

MRI of Rectal Cancer: Tumor Staging, Imaging Techniques, and Management

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Abbreviations: CRM = circumferential resection margin, CRT = chemoradiotherapy, DCE = dynamic contrast material-enhanced, DWI = diffusion-weighted imaging, EMVI = extramural vascular invasion, FSE = fast spin-echo, LARC = locally advanced rectal cancer, MRF = mesorectal fascia, TME = total mesorectal excision, 2D = two-dimensional

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Identify the anatomic landmarks relevant for local staging of rectal cancer at MRI.
- Recognize the optimal rectal MRI protocol indicated for primary tumor staging and restaging.
- List the key points to include in the radiologic report for primary staging, restaging after neoadjuvant CRT, and local recurrence.

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Rectal cancer is prone to local recurrence and systemic metastasis. However, owing to improvements in TNM staging and treatment, including a more widespread use of rectal MRI and increased radiologist awareness of the key rectal cancer TNM staging features, the mortality rate of rectal cancer has been declining over the past few decades in adults over 50 years of age. Currently, rectal MRI plays a key role in the pre- and posttreatment evaluation of rectal cancer, assisting the multidisciplinary team in tailoring the most appropriate treatment option. The benefits achieved with rectal MRI are strictly dependent on obtaining good-quality images, which is important for the characterization of the main anatomic structures and their relationship with the tumor. In primary staging, rectal MRI helps the radiologist (a) describe the tumor location and morphology, (b) provide its T and N categories, (c) detect the presence of extramural vascular invasion, and (d) identify its relationship with surrounding structures, including the sphincter complex and involvement of the mesorectal fascia. These features help diagnose locally advanced rectal tumors (categories T3c-d, T4, N1, and N2), for which neoadjuvant chemoradiotherapy (CRT) is indicated. In restaging after neoadjuvant CRT, in addition to reassessing the features noted during primary staging, rectal MRI can help in the assessment of treatment response, especially with the emergence of nonsurgical approaches such as “watch and wait.”

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Introduction

Colorectal cancer is the third most common cancer in men and the second most common in women (1). In the United States, it represents the third leading cause of new cancer cases and cancer-related deaths in both men and women. For 2018, it was projected that there would be 97–220 new cases of colorectal cancer and 44% would have occurred in the rectum (2). The prevalence is considerably higher in more developed countries than in less developed countries. However, the mortality rate in more developed countries is lower, reflecting increased screening and improvements in rectal cancer staging and treatment (2). On the other hand, the prevalence has increased among patients younger than 50 years (3), and specifically in this group, the death rate has increased by 1% per year (2).

The prognosis of rectal cancer is directly related to tumor infiltration into the mesorectum and the ability to surgically achieve negative circumferential resection margins (CRMs) (4). The use of total mesorectal excision (TME) as the standard treatment of rectal cancer and the adoption of neoadjuvant chemoradiotherapy (CRT) for patients with locally advanced rectal cancers (LARCs), diagnosed on the basis of MRI features, has led to substantial improvements in local disease control (5–9). Currently, rectal MRI is the preferred imaging modality for local staging of rectal cancer.

TEACHING POINTS

- The use of TME as the standard treatment of rectal cancer and the adoption of neoadjuvant CRT for patients with LARCs, diagnosed on the basis of MRI features, has led to substantial improvements in local disease control. Currently, rectal MRI is the preferred imaging modality for local staging of rectal cancer.
- In primary staging (preoperative setting), MRI can assist in (a) selecting patients with LARC who are suitable for neoadjuvant CRT; (b) guiding surgeons in surgical planning; and (c) identifying poor prognostic factors, including EMVI, mucin content, and involvement of the MRF.
- High-spatial-resolution T2-weighted imaging is the most important MRI sequence in the evaluation of rectal cancer and anatomic structures. Standardized imaging protocols also allow for more accurate and reproducible interpretations, which facilitate the widespread use of this technique.
- Before the restaging of rectal cancer after rectal MRI is performed, it is important to verify the neoadjuvant treatment the patient underwent and to evaluate the results of previous examinations (digital rectal examination, endoscopy, and pre-treatment MRI) to understand the primary tumor's location and morphology.
- The main risk factors for local recurrence are lack of preoperative radiation therapy, CRM positivity, EMVI, close proximity of the tumor to the anal verge, perforation of the tumor at surgery, anastomotic leak, higher pathologic TNM stage, and lower tumor differentiation. Although 30% of patients can be asymptomatic, the majority of patients with local recurrence manifest with symptoms and an increased carcinoembryonic antigen level.

The standard treatment in patients with MRI-staged LARC is neoadjuvant CRT followed by TME (10,11). In approximately half of patients, the disease is downstaged after CRT, and almost one-third of patients demonstrate complete pathologic response after undergoing TME (12–15). Habr-Gama et al (13) and other authors (16–18) have shown that select patients with clinical complete response to CRT can be safely followed up in a nonsurgical approach.

Rectal MRI may add value in patient care in various scenarios. In primary staging (preoperative setting), MRI can assist in (a) selecting patients with LARC who are suitable for treatment with neoadjuvant CRT; (b) guiding surgeons in surgical planning; and (c) identifying poor prognostic factors, including extramural vascular invasion (EMVI), mucin content, and involvement of the mesorectal fascia (MRF) (19,20). In the restaging setting (after treatment with neoadjuvant CRT), rectal MRI can help in (a) evaluating tumor regression; (b) tailoring surgical planning; (c) detecting a complete clinical response, along with a review of the results of digital rectal examinations and endoscopic procedures; and (d) monitoring patients undergoing the nonsurgical treatment approach. Finally, after local treatment, performing rectal MRI is relevant

during follow-up for the early diagnosis of local recurrence. MRI in the recurrence setting may contribute to management by outlining disease extension within the pelvis and providing a road map to determine the resectability of lesions and the best surgical approach (21).

In this article, we review rectal MRI techniques, relevant anatomic landmarks with correlating MRI findings, and current concepts in the management of patients with rectal cancer, including the most common surgical techniques. Furthermore, we discuss the role of MRI in the assessment of local staging, restaging, and recurrence and the future directions of imaging research in rectal cancer. We also propose a schematic step-by-step approach to facilitate comprehension of the key features to address in a rectal MRI radiologic report, represented by the mnemonic RECTAL CANCER (for medical records, evaluate MRI sequences, C-shape appearance, T category, appearance and location of the tumor, CRM status, analyze prior MR images, N category, sphincter complex status, EMVI status, and tumor regression).

Managing Rectal Cancer and Current Concepts

Table 1 demonstrates TNM staging of rectal cancer, where *T* represents the tumor, *N* represents the lymph nodes near the tumor, and *M* represents whether the tumor has metastasized (11,12). The prefixes *c*, *p*, and *y* represent clinical, pathologic, and postneoadjuvant therapy, respectively. The management concepts of rectal cancer in the United States and Europe are summarized in Figure 1. Surgical resection is still considered the curative treatment of rectal cancer. The surgical techniques may vary depending on the location and extent of the disease.

Transanal endoscopic microsurgery (Fig 2a) is characterized by a focal endoscopic resection of the tumor and can be indicated for select patients with early rectal cancer. The selection criteria for transanal endoscopic microsurgery include well- or moderately differentiated rectal cancers and tumors that are categorized as cT1 or cN0, are less than 3 cm, are within 8 cm of the anal verge, or involve less than 30% of the wall circumference (12,23).

TME is the standard transabdominal surgery indicated for the curative treatment of rectal cancer (10). After its implementation, patient outcome and quality of life improved considerably. TME involves a complete resection of the mesorectum along the MRF plane.

Low anterior resection (Fig 2b) is the most common transabdominal resection indicated for tumors located in the middle or upper rectum.

Table 1: TNM Classification of Rectal Cancer

Category	Descriptor
T category	
Tx	Primary tumor cannot be assessed
T0	No evidence of a primary tumor
Tis	Carcinoma in situ: intraepithelial or invasion of the lamina propria
T1	Submucosa
T2	Muscularis propria
T3	Subserosa and perirectal tissue
a*	<1 mm
b*	1–5 mm
c*	5–15 mm
d*	>15 mm
T4	
a	Tumor penetrates to the surface of the visceral peritoneum
b	Tumor invades or is adherent to other organs or structures
N category	
Nx	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	
a	1 lymph node
b	2–3 lymph nodes
c	Tumor deposit(s) in the subserosa, mesentery, or nonperitonealized perirectal tissues
N2	
a	4–6 lymph nodes
b	7 or more regional lymph nodes
M category	
M0	No distant metastasis
M1	Distant metastasis
a	Metastasis confined to one organ or site (eg, liver, lung, nonregional lymph nodes)
b	Metastasis in more than one organ and/or site or in the peritoneum

*The subclassification of the T3 category is determined on the basis of an MRI evaluation and is used in the European guidelines for treatment recommendations (11).

This technique is characterized by TME and the resection of the whole sigmoid or part of it.

Ultra-low anterior resection is a sphincter-sparing surgery that can be performed in patients with low rectal cancer above the anorectal junction. The coloanal anastomosis is created 1 cm distal to the lower edge of the tumor in this procedure.

Standard abdominoperineal resection (Fig 2c) with TME is indicated for tumors that infiltrate the anal canal or the levator ani and/or external sphincter, located less than 1 cm from the anal

verge or in cases where the resection will result in incontinence. It is characterized by the resection of the sphincter complex, resulting in a permanent colostomy.

Intersphincteric abdominoperineal resection (Fig 2d) is a sphincter-sparing surgery that can be considered in cases where the intersphincteric plane is not infiltrated by the tumor. Therefore, the dissection is performed within the intersphincteric plane and the external sphincter is preserved.

Extralevator abdominoperineal resection (Fig 2e) is indicated for tumors that infiltrate the intersphincteric plane and external sphincter and/or levator ani. The technique consists of a broader dissection of the sphincter complex and consequently avoids the “waist” effect that is created in a standard abdominoperineal resection, thus creating a cylindrical specimen. This surgery aims to reduce bowel and tumor perforation during the surgery and to avoid positive CRM.

Rectal MRI Protocol

The potential benefits achieved with rectal MRI are strictly dependent on obtaining good-quality images to allow for characterization of the main anatomic structures and their relation to the tumor. High-spatial-resolution T2-weighted imaging is the most important MRI sequence in the evaluation of rectal cancer and anatomic structures. Standardized imaging protocols also allow for more accurate and reproducible interpretations, which facilitate the widespread use of this technique (24). Figure 3 summarizes the MRI techniques frequently recommended (“Dos”), those that are not recommended (“Don’ts”), and some that are controversial practices (“Maybes”) that may be performed in select cases.

Dos

Patients must be informed about the time required for imaging, and they must be positioned comfortably in the supine position in the MR imager (20). High-field-strength MRI provides fast image acquisition, high spatial resolution, and high signal-to-noise ratio, improving the visibility of the rectal wall (25). Ideally, higher field strengths (eg, 1.5 T or 3.0 T) are preferred, with some studies demonstrating similar accuracies for staging for both (26–28). While 1.5 T is the most widely available and used, 3.0 T may improve spatial resolution, with an increase of the signal-to-noise ratio, and may be preferable to 1.5 T. However, some experts cite greater magnetic susceptibility artifact at 3.0 T, which may occur during DWI, as a potential disadvantage (29,30). Pelvic phased-array surface coils are recommended and must cover from the aortic bifurcation to the anal verge.

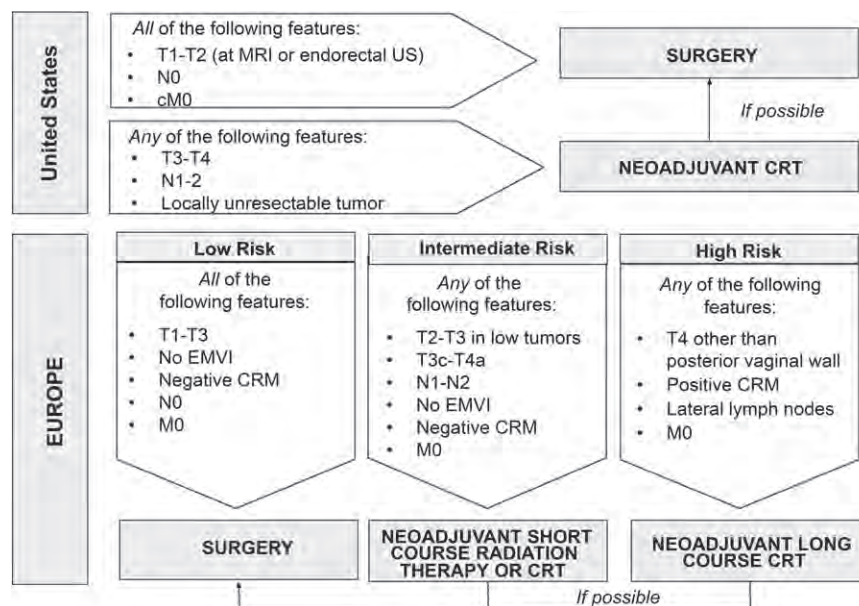


Figure 1. Schematic flowchart summarizes the current management concepts of rectal cancer in the United States and Europe.

The standard rectal MRI protocol in the evaluation of rectal cancer includes performing two-dimensional (2D) FSE T2-weighted sequences without fat suppression, using a small field of view and a section thickness less than 3 mm (high-resolution protocol) (26). Images in this sequence should be obtained in the (a) oblique axial plane (perpendicular to the tumor), as incorrect plane obliquity leads to blurring of the muscularis propria, which can cause incorrect T staging (31); (b) sagittal plane, which is determined by the longitudinal tumor axis; and (c) oblique coronal plane (parallel to the anal canal), which is important to depict low rectal tumors and to better evaluate their relationship with the anal sphincter. These sequences have a proven high diagnostic accuracy, between 90% and 100%, for the evaluation of tumor invasion into the MRF and adjacent organs and are recommended by the Magnetic Resonance Imaging and Rectal Cancer European Equivalence (MERCURY) group (19).

FSE T2-weighted MRI with a large field of view without fat suppression obtained in the axial plane of the entire pelvis, from the aortic bifurcation to the sphincter, allows for evaluation of distant lymph node chains (eg, inferior mesenteric, lateral, and inguinal). In the sagittal plane, from one side of the pelvic wall to the other, FSE T2-weighted MRI allows for localization of the primary tumor, enabling the measurement of its height and its relationship to the midline structures, such as the anal verge (25,28).

Don'ts

It is not recommended to use a routine bowel preparation such as air insufflation to distend the rectum with any contrast material or to use intravenous contrast material (20,25,26,31–34). The

use of an endorectal coil it is also not endorsed owing to patient comfort and cost (20,28). In regard to MRI sequences, T2-weighted imaging with fat suppression is not routinely recommended (28,33).

Maybes

For certain MRI techniques in imaging rectal cancer, there is no consensus. Administering spasmolytic agents such as glucagon (1 mg administered intravenously, intramuscularly, or subcutaneously) or hyoscine butylbromide (20 mg administered intravenously) is not mandatory but may reduce artifacts caused by peristalsis when administered immediately before the examination or just before the most motion-sensitive sequences (eg, DWI or dynamic contrast material-enhanced [DCE] sequences) are obtained (26).

Endorectal filling is not routinely used because, although it may facilitate detection of small tumors with rectal distention, it may alter staging owing to compression of the mesorectal fat. This can change the distance of the tumor to the MRF, possibly leading to nonvisualization of the mesorectal nodes (35). However, there are some studies that favor endorectal filling that can be found in the literature (28,36).

Another optional MRI sequence includes DWI with a high *b* value (≥ 800 sec/mm²), which may improve the diagnostic performance of MRI for tumor restaging after CRT. For primary staging, it may improve tumor and lymph node detection, although it is not officially recommended (20,25,26,31,37). Using a microenema 15 minutes before performing DWI may help remove rectal air and reduce artifacts, which can be

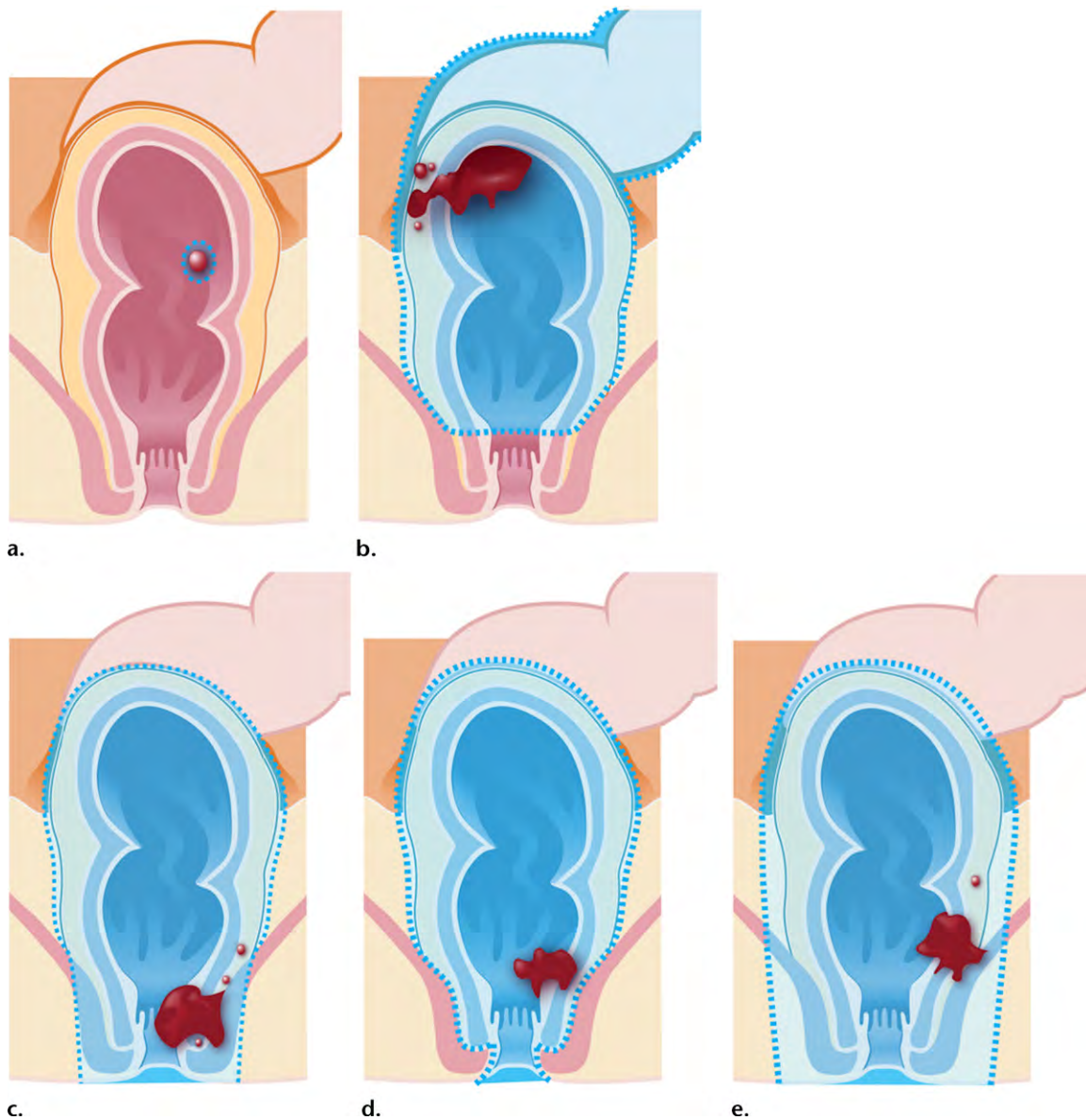


Figure 2. Illustrations of the anatomy of the rectum depict various surgical techniques used to treat rectal cancer. Dotted blue lines = anatomic structures removed during the procedure. Red area = rectal tumor. (a) Illustration shows a transanal endoscopic microsurgery with focal endoscopic resection of a tumor. (b) Illustration depicts a low anterior resection and TME and resection of the whole sigmoid or part of it, which preserves the sphincter complex. (c) Illustration depicts an abdominoperineal resection and TME, with resection of the sphincter complex. (d) Illustration depicts an intersphincteric abdominoperineal resection and TME, with dissection within the intersphincteric plane and a portion of the internal sphincter. The entire external sphincter is preserved. (e) Illustration depicts an extralevator abdominoperineal resection and TME, with a broader dissection of the sphincter complex. (Reprinted, under a CC BY-ND 4.0 license, from Memorial Sloan Kettering Cancer Center.)

particularly helpful for assessing residual tumor at restaging MRI (38).

Three-dimensional T2-weighted MRI is not routinely recommended but may be useful for evaluating response to neoadjuvant therapy. However, 2D imaging still seems preferable (39). T1-weighted imaging with a wider field of view may help in assessment of the common iliac and lower para-aortic nodes or incidental findings in the pelvis (with the same principle of FSE T2-weighted MRI with a large field of view) and especially the bones. It may also be useful in cases

of mucinous neoplasm when T2 signal intensities can be identical to those of fat.

It is known that contrast-enhanced T1-weighted imaging does not improve the diagnostic accuracy of local staging of rectal cancer (20). Studies found no difference for distinction between T1-T2 and borderline T3 tumors for the evaluation of tumor extension into the MRF (40). However, particularly at restaging, the use of intravenous contrast material may help identify local recurrence, depicted on images as heterogeneous enhancement (41).

Figure 3. Chart categorizes rectal MRI protocol according to techniques that are frequently recommended ("Dos"), those that are not recommended ("Don'ts"), and some that are controversial practices ("Maybes.") T2-weighted imaging with fat saturation is rarely necessary but may be useful for imaging mucinous tumors. AX = axial, COR = coronal, DWI = diffusion-weighted imaging, FOV = field of view, FSE = fast spin-echo, OBL-AX = oblique axial, SAG = sagittal, 3D = three dimensional.

MRI DOS		MRI MAYBES	MRI DON'TS
Supine and comfortable position		Administering spasmolytic agents	Endorectal coil
1.5 T–3.0 T field strength		Bowel preparation	Fat saturation on T2-weighted imaging
T2-weighted FSE without fat saturation		Endorectal filling	
Small FOV OBL-AX SAG COR	Large FOV AX SAG	Microenema at restaging	
		DWI at restaging	
		3D T2-weighted imaging	
		Contrast-enhanced T1-weighted imaging at restaging	

Table 2: Rectal MRI Parameters among Common Vendors

Imaging Parameters	GE		Siemens		Phillips	
	1.5 T	3.0 T	1.5 T	3.0 T	1.5 T	3.0 T
Axial T2-weighted						
Sequence/ETL	FRFSE/19	FRFSE/19	FRFSE/24	TSE/29	TSE/32	TSE/29
Field of view	200–240	200–240	380	200–240	200–240	200–240
Section thickness	5	5	5	5	5	5
Matrix	320 × 224	320 × 320	320 × 320	320 × 320	348 × 248	348 × 248
TR/TE	2500–3500/120	2500–3500/120	3500–5000/90–150	2500–3500/100	2500–3500/100	2500–3500/100
Sagittal T2-weighted						
Sequence/ETL	FRFSE/19	FRFSE/19	FRFSE/24	TSE/29	TSE/32	TSE/29
Field of view	200–240	200–240	380	200–240	250	200–240
Section thickness	4	4	4	4	4	4
Matrix	320 × 224	416 × 384	320 × 240	320 × 320	312 × 256	360 × 243
TR/TE	2500–3500/120	2500–3500/120	3500–5000/90–150	2500–3500/100	3000–5000/100	2500–3500/100
Coronal T2-weighted						
Sequence/ETL	FRFSE/19	FRFSE/19	FRFSE/24	TSE/29	TSE/32	TSE/29
Field of view	180	180	180	200–240	250	200–240
Section thickness	3	3	3	3	3	3
Matrix	320 × 224	320 × 320	320 × 240	320 × 320	464 × 288	360 × 243
TR/TE	2500–3500/120	2500–3500/120	3500–5000/90–150	2500–3500/100	3000–5000/120	2500–3500/100
Oblique axial T2-weighted						
Sequence/ETL	FRFSE/19	FRFSE/19	FRFSE	TSE/29	TSE/29	TSE/29
Field of view	180	180	180	200–240	250	200–240
Section thickness	3	3	3	3	3	4
Matrix	320 × 224	320 × 320	256 × 256	320 × 320	416 × 266	360 × 243
TR/TE	4000–6000/120	4000–6000/120	3500–5000/90–150	2500–3500/100	3000–5000/120	2500–3500/100

Note.—Field of view and section thickness are measured in millimeters. TR/TE is measured in milliseconds. ETL = echo train length, FRFSE = fast relaxation FSE, TE = echo time, TR = repetition time, TSE = turbo spin-echo.

	Illustration	T2-Weighted MR Images	Anatomical Landmark	Definition	Clinical Relevance
A OBLIQUE AXIAL			MRF (arrowheads)	A thin low signal intensity line surrounding the mesorectum; CRM is measured by the shortest distance between the tumor and MRF (< 1 mm = positive; 1–2 mm = threatened).	CRM is the surgical margin of TME; a positive CRM is a strong predictor of local recurrence and poor survival.
			Mesorectum (*)	Fatty tissue surrounding the rectum, with lymph nodes and lymphatic vessels.	T-staging: tumor that extends beyond the muscularis propria (≥ T3a) enters into the mesorectum.
			Rectal wall layers	Visible layers at T2-weighted MRI include the mucosa (innermost thin hypointense area); submucosa (middle hyperintense area); and muscularis propria (outer hypointense area).	Assessment of the depth of the tumor penetration within the wall at T staging (T1: up to the submucosa; T2: up to the muscularis propria; T3: beyond the muscularis propria).
			Anterior peritoneal reflection (curved arrow)	Hypointense line of the peritoneum attached to the anterior wall of the rectum in a V-shape (seagull sign). In the sagittal plane, this is seen above the top of the seminal vesicle in the sagittal plane in men and in the plane of the uterocervical region in women.	A tumor that invades the peritoneum is T4a, and the prognostic factors include poor survival and independent risk of intraperitoneal recurrence after surgery.
B SAGITTAL			Retrorectal space (red *)	Virtual space between the posterior aspect of the MRF and presacral fascia.	Posterior plane of dissection in TME.
			Anorectal ring (red arrow)	Muscular structure at the anorectal junction, on the top of the puborectalis muscle.	Distance from the inferior edge of the tumor to the anal verge defines the tumor location as low, mid-, or high rectum.
			Anal verge (red arrowhead)	Lower edge of the anal canal.	Inferior edge of tumor in relation to the anal verge indicates high, mid-, or low rectal cancer.
C CORONAL			Internal sphincter (gray arrow)	Continuation of the circular muscular layer of the rectum (smooth muscle).	Helps determine the stage of low rectal cancer; a higher risk of involvement of the CRM (narrow mesorectum); involvement indicates worse outcomes; provides relevant information for determining whether to perform a sphincter-sparing surgery.
			External sphincter complex (green arrow)	Mainly the continuation of the levator ani with the puborectalis sling (skeletal muscle).	
			Intersphincteric groove (red line)	Plane between the external and internal sphincter.	

Figure 4. Chart shows the anatomic landmarks of the rectum, describes their clinical relevance, and summarizes their imaging appearance. *A*, Illustration and MR images in the oblique axial view best depict the MRF, mesorectum, rectal wall layers, and anterior peritoneal reflection. *B*, Illustration and MR image in the sagittal view best depict the retrorectal space, anorectal ring, and anal verge. Curved arrows = anterior peritoneal reflection, white asterisk = mesorectum. *C*, Illustration and MR image in the coronal view best depict the internal sphincter, external sphincter complex, and intersphincteric space. (Illustrations adapted and reprinted, under a CC BY-ND 4.0 license, from Memorial Sloan Kettering Cancer Center.)

The main MRI parameters of the most important rectal MRI sequences among common MRI equipment vendors are summarized in Table 2.

Anatomic MRI Features

It is imperative for radiologists to be familiar with key anatomic landmarks of the rectum to provide an accurate local staging of rectal cancer. High-resolution T2-weighted MRI is the main sequence performed for the evaluation of relevant structures. Figure 4 summarizes the main anatomic landmarks seen at rectal MRI, provides details regarding which imaging plane is best suited for the identification of each landmark, and describes their clinical relevance.

Staging Rectal Cancer with MRI

In the context of primary tumor staging, performing rectal MRI is important for the evalu-

ation of tumor location and morphology, T category, anal sphincter complex involvement, CRM status, involvement of the pelvic sidewall, EMVI, and N category. These features should be included in the rectal MRI report. A suggested radiologic report template for primary staging can be found in Figure 5.

Location and Morphology

It is crucial to describe the tumor location in the craniocaudal direction (lower, middle, or upper rectum) and in the circumferential plane (clock-face position), as well as its length, relationship to the anterior peritoneal reflection, and distance from the inferior border of the tumor to the anal verge and the anorectal junction. This information helps determine the best surgical approach. The location of the tumor is categorized as low (0–5 cm from the anal verge), middle (5.1–10 cm

Rectal Cancer Primary Staging MRI Report Template
Clinical information:
Technique:
Comparison:
Tumor location and morphology:
Location from the anal verge:
☐ Low (0–5 cm) - Distance of inferior border of the tumor to anal verge: [] cm ☐ Mid (5.1–10 cm) ☐ High (10.1–15 cm)
Distance of inferior border of the tumor to anorectal junction: [] cm
Relationship to anterior peritoneal reflection: ☐ Above ☐ Straddles ☐ Below
Craniocaudal length: [] cm
Circumferential location (o'clock position):
Morphology: ☐ Polypoid ☐ Ulcerating ☐ (Semi-)circumferential
Mucinous: ☐ No ☐ Yes
T-category: ☐ Tx ☐ T1-2 ☐ T3a ☐ T3b ☐ T3c ☐ T3d ☐ T4a ☐ T4b
If T4b, describe structures with possible invasion:
Genitourinary: ☐ Bladder ☐ [Left/Right] Ureter ☐ Cervix ☐ Uterus ☐ Vagina ☐ Prostate ☐ Seminal vesicle ☐ Urethra
Vessels: ☐ [Left/Right] Internal iliac vessels ☐ [Left/Right] External iliac vessels
Nerves: ☐ Lumbosacral nerve roots
Pelvic muscles: ☐ Obturator internus ☐ Piriformis ☐ Ischiococcygeus
Pelvic floor (levator ani): ☐ Pubococcygeus ☐ Iliococcygeus ☐ Puborectalis
Bones: ☐ Sacrum ☐ Coccyx ☐ Ilium ☐ Ischium ☐ Pubis
* Low rectal tumors:
Invasion of sphincter complex: ☐ No ☐ Yes
If yes:
☐ Internal sphincter only ☐ + Intersphincteric plane ☐ + External sphincter
Length of anal canal: [] cm
EMVI: ☐ No ☐ Yes
CRM (for T3 only):
Shortest distance of tumor to MRF (or anticipated CRM): [] cm - location (o'clock position)
☐ Not applicable (peritonealized portion of the rectum)
Separate tumor deposit, suspicious lymph node, or EMVI threatening (≤ 2 mm) or invading (≤ 1 mm) the MRF:
☐ No ☐ Yes [If yes, note location and distance]
Suspicious mesorectal lymph nodes and/or tumor deposits: ☐ No ☐ Yes
Number of suspicious lymph nodes: []
Distance from tumor deposit to mesorectal fascia: [] cm
Extrameresorectal lymph nodes: ☐ No ☐ Yes [If yes, note location.]
Other findings/Additional comments:
Impression:
- Stage: T [] N []
- CRM: ☐ Clear ☐ Threatened ☐ Involved
- Suspicious node and/or EMVI near CRM: ☐ Yes ☐ No
- Sphincter involvement: ☐ Absent ☐ Present
- Suspicious extra mesorectal nodes: ☐ Yes ☐ No

Figure 5. Radiologic report template lists the key imaging findings and features that should be evaluated at primary staging and included in the rectal MRI report.

from the anal verge), and high (10.1–15 cm from the anal verge) (Fig 6). Tumors located above 15 cm from the anal verge are treated as colon cancer and, consequently, their staging and treatment differ from those of rectal cancer.

The tumor's morphologic pattern (polypoid, ulcerating, circumferential, or semicircumferen-

tial) and especially its appearance (nonmucinous or mucinous) should also be described (Fig 7). Mucinous tumors show high signal intensity at T2-weighted MRI and have a worse prognosis than that of nonmucinous tumors, with a higher metastatic propensity and often a higher stage at the time of diagnosis (42).

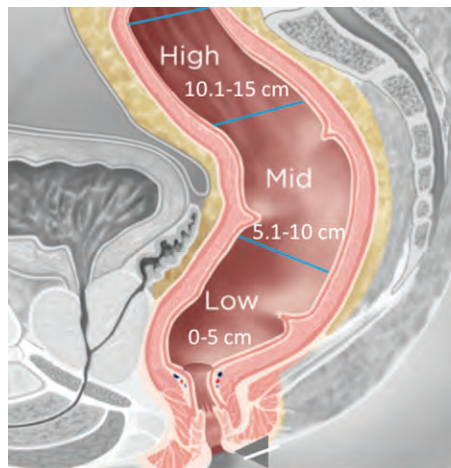
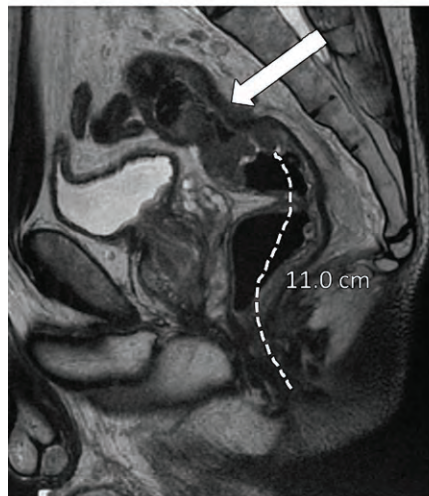


Figure 6. Tumor location in the craniocaudal direction. (a) Illustration depicts the sagittal view of the rectum and provides the measurements of the tumor from the anal verge, which help categorize tumor location. Blue lines separate the low, mid-, and high rectum. (Figure 6a reprinted, under a CC BY-ND 4.0 license, from Memorial Sloan Kettering Cancer Center.) (b–d) Sagittal T2-weighted MR images show tumors (arrow) in the high (b), mid- (c), and low (d) rectum. Dotted line = measurement from the rectum entrance to the tumor location.

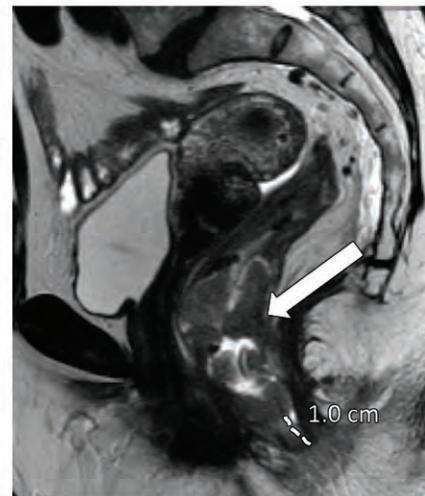
a.



b.



c.



d.

Sometimes identifying the tumor may be challenging for radiologists who are not experienced in reading rectal MR images in daily practice. Two imaging characteristics can be helpful in tumor identification: rectal cancer usually appears with elevated borders and can accumulate mucoid material in the rectal lumen of the tumoral region, which can also be visualized in nonmucinous lesions (Fig 8).

Mid- and High Rectal Cancer Tumor Staging

Figure 9 demonstrates the location of rectal cancer and its corresponding T category. Diagnostic accuracy, sensitivity, and specificity of high-resolution rectal MRI in assessing T category are 85%, 87%, and 75%, respectively (43). T category is characterized by the depth of tumor penetration into the rectal wall and extramural spread into the mesorectum and adjacent structures. It is important to identify the most invasive portion of the tumor, corresponding to the area of deepest infiltration, which is usually located halfway in the

craniocaudal direction and at the center of the C shape depicted on oblique axial images (Fig 8). The T category is better applied to mid- and high rectal cancers and differs from that of low rectal cancer, especially owing to the narrowing of the mesorectum, which is a barrier to circumferential tumor spread (25,44), with a resultant higher risk of involvement of the MRF (45).

T1 tumors infiltrate the submucosa, and T2 tumors extend into the muscularis propria. Rectal MRI does not provide a reliable distinction between these two categories, except in some patients with T1 tumors when it is possible to identify a preserved submucosal layer (hyperintense signal) beneath the lesion (46,47). Therefore, patients should undergo endorectal US owing to its superior diagnostic performance in these cases (26).

T3 tumors are characterized by a discontinuity of the muscularis propria, with extension of the tumor into the mesorectum without infiltration of the MRF or adjacent organs (20) (Fig 10c). They are classified into four categories dependent on the distance between the outermost edge of the

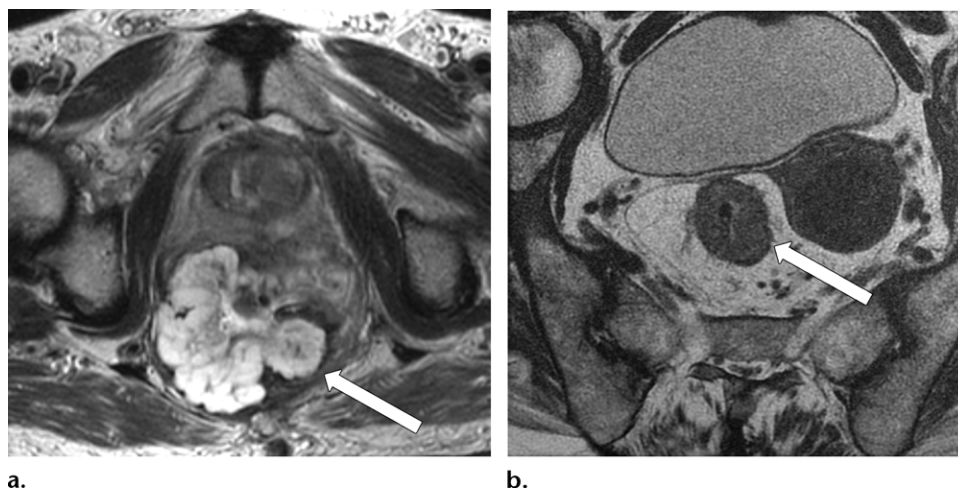


Figure 7. Mucinous and nonmucinous tumors. Axial oblique T2-weighted MR images in two different patients show a mucinous tumor (arrow in **a**) and a nonmucinous tumor (arrow in **b**). Mucinous tumors typically show high signal intensity, and nonmucinous tumors show intermediate signal intensity.

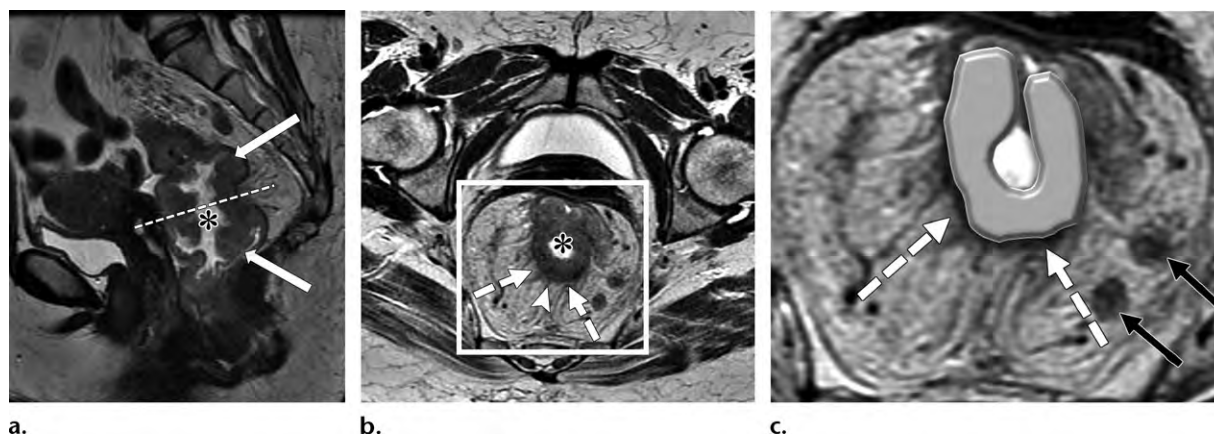


Figure 8. Tumor within the middle rectum clinically staged as T3b, with positive mesorectal lymph nodes, accumulation of mucoid material within the rectal lumen (* in **a** and **b**), and elevated borders in the superior and inferior edge of the tumor. (**a**) Sagittal T2-weighted MR image shows a tumor with elevated borders (arrows) in the superior and inferior edge of the tumor. Dashed line = plane of the axial oblique MR image shown in **b**. (**b**, **c**) Axial oblique T2-weighted MR image (**b**) and magnified area of interest (square outline in **b**) (**c**) obtained perpendicular to the tumor, halfway in the craniocaudal direction, show a C-shape tumor (dashed arrows). An added gray overlay in **c** depicts the shape of the tumor. The most invasive portion of the tumor is frequently located around the center of the C shape. The tumor infiltrates beyond the muscularis propria, 2 mm into the mesorectum (T3b) (arrowhead in **b**), and two 7-mm round heterogeneous mesorectal lymph nodes (solid arrows in **c**) are depicted, making this tumor positive for lymph node involvement.

muscularis propria and the maximum extramural spread of the tumor (T3a, <1 mm; T3b, 1–5 mm; T3c, 5–15 mm; and T4d, >15 mm).

Differentiating T2 tumors from early T3 tumors can be difficult (48). Penetration into the muscular layers by small vessels and desmoplastic reaction are common pitfalls that can lead to overstaging a T2 tumor as a T3 tumor (20). Desmoplastic reaction is depicted as spicules with low signal intensity at T2-weighted imaging, while T3 tumors have a broad-based or nodular appearance with intermediate signal intensity at T2-weighted imaging (20). Lastly, T4 tumors are those that infiltrate the peritoneal reflection (T4a) or other pelvic organs and structures (T4b).

Low Rectal Cancer and Anal Sphincter Complex Status

In patients with low rectal cancer, radiologists play a pivotal role in preoperative evaluation. Accurate staging is required to determine the need for neoadjuvant CRT or more extensive surgery and to provide the surgeon with a guide for planes of excision (45,49). Conventional staging is insufficient because tumors in the lower rectum are in close proximity to the anal sphincter complex and are more likely to invade the MRF and adjacent organs, with positive surgical margins in about 30% of cases owing to the narrowing of the mesorectum in this location (49).

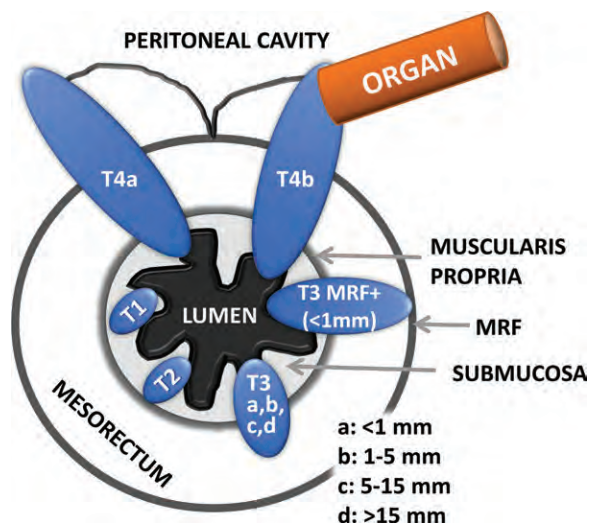


Figure 9. Illustration depicts the anatomy of the rectum and the possible locations of rectal cancer, along with corresponding T categories and potential tumor sizes for each location.

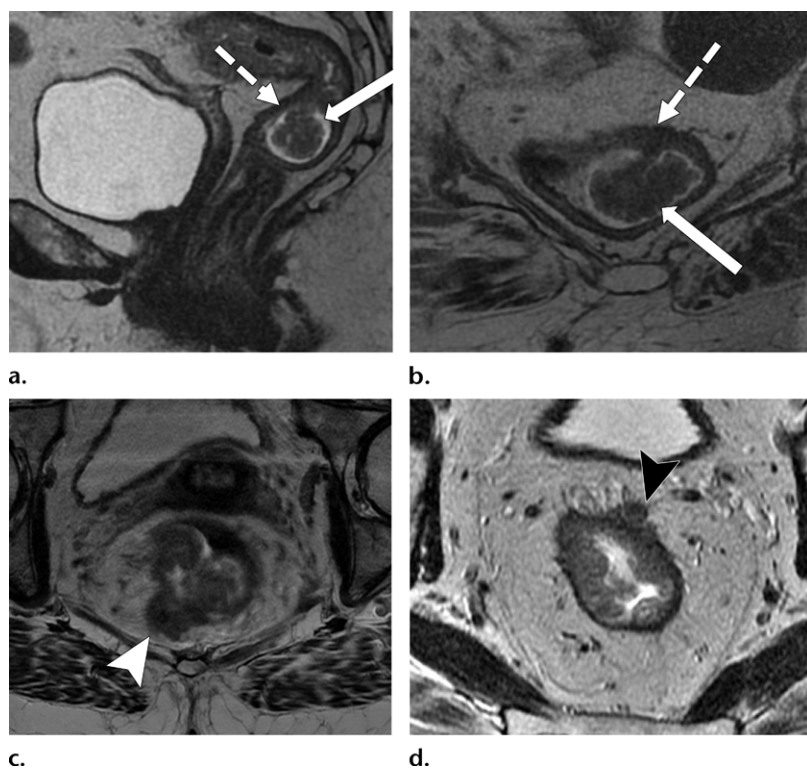


Figure 10. Rectal MR images that show distinct tumor stages obtained from three different patients. (a, b) Sagittal (a) and axial (b) T2-weighted MR images show a polypoid lesion (solid arrow) surrounded by mucoid material, with a thin stalk attached to the rectal wall and the intact muscularis propria (dashed arrow), findings characteristic of a T1 or T2 tumor. (c) Oblique axial T2-weighted MR image in another patient shows a tumor infiltrating 7 mm beyond the muscularis propria (T3c), with positive MRF infiltration (arrowhead). (d) Oblique axial T2-weighted MR image in a third patient shows a tumor invading the anterior peritoneal reflection (arrowhead), a characteristic finding of a T4a grade tumor.

Taylor et al (50) revised a specific staging system on the basis of invasion of the anal sphincter complex owing to the extension through the muscular layer for surgical planning and the risk of traditional abdominoperineal resection. The report should describe if the tumor invades the internal sphincter, intersphincteric plane, and external sphincter and/or levator ani (Fig 11). The coronal oblique plane is the best plane for this evaluation at T2-weighted MRI.

CRM Status

CRM is the surface of the nonperitonealized part of the rectum that is resected during surgery.

MRI is the most reliable imaging modality to determine potential CRM involvement (43,51). At MRI, CRM status can be obtained by measuring the shortest distance between the outermost part of the rectal tumor and the MRF (52). The CRM status is potentially positive if this measurement is less than 1 mm, and threatened if it is between 1 and 2 mm (33). It is important to highlight that the rectum is not entirely surrounded by MRF (Fig 12), and thus CRM status is not applicable if the tumor is situated in a peritonealized aspect of the rectal wall.

A tumor–MRF distance of more than 1 mm is a reliable predictor for negative margins after

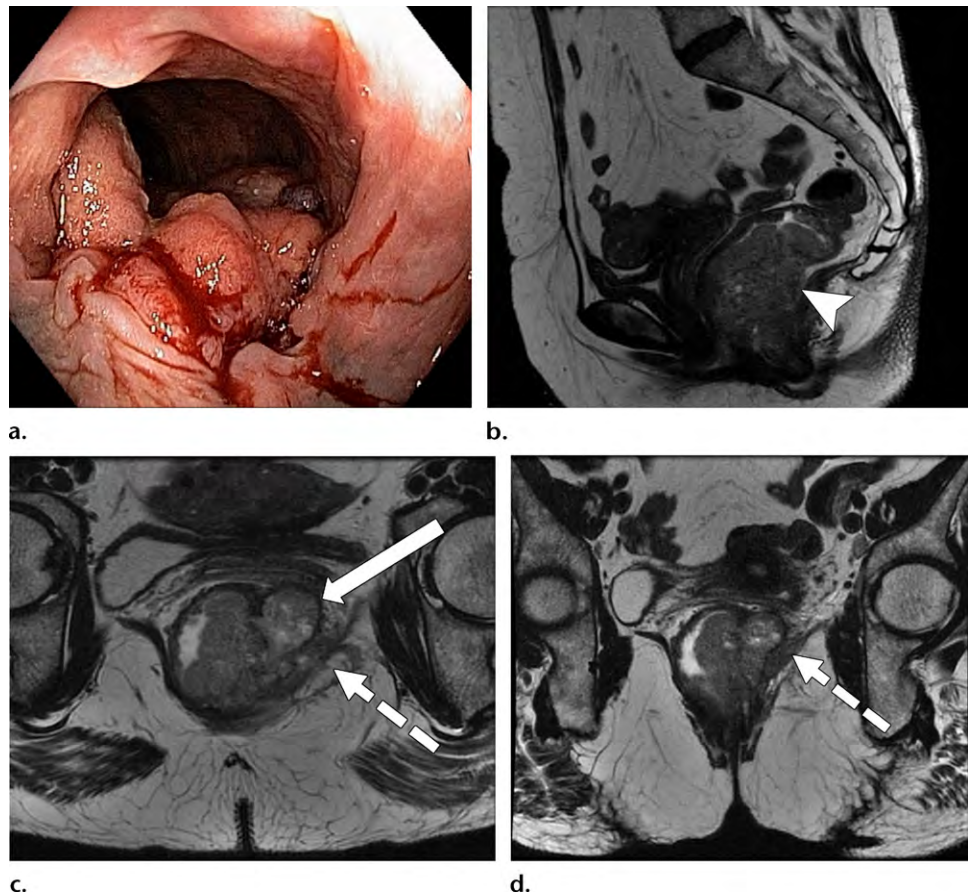
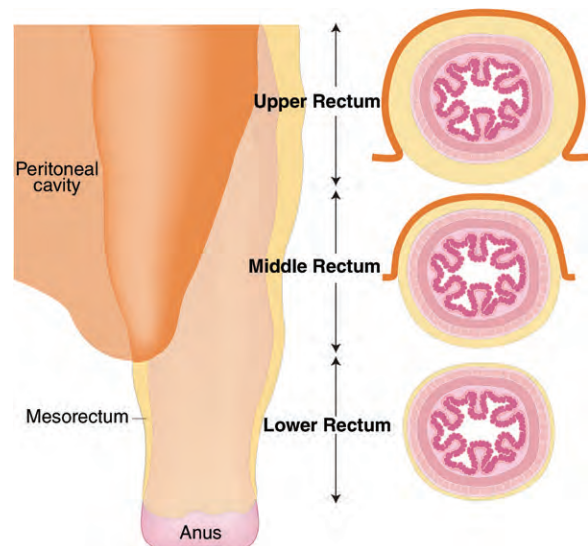


Figure 11. Tumor in the lower rectum. (a) Colonoscopic image shows a semicircumferential ulcerated tumor. Rectal MRI was performed for local staging. (b) Sagittal T2-weighted MR image shows a semicircumferential tumor (arrowhead) in the lower rectum. (c, d) Axial oblique (c) and coronal (d) T2-weighted MR images show the tumor (solid arrow in c) infiltrating beyond the muscularis propria and invading the left external sphincter and levator ani muscle (dashed arrow), which are thickened and have intermediate signal intensity.

Figure 12. Illustration depicts sagittal and axial views of the peritoneal and MRF coverage of the rectum. Note that the potential CRM described in the radiologic report corresponds to the distance between the tumor and the MRF and does not include the portions of the rectum surrounded by peritoneum. (Reprinted, under a CC BY-ND 4.0 license, from Memorial Sloan Kettering Cancer Center.)



TME (50). On the other hand, a positive CRM is the most important predictor of local recurrence and poor survival (53). Therefore, every report should include the CRM status and the location of potential involvement (clock-face method).

Pelvic Organs and Sidewall Involvement

In T4b tumors, it is important to describe if adjacent structures are involved, including the uterus, vagina, prostate gland, seminal vesicles, ureters, presacral fascia, sacral nerve roots, sacrum, iliac vessels, and pelvic muscles.

EMVI

MRI can depict EMVI with moderate sensitivity and high specificity, which is an important prognostic factor and predictor of metastatic disease

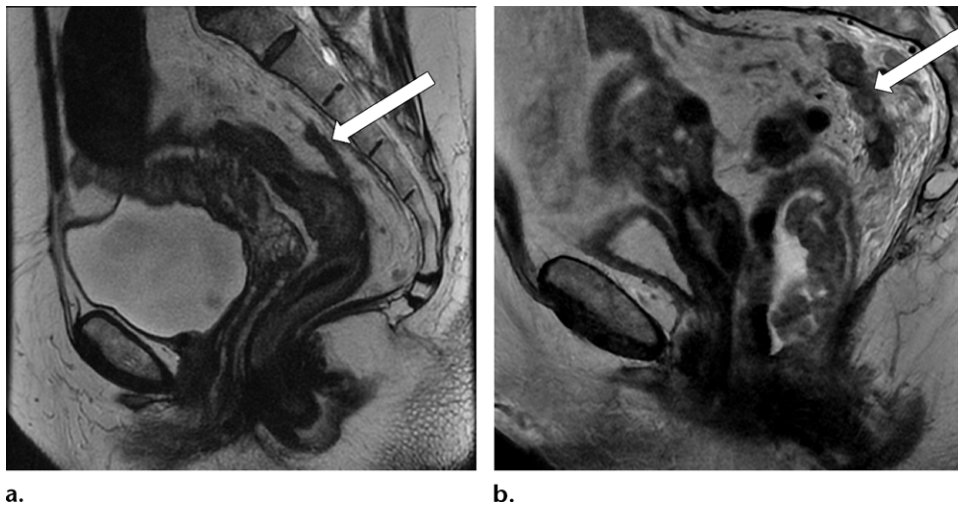


Figure 13. EMVI. Sagittal T2-weighted MR images in two different patients show signs of EMVI, characterized by focal enlargement of the vessel, signal intensity of the tumor replacing the flow void, and wall irregularity (arrow).

Table 3: Malignant Morphologic Criteria and Lymph Node Size

Number of malignant morphologic criteria* that have manifested	Lymph Node Size [†]		
	<5 mm	5–9 mm	>9 mm
None	–	–	+
Two	–	+	+
Three	+	+	+

*Irregular borders, heterogeneous signal intensity, and round shape.

[†]Measured in the largest short axis. – indicates not suspicious for malignancy, + indicates suspicious for malignancy.

(54–56). EMVI is an extension of the tumor to the vessels in the mesorectum, resulting in wall irregularity, focal enlargement, and/or signal intensity of the tumor (intermediate at T2-weighted imaging) within the vessel (56) (Fig 13).

Lymph Node Involvement

Compared with the accuracy of MRI in tumor staging, the accuracy of MRI in assessing the involvement of metastatic lymph nodes in rectal cancer is less accurate, which is an important prognostic factor and indicator for the use of neoadjuvant CRT (43). The presence, number, and precise location of suspicious lymph nodes should be reported.

The proximity between the suspicious lymph nodes and the MRF is also important to report for surgical planning, although it has been shown that it does not confer poor prognosis in the same manner as that of the primary tumor (12).

As a large proportion of metastatic lymph nodes in rectal cancer measure less than 5 mm, size is not a reliable criterion (57,58). However, some studies have demonstrated that

lymph nodes measuring greater than 8 mm in the short axis are highly specific for metastatic involvement (26,59,60). Therefore, it has been proposed for nodal assessment to include size and morphologic characteristics of malignancy, including the presence of irregular borders, heterogeneous signal intensity, and round shape (Table 3) (Fig 8) (33,57).

Regional lymph nodes involved in rectal cancer include the mesorectal, superior rectal, middle rectal, inferior rectal, sigmoid mesenteric, inferior mesenteric, lateral sacral, presacral, sacral promontory, or internal iliac (61). Lymph nodes out of these chains are considered distant metastases (M1). Extramesorectal nodes are important to describe, including those along the pelvic sidewall, as they are a negative prognostic predictor and are not routinely resected (62). Lesions that infiltrate the presacral space can manifest with retroperitoneal lymph nodes; therefore, those chains are also important to evaluate. A group of tumor cells not associated with lymphoid or vascular tissues, defined as *tumor deposits*, are characterized as N1c.

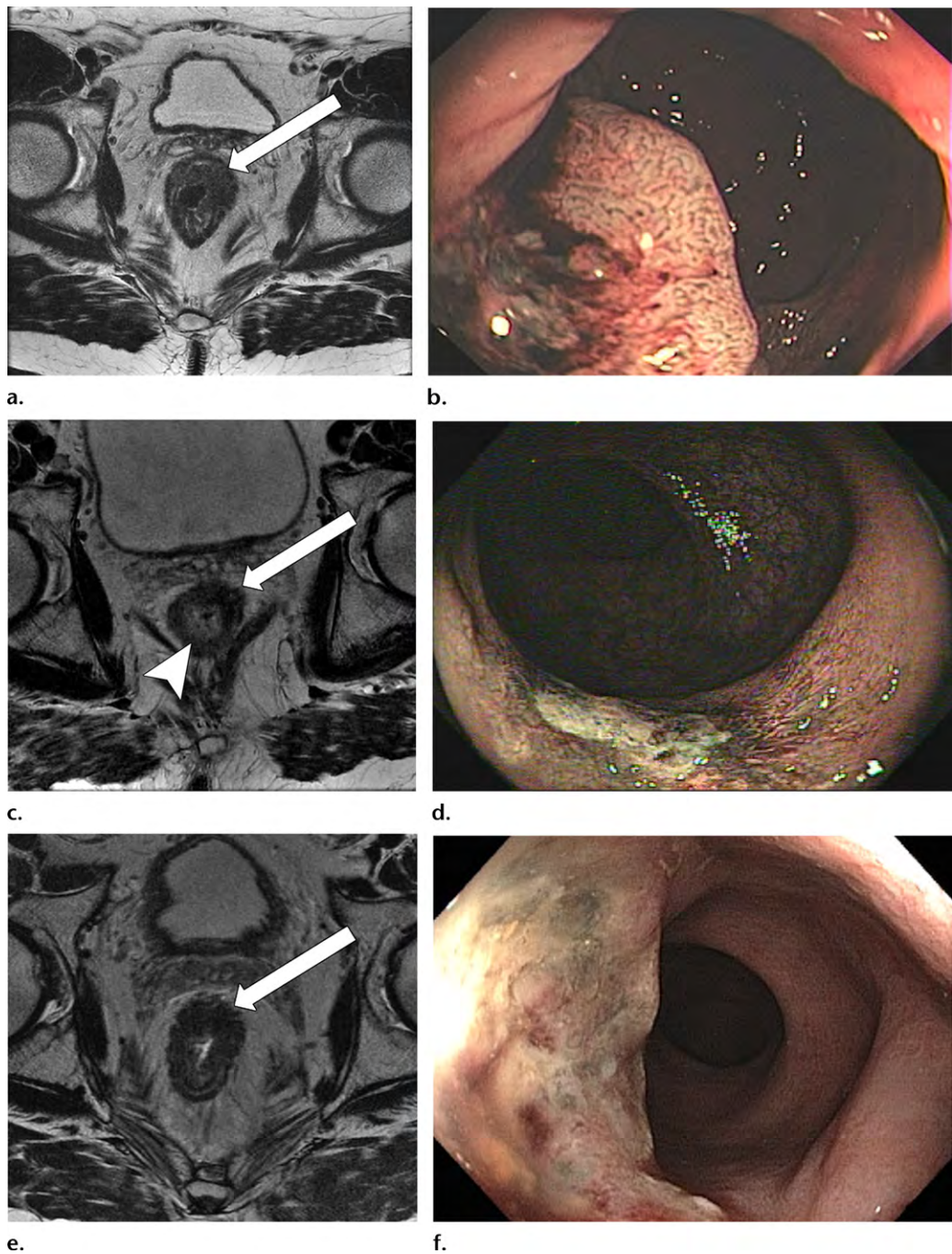


Figure 14. Low rectal cancer in a 56-year-old man who underwent neoadjuvant CRT and had clinical complete response, with tumor regrowth 9 months later. (a, b) Oblique axial T2-weighted MR image (a) obtained during primary staging shows an infiltrative tumor (arrow) with the most invasive border between the 1-o'clock and 3-o'clock position, infiltrating 1 mm beyond the muscularis propria (T3a), which corresponds to a polypoid lesion seen on the colonoscopic image (b). (c, d) Oblique axial T2-weighted MR image (c) obtained after neoadjuvant CRT shows an area with low signal intensity (arrow), and colonoscopic image (d) shows a scar in the tumor bed, without residual tumor. Note the wall thickening and mucosal edema within the normal rectal wall, which were caused by CRT (arrowhead in c). The patient was selected for a watch-and-wait protocol. (e) Oblique axial T2-weighted MR image obtained 9 months later shows thickening in the tumor bed, with areas of intermediate signal intensity (arrow), a finding suspicious for tumor regrowth. (f) Colonoscopic image shows tumor regrowth.

Restaging Rectal Cancer with MRI

For patients with LARC, neoadjuvant CRT is considered the standard treatment. It has been shown to improve local control, inducing tumor downstaging in approximately 50% of patients,

and results in pathologic complete response in 15%–38% of cases (13–15,63,64). This can allow for a sphincter-preserving surgery to be performed or may even offer a nonsurgical treatment approach in some patients.

Digital rectal examination and endoscopy have been used to evaluate pathologic complete response, but these assessments are limited to the luminal view, leaving residual tumors in other layers of the bowel wall undetected (65). In this context, MRI has an important role in the assessment of tumor response after neoadjuvant CRT.

Before the restaging of rectal cancer after rectal MRI is performed, it is important to verify the neoadjuvant treatment the patient underwent and to evaluate the results of previous examinations (digital rectal examination, endoscopy, and pretreatment MRI) to understand the primary tumor's location and morphology. The normal rectal wall adjacent to the tumor can manifest with post-CRT changes such as submucosal edema (thickened and intermediate to high signal intensity on T2-weighted images) that can lead to a common pitfall usually misinterpreted as residual tumor (Fig 14c). After treatment, the tumor may be similar in appearance to that of the pretreatment tumor or may appear atrophic and fibrotic, with low signal intensity on T2-weighted images, which is dependent on the type of response (66).

Mucin Response

As described previously, mucin within the tumor appears as an area of high signal intensity on T2-weighted images. Regarding this characteristic, tumors can manifest with one of three different mucin responses after CRT:

1. Mucin (or colloid degeneration) response can occur in nonmucinous tumors that become mucinous after CRT (66). It indicates a response to treatment and better prognosis (4).
2. Acellular mucin response represents a pathologic response of a mucinous tumor with no impact on recurrence-free survival (67). Until recently, there has been no reliable imaging method to differentiate cellular from acellular mucin.
3. Mucinous tumor without response is characterized as a mucinous tumor at the primary staging that did not respond to CRT. It is related to an increased risk of local recurrence and poor outcome (4,66).

Comparing pretreatment MR images with post-treatment MR images is important to differentiate colloid degeneration in a nonmucinous tumor from a genuinely mucinous tumor.

Residual Tumor and Fibrosis

A residual tumor has intermediate signal intensity on T2-weighted images whereas fibrosis and/or scarring has low signal intensity. However, differentiation is still challenging as residual tumor may occur within a scar. Additional functional MRI sequences, including DWI, have demonstrated promising results in tumor restaging at

MRI. Fibrosis demonstrates low signal intensity on high *b*-value diffusion-weighted images, while residual tumor shows high signal intensity (Fig 15). In the tumor restaging setting, performing a microenema is suggested before performing rectal MRI to reduce the amount of gas within the rectum to decrease artifacts at DWI (68,69).

Assessing Other Posttreatment Features

A tumor regression grading system for rectal cancer has been proposed (Table 4) and demonstrates a correlation with survival outcomes (19). Regression grades range from 1 to 5, with grade 1 indicating complete radiologic response to treatment and grade 5 indicating no response.

The accuracy of rectal cancer staging at MRI in post-CRT tumors is lower than that of primary staging at MRI (70). Therefore, it is important to use a multidisciