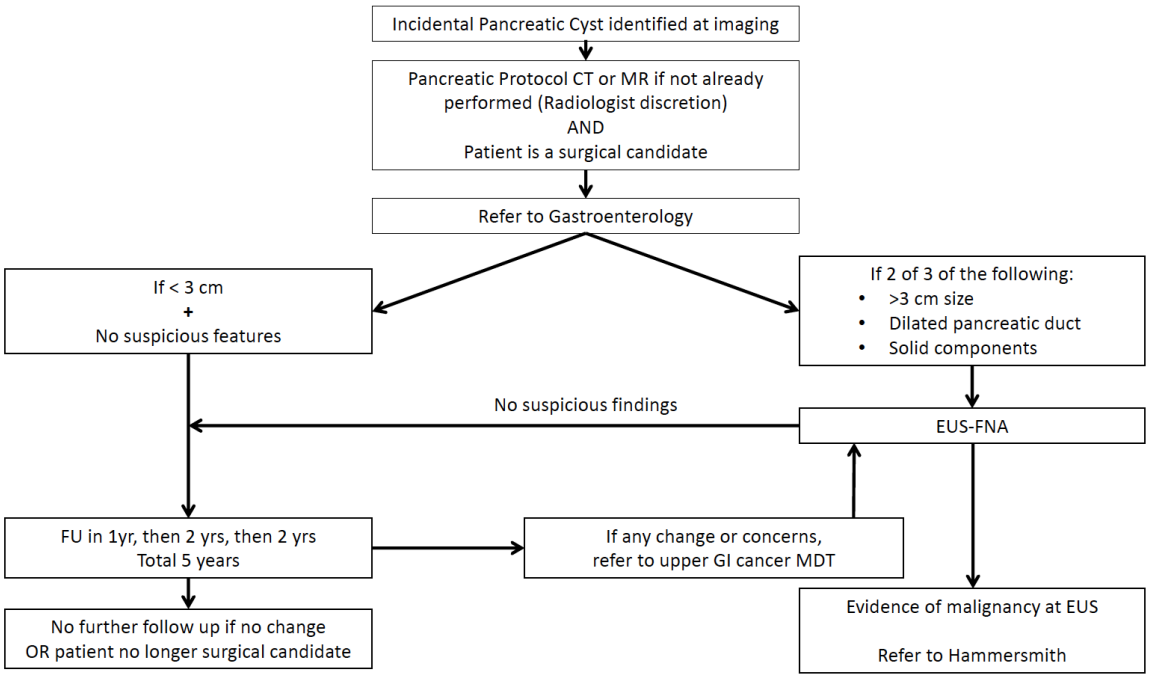
Whipple's procedure (pancreaticoduodenectomy)

3 anastomoses:

1. Hepatico / choledochojejunostomy
2. Pancreaticojejunostomy [vvv]
3. Gastrojejunostomy

In some cases can do a pylorus-sparing pancreaticoduodenectomy (modified Whipple's), which leads to better gastrointestinal function long term with more post-operative weight gain, less peptic ulceration, and less dumping syndrome.

Pancreatic cyst surveillance strategy at St Mark's:



In short, pancreatic cyst should be followed up at: 1, 3, and 5 years from the index study.

[vvv] Sometimes it is easier to intra-operatively fashion a pancreaticogastrostomy instead.

8.2.3. Cholangiopathy

- Causes of cholangiopathy

a) Common

- Primary sclerosing cholangitis (PSC)

b) Uncommon

- IgG4 disease (IgG4-related sclerosing cholangitis)
- Secondary sclerosing cholangitis (SSC); e.g. due to intraductal stone disease, chronic pancreatitis, trauma [tends to be focal causing common duct stricture *]

c) Rarer causes:

- ICU cholangiopathy, ischaemia (almost exclusively in liver transplantation), HIV, histiocytosis and eosinophilic cholangiopathy.

PSC is classically associated with IBD but can occur spontaneously and predisposes to malignancy (cholangiocarcinoma). This typically occurs in young-middle age but there is a second peak in late age (70s).

- Imaging techniques and features

MR cholangiopancreatography (MRCP) is the main imaging technique for assessment of cholangiopathy.

- The main feature of cholangiopathy is ductal irregularity, which can be focal or diffuse.
- Multiple intra/extrahepatic ductal strictures* can also be a feature seen though these tend to be seen mostly in primary sclerosing cholangitis (PSC).
- Early disease can be subtle and can be obscured by motion artifact.
    - MRI technique and patient compliance is critical.

- Main clinical questions for PSC imaging [132]

- is there a dominant stricture? † → ERCP/cholangioscopy
- is there evidence of malignancy? (e.g new stricture/mass) → ERCP/cholangioscopy
- is there duct dissociation ‡ (i.e. are some of the ducts not in continuity, for example due to complex strictures/mass)?

In IgG4 disease there may be other features (e.g. narrowed pancreatic duct, 'sausage pancreas' and other non-HPB features). This can be evaluated by checking serum IgG4 levels and histological analysis.

Notes:

*A biliary stricture is an abnormal narrowing of a bile duct. A *complex stricture*, most commonly at the hepatic hilum, refers to multiple closely related biliary strictures often due to the same disease process (e.g. hilar cholangiocarcinoma).

† The definition of a dominant stricture is variable but is generally taken to mean a *stricture with upstream biliary dilatation causing new or worsening cholestatic function*.[133]

- Pragmatically it is a stricture that is most likely to make a difference to biliary drainage if targeted endoscopically.

‡ The presence of duct dissociation (due to a complex stricture) is important to note when planning the approach to biliary intervention and generally makes it more difficult (may need combination of endoscopic and percutaneous transhepatic biliary approaches to stent placement/dilatation, though endoscopic is first choice where possible).

- How to further investigate cholangiopathy

- focal stricture → ERCP/cholangioscopy and brushings [need to exclude cholangiocarcinoma]/EUS for distal CBD strictures
- diffuse ductal irregularity/strictures → likely to be PSC but check serum IgG4 levels/biopsy

8.2.4. Approach to common scenarios

Isolated pancreatic duct dilatation

- Dilatation defined as > 3-4 mm
- If history of chronic pancreatitis then MRCP first, which helps assess the likelihood of proximal (i.e. downstream towards pancreatic head) duct stricture vs. cancer as the culprit. Otherwise MRCP is unlikely to be helpful and adds little over a CT (especially if a pancreatic protocol with arterial and portal venous phases)
- And / or Endoscopic ultrasound (EUS) to assess for obstructing lesion

Double duct dilatation

- Gastroenterology review for EUS to assess for obstructing lesion

8.2.4 Gallbladder Polyps

Local management of Gallbladder Polyps at STM
< 6 mm: routine follow-up not recommended
6-9 mm: 1 year follow-up with single ultrasound and discharge unless size changes
≥ 10 mm: surgical referral

Make sure a suspected polyp is not simply a calculus (does it move on repositioning the patient or on agitating the gallbladder using the transducer?). Tumerfactive sludge (non-mobile and does not cast posterior acoustic shadow) is another cause.

8.2.5. Biliary Stents [87]

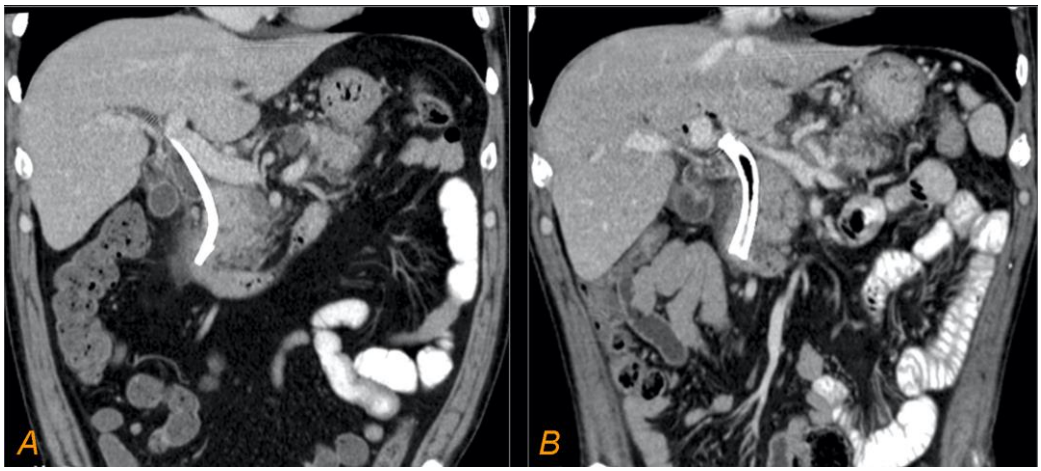
The aim of biliary stenting is to relieve biliary obstruction by providing a route through a stricture. Biliary stents can also be used to treat bile leaks.

- Three main types of stent:

i. Plastic
ii. Covered metallic
iii. Uncovered metallic

A *covered stent* has a solid wall, whereas an *uncovered stent* has holes, hence can allow tumour ingrowth into the stent's lumen but reduces risk of blockages (e.g. cystic duct causing cholecystitis). Covered stents are also more likely to migrate.

Metallic stents are known as *self-expandable metallic stents* (SEMs). They are wider but more expensive than plastic stents and have better long term patency rates (8-12 months vs 3 months).



Head of pancreas mass. **A**: plastic biliary stent; **B**: metallic biliary stent
Images from European Society of Radiology Conference 2012
https://epos.myesr.org/posterimage/esr/ecr2012/108698/mediagallery/395035

Main considerations when choosing type of stent:

- Benign vs malignant stricture
- Patient prognosis
- Cost

Benign strictures (e.g. iatrogenic, chronic pancreatitis, PSC, IgG4)

- Typical approach involves multiple plastic stents with a view to serial dilatation every 3 months or so typically over the course of one year (increased potential for morbidity owing to multiple procedures)
- Can also use *covered* metal stent

Malignant strictures (e.g. pancreatic head mass/cholangiocarcinoma)

- SEMs are generally used for patients with longer term prognosis
    - Can use plastic stent in poor prognosis (< 3 months), as similar to SEMs in short term and less expensive
- *Covered* stents are used for patients who have resectable disease while uncovered stents are used for unresectable disease (covered stents can be retrieved)
    - *Uncovered* stent allows ingrowth of tumour, which can be a problem for patients with resectable disease if surgery is delayed

In some particularly difficult cases, a 'rendezvous' procedure can be performed, which combines a percutaneous transhepatic and endoscopic approach to cross a stricture.

Plastic stents are used to treat bile leaks in cases where the common duct has not been transected [www]. Stenting allows the bile duct to heal spontaneously in most cases.

[www] This requires surgical management.

III. References

Other general useful resources:
Radiology Assistant: https://radiologyassistant.nl/abdomen
BSGAR: trainee membership gives access to video lectures
ESGAR: junior membership is affordable and allows you to watch old lectures

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