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Magnetic rResonance iImaging for diagnosis and neoadjuvant treatment evaluation in locally -advanced rectal cancer: Aa pictorial review

Engin G. Magnetic resonance imaging MRI in locally -advanced rectal cancer

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Abstract

High-resolution pelvic magnetic resonance imaging (MRI) is the primary method for staging ~~of~~ rectal cancer. ~~–~~MRI is highly accurate in the primary staging of rectal cancer~~;~~, however, ~~MRI~~it has not proven to be effective in re-staging, especially in complete response evaluation after neoadjuvant therapy. Neoadjuvant chemoradiotherapy produces many changes ~~changes i~~on rectal tumors and on surrounding structures, as a result, local tumor extent may be overestimated or underestimated. However, adding ~~of~~ diffusion~~-~~weighted sequences to the standard~~ised~~ approach can improve diagnostic accuracy. In this pictorial review, an overview of the status of MRI in the loco-regional assessment and management of rectal cancer is presented as a pictorial assay. Limitations and difficulties in interpretation are also presented, based on published literature and our own experience.

Key Words: rectal cancer,~~-~~ locally advanced, MRI, staging, neoadjuvant treatment

Core tip: In rectal cancer, accurate staging and circumferential resection margin assessment are essential for determining~~ation~~ the risk of local recurrence and optimal therapeutic strategy. In the preoperative setting, ~~magnetic resonance imaging (~~MRI~~)~~ is highly accurate, whereas it has not been proven ~~to be~~ effective in re-staging. However, adding ~~of~~ diffusion~~-~~weighted sequences to the standard~~ised~~ approach can improve diagnostic accuracy of MRI.

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Magnetic Rresonance Iimaging for diagnosis and neoadjuvant treatment evaluation in locally advanced rectal cancer: Aa pictorial review

INTRODUCTION

Multimodal~~ity~~ treatment of rectal cancer, with the combination of preoperative (neoadjuvant) chemoradiatherapy (CRT) followed by surgery improves local control in locally advanced cancers and has become the standard approach to locally advanced rectal cancer (1-~~7~~5).

High-resolution pelvic magnetic resonance imaging (MRI) is the primary method for staging rectal cancer (6~~8~~-10). When performed in accordance with the recommended standards, high-resolution MRI accurately identifies prognostic markers for risk of local recurrence and helps to stratify patients into those needing neoadjuvant CRT (11). Moreover, MRI posttreatment tumour response assessment also predicts the likely survival outcomes, and in the future will be used to modify treatment further by stratification into good and poor responders (12). In recurrent rectal cancer, MRI allows the delineation of tumo~~u~~r extent within the pelvic compartments, and can assess resectability of the disease (13,14).

Despite many expectations, MRI has not proven ~~to be~~ effective in re-staging, especially in complete response evaluation after neoadjuvant CRT because of posttherapeutic fibrosis and inflammation (15-19). However, adding ~~of~~ functional MR sequences such as dynamic contrast-enhanced and diffusion~~-~~-weighted sequences to the standard~~ised~~ approach can improve diagnostic accuracy of MRI (20-23).

In this pictorial review, ~~a~~an overview of the ~~current~~ status of MRI in the loco-regional assessment and management of rectal cancer is presented. Limitations and

difficulties in interpretation are also presented, based on published literature and our own experience.

MR Imaging Technique

Rectal MR imaging is best performed with phased-array surface coils. Rectal MR imaging with a phased-array surface coil yields high- -spatial- -resolution images, thereby providing a full evaluation of the rectal wall layers, and has the additional advantage of a large field of view (15,24).

Patient Preparation

Routine rectal filling (e.g. with ultrasonography gel) is not recommended (24). Because distension of the rectum by endoluminal contrast agents can compress the mesorectal fat, which may overestimate fascial involvement and hamper evaluation of mesorectal nodes (25).

Bowel preparation is generally not necessary before the examination, but spasmolytics can be used in cases where significant bowel movement artefacts are visible on the planning images (15,24). For this purpose, a dose of 40 mg butylscopolamine etc) is used intramuscularly unless contraindicated, immediately prior to placing the patient on the MR imaging table.

Imaging Protocol

The minimum requirement for a standard MR rectal protocol is 2D T2-weighted sequences in sagittal, axial, and oblique coronal planes with a recommended slice thickness ranging between 1 and 3 mm (maximum 4 mm). The sagittal sequence should be used to determine the longitudinal tumour axis in order

to angle the axial and coronal planes as perpendicular and parallel to the tumour axis as possible, respectively. For low tumours, coronal planes should be angled parallel to the anal canal so that the relation of the tumour's lower pole to the anal sphincter muscles and its relationship to the adjacent pelvic floor can be evaluated (15,24,26) (Figure 1). Axial images help evaluate of the tumor and its relationship to the intestinal wall, mesorectal fascia, and the pelvic organs. Sagittal images help assess tumour height and length and the relationship of the tumor to the peritoneal reflection and other adjacent tissue.

In addition to T2-weighted sequences, a diffusion-weighted sequence should be included in the restaging MR protocol. There is no evident benefit for diffusion-weighted imaging (DWI) at primary staging, but there is growing evidence that DWI improves the diagnostic performance of MRI when evaluating response (the yT-stage) after CRT (24). DWI is of additional value to T2-weighted fast-spinecho (FSE) sequences to differentiate between the patients whose response is "good" versus "poor" (20-23). However, currently, there is insufficient evidence for the use of DWI for primary T-staging and for assessment ofing lymph nodes (27).

Anatomical landmarks

The rectum is approximately 15 cm in length from the anal verge, which is the lowermost portion of the anal canal. The rectum has traditionally has been divided into three segments according to the distance from the anal verge: the upper, (>10 cm),; the middle, (5-10 cm), and the lower, (<5 cm) (27,28) (Figure 2).

The upper and middle rectal walls consist of three different layers that can be recognized inat MR imaging. T2-weighted MR imaging sequences are the most suitable for depicting the rectal wall anatomy. MR imaging can help distinguish an

inner hyperintense layer, which represents the mucosa and submucosa (no differentiation is possible between these two components); an intermediate hypointense layer, which represents the muscularis propria; and an outer hyperintense layer, which represents the perirectal fat tissue (15,29) (Figure 3).

The ~~L~~lower rectum (anal canal) extends to the upper portion of the puborectal muscle. The puborectal muscle is the thicker portion of the pelvic floor musculature. The inner muscular wall of the anal canal consists of the internal sphincter, which is the direct continuation of the circular layer of the muscularis propria of the rectum. The outer muscular wall of the anal canal is cranially composed of the puborectal muscle and caudally of the external sphincter (15,26) (Figure 4).

The anterior wall of the upper rectum is covered by the peritoneal reflection; the risk of peritoneal perforation in upper rectal tumors is high (27). The peritoneal reflection can be easily identified on sagittal and axial high-resolution T2-weighted images. On sagittal images, the peritoneal reflection may be depicted above the tip of the seminal vesicles in men and at the uterocervical angle in women (15). The relationship between tumor and the peritoneal reflection is important in staging~~, since~~ because rectal tumors with invasion through the peritoneal reflection are categorized as stage T4a lesions (Figure 5).

The ~~M~~middle rectum, which lies below the peritoneal reflection, is completely encircled by fatty tissue ~~that~~ forms~~s~~ing a structure known as the mesorectum. The mesorectum contains lymph nodes, vessels, and several fibrous septa and is surrounded by the mesorectal fascia (MRF), which represents the circumferential resection margin (CRM) when total mesorectal excision (TME) is used as the surgical approach (26-29). The MRF is seen as a thin, low-signal intensity layer that envelop~~s~~ing the mesorectum and rectum (Figure 6). The mesorectal envelope tapers

downward at the lower rectal level (26). The MRF is clearly visible ion ~~the~~ posterolateral views, although it is difficult to differentiate this entity from ~~the~~ Denonvilliers' fascia in the anterior wall (30).

Primary ~~s~~Staging of Rectal Cancer

Tumo~~u~~r height and length

Tumo~~u~~r height and length should be routinely reported because~~since~~ outcomes and surgical management are affected by the location of the tumor (24).

The distance and length are measured on a line drawn on the sagittal MR images. For tumor localization, the distance of the lowest portion of the tumor from the anal verge is measured. A rectal tumor is characterized as high, middle ~~and~~or low when its most caudal border is more than 10 cm from the anal verge, 5–10 cm from the anal verge, or less than 5 cm from the anal verge, respectively (15) (Figure 7).

T staging for middle and high tumors

On T2-weighted imaging, the muscularis propria appears as a hypointense line between the hyperintense mesorectal fat and the inner submucosa and mucosa, which show intermediate to mild hyperintensity. The signal intensity of a rectal tumor on T2-weighted images is typically intermediate between the signal intensity of the muscularis propria and mucosa (Figure 8).

T1 tumors are confined to the submucosa; T2 tumors extend into, but not beyond, the muscularis propria. The differentiation of T1 tumors from T2 tumors on MRI is usually not reliable without an endorectal coil or endorectal ultrasound, and tumors should generally be ~~generally~~ staged as "T1/T2" (15). A tumor is staged as

T3 when it extends beyond the muscularis propria and strands theing into mesorectal fat. Disruption of the muscularis propria because of the penetrating vessels should not be overstaged as T3 (Figures 8,9).

The extramural depth of invasion refers to extension of tumor beyond the muscularis propria and is a prognostic factor (31). The American Joint Committee on Cancer suggested an optional stratification of T3 tumors based on the extramural depth of invasion: less than 5 mm, T3a; 5–10 mm, T3b; and more than 10 mm, T3c (32). An extramural depth of invasion of less than 5 mm presents a significantly higher survival rate, and these early T3 tumors may be adequately managed with surgery alone and have a prognosis comparable to that of tumors characterized as "T1/T2" (33). T4 tumors extend ointo the surface of the visceral peritoneum or an adjacent structure (Table 1) (Figures 8,10).

Distance to the mesorectal fascia

For T3 tumors, the shortest distance between the most penetrating parts of the tumor and the MRF should be measured (34,35). The distance to the MRF is the single most important local prognostic factor for rectal cancer (36,37). A tumor-MRF distance of more than 1 mm is a reliable predictor for negative margins after TME (38). In the presence of satellite nodules (such as tumor deposits, lymph nodes or extramural vascular invasion,) the shortest distance between the nodules and the MRF should also be reported (15) (Figures 11,12).

Extramural vascular invasion

Extramural vascular invasion (EMVI) is associated with local and distant recurrence and poor survival (39). It is defined as the presence of malignant cells within blood

vessels located beyond the muscularis propria in the mesorectal fat. EMVI is suggested ~~-~~when vessels close to the tumor are obviously irregular or expanded by tumoral signal intensity (39) (Figure 13).

