



IMAGING IN COLORECTAL CANCER

1403/5/14

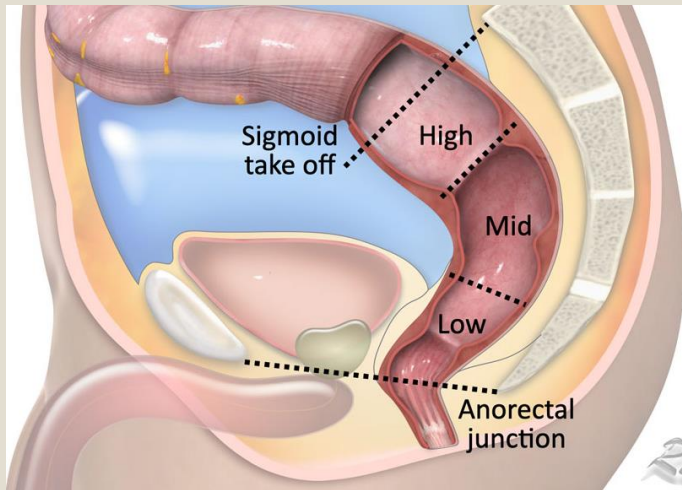
ANATOMY- colon

- At CT scan, Colon is identified by typical haustrations and its location.
- The large bowel comprises the colon, vermiform appendix, rectum and anus.
- The caecum, ascending and descending colon are covered anteriorly by visceral peritoneum, whereas approximately 50% of the posterior aspect of these segments is retroperitoneal.
- The transverse and sigmoid colon have a mesentery formed from a double layer of visceral peritoneum sandwiching connective and adipose tissue with vessels, nerves and lymphatics.
- NL colonic wall thickness: $\leq 3\text{mm}$
- The pericolonic fat should be homogeneous with only a few vascular channels. The normal colonic mucosa enhances after IV contrast agent administration, but the pattern of mural enhancement in an abnormal colon may provide clues as to the underlying diagnosis

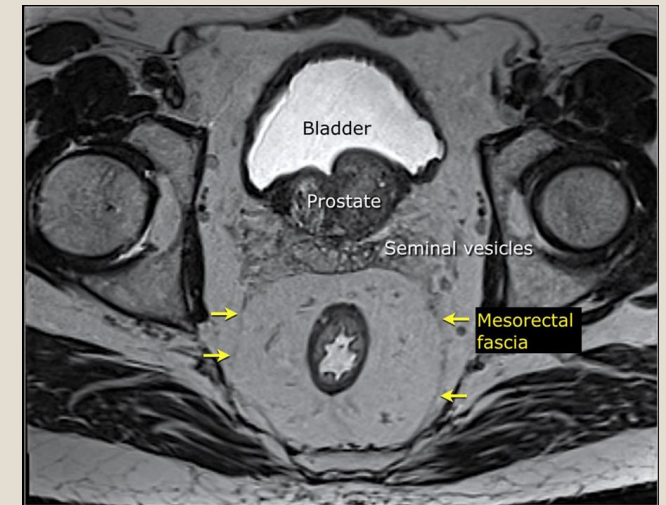


ANATOMY- rectum

- The rectum is defined as: commencing at the third sacral level, although the sacral promontory is often taken surgically as the reference point. Others define it as the distal 15 cm of large bowel proximal to the anus.
- Anteriorly the rectum is covered by peritoneum to the level of the junction of the upper two-thirds and lower one-third. The lateral and posterior aspects of the upper rectum and all the lower one-third are surrounded by the mesorectum, which is composed of loose adipose connective tissue containing the small perirectal lymph nodes and the superior rectal vessels. The **mesorectum** itself is enclosed by **the mesorectal fascia**.
- Posteriorly the mesorectal fascia is separated from the presacral fascia by the thin retrorectal space; anteriorly it blends with the urogenital septum (Denonvillier fascia/rectovaginal septum); superiorly it is contiguous with the sigmoid mesentery; and inferiorly it terminates close to the anus in the parietal fascia covering the levator ani.



Rectum, perirectal anatomy, MRF
The key MRI images for rectal cancer staging: HR T2W MRI



RADIOLOGICAL INVESTIGATION

- The mainstays of are intraluminal contrast examinations and cross-sectional techniques.
- Although cross-sectional imaging is largely replacing contrast studies, the latter still maintain a role in specific clinical situations.
- A water-soluble contrast enema (e.g. Gastrografin diluted 3:1 with water or Urografin 150; Schering AG, Berlin, Germany) allows real-time evaluation of colonic anatomy and is most commonly used to test the integrity of surgical anastomoses, define colonic calibre (e.g. in suspected megacolon), delineate colonic fistulae and exclude mechanical obstruction
- Double-contrast barium enema (DCBE): to acquire a series of images so that the entire colon is seen in double contrast, with no segment coated poorly or obscured by a barium pool, is now obsolete for detection of polyps or cancer, having been replaced by CT colonography (CTC).
- Magnetic resonance colonography (MRC) follows similar principles to CTC, and is most commonly performed after bowel purgation
-

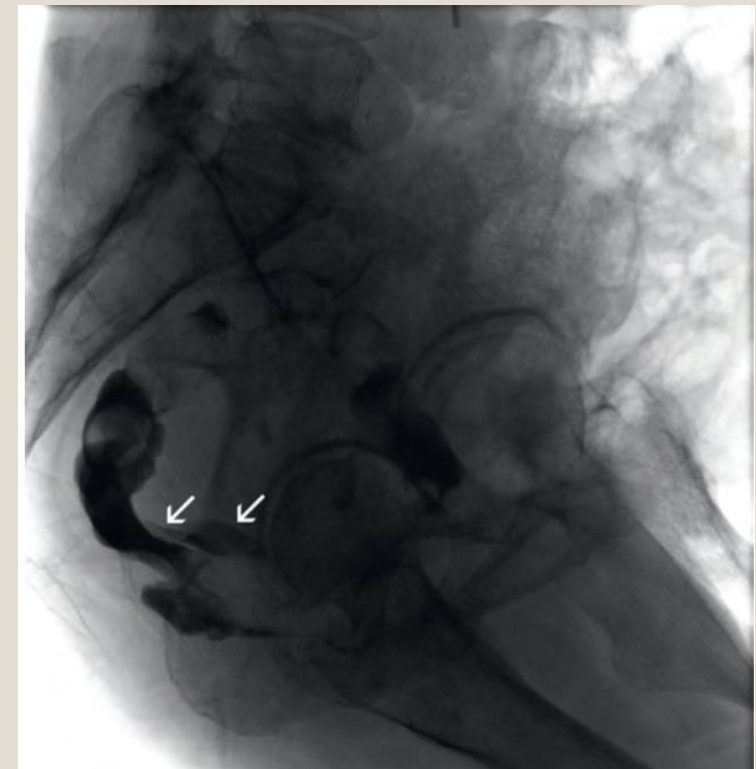
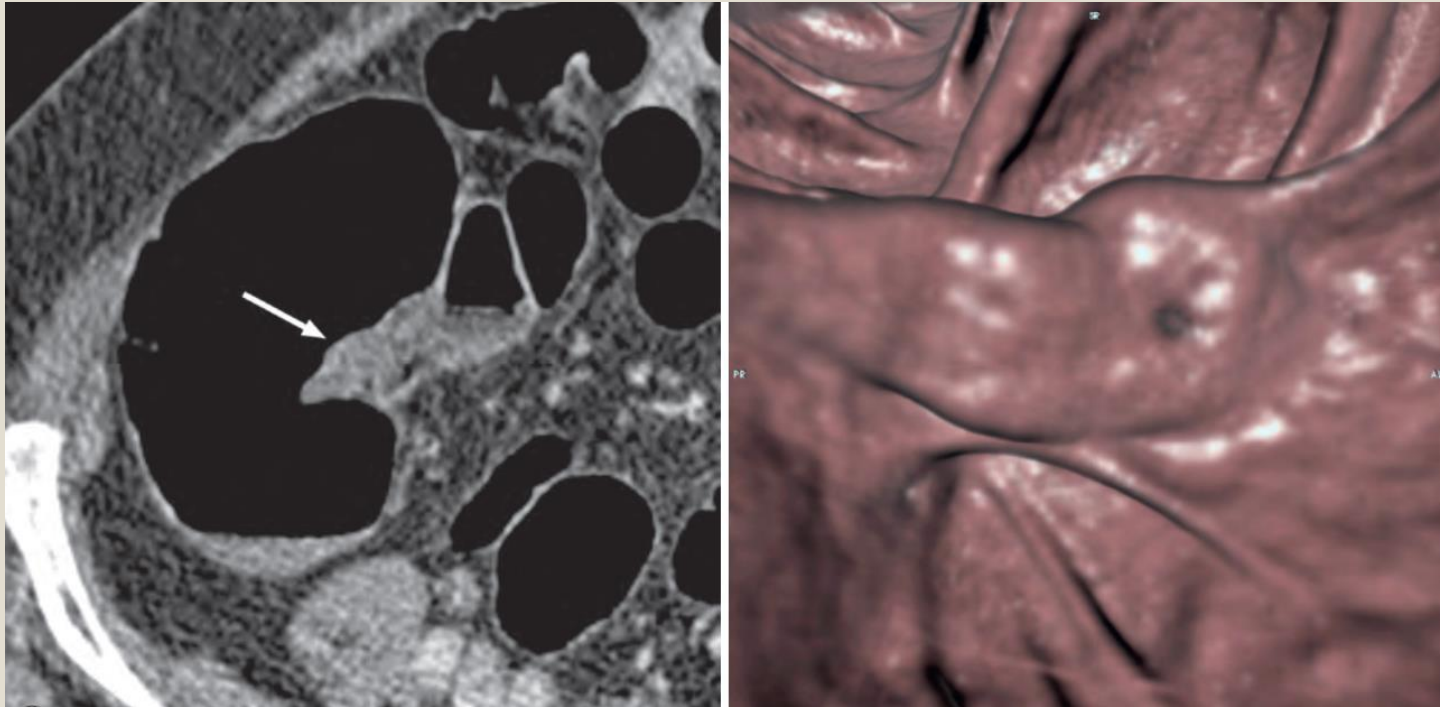


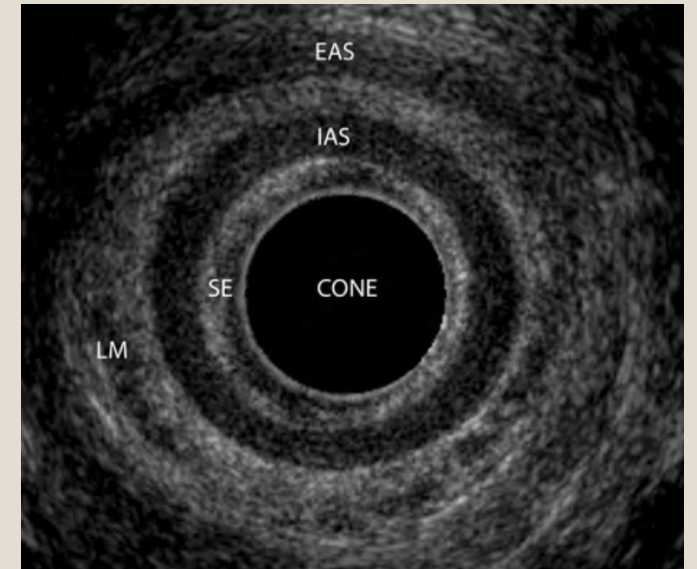
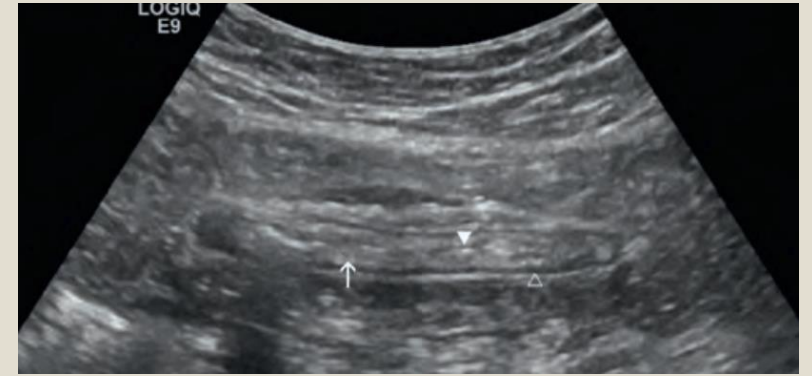
Fig. 22.3 Sagittal pelvic radiograph performed as part of a Gastrografin enema series showing rectal contrast passing anteriorly into the vagin

CT colonography (CTC) describes CT of the gas-distended colon: Cross-correlation between 2D and 3D images is required to differentiate normal colonic structures such as the ileocaecal valve, haustral folds and faecal residue from pathology

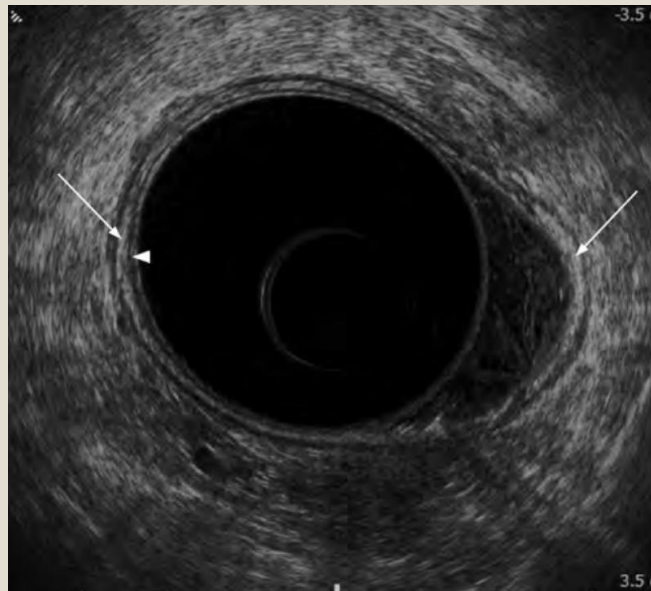


Two-dimensional computed tomography colonogram of the normal ileocaecal valve, The three-dimensional endoluminal reconstruction shows the bicuspid, lobulated contour

- Abdominal ultrasonography requires a graded compression technique for good views of the colon. Intraluminal gas often prevents demonstration of both walls, but the haustral pattern of the anterior wall should still be seen.
- Endosonography allows higher frequency probes to be used (10 to 20 MHz range) to show the wall layers in detail. The sonographic pattern is created by a mixture of interface reflections between, and reflections from the thin layers.
- Nuclear medicine isotope studies: limited role in large bowel imaging with the exception of PET, usually combined with either CT (PET-CT) or MRI (PET-MRI)



Endorectal ultrasound (ERUS) is not able to resolve the mesorectal fascia, but has better differentiation of the wall layers than MRI and hence is utilised in some centres as an adjunct to establish local resectability of early-stage disease.



Endorectal Ultrasound of an Early Rectal Cancer. The normal layered rectal wall architecture is shown on the left of the image, with (from superficial to deep) the echogenic superficial mucosa, hypoechoic deep mucosa (arrowhead), echogenic submucosa (arrow) and hypoechoic muscularis propria. The tumour is confined by submucosa (right arrow) and does not reach the muscularis propria (T1 stage)

Polyps

- A polyp is an elevated mucosal lesion. The majority occur sporadically in the general population, although there are many rare polyposis syndromes. The most clinically significant polyps are adenomas.
- By definition, adenomata contain dysplasia (i.e. intra-epithelial neoplasia). Colorectal cancer (CRC) represents an extension of this neoplasia beyond the muscularis mucosae into the submucosa. Perhaps two-thirds of CRCs originate via an adenomatous precursor (sometimes called the adenoma-carcinoma sequence).
- size
- Morphology

Radiographic Features of Polyps

Computed tomography colonography. CTC is the most accurate radiological technique for polyp detection, surpassing DCBE and approaching that of colonoscopy for larger polyps. The entire colonic surface must be evaluated using either a primary 2D approach with 3D problem-solving or a primary 3D endoluminal fly-through with 2D review of potential lesions. CTC has equivalent sensitivity to colonoscopy for detecting CRC and recent data suggest the rate of interval cancer after CTC is similar to that of colonoscopy, although one advantage of colonoscopy is the ability to obtain biopsy confirmation of malignancy.

Magnetic resonance colonography.

Dark-lumen sequences depict polyps as enhancing protrusions from the normal mucosa. Endoluminal projections are feasible but may appear pixelated due to the current lower spatial resolution of MR.

Double-contrast barium enema.

As the evidence base for CTC evolves, DCBE declines and is becoming increasingly obsolete. Randomized trial data show that, in symptomatic adults, barium enema misses twice as many cancers as CTC and should be abandoned.

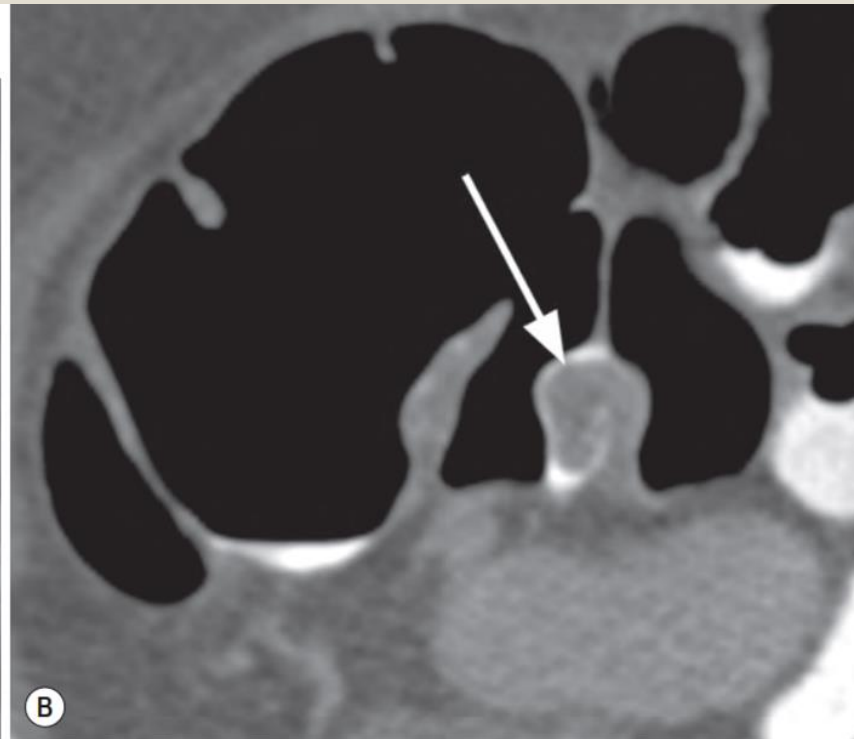
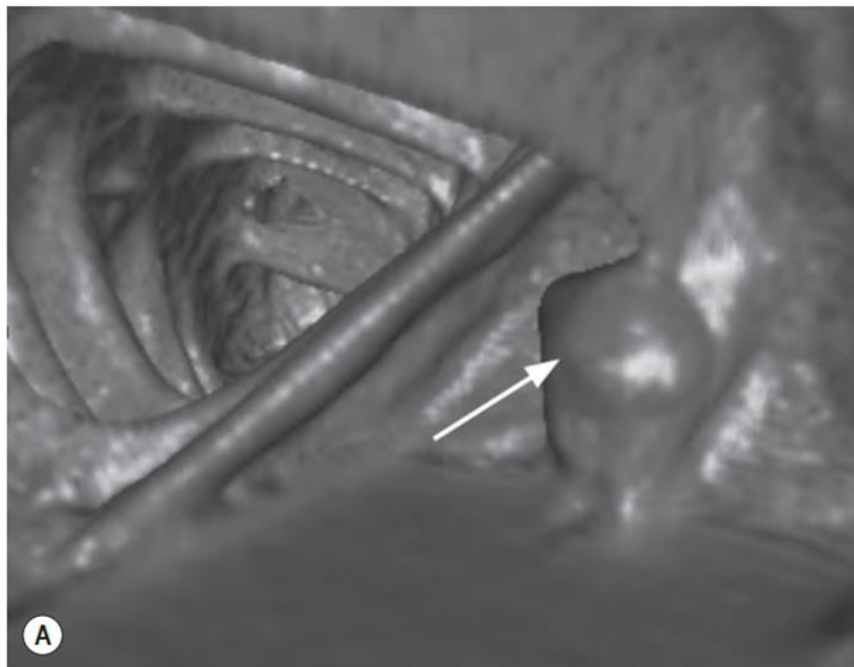
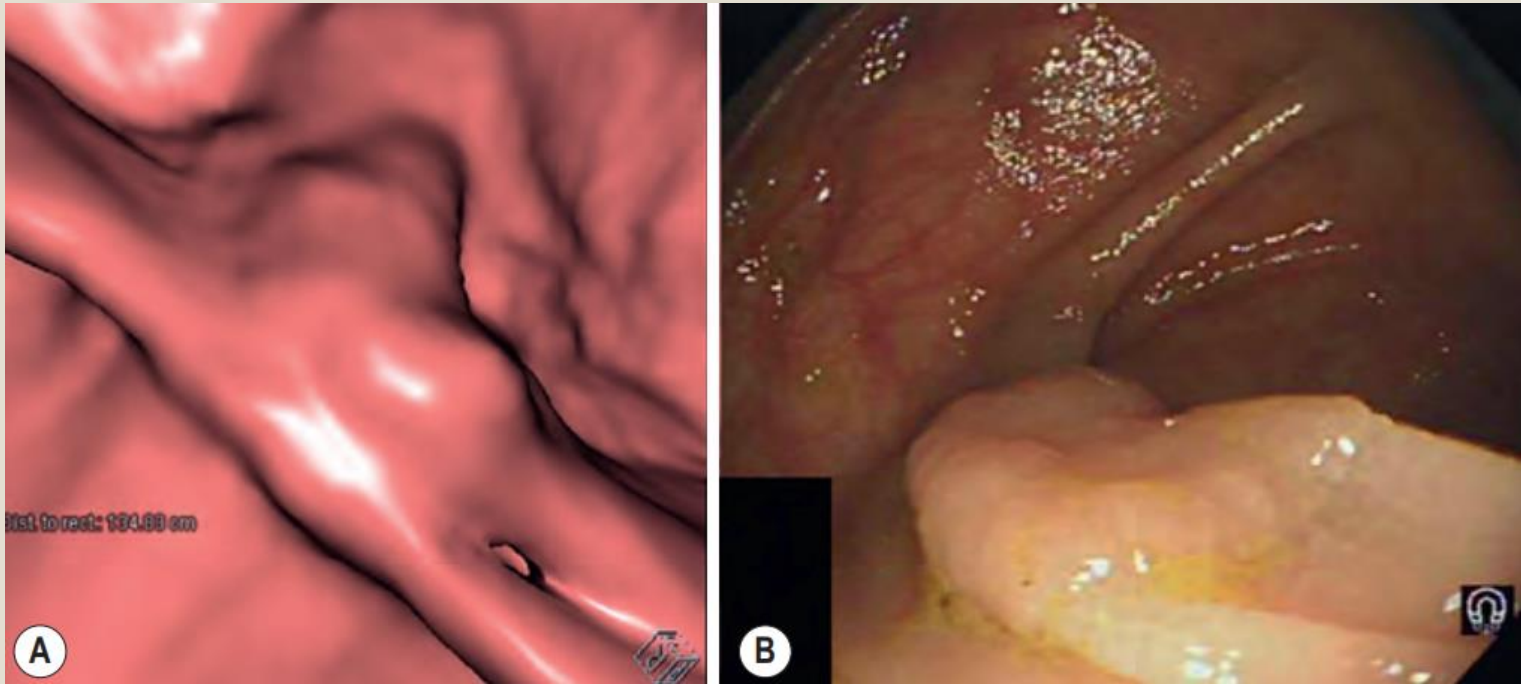


Fig. 22.12 (A) Endoluminal CTC image depicts a polyp (*arrow*) growing on a haustral fold just above residual colonic fluid. (B) The corresponding 2D image shows a stalked lesion (*arrow*) coated by a thin rim of tagged fluid.



Computed tomography colonography endoluminal three-dimensional reconstruction showing a minimally elevated lesion with irregular haustral fold thickening and a small central depression (0-IIa+c Paris classification). (B) Endoscopic correlation of the lesion; histopathology confirmed T1 adenocarcinoma.

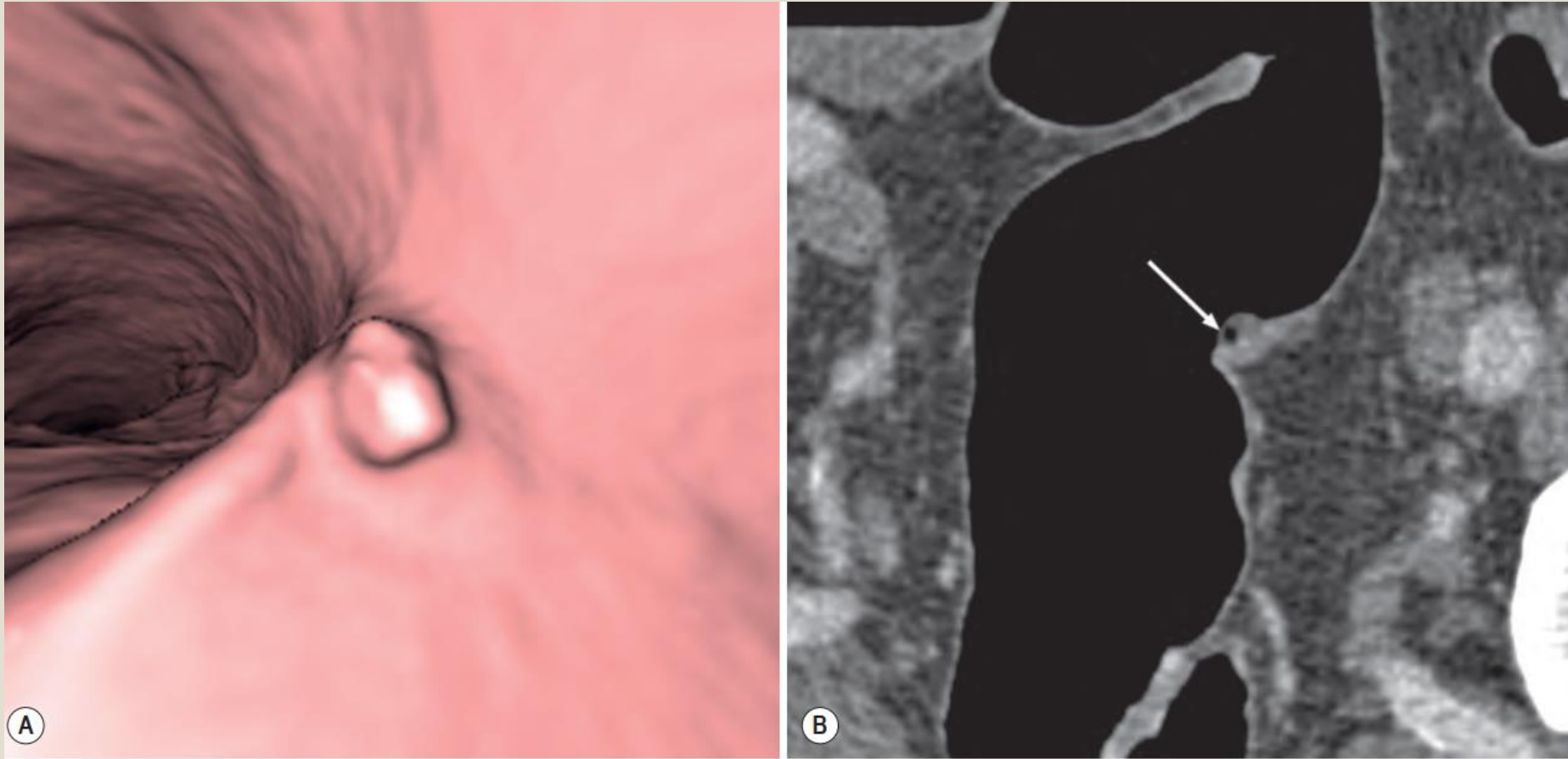


Fig. 22.14 (A) 3D view from CT colonogram shows a polypoid lesion that might be mistaken for a sessile polyp. However, the 2D view (B) shows a tiny locule of gas (*arrow*), demonstrating that this is, in fact, retained faecal residue.

Colorectal Cancer

- It is generally accepted that just over half of all CRCs arise in the rectum or sigmoid, with the rectum alone accounting for one-third of cases.
- Overall 5-year survival is about 50%.
- Major prognostic factors include: local tumour stage, vascular or lymphatic invasion, preoperative elevation of carcinoembryonic antigen (CEA) and tumour differentiation (grade).
- Colon cancer and rectal cancer are currently treated slightly differently; the mainstay of therapy for both is surgical excision, but in the rectum it is more difficult to achieve adequate clearance margins to prevent local recurrence whilst avoiding significant complications. However, the static nature and pelvic position of the rectum make it amenable to chemoradiotherapy, which has been shown to decrease local recurrence in later-stage disease. Local staging is therefore particularly important in rectal cancer and will likely become increasingly so for colon cancer should current large-scale trials confirm the utility of preoperative chemotherapy for locally advanced disease.

Both colon and rectal cancers can be staged according to the Dukes and TNM (tumour, nodes, metastasis) systems.

TABLE 22.3 Colorectal Cancer Staging (TNM 8th Edition)

UICC/ TNM	Tumour Extent	Dukes	5-Year Survival
Stage I	Invasion submucosa T1 Invasion muscularis propria T2 No nodal involvement, no distant metastasis	A	85%–95%
Stage II	Invasion outside muscularis propria T3 Invasion visceral peritoneum T4a Invasion other organs T4b No nodal involvement, no distant metastasis	B	60%–80%
Stage III	1–3 lymph nodes involved N1 >3 N2	C	30%–60%
Stage IVa	Distant metastasis in one organ M1a	D	<10%
Stage IVb	Distant metastasis in >1 organ M1b	D	<10%
Stage IVc	Metastasis to the peritoneum with or without distant organ involvement	D	<10%

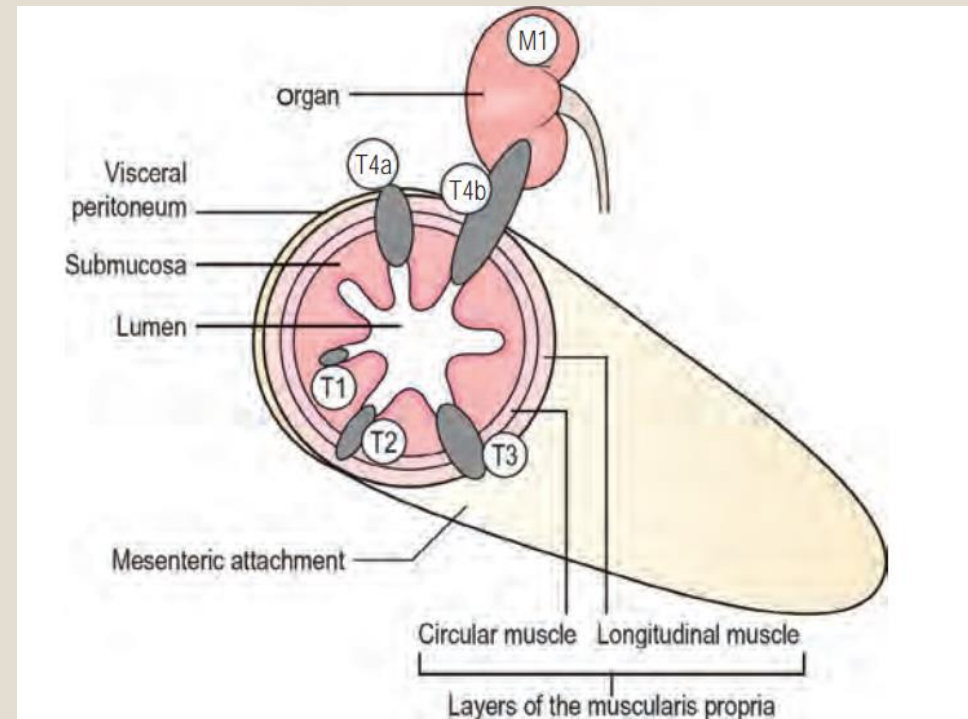


Fig. 22.25 The Layers Involved in T1 to T4 Colorectal Cancers According to Tumour Node Metastasis, 8th Edition. Note how the mesenteric attachments determine the likelihood of T3 versus T4a disease status.

CTC readily depicts annular or semi-annular lesions with shouldered ends and luminal narrowing.

Similarly, flat or plaque-like cancers show wall thickening and irregularity

At conventional CT, malignancy is usually seen as an area of focal wall thickening (>3 mm), often with extension into the pericolic fat and local nodal enlargement. Tumours are usually homogeneous, but may be heterogeneous: in the context of large adenocarcinomas, mucinous tumours, when associated with abscess.



axial axial computed tomography colonogram demonstrating a tumour (arrow).



axial axial computed tomography colonogram demonstrating a flat cancer manifesting as wall thickening (arrows).



Fig. 22.22 Sagittal oblique computed tomography through a mid-sigmoid colon shows an irregular outer margin (arrow) with soft tissue extending into the pericolic fat, indicating T3 disease.

Colon Cancer- T staging

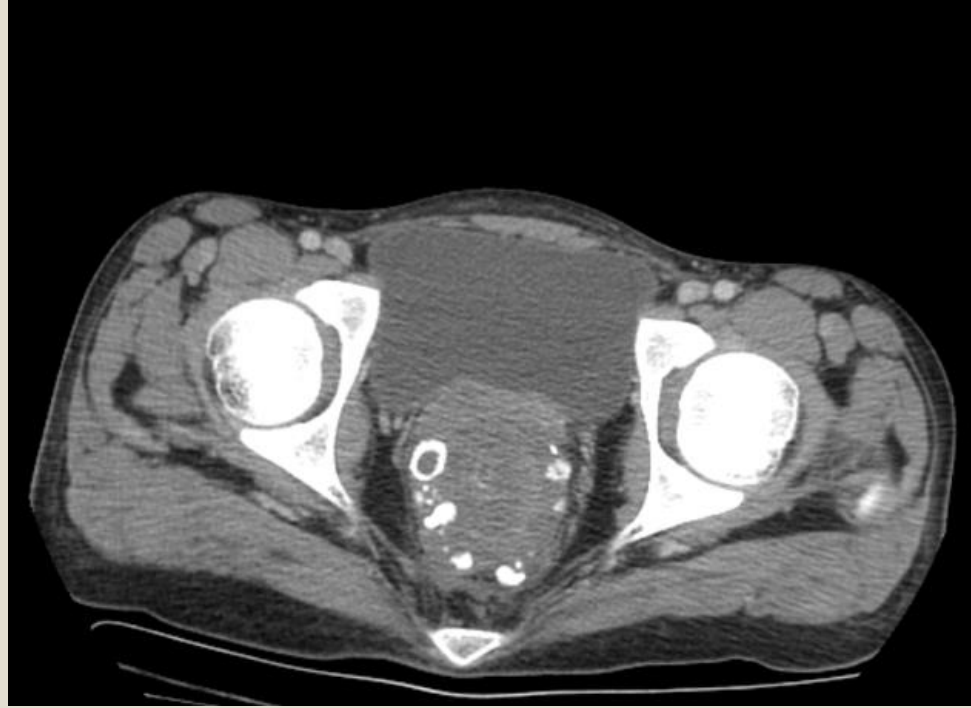
- CT estimates the T stage:

with accuracy for identification of disease extension beyond the bowel wall of around 86%.

Generally, CT is better suited to broad categorization of tumours into good-prognosis and poor-prognosis groups.

Adverse prognostic features are unequivocal T3 tumours, T4 tumours and tumours with extramural venous invasion (EMVI).

- T3 disease should be suspected when there is extension of a discrete mass through the muscle coat into pericolic fat.
- EMVI is recognised by nodular or undulating expansion of colic veins.



Mucinous tumours, both primary and metastatic: heterogenous, propensity to calcify, may show little uptakePET-CT.

Colon Cancer- N and M staging

- CT performs poorly for nodal staging, as size thresholds are neither sensitive nor specific; over 50% of nodes shown to be involved at pathology measure less than 1 cm. Abnormal clustering of normal-sized nodes has been used as an alternative criterion but does not substantially improve performance.
- Micrometastasis have a high occurrence in normal sized LNs in rectal cancer, so it is recommended to use a **lower threshold for perirectal LAP ≥ 5 mm**. spiculated or indistinct margins and heterogenous signal are suspicious findings for malignancy.
- The **most common site** for hematogenous metastasis for CRC is **liver**: CT scan and MRI- portal phase
- **CT scan** is the **first choice** to evaluate **lung** metastasis of CRC but is not specific.
- Ascites and omental or peritoneal nodularity indicate disseminated intraperitoneal disease.

Ischemic colitis VS CRC

- Ischemic; may occur proximal to CRC, smooth and regular thickening, target sign with central hypointensity, **average thickness: 1 cm**
- Tumoral; irregular thickening, **average thickness: 2 cm**

Rectal Cancer

- The dominant malignancy is adenocarcinoma.
- MRI is the imaging investigation of choice for local staging of rectal cancer. In particular, **high resolution (1 mm³ voxel size), T2 weighted (T2W) fast spin-echo (SE) sequences perpendicular to the lesion provide** information on local stage and relationship to the mesorectal fascia.
- Local staging with MRI is performed to determine the best surgical strategy and the necessity for neoadjuvant treatment.
- Pre-operative MRI stratifies tumours into three main groups:

Risk Stratification

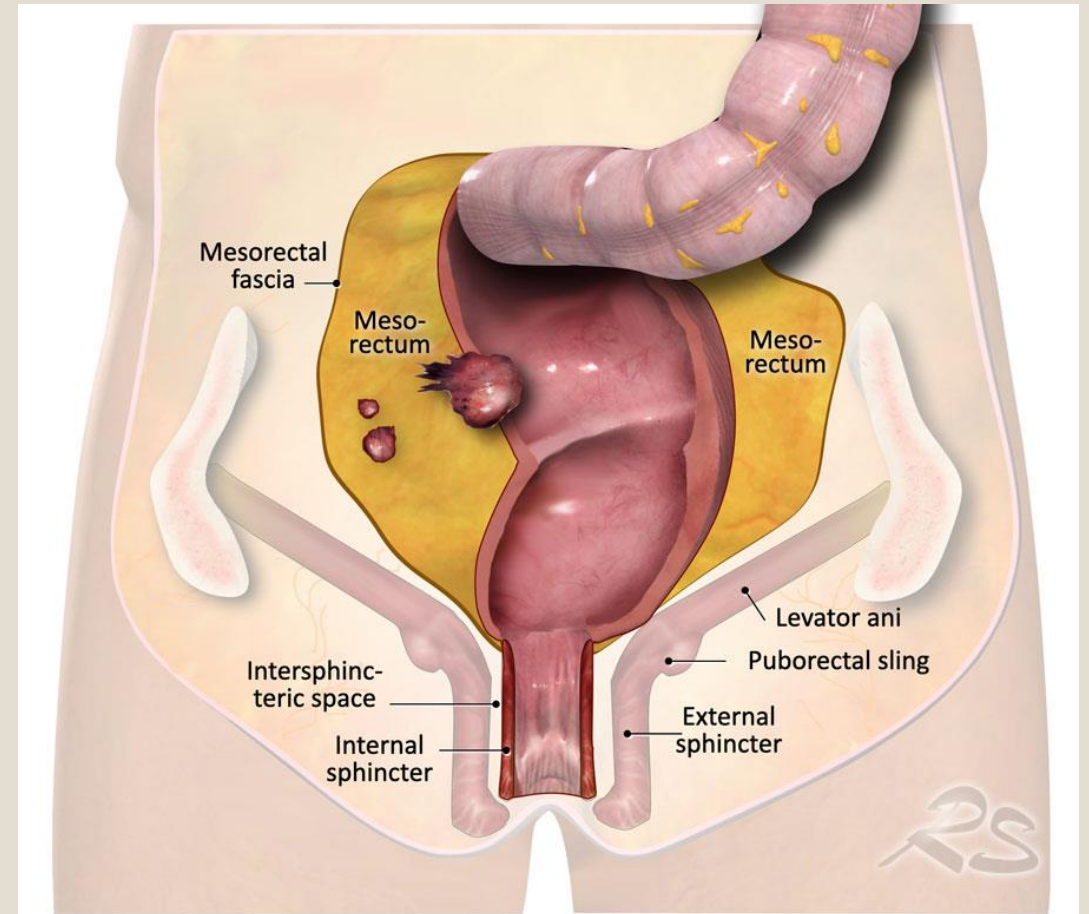
Criteria for treatment stratification

Low risk	- cT ₁₋₂ N ₀ or - cT _{3ab} (\leq 5mm invasion) - cN ₀ - Distance to MRF $>$ 1mm	Total mesorectal excision or Local excision
Intermediate risk	- cT _{3cd} ($>$ 5mm extramural invasion) - cN ₁ - Distance to MRF $>$ 1mm	+ Short course (5x5 Gy) neoadjuvant radiotherapy
High risk	- cT _{3cd} or cT ₄ - cN ₂ - Distance to MRF \leq 1mm	+ Long course neoadjuvant treatment (chemoradiotherapy) + restaging

- More recently, the presence of extramural vascular (or venous) invasion has been proposed as an additional adverse prognostic feature that should be considered a sign of high risk disease.

Total Mesorectal Excision

Treatment of rectal cancer involves *en bloc* resection of the tumour, rectum and mesorectum perirectal lymph node (total mesorectal excision, TME) to minimize the risk of local recurrence. The dissection plane extends along the mesorectal fascia, constituting the circumferential resection margin (CRM).



Morphology

Polypoid and Sessile tumors

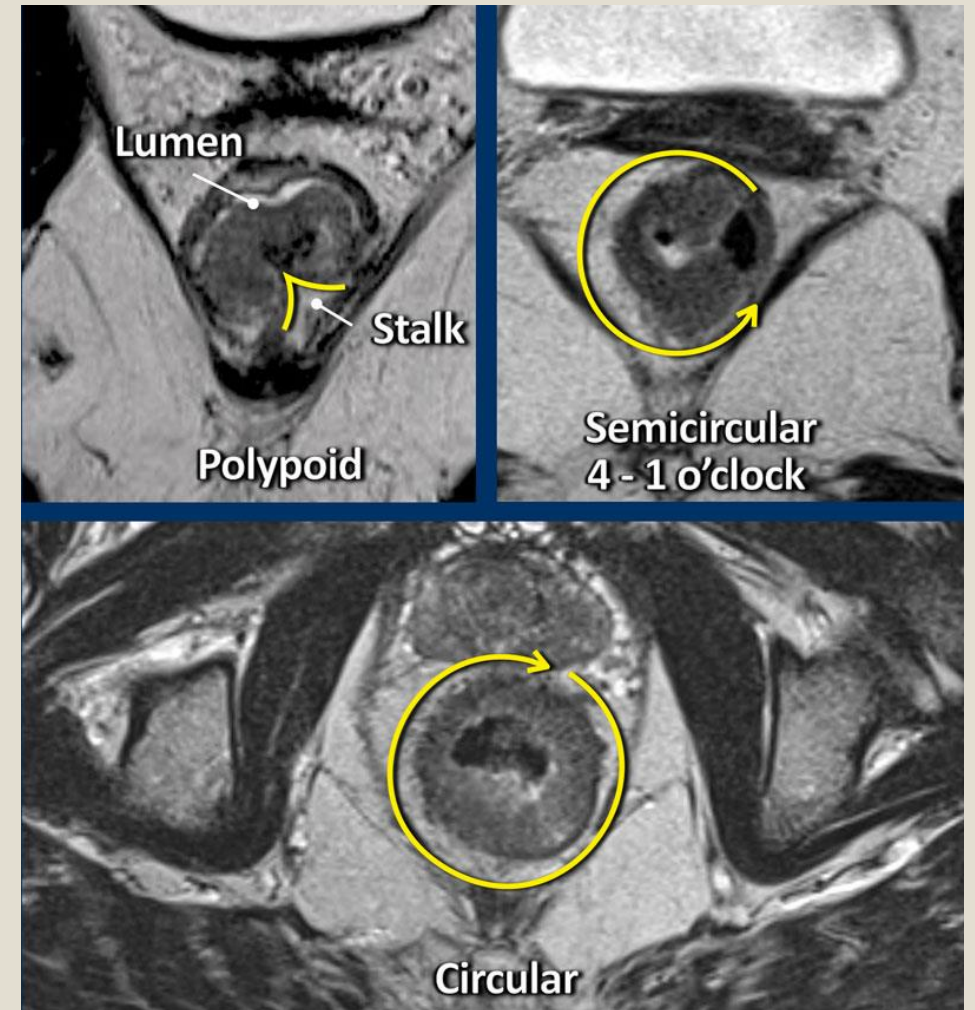
Rectal adenocarcinomas typically arise from adenomas: polypoid or sessile.

Polypoid: more low-grade malignancies

Sessile tumors: typically present as a semi-circular or circular wall thickening.

The site where the tumor is attached to the rectal wall is often referred to as the “invasive margin”.

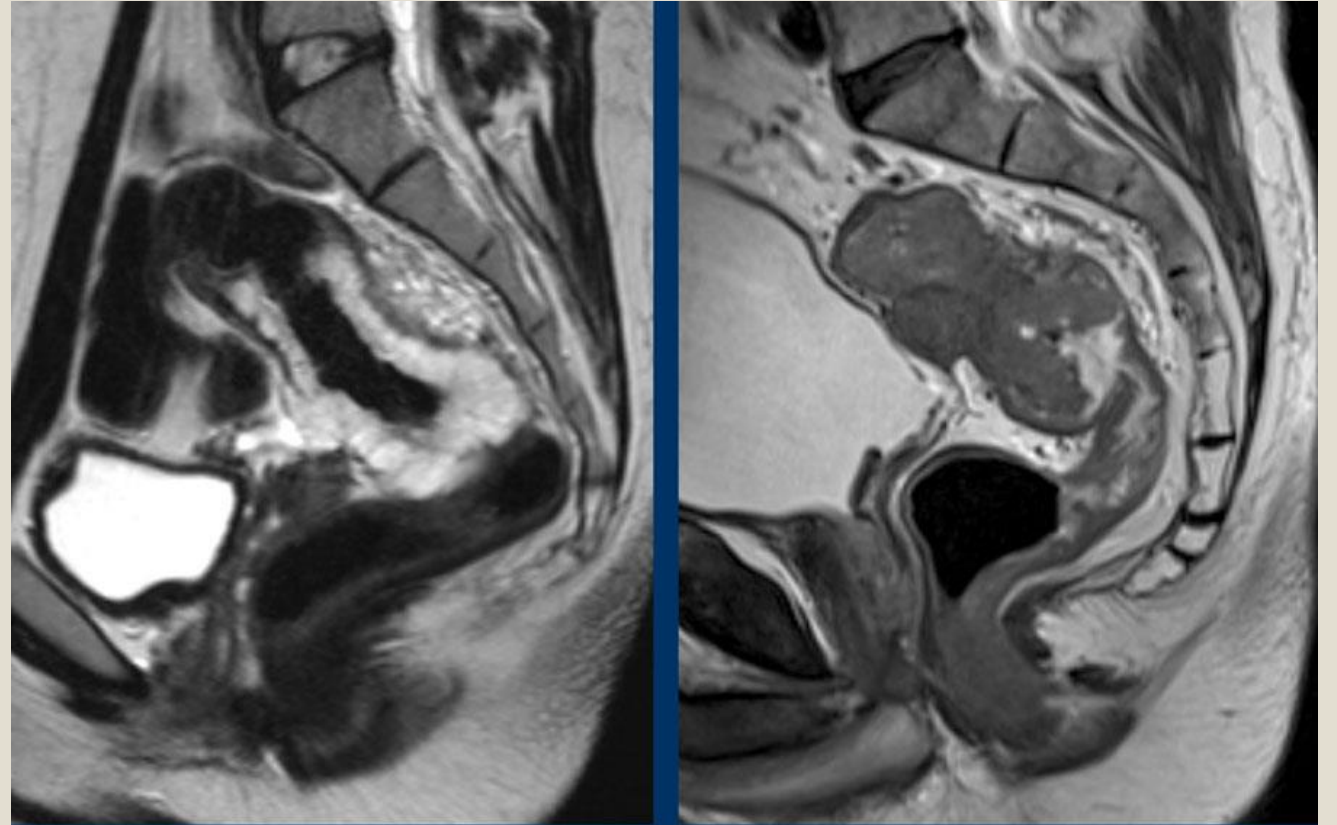
the tumor circumference, can be described in the radiology report as “from ... to ... o'clock”, or alternatively using prose descriptions such as “left anterolateral”.



Solid and Mucinous

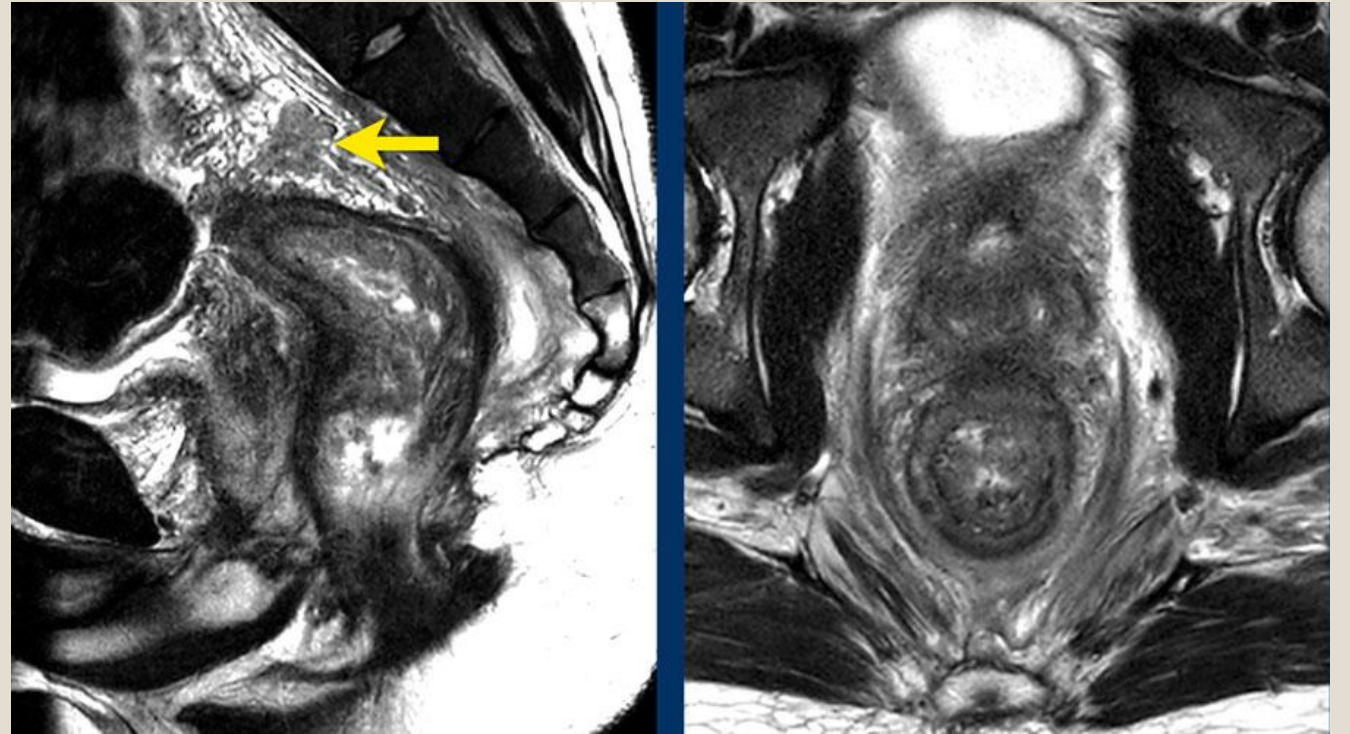
mucinous adenocarcinomas have a poorer prognosis and typically show a poorer response to neoadjuvant treatment.

Mucinous tumors show distinct bright signal on T2-weighted MRI compared to the more intermediate signal of solid type tumors.



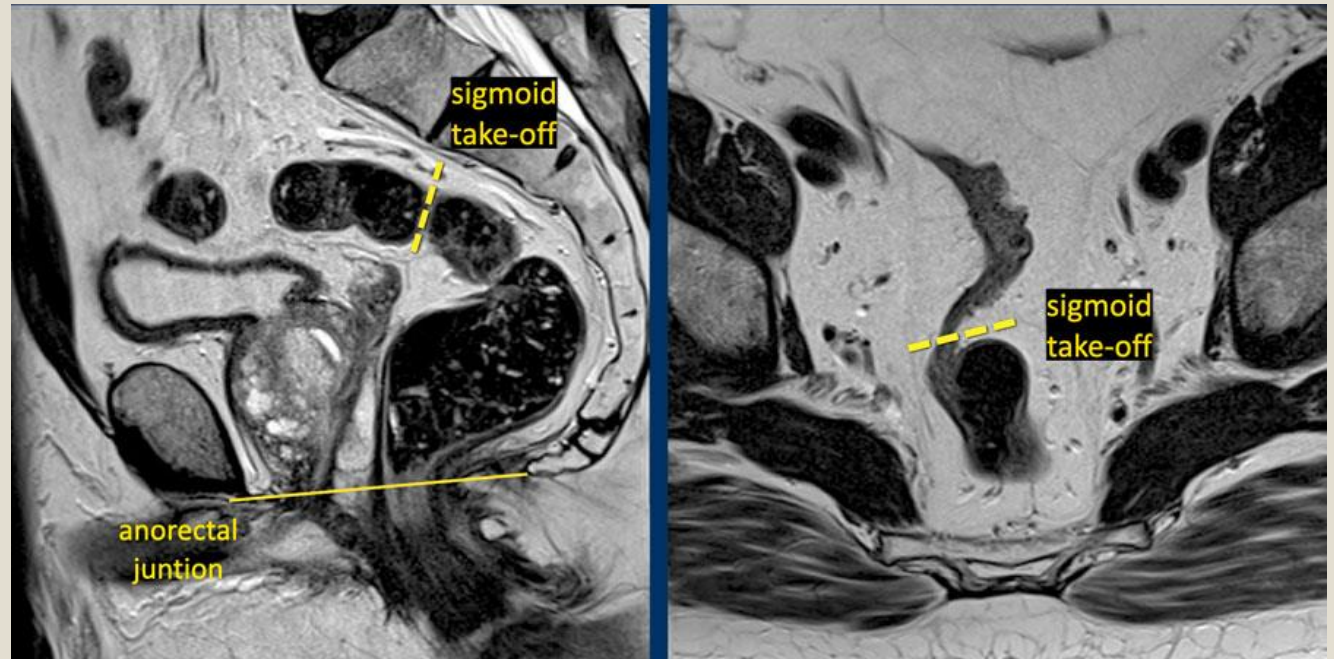
signet-ring cell carcinoma

associated with a high risk for nodal and distant metastases and poor overall survival. It is seen in only approximately one percent of cases. In MRI signet-ring cell carcinomas can be difficult to discern, though they typically show long-segment diffuse bowel wall thickening and a submucosal growth pattern that results in a 'target' appearance on axial images.



Location

- **Sigmoid take-off**
- Discriminating rectal from sigmoid cancer is important because the treatment approach differs considerably.
- In 2019 an international consensus panel: The sigmoid take off can be recognized on sagittal MRI as the point from which the sigmoid sweeps horizontally away from the sacrum.



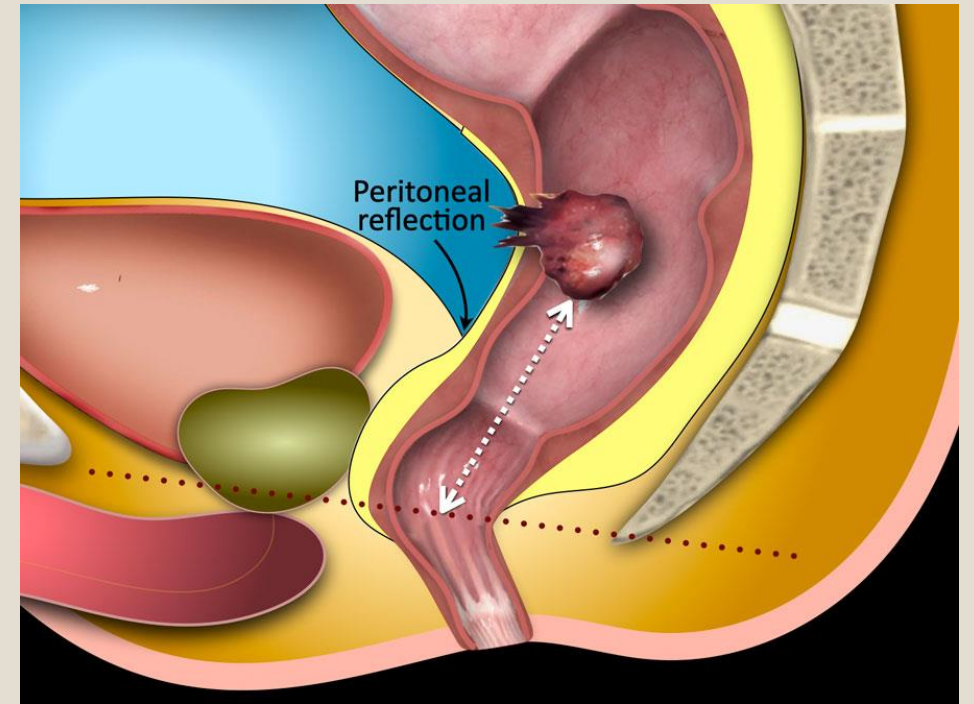
Tumor height

The anorectal junction marks the transition between the anal canal and distal rectum.

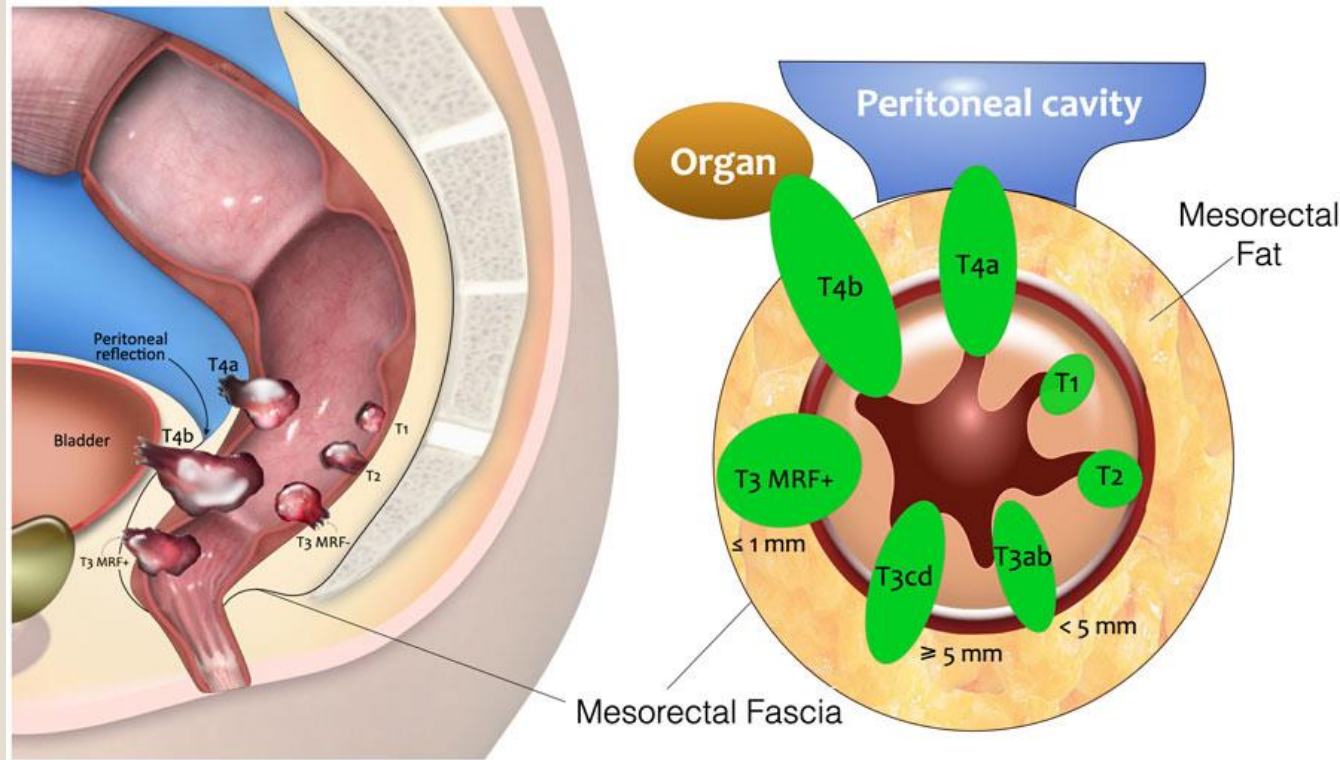
It is situated at the level of the anorectal angle, which is caused by contraction of the puborectalis muscle.

an imaginary line between the lower margin of the sacral bone and pubic bone.

the distance between the lower margin of the tumor and the anorectal junction, or alternatively the distance from the anal verge location of the tumor in relation to the anterior peritoneal reflection is commonly used as a landmark to determine the tumor height.



T-stage



T-stage of Rectal Cancer

T1-2	Confined to the rectal wall	<ul style="list-style-type: none"> - T1 invade submucosa - T2 invade muscularis propria (the outer layer of the rectal wall)
T3	Extend beyond the bowel wall into the mesorectal fat.	<ul style="list-style-type: none"> - T3a: < 1 mm extension of infiltration - T3b: 1-5 mm extension - T3c: 5-15 mm extension - T3d: > 15 mm extension <p>Note: low risk T3: T3ab MRF- high risk T3: T3cd and/or MRF+</p>
T4a	invade the peritoneum or peritoneal reflection	
T4b	invade other organs or structures outside the meso-rectum:	<ul style="list-style-type: none"> - pelvic organs (incl. uterus, ovaries, vagina, prostate, seminal vesicles, bladder) - bone - striated/skeletal muscle (incl. external anal sphincter, puborectalis and levator ani, obturator, piriformis, and ischiococcygeus) - ureters and urethra - sciatic or sacral nerves - sacrospinous/sacrotuberous ligaments - any vessel outside the mesorectal compartment - any loop of small or large bowel in the pelvis (separate from the primary site from which the tumor originates) - any fat in an anatomical compartment outside the mesorectal compartment (i.e. obturator, para-iliac or ischiorectal space)

T1-T2 - limited to the bowel wall

an intact muscularis propria, which can be recognized on MRI as an intact hypointense line surrounding the rectum.



T3 – invasion into the mesorectal fat

T3-tumors grow through the muscularis propria into the surrounding mesorectum.

On MRI this can be recognized as an interruption of the hypointense muscularis propria with spicular or nodular extension of tumor signal beyond the rectal wall into the mesorectal fat.

A semicircular rectum tumor with invasion into the mesorectum from approximately 1 to 4 o'clock. It does not grow within 1mm of the mesorectal fascia.

The T-stage is T3 MRF- rectal cancer.



Subclassification of T3 stage according to invasion depth:



Low-risk T3-tumors:

- T3a: tumor extends <1 mm beyond muscularis propria
- T3b: tumor extends 1-5 mm beyond muscularis propria

High-risk T3-tumors:

- T3c: tumor extends 5-15 mm beyond muscularis propria
- T3d: tumor extends > 15 mm beyond muscularis propria
- T3 MRF+ tumor \leq 1mm of the MRF

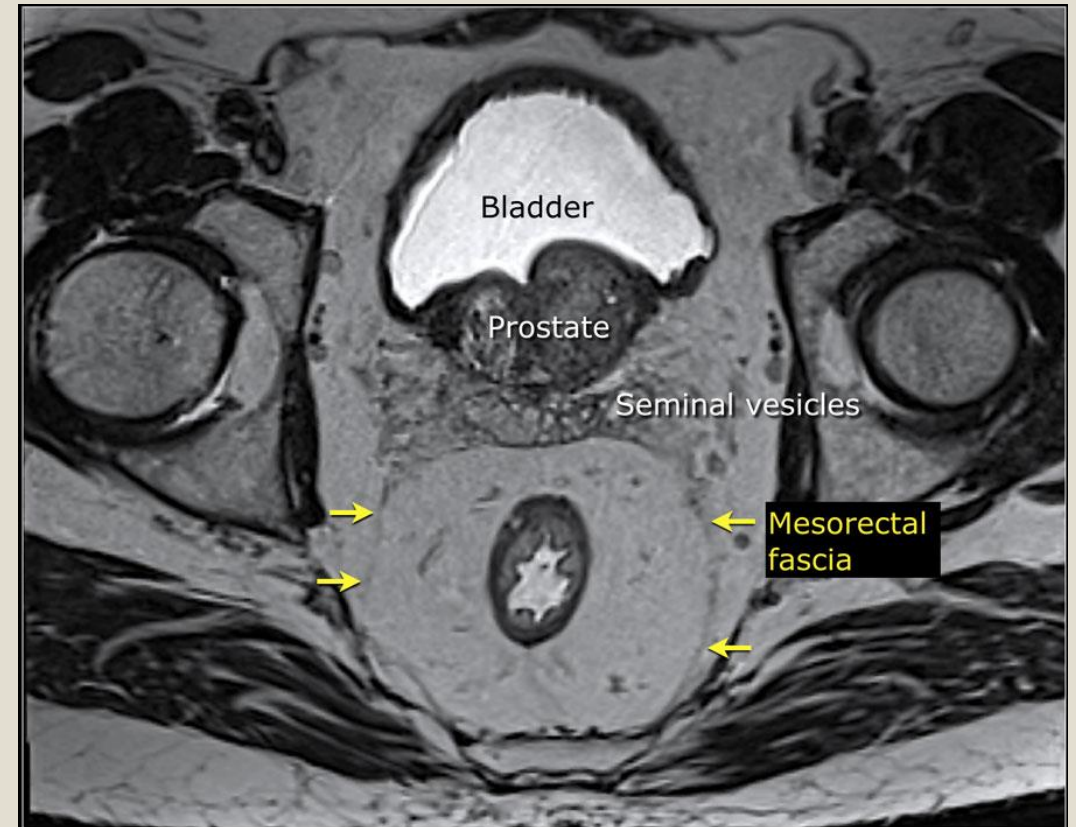
Mesorectal fascia involvement

The mesorectal fascia (MRF) is a thin fibrous structure that encloses the mesorectal compartment and comprises the anticipated resection plane in TME surgery.

On T2-weighted MRI the mesorectal fascia can be recognized as a thin hypointense line surrounding the mesorectum.

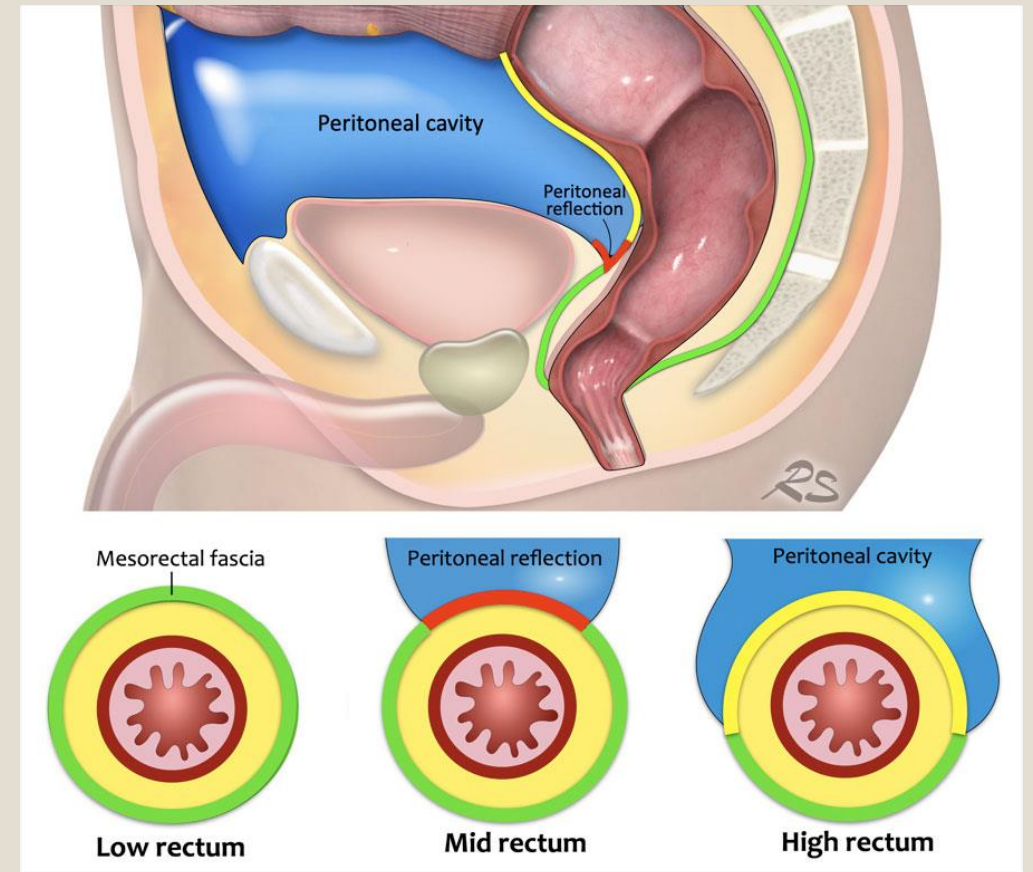
When a tumor directly invades the MRF or the margin between the tumor and MRF is ≤ 1 mm, the MRF is *involved*.

When describing involvement of the MRF, you should always describe the location of involvement (e.g., “MRF+ at ... o’clock” or “MRF+ at the left anterior side”)



Mesorectal fascia versus Peritoneum

This distinction is important because invasion of the MRF constitutes T3 MRF+ disease, while growth into the visceral peritoneum entails a risk for tumor spread into the peritoneal cavity and is staged as T4a disease.



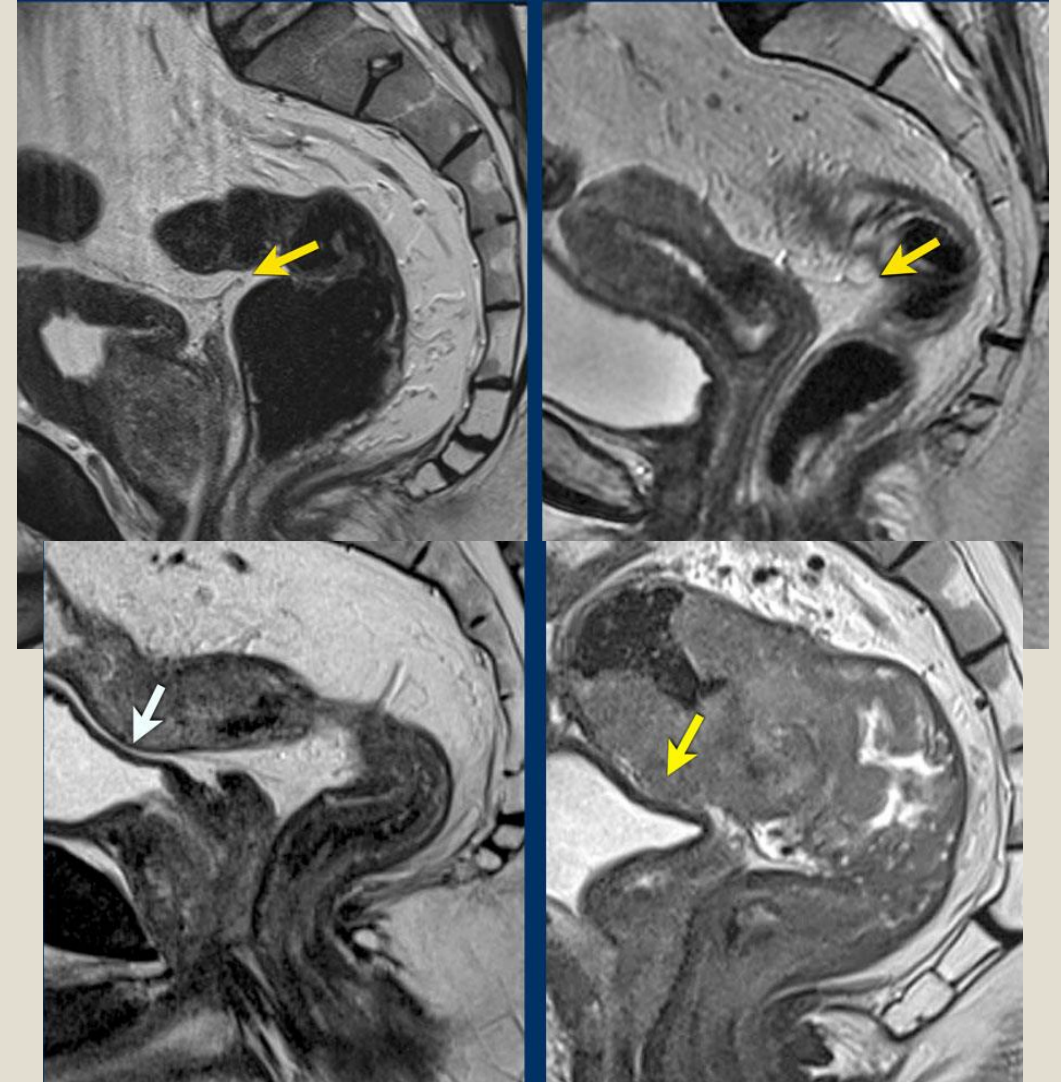
T4a - Invasion of peritoneum or peritoneal reflection

The anterior peritoneal reflection marks the transition between the non-peritonealized and peritonealized portions of the rectum.

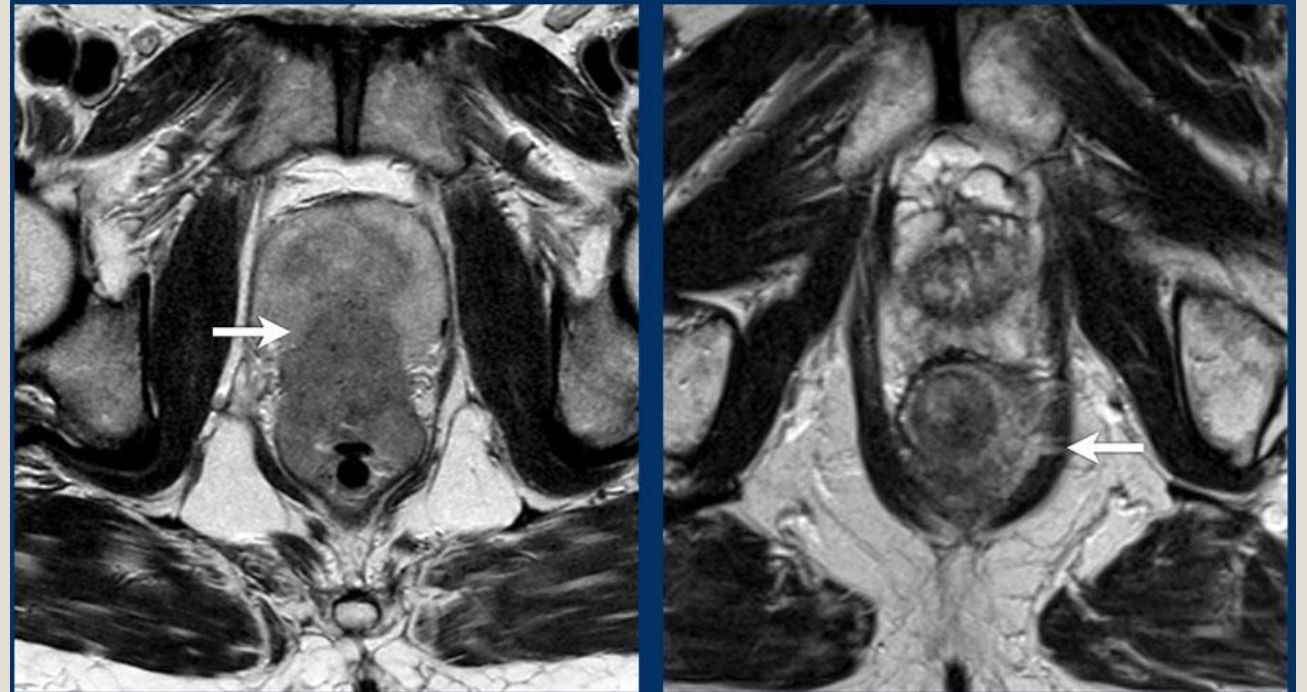
On sagittal T2-weighted images the peritoneal reflection can be recognized as a hypointense V-shaped thin line, sometimes referred to as the 'seagull sign'.

In males it is located just above the seminal vesicles.

In females it is located at the level of the cul-de-sac (Douglas).

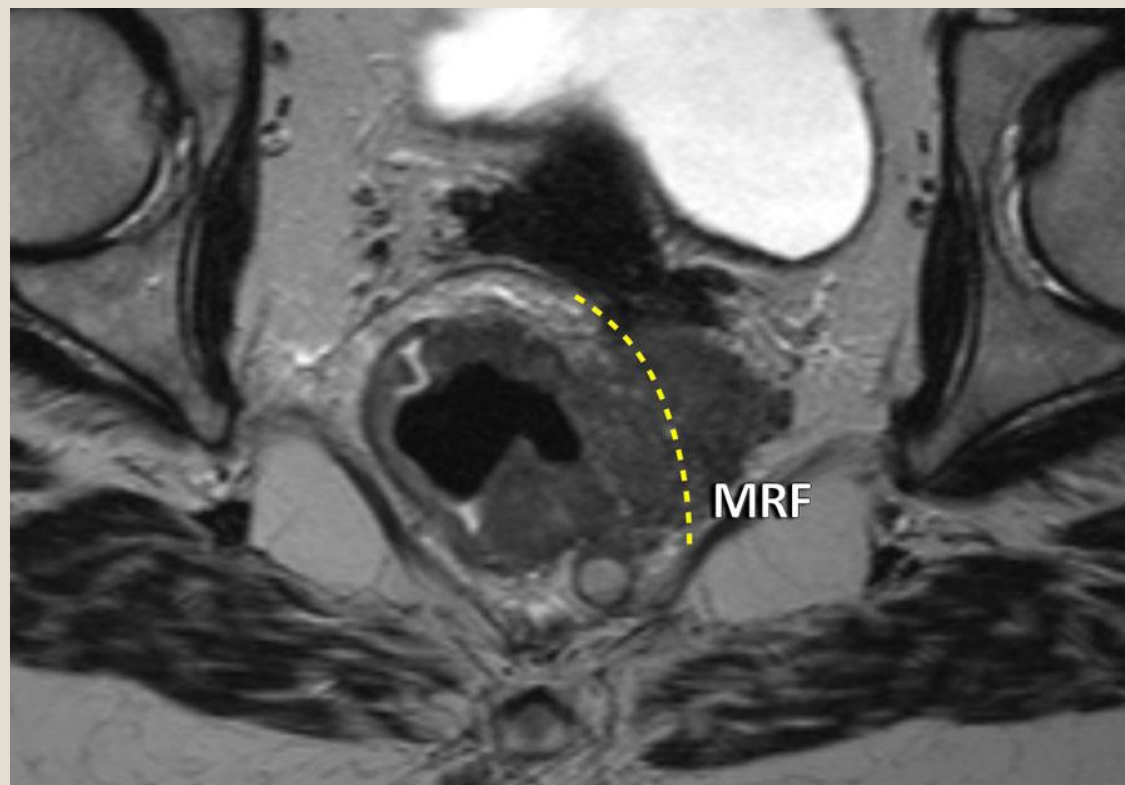


T4b – Invasion of surrounding organs or structures



Examples of T4b disease with respective invasion of the prostate (left) and invasion of the levator ani (right).

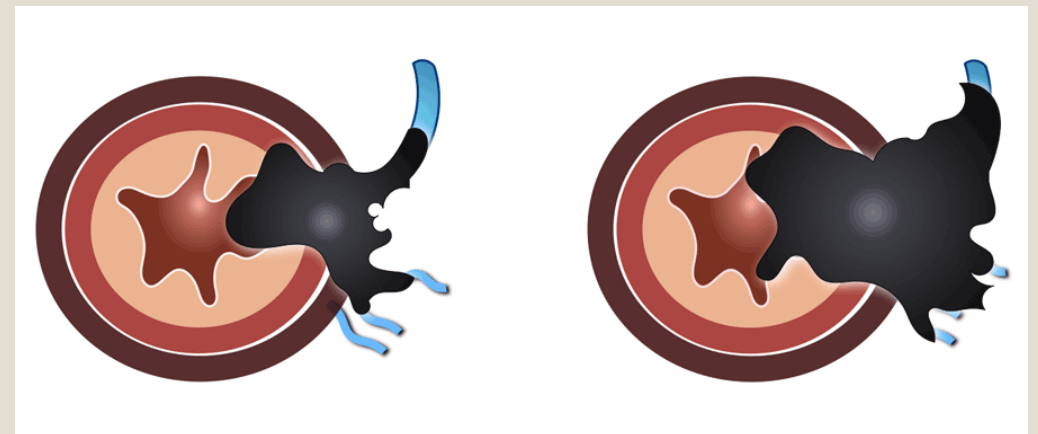
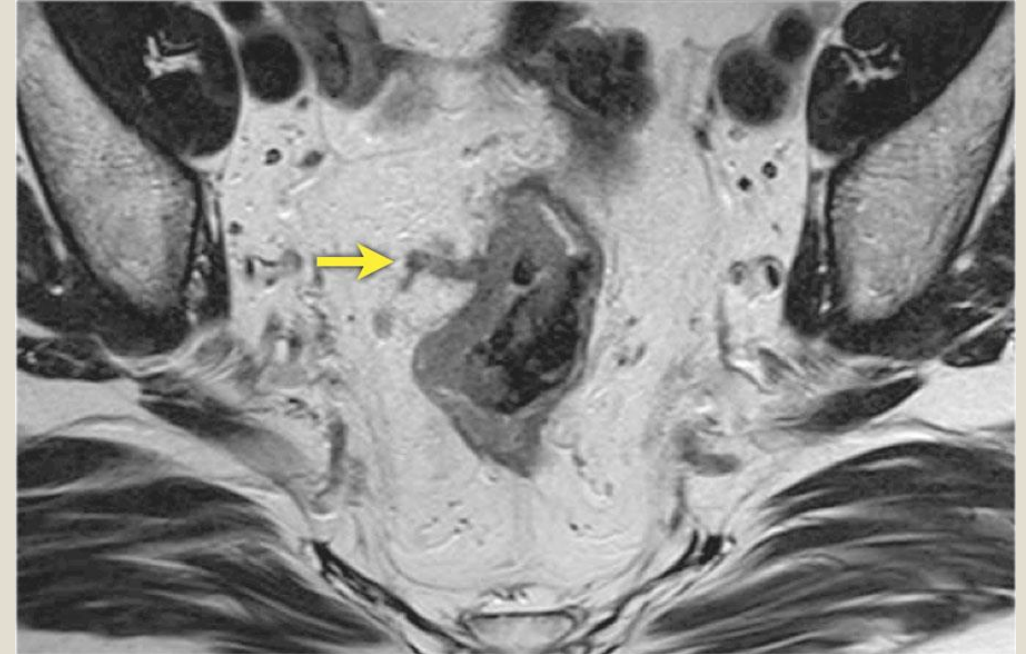
Note: Invasion of striated muscles is considered T4b disease, which includes invasion of the external anal sphincter, puborectalis and levator ani muscles.



This is an example of a cT4b tumor growing beyond the mesorectal compartment into the fat of the obturator space.

EMVI -Extramural vascular invasion

- Extramural vascular invasion is a risk factor for recurrent disease, metastases and impaired overall survival.
- EMVI is suspected if we see tumor-signal extending into a vascular structure in close proximity to the tumor, when the vessel is expanded by tumor, or if the tumor infiltrates the vessel borders (illustration).
- Example of an EMVI+ tumor with tumor signal extending into an adjacent vessel structure, expanding and disrupting the vessel contour.



Lymph Node Map

Regional lymph nodes:

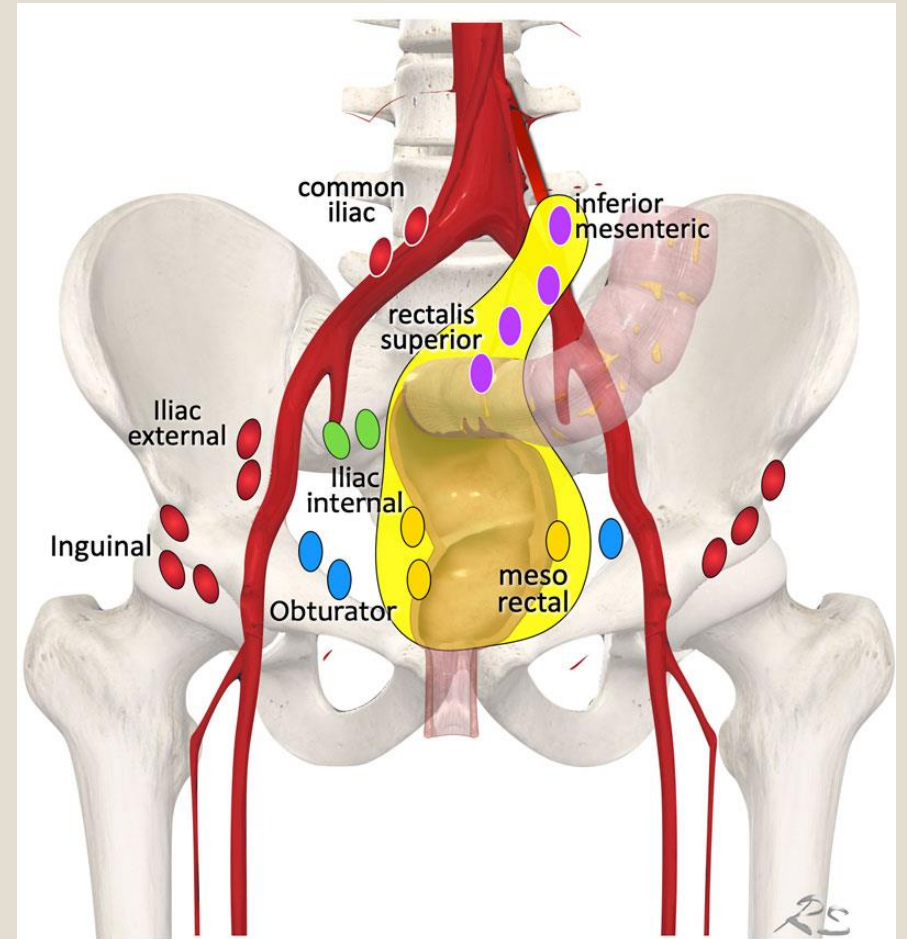
- Mesorectal lymph nodes (yellow): Nodes in the mesocolon of the distal sigmoid, along the “presacral” inferior mesenteric and rectalis superior blood vessels (purple)
- Nodes in the obturator spaces (blue)
- Nodes in the internal iliac spaces (green)

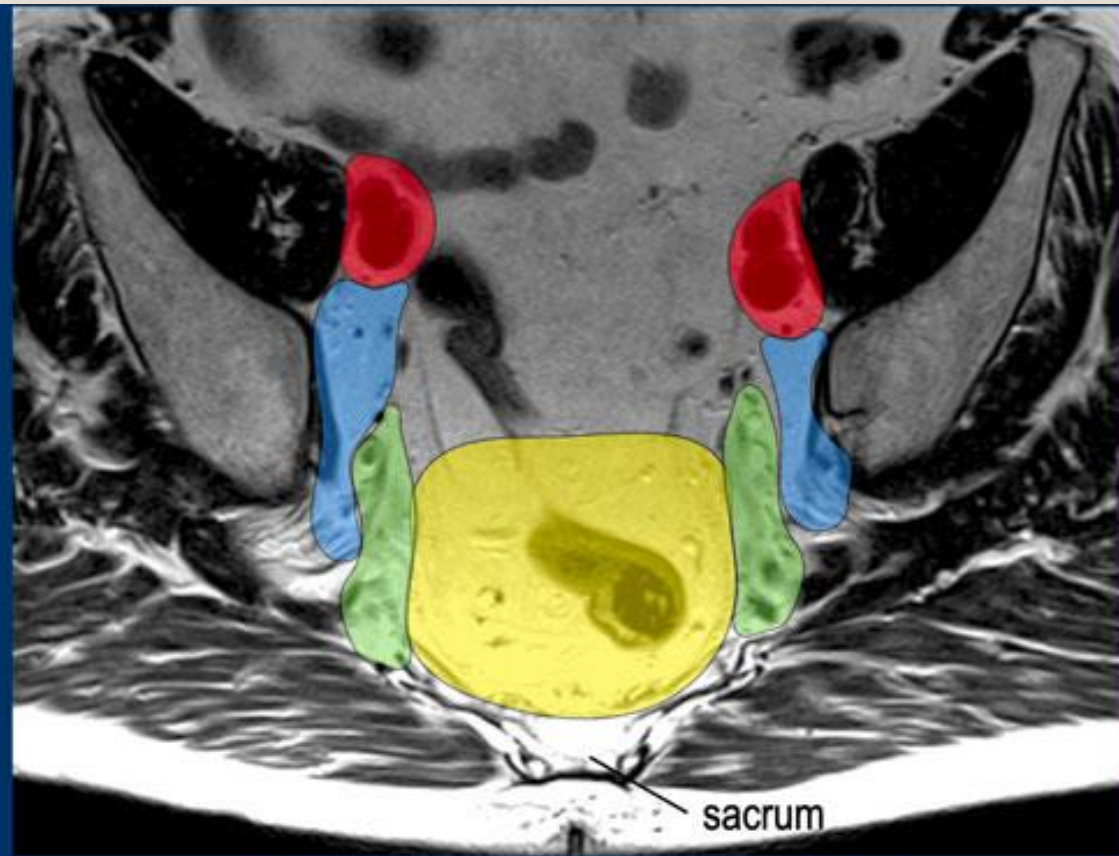
Non-regional lymph nodes (all in red): when involved are considered distant nodal metastases and are therefore part of the M-stage:

- External iliac nodes
- Common iliac nodes
- Inguinal nodes

Note

As an exception to this rule the AJCC TNM (8th ed.) considers inguinal nodes as regional nodes in case of low rectal tumors extending into the distal anal canal, below the level of the dentate line.





external iliac




obturator

internal iliac

mesorectal

Mesorectal lymph nodes

- Best results are obtained when applying a combination of nodal size and morphology to characterize mesorectal lymph nodes.
- Nodes ≥ 9 mm and nodes with mucinous signal characteristics are always regarded as suspicious.
- Smaller lymph nodes require additional morphologically suspicious features (round shape, indistinct border, heterogeneous signal) in order to be considered as cN+ as detailed in the Table.

Criteria for Mesorectal lymph nodes	
cN0	no suspicious lymph nodes
cN1	1-3 suspicious lymph nodes
cN2	≥ 4 suspicious lymph nodes
Suspicious if	> 9 mm 5-9 mm + 2 malignant characteristics < 5 mm + 3 malignant characteristics
	Note: <i>Mucinous lymph nodes are always suspicious</i>
Malignant characteristics	  
	Indistinct Heterogeneous Round

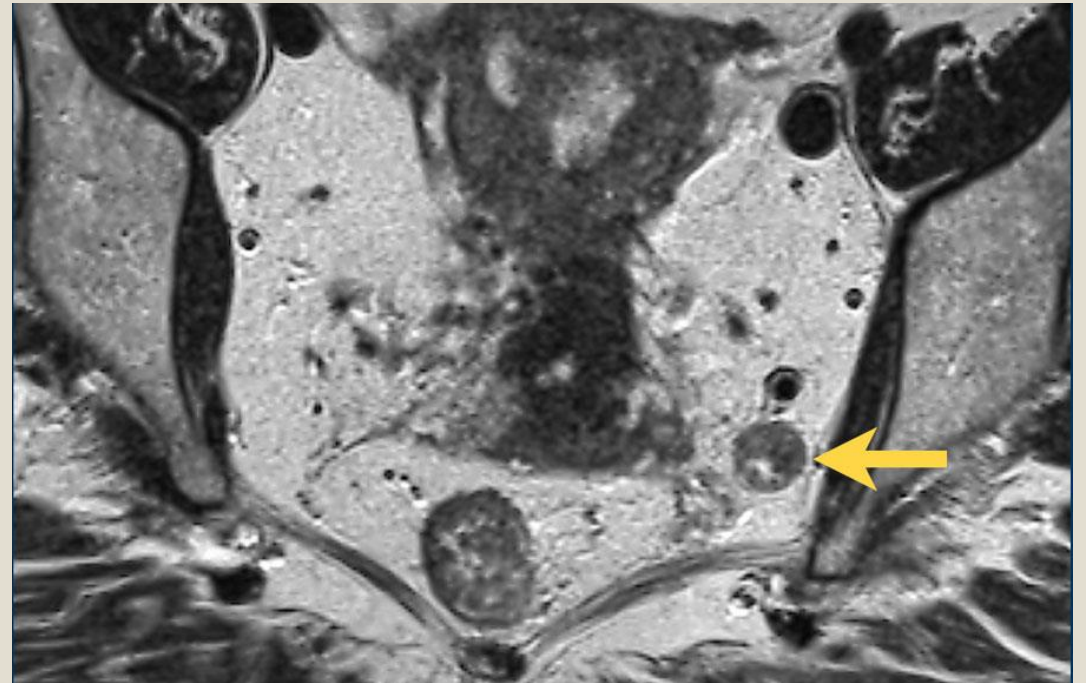
Criteria for Lateral lymph nodes

Suspicious if

≥ 7 mm (obturator & internal iliac)

Size criteria only

Any morphology



Example of a pathologic lymph node measuring 9 mm in the left obturator space

M-stage

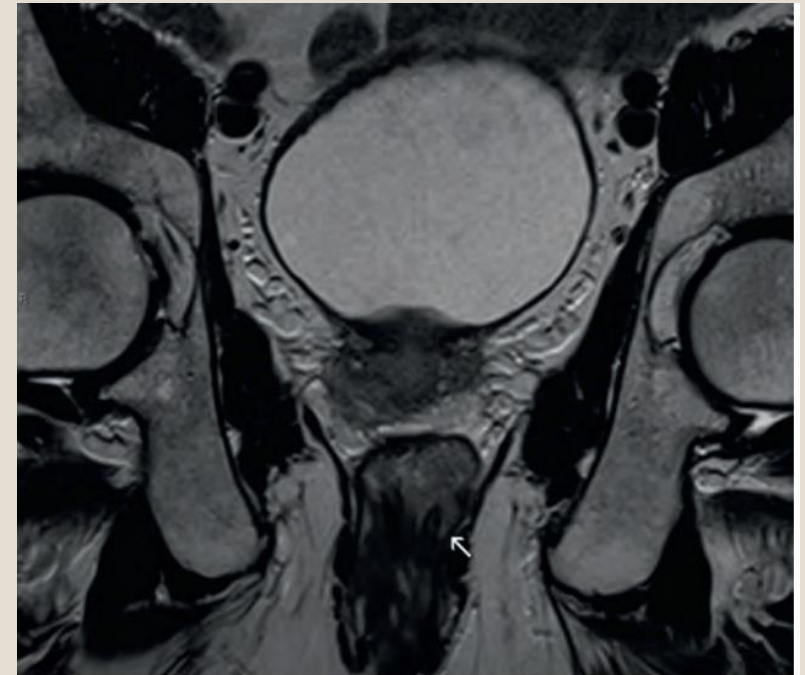
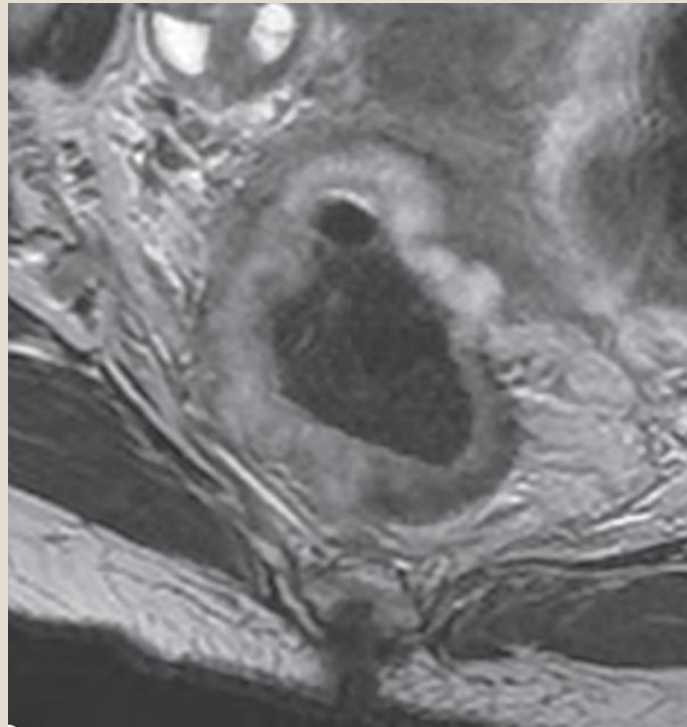
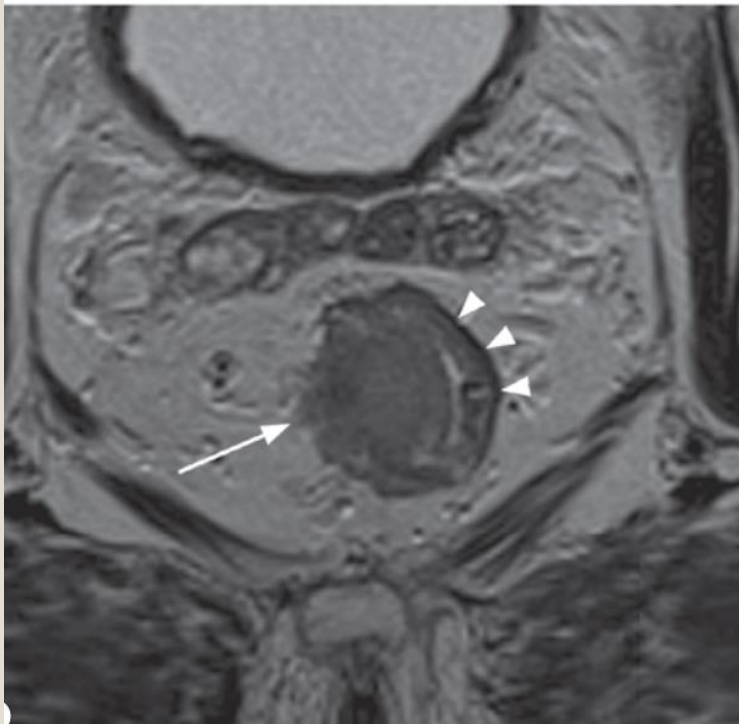
The M-stage in rectal cancer is based on the presence of suspicious *non-regional* lymph node metastases and other distant metastases.
Note that non-regional lymph nodes are together considered as one “organ”.

M-stage of Rectal Cancer

M0	No metastases
M1a	Metastases to one organ without peritoneal metastases (N.B. metastases in a bilateral paired organ, e.g. both lungs, both kidneys, or both ovaries is still M1a)
M1b	Metastases to two or more organs
M1c	Peritoneal metastases with or without organ metastases

CRM involvement is likely if MRI shows a tumour within 1 mm of the mesorectal fascia.

Low rectal tumours that extend into the intersphincteric plane are also high risk and may require neoadjuvant treatment and/or an extra-levator surgical approach to ensure clear resection margins.



g. 22.27 Coronal T₂ Weighted FSE Image Showing Intersphincteric infiltration of Low Rectal Carcinoma. The small left-sided tumour centre on the anorectal junction extends into the intersphincteric plane (*arrow*). Neoadjuvant therapy is often required to downstage such lesions despite their small size as their relationship to the sphincter complex otherwise necessitates an extralevator approach or abdominoperineal excision.

SUMMARY BOX: Summary of Cross-Sectional Techniques for Large Bowel Imaging

- Cross-sectional techniques are increasingly becoming remain the mainstay of colonic imaging.
- Fluoroscopic studies remain useful for problem solving in complex cases, for assessing post-operative intestinal integrity, diagnosing leaks and for delineating fistulae.
- Computed tomography colonography should replace barium enema for the detection of colorectal cancer and polyps.
- Magnetic resonance imaging (MRI) following oral contrast agent or rectal enema has an important role in evaluating the colonic lumen, colon wall and extraluminal tissues in inflammatory bowel disease as a non-invasive alternative to endoscopy.
- MRI remains the cross-sectional radiological technique of choice for pelvic imaging. It is accurate for local staging of malignancy in addition to assessing benign disease such as fistulae and pelvic floor dysfunction.
- High frequency ultrasound provides detailed imaging of the colon wall and has a valuable role for assessing extent and activity of inflammatory bowel disease, diagnosis of appendicitis and local staging of rectal tumours.

Thank You