The assessment of EMVI is a routine component of MR evaluation for primary staging~~;~~, however, for restaging, there is~~was~~ no agreement as to whether evaluation of EMVI remains beneficial (24).

T staging for low tumors~~,~~

A specific T staging system is used for identif~~ication~~ying ~~of~~ tumors that will need a circumferential resection margin (CRM) (40). This staging is based on the coronal and axial T2-weighted images (Table 1) (Figure 14,15).

N-staging

Nodal staging is very important for planning preoperative treatment (41). In the TNM system, disease involving only the regional nodes, including the mesorectal and internal iliac nodes, accounts for the N stage (Table 1); involvement of other nodes is regarded as metastasis (38).

Mesorectal nodes are often the first and the most commonly involved group of nodes ~~that are involved~~. Nodal metastases are usually within the proximal 5 cm of the tumor (41). Extramesorectal nodes (iliac, superior rectal or inferior mesenteric nodes) are generally involved in locally advanced cancers (42). Low rectal tumors may also involve superficial inguinal nodes and imply poor prognosis (43).

Nodal staging using~~by~~ MRI usually relies on size criteria. Typically, a lymph node is considered malignant when its short axis measures over 0.5 cm, but~~-~~ there is no optimal cut-off threshold for involved nodes (24). However, adding morphologic

features, such as round shape, irregular border contour and heterogeneous signal intensity~~,~~ to a size cut~~-~~off increases the accuracy of MR (44). DW MRI, although not accurate for nodal characterisation, may be useful for locating nodes (45) (Figure 16).

Restaging after neoadjuvant treatment

Neoadjuvant CRT provides downstaging and downsizing along with ~~include~~ improvement in resectability, sphincter preservation, decreased rates of local recurrence, and overall survival (12,46).

Tumor restaging involves correlating the posttreatment images with the pretreatment images with respect to all the elements assessed in the initial staging, and necessitates image acquisition with almost the same protocol and on the same planes.

T staging

Post-CRT restaging using conventional MR sequences is less accurate than primary staging, particularly in confirming complete response (yT0), largely owing to the difficulty in distinguishing fibrosis, ~~o~~edema and normal mucosa from small foci of residual tumo~~u~~r (46-48). ~~So that~~As such, a normal, two-layered rectal wall after CRT is suggestive of a complete response (yT0), whereas any fibrotic residue is an equivocal feature that may indicate either residual tumo~~u~~r or complete response (Figure 17). ~~-~~Actually, on post-CRT T2-weighted~~-~~ MRI, areas of fibrosis have very low signal intensity, whereas areas of residual tumor have intermediate signal-intensity (46). Careful review of high-resolution images and DWI can enable

delineation of small foci of intermediate-signal-intensity tumor within areas of low-signal-intensity fibrosis (Figure 18).

In addition to morphologic findings, DWI can provide functional information ~~in addition to on morphologic findings~~ that can be correlated with changes at the cellular level in response to treatment. After CRT, the decrease in cellularity and ~~the~~ development of fibrosis or necrosis in responders results in an increase in diffusion, ~~so that~~ which decreases ~~in~~ diffusion signal intensity in diffusion~~-~~ weighted images and ~~, whereas~~ increases ~~in the~~ ADC values and ADC signal intensity in ADC images (20,23) (Figures 18,19). Although DWI can differentiate viable tumor from fibrosis and good and bad response, ~~however~~ it does not allow for predicting ~~of~~ complete response (19) (Figure 20). Moreover, the response of mucinous tumors to CRT cannot be assessed using DWI because they ~~mucinous tumors~~ exhibit ADC hyperintensity even before treatment~~, their response to CRT cannot be assessed using DWI~~ (Figure 21).

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Distance to the mesorectal fascia

If a fat pad reappears between the tumo~~u~~r and MRF after CRT, the MRF is considered uninvolved. This finding has strong negative predictive value (98%) of MR imaging for radial margin involvement, whereas it has low positive predictive value (49). The main difficulty is int~~o~~ assessing whether ~~the~~ low-signal-intensity areas represent~~s~~ fibrotic scarring or residual tumor. The major MR imaging finding that causes overstaging is diffuse hypointense tissue infiltration into the MRF fascia. This finding is related to two histopathologic findings: marked fibrosis of the bowel wall and peritumoral infiltration of inflammatory cells and vascular proliferation (desmoplastic reaction) (50) (Figures 22,23).

N-staging

Nodal size (short axis diameter) after CRT is more reliable for nodal re-staging. It is difficult to differentiate a metastatic lymph node from a lymph node with irradiation changes ~~by~~ using morphologic criteria or DWI~~;~~, therefore, lymph node~~s~~ restaging often results in overstaging (27,50) (Figures 24,25).

The accuracy of MRI for restaging is generally lower than the accuracy of MRI for initial staging, mainly owing to overstaging of nodal disease, failure to differentiate tumoral infiltration or residual tumor from desmoplastic reaction or radiation fibrosis (50). According to ~~the~~ recent meta-analysis~~-~~ results, ~~-~~MRI accuracy was~~is~~ vary variable for restaging rectal cancer after neoadjuvant treatment, but significantly better results ~~is~~were ~~-~~demonstrated when DWI was ~~-is~~ used or with experienced observers. The authors~~y~~ also reported~~say~~ that MRI could~~can~~ ~~also~~ be used for evaluating~~ion of~~ CRM staging, but nodal staging remains challenging (51).

In conclusion, using high-resolution MRI, standardi~~z~~z~~s~~ation of image acquisition techniques and interpretation of the images, comparing both pre- and post-CRT MR images before interpreting the post-CRT images, adding DWI to the standard approach, and importantly, ~~moreover,~~ experience and awareness of the~~on~~ limitations ~~and adding of DWI to the standardised approach~~ can improve diagnostic accuracy of MRI for staging.

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~~LANGUAGE EDITING PROCESS FOR MANUSCRIPTS SUBMITTED BY NONNATIVE SPEAKERS OF ENGLISH~~

TABLE

Table 1 Staging systems for rectal cancer (Note—[a]Adapted from (32) Edge SB, Byrd DR, Compton CC. AJCC cancer staging handbook: from the AJCC cancer staging manual, 7th ed. New York, NY: Springer, 2010:718 [b]Adapted from (40): Taylor FG, Swift RI, Blomqvist L, Brown G. A systematic approach to the interpretation of preoperative staging MRI for rectal cancer. *AJR* 2008; 191:1827-1835)

Stage	MRI Findings
T stage for middle and high tumors[a]	
T1	Tumor signal intensity is confined to the submucosal layer
T2	Tumor signal intensity extends into the muscle layer, with loss of the interface between the submucosa and circular muscle layer
T3	Tumor signal intensity extends through the muscle layer into the perirectal fat, with obliteration of the interface between muscle and perirectal fat
a	Tumor < 5 mm into the perirectal fat
b	Tumor 5–10 mm into the perirectal fat
c	Tumor >-10 mm into the perirectal fat
T4	
a	Tumor signal intensity extends to surface of visceral peritoneum
b	Tumor signal intensity extends into an adjacent structure or viscus
T stage for low tumors[b]	
T1	Tumor signal intensity confined to bowel wall, outer muscle coat intact
T2	Tumor signal intensity replaces muscle coat but does not enter intersphincteric plane
T3	Tumor signal intensity extends intersphincteric plane or lies within 1 mm of levator muscle
T4	Tumor signal intensity extends external anal sphincter or is within 1 mm or beyond levator muscle with/without adjacent organ invasion
N stage	
Nx	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	Metastasis in 1–3 regional lymph nodes
N2	Metastasis in > 3 regional lymph nodes

FIGURES

Figure 1. MRI planes. T2-weighted sagittal images are used to determine the longitudinal tumour axis in order to angle the axial and coronal planes. A: Oblique axial plane is obtained perpendicular to the rectal wall at the level of the rectal mass. B: Oblique axial plane is angled perpendicular to the pelvic floor, used to cover lymph node drainage territory. C: Coronal plane is angled parallel to the anal canal for imaging of low rectal tumors. Rectal tumor is indicated by arrows.

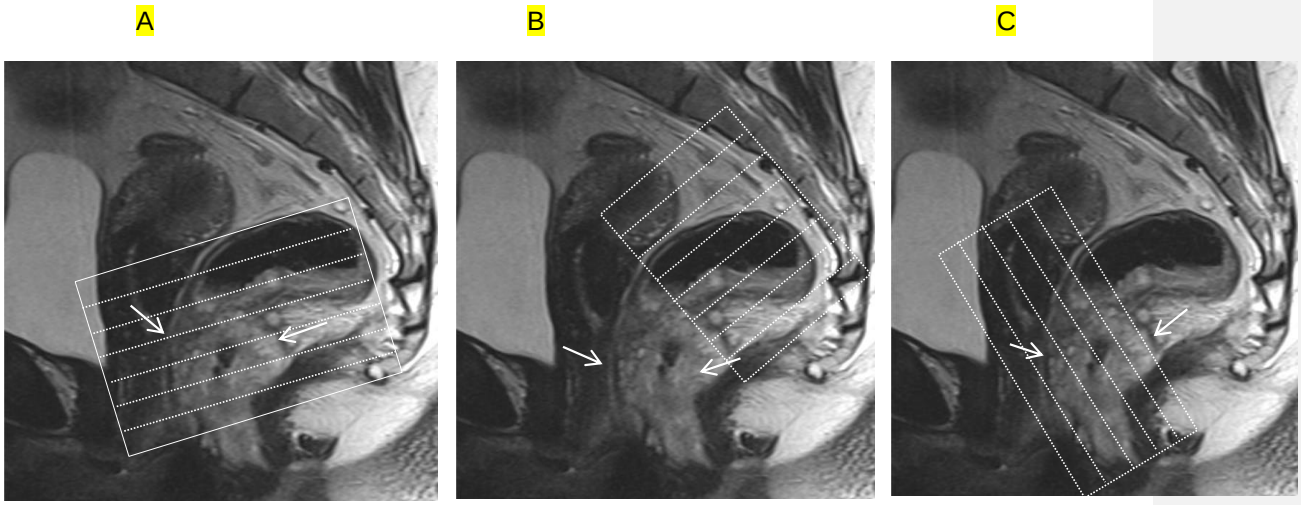


Figure 2. Rectal segments. T2-weighted sagittal image shows rectal segments: lower, <5 cm; middle, 5–10 cm; upper, >10 cm from the anal verge.

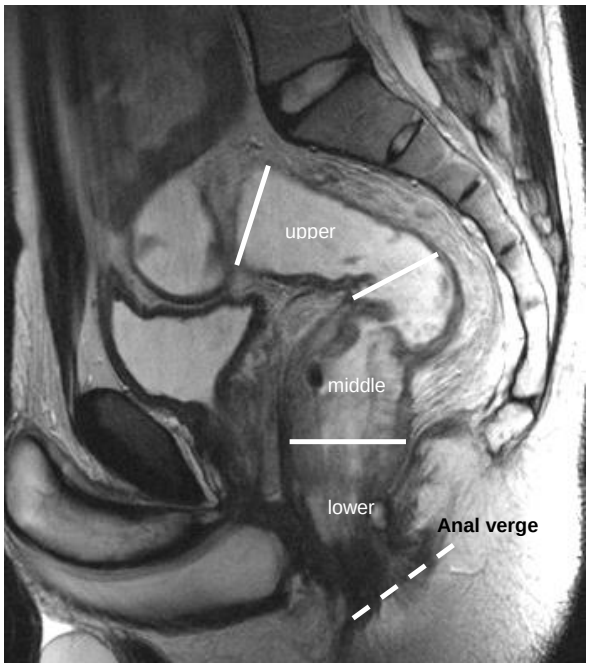


Figure 3. Normal rectal wall anatomy of higher and middle rectum on A: schematic and B: T2-weighted axial MRI presentation. The inner hyperintense layer represents the mucosa and submucosa (no differentiation is possible between these two components); the intermediate hypointense layer and outer hyperintense area represent the muscularis propria and the mesorectum, respectively. Mesorectal fascia is seen thin hypointense layer enveloping the mesorectum (arrows).

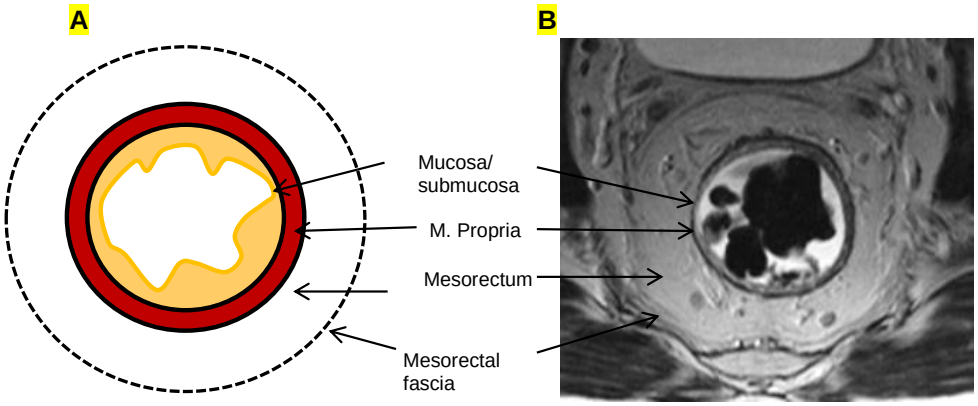
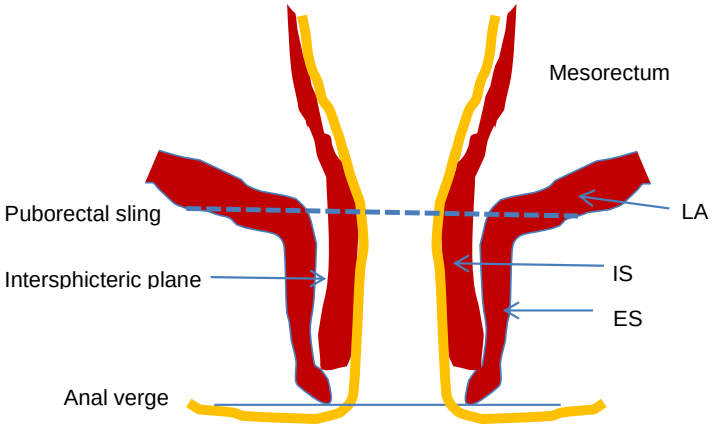


Figure 4. Normal anatomy of lower rectum on A: schematic and B: coronal plane T2-weighted MRI presentation. -Puborectal sling, the upper portion of the puborectal muscle displaying the uppermost portion of the anal canal (intermittent line). Anal verge is the lowermost portion of the anal canal (line). LA-Levator ani muscle; IS- Internal sphincter; ES-External sphincter

A



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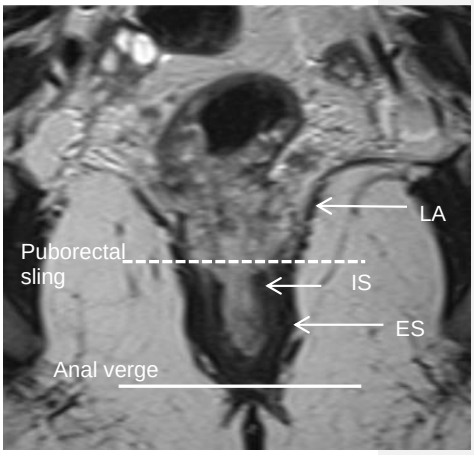

Figure 5. Periton invasion in female (A, B) and male (C, D) patients with T4a rectal tumors.- On sagittal T2-weighted images, periton is seen as a hypointense linear structure in front of the tumor (arrows in A,C). On axial T2-weighted images, the peritoneum has a V shape and attaches onto the anterior aspect of the rectal cancer (arrows in B,D). -T-tumor, U-uterus, P-prostate.

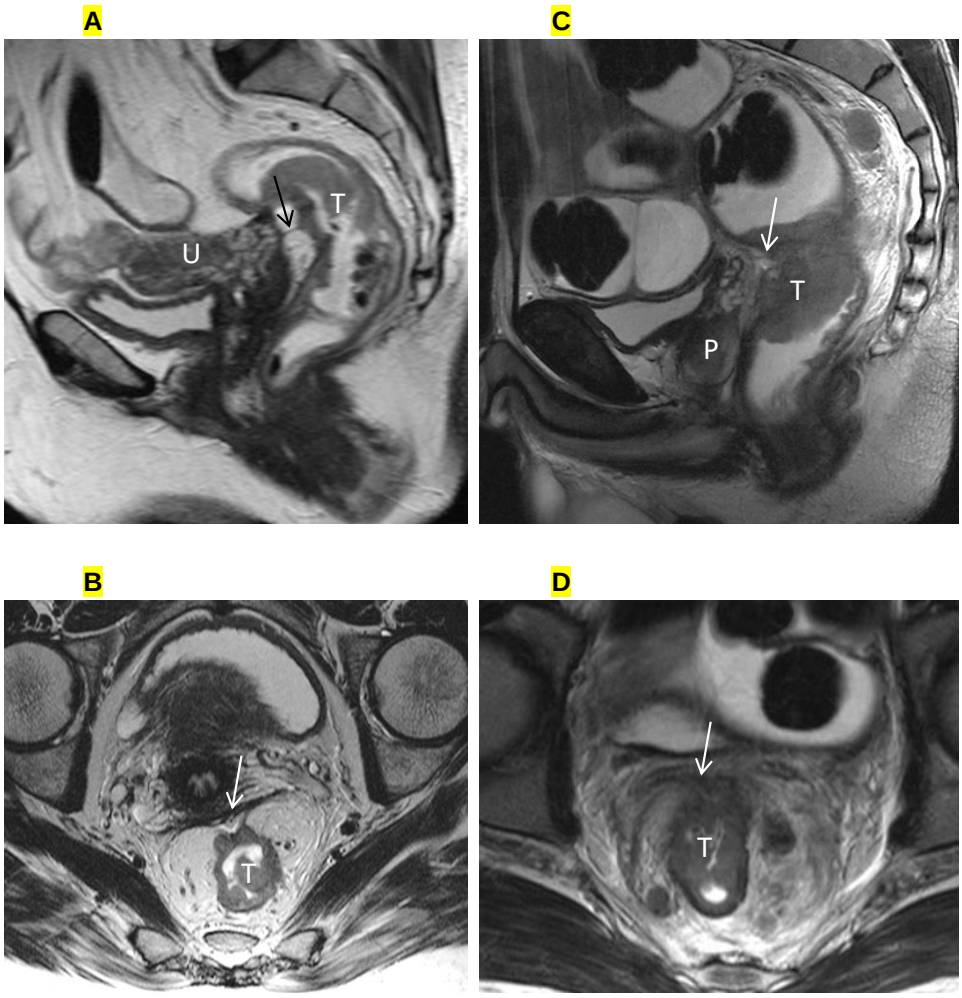

Figure 6. MRI anatomy of mesorectum and mesorectal fascia. -On T2-weighted A: axial and B: coronal plane MR images, mesorectal fascia (arrows) is seen as a thin, low-signal intensity layer enveloping the mesorectal fatty tissue (*) and rectum in a male patient with rectal carcinoma (arrowheads). EKLE

A **B**

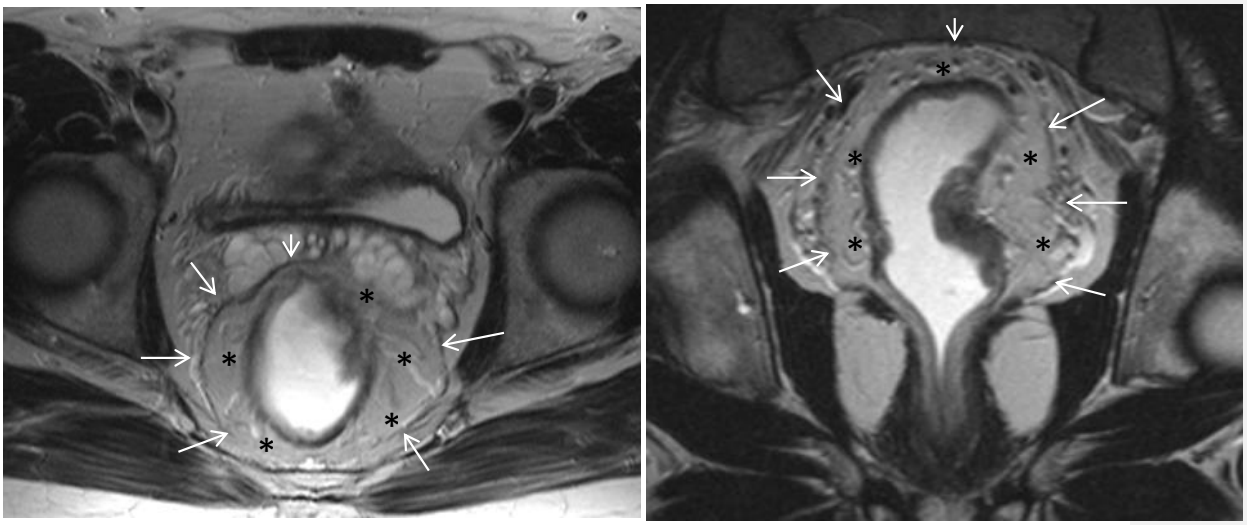

Figure 7. Rectal tumor levels. T2-weighted sagittal images in different patients with rectal carcinoma show distance from the anal verge (double-headed arrows) in A: low rectal, B: midrectal, and C: upper rectal tumors (low rectal tumor, <5 cm; midrectal, 5–10 cm; upper rectal, >10 cm).

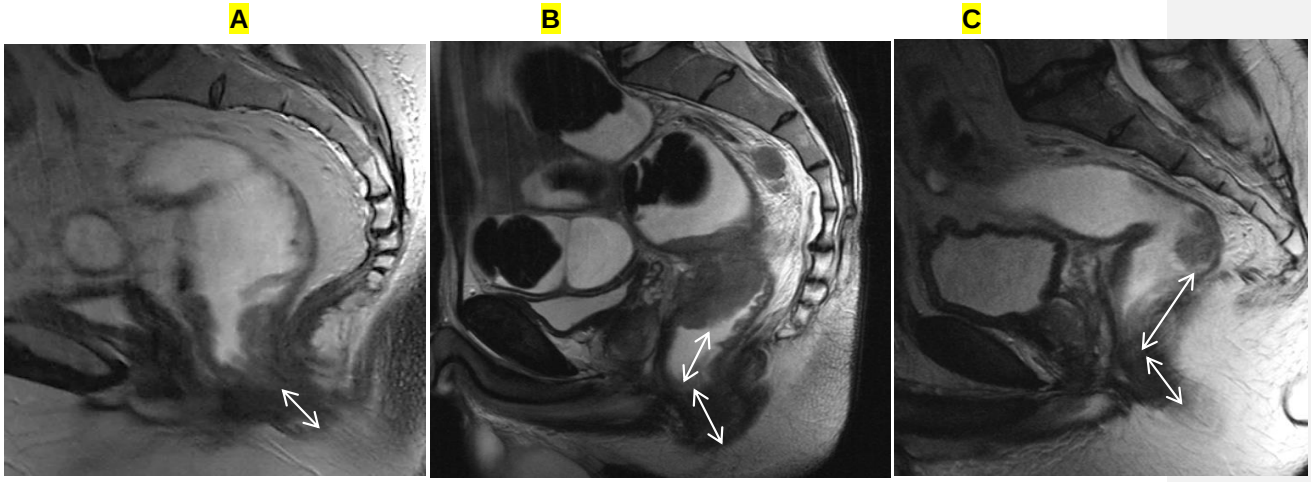

Figure 8. Rectal tumor T staging. The American Joint Committee on Cancer suggested an optional stratification of T3 tumors based on the extramural depth of invasion: less than 5 mm, T3a; 5–10 mm, T3b; and more than 10 mm, T3c (Note—Adapted from (27): Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G. The use of MR imaging in treatment planning for patients with rectal carcinoma: have you checked the "DISTANCE"? Radiology 2013;268:330-344)

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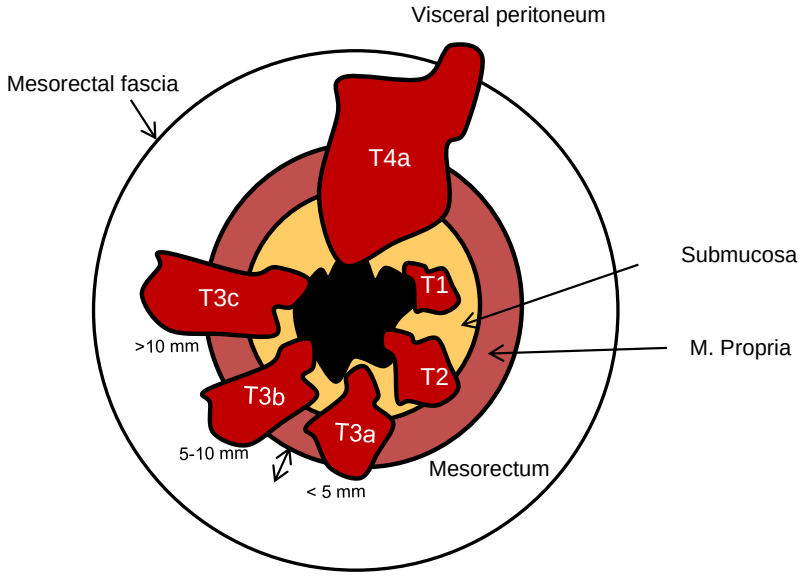
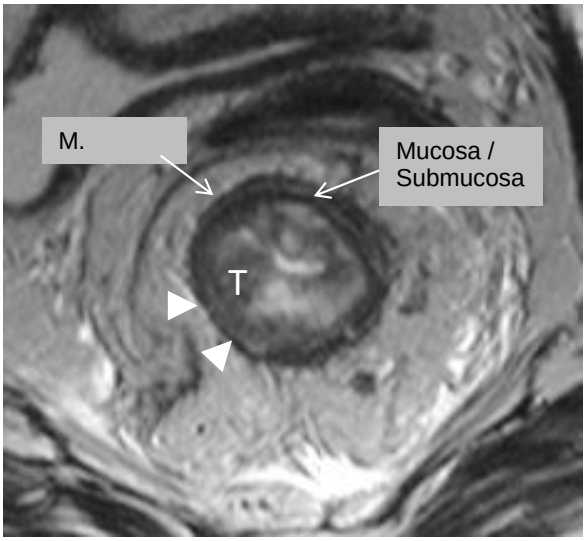


Figure 9. Rectal cancer T staging on MRI. T2-weighted axial images showing rectal carcinomas with different T stages. A: T1 tumor is confined to the submucosa, has not ~~into~~entered the muscularis propria (arrowheads). B: T2 tumor extends into, but not beyond, the muscularis propria (arrowheads). C: T3 tumor extends beyond the muscularis propria and strand~~s~~ing into mesorectal fat (arrowheads). D: T4a tumor invades ~~to~~ the visceral peritoneum (arrowheads). T-tumor.

A



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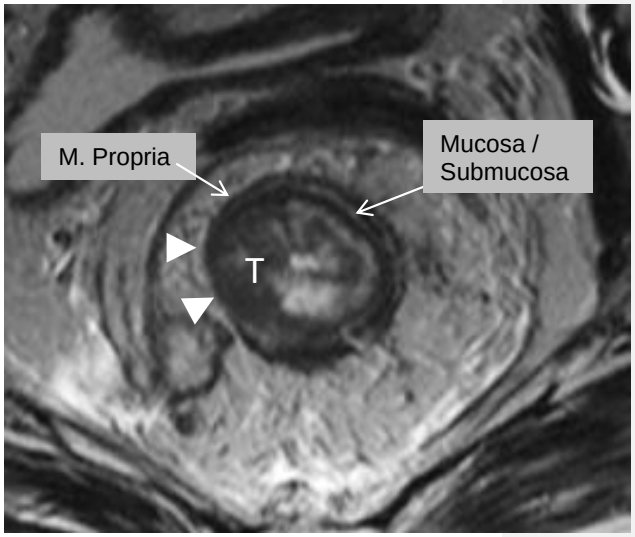

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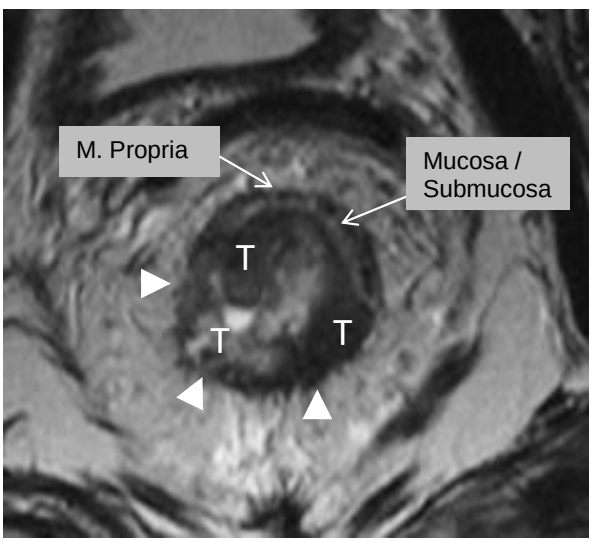

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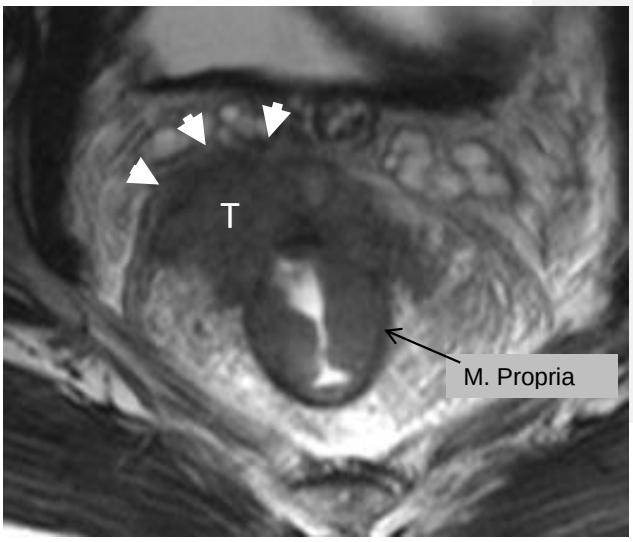


Figure 10 Stratification of T3 tumors on MRI. T2-weighted axial MR images in different patients with T3 rectal carcinoma showing extension of the tumor beyond the muscularis propria (double-headed arrows). The distance A: less than 5 mm, T3a; B: 5-10 mm, T3b; and C: more than 10 mm, T3c.

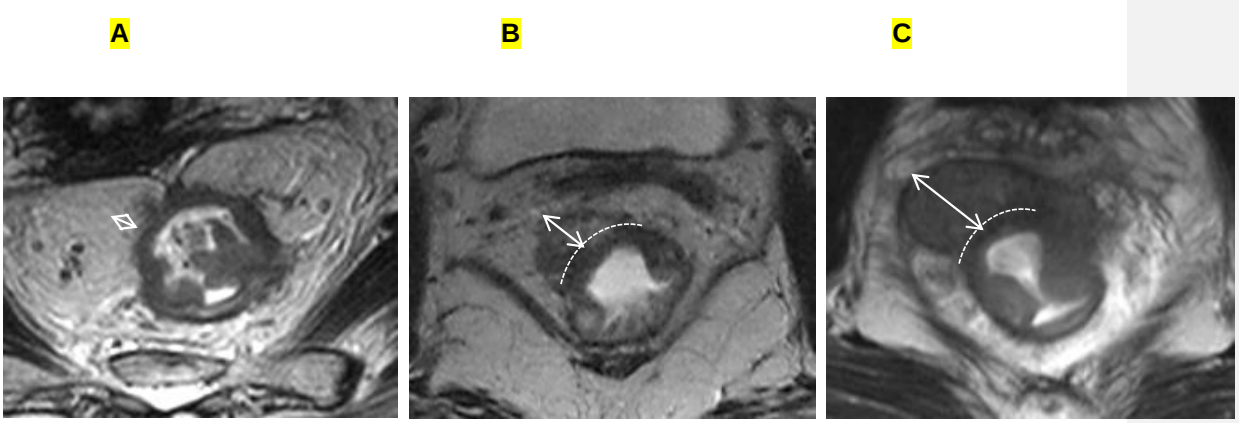


Figure 11. Schematic representation of positive resection margin. For T3 tumors, the shortest distance between the most penetrating parts of the tumor and the MRF is measured (double-headed arrows). A tumor mesorectal fascia distance of more than 1 mm is a reliable predictor for negative margins. In the presence of satellite nodules such as tumor deposits, lymph nodes or extramural vascular invasion the shortest distance between the nodules and the MRF should also be reported (Note—Adapted from (27): Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G. The use of MR imaging in treatment planning for patients with rectal carcinoma: have you checked the "DISTANCE"? Radiology 2013;268: 330-344).

Biçimlendirilmiş: Altı çizgisiz

A. Lymph nodes
B. Tumor
C. Extramural vascular invasion
D. Tumor deposits

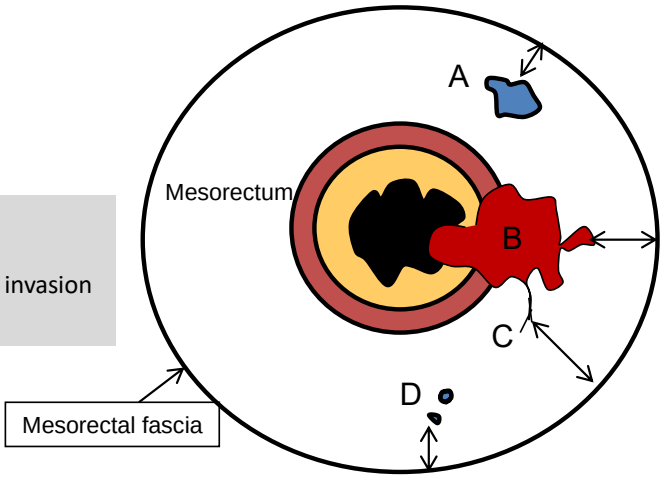


Figure 12. Distance to mesorectal fascia and mesorectal fascia invasion in different patients on T2--weighted axial images. A: T3a tumor is far away from the mesorectal fascia (~~double-headed~~double-headed arrow). B: T4a tumor (white arrowhead) and a suspicious mesorectal lymph node (arrow) are abutting the mesorectal fascia. C: Rectal- tumor is lying ~~in~~ >1 mm from~~of~~ the mesorectal fascia;~~,~~ however, a suspicious lymph node, located out of the mesorectal fascia, is lying within <1 mm of the mesorectal fascia (arrow). Mesorectal fascia is -indicated with black arrowheads.

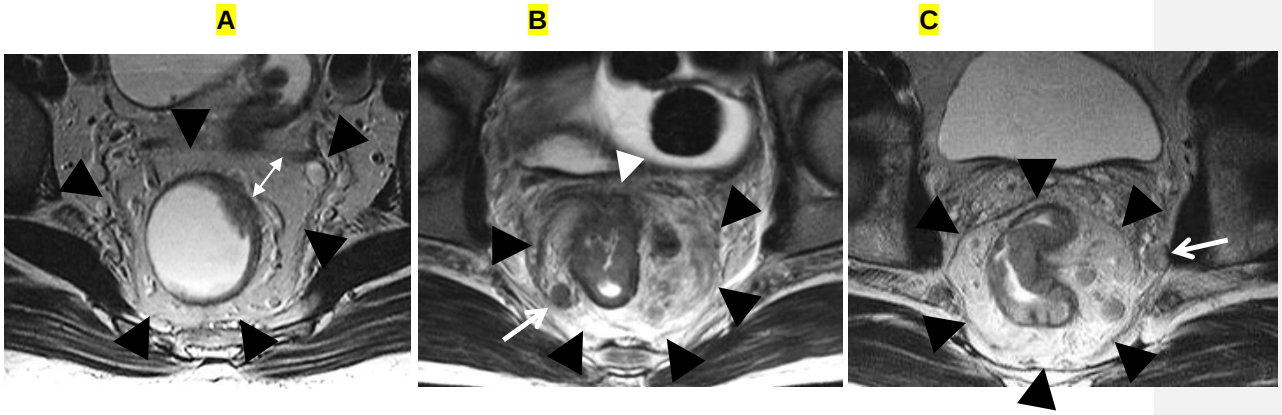


Figure 13. Extramural vascular invasion. T2-weighted A: coronal and B, C: serial axial MR images in the same patient with T4a rectal cancer showing an irregular and expanded vessel insert to the tumor with tumoral signal intensity (circles).

A **B** **C**

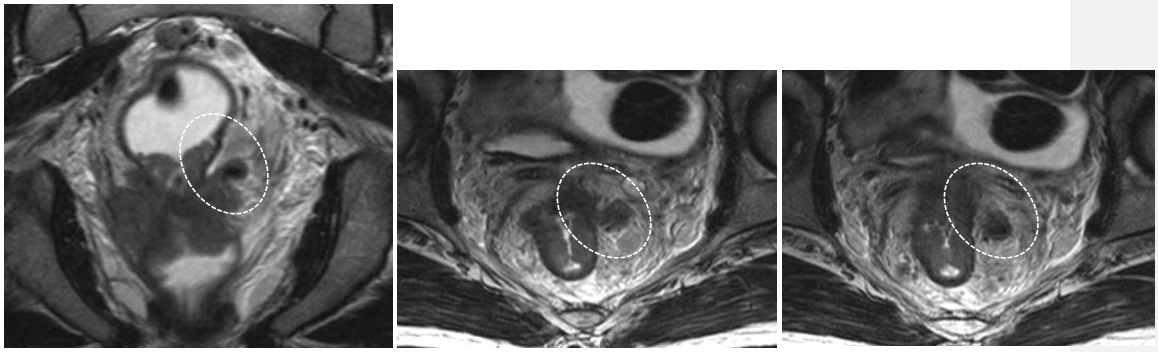


Figure 14. Schematic and high-spatial-resolution coronal T2-weighted MR images for each stage according to the low rectal cancer. Rectal tumors in different patients are indicated with arrows on MR images (Note—Adapted from (27): Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G. The use of MR imaging in treatment planning for patients with rectal carcinoma: have you checked the "DISTANCE"? Radiology 2013;268: 330-344).

Biçimlendirilmiş: Altı çizgisiz

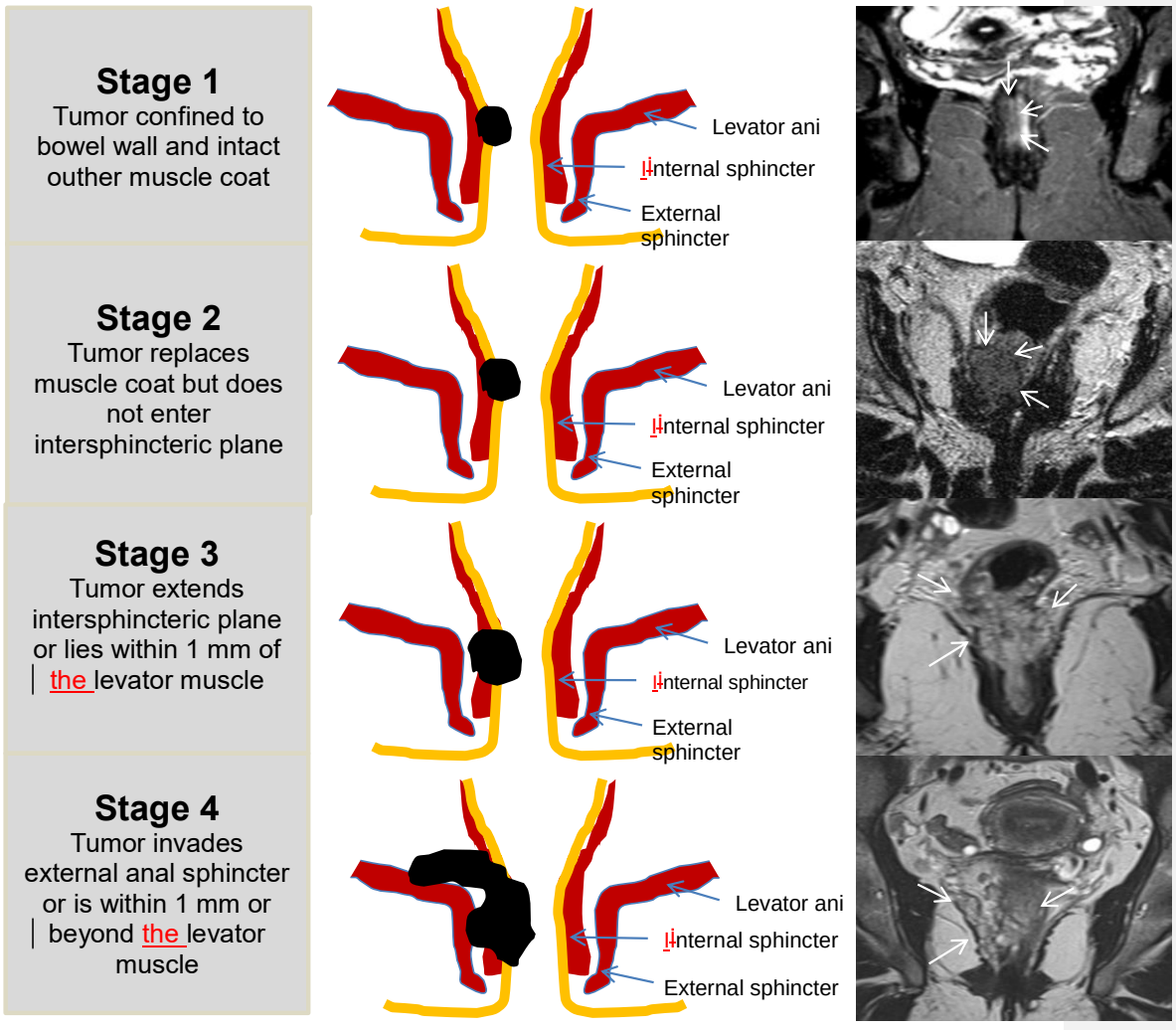


Figure 15. Stage 4 low rectal cancer. On T2-weighted A: coronal, B, C: serial axial MR images, rectal cancer showing invasion of levator ani (black arrowheads) and mesorectal fascia (white arrowhead). LA-levator ani, PR-puborectal, MRF-mesorectal fascia, BL-bladder, V-vagina.

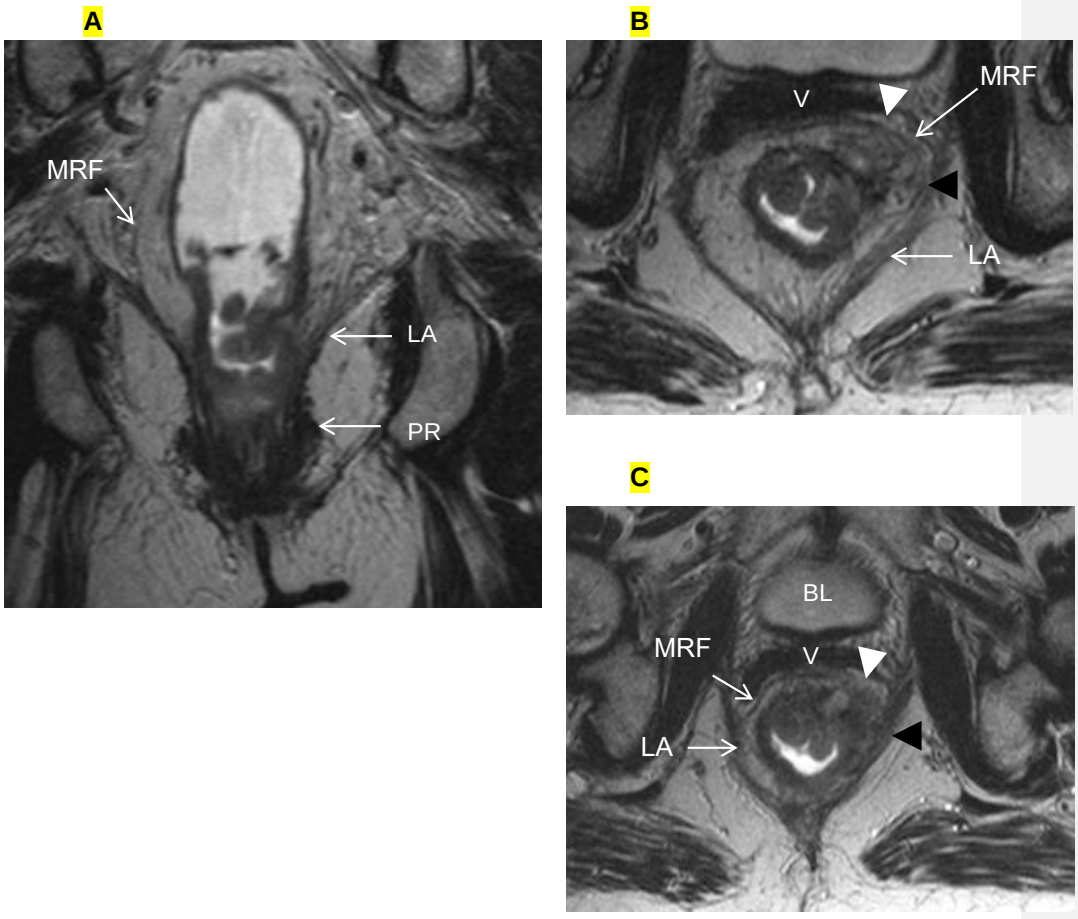


Figure 16. Mesorectal and extramesorectal lymph node involvement in rectal cancer. A: T2-weighted, B: T1-weighted contrast-enhanced axial MR images, C: 18FFDG PET-CT and D: DWI showing suspicious lymph nodes in mesorectal (thin arrows) and extramesorectal areas (thick areas). On DWI, extramesorectal lymph node is more remarkable than T2W and contrast-enhanced T1W sequences.

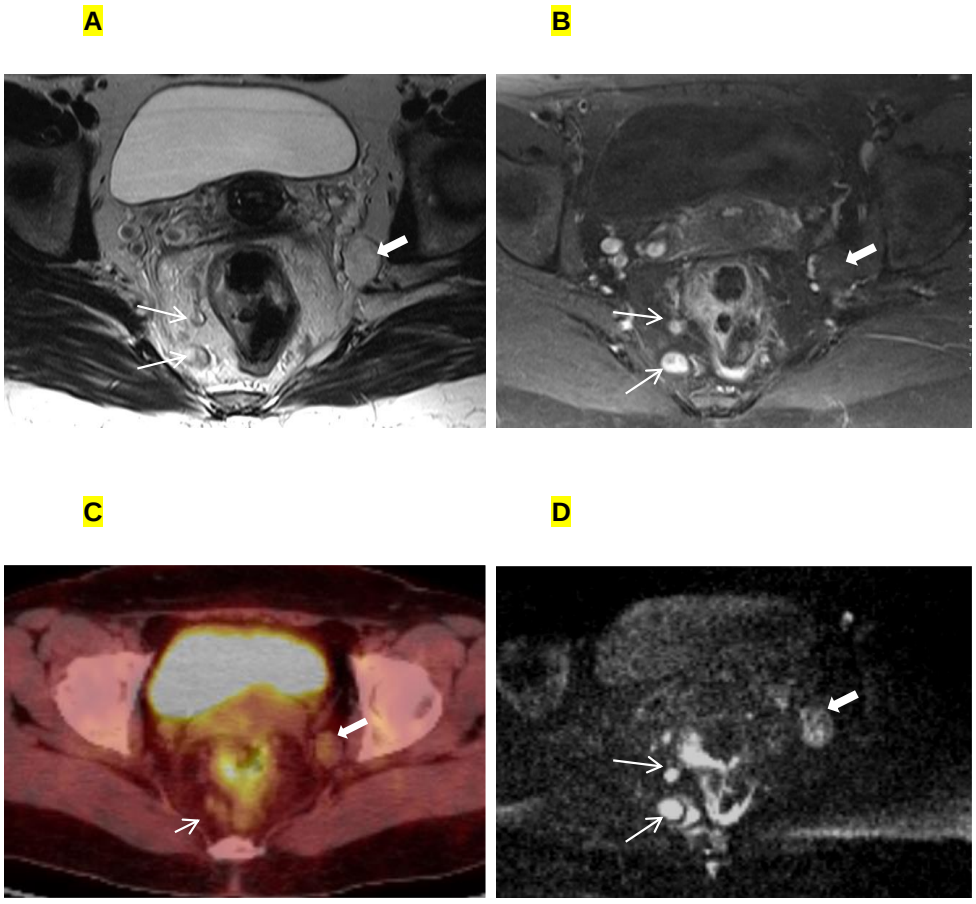


Figure 17. Tumor restaging after neoadjuvant chemoradi~~o~~a~~t~~herap~~h~~y (CRT). On T2-weighted MR images in different patients showing baseline and post-CRT images on upper and lower series, respectively. A: In ypT0 rectal tumor, posttreatment axial image shows a normal, two-layered rectal wall (arrow), corresponding to complete response. B: In ypT3 rectal tumor, posttreatment axial image shows normal, two-layered rectal wall (arrow). This is an example for false--negative MR assessment of complete tumor regression. C: In ypT0 rectal tumor, posttreatment axial image shows thick, fibrotic low signal intensity scar (arrow) in pretreatment T3 tumor area.

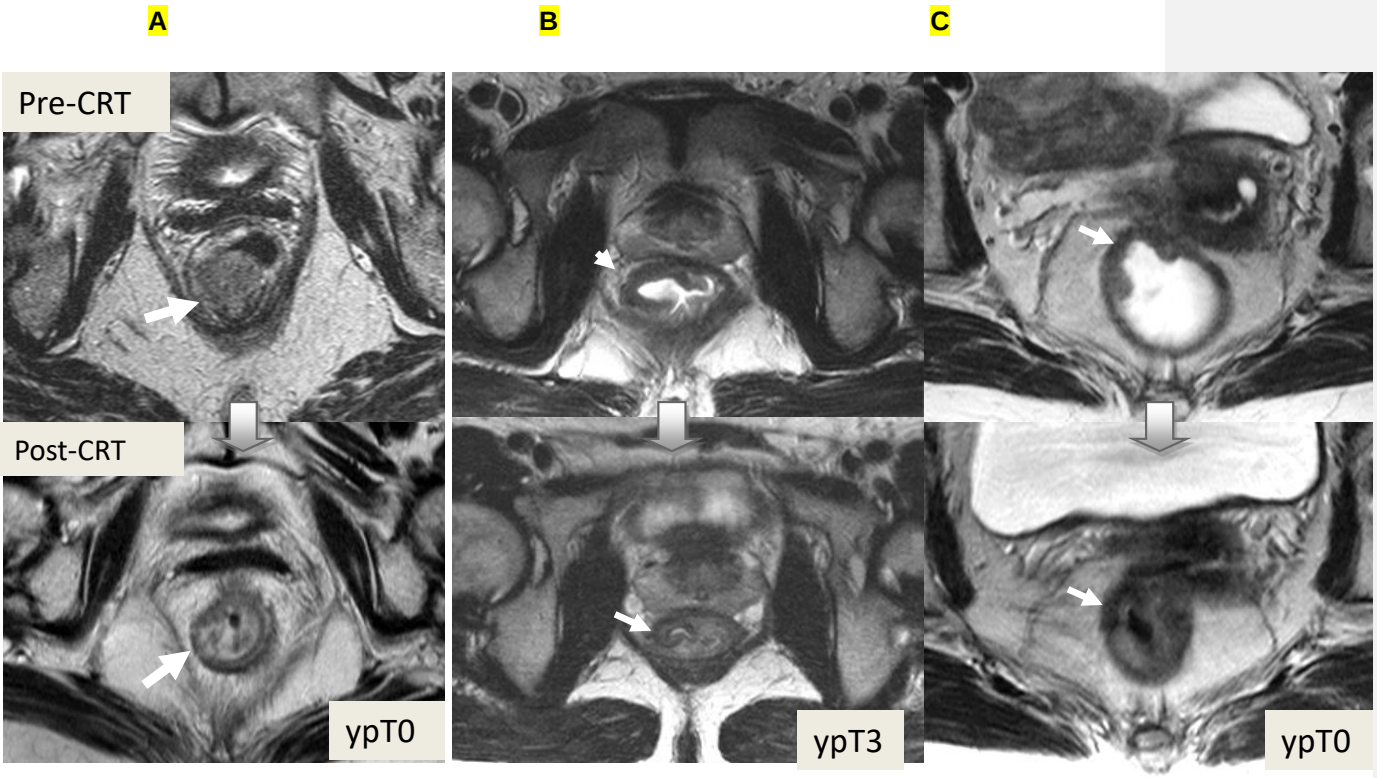


Figure 18. Post-CRT restaging using DWI in ypT3 rectal tumor. ~~-~~On T2-weighted (A), DW (B) and ADC (C) images in the same patient, baseline and post-CRT images are~~is~~ shown on upper and lower series, respectively. A: Posttreatment T2-weighted axial image shows semiannular infiltrating tumor, compatible with a residual T3 tumor (*arrow*). B: Posttreatment DW and C: ADC images delinate high and low signal-intensity corresponding to the tumor, respectively (arrow). Pre- and post-treatment mean ADC values are 0.68-0.72, 1.22-1.44 x 10^{-3} mm²/s, respectively, in the tumor area. Post-th~~r~~erap~~h~~y ADC increase is compatible with th~~r~~erap~~h~~y response.

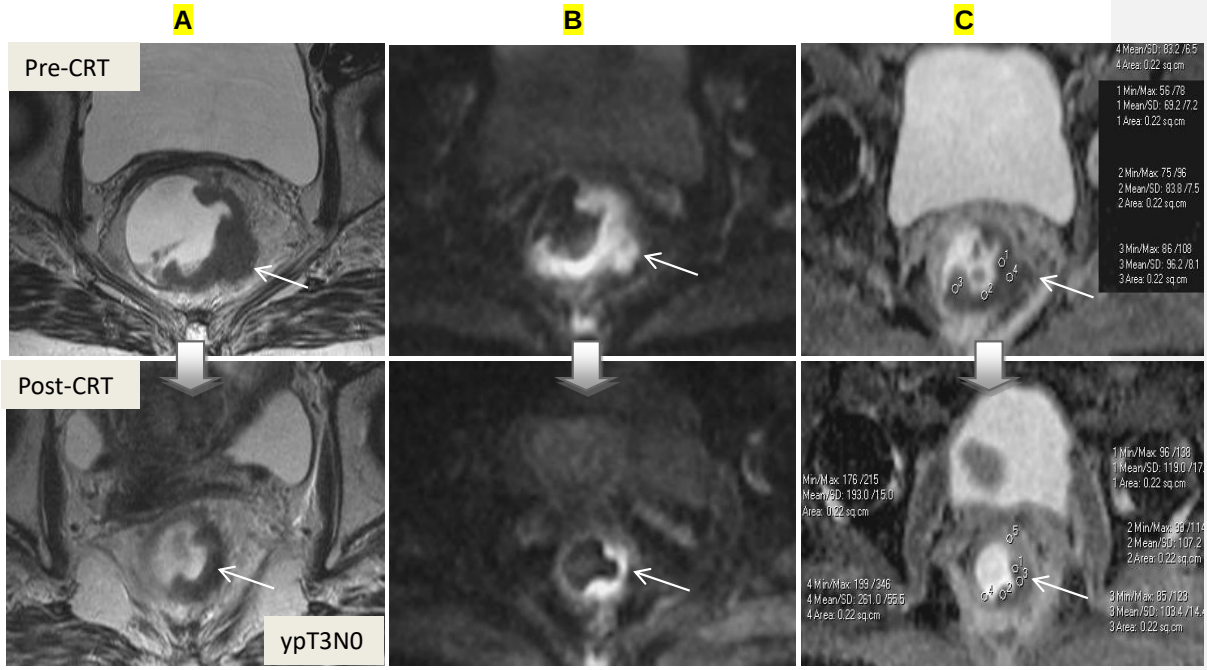


Figure 19. Post-CRT restaging using DWI in ypT0 rectal tumor. On T2-weighted (A), DW (B) and ADC (C) images in the same patient, baseline and post-CRT images are~~is~~ shown on upper and lower series, respectively. A: Posttreatment T2-weighted axial image shows a thick wall of low-signal-intensity fibrosis in the previous rectal tumor area (arrow). Any fibrotic residue is an equivocal feature that may indicate either residual tumo~~u~~r or complete response. B: On posttreatment DW image (B-800), there is no diffusion signal in previous~~r~~ tumor area (arrows), compatible with complete response. In this case, DWI allows the ~~to~~ correct differentiation of~~e~~ viable tumor from fibrosis ~~correctly~~. C: ADC images show post-therap~~h~~y mean ADC increase (0.70 vs 1.40 x 10^{-3} mm^2/s)~~,~~ compatible with therap~~h~~y response, but does not allow prediction of complete response.

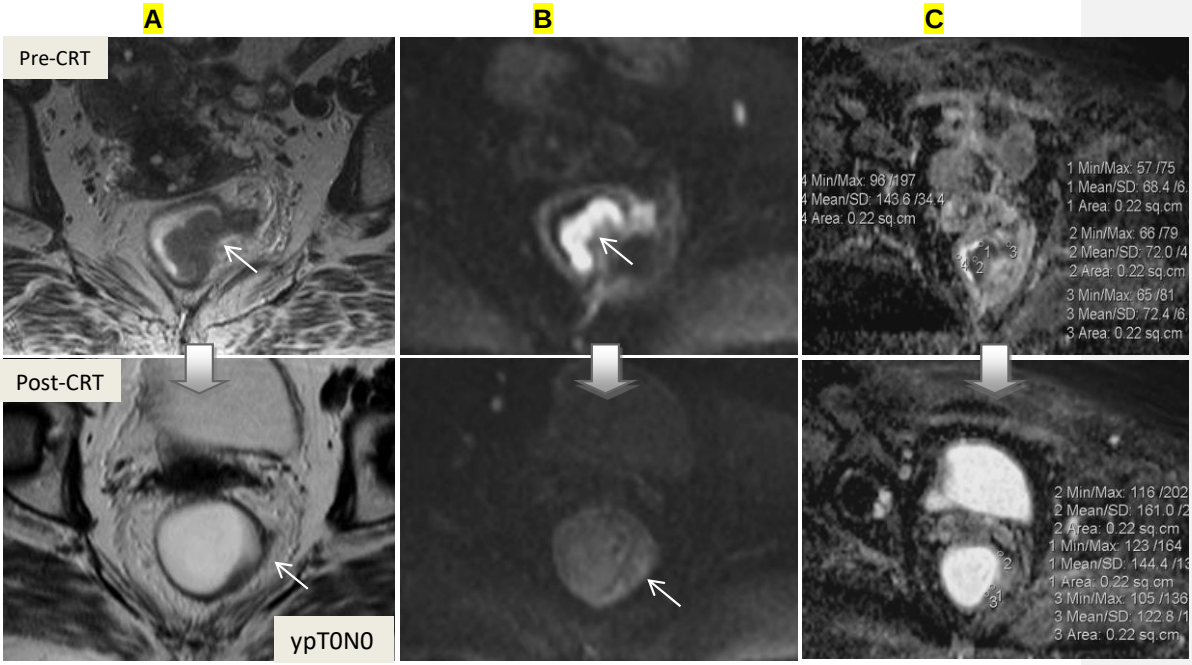


Figure 20. Post-CRT restaging using DWI in ypT0 rectal tumor. On T2-weighted (A), DW (B) and ADC (C) images in the same patient, baseline and post-CRT images are~~is~~ shown on upper and lower series, respectively. A: Posttreatment T2-weighted axial image shows a thick wall of low-signal-intensity fibrosis and areas ~~of~~ suspicious for residual tumor have intermediate signal-intensity in the previous rectal tumor area (long arrow). B: Posttreatment DW images delinate a small foci of intermediate and low signal-intensity, ~~-~~respectively, compatible with residuale~~e~~ tumor (long arrow). C: ADC images show post-threrap~~h~~y mean ADC increase (1.05 vs 1.80 x 10^{-3} mm²/s), compatible with therap~~h~~y response, but not with complete response. The suspicious mesorectal lymph node (arrowheads) is invisible on T2 and DWI after CRT, but the other two are still visible (short arrows). This case is an example for false~~-~~-positive tumor and lymph node response evaluation of DWI.

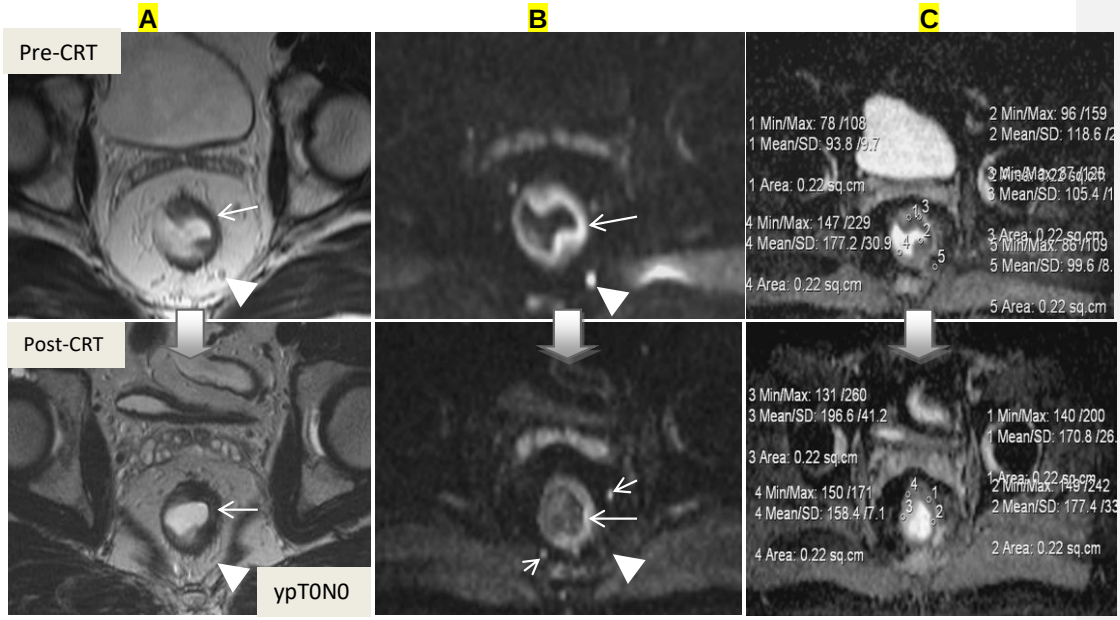
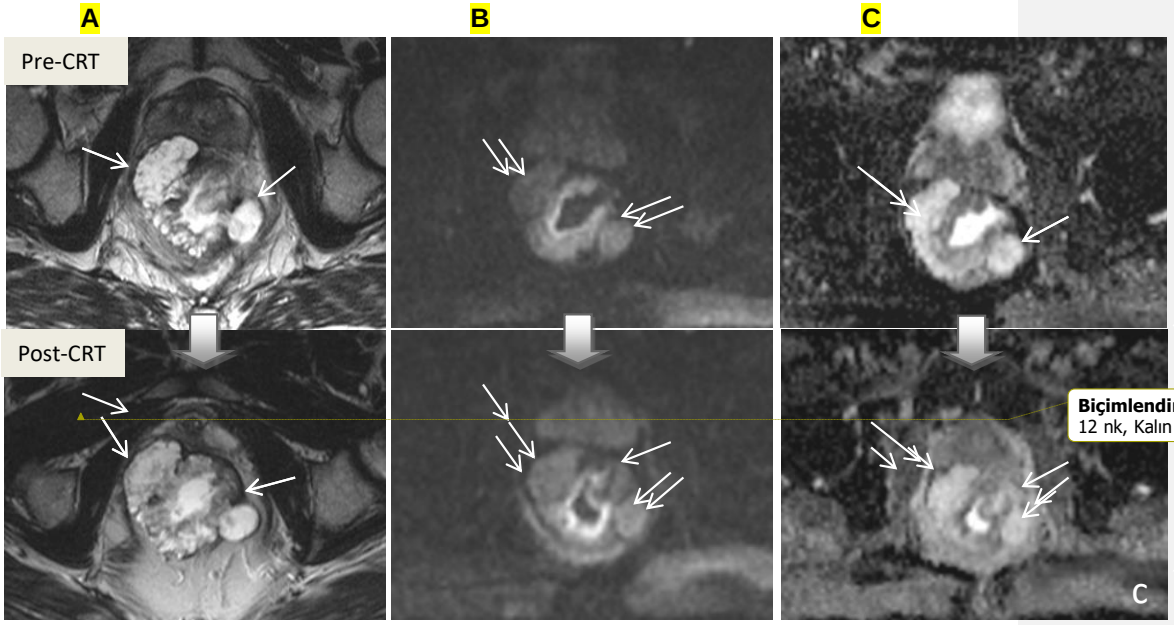


Figure 21. Mucinous adenocarcinoma. A: T2, B: Diffusion-weighted and C: ADC images in the same patient, baseline and post-CRT images are shown on upper and lower series, respectively. The mucinous tumor exhibits hyperintensity on T2, diffusion, and ADC images before and after treatment regardless of their response to treatment. Pre- and post-treatment ADC values are 1.70 and 2.10 x 10^{-3} mm^2/s, respectively. Their response to CRT cannot be assessed using DWI.



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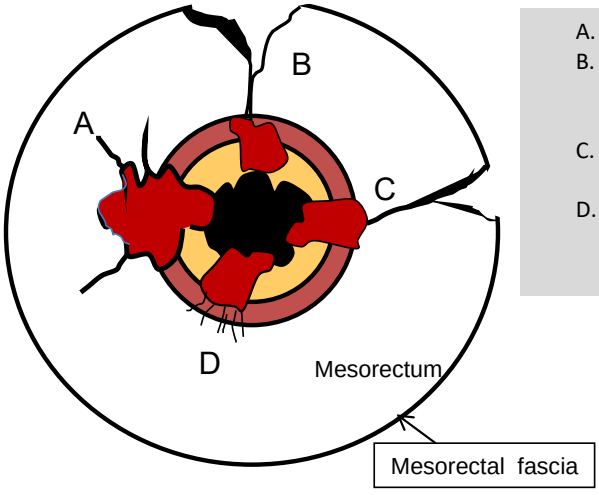
12 nk, Kalın

Figure 22. Schematic representation of effects of chemoradiotherapy on a rectal tumor and circumferential resection margins (CRM) (Note—Adapted from (27): Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G. The use of MR imaging in treatment planning for patients with rectal carcinoma: have you checked the "DISTANCE"? Radiology 2013;268: 330-344).



A. **Tumor remains, mainly gross nodular pattern.**
B. **Scarring contiguous to mesorectal fascia, a thick scar cannot exclude residual tumor, careful evaluation to signal intensity can be helpful.**
C. **Thin, linear scar extending to the mesorectal fascia can be interpreted as fibrotic reaction.**
D. **Multiple linear thin scar in the mesorectum can be interpreted as fibrosis, if they demonstate very low signal intensity.**

Figure 23. The effects of chemoradiotherapy on a rectal tumor and circumferential resection margins (CRM). T2-weighted axial MR images in different patients show baseline and post-CRT images on upper and lower series, respectively. A: Overstaging due to thick, hypointense tissue infiltration at the mesorectal fascia (arrow) in ypT2 rectal tumor with no MRF invasion. B: In ypT3 rectal tumor with no MRF invasion, thick fibrous retractions of the tumor, suspicious for CRM positivity (arrow). C: Rectal mass is markedly shrunken with low-signal-intensity tissue infiltration at the mesorectal fascia (arrow). At surgery, there was tumor invasion of the mesorectal fascia.

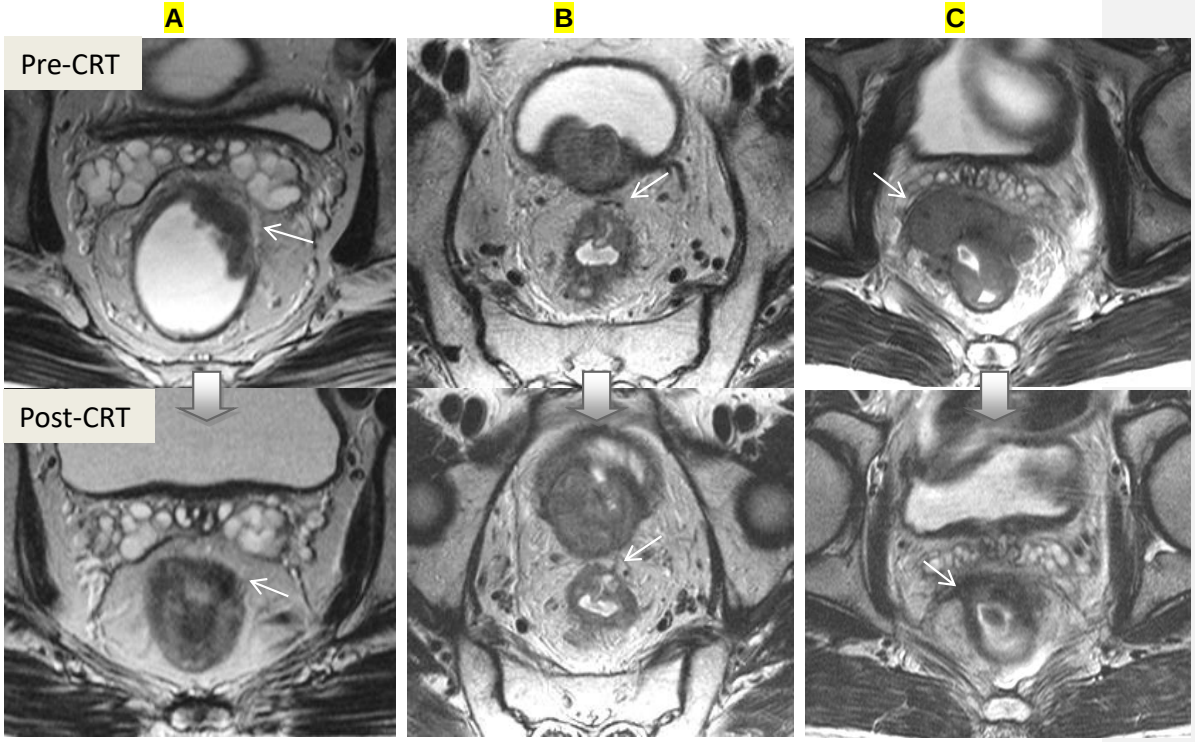


Figure 24. On DWI, false-positive mesorectal lymph node evaluation after chemoradiotherapy in ypT0N0 rectal cancer. A: T2-weighted axial MR images show significant diminution in nodal size after chemoradiotherapy, compatible with negative lymph node (arrows). B: DW images, high diffusion signal continues after treatment in the perirectal lymph~~a~~ node, incorrectly compatible with positive lymph node (arrows).

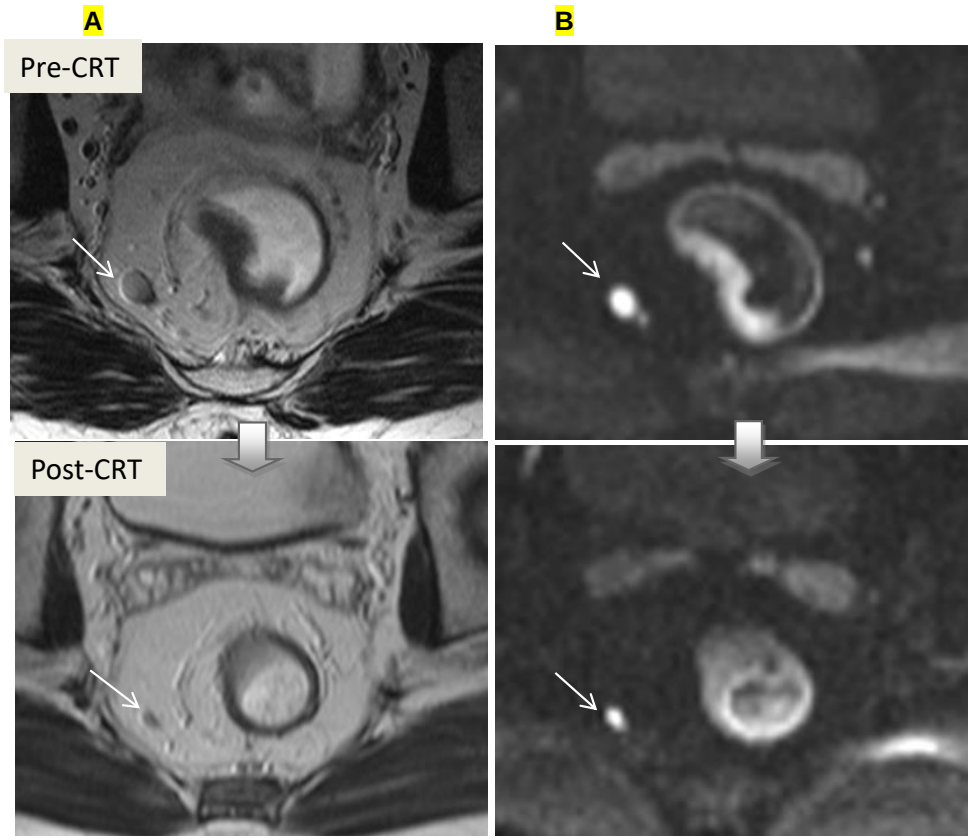


Figure 25. On DWI, false~~-~~-positive mesorectal lymph node after chemoradiotherapy in ypT0N0 rectal cancer. A: T2-weighted axial images show significant diminution in nodal size after chemoradiotherapy~~e,~~ compatible with complete response. B: The contuniation of high diffusion signal intensity on residu~~e~~al fibrotic lymph node incorrectly ~~is~~ correspond~~ing~~ s to a metastatic lymph node~~,~~ ~~incorrectly~~ (arrows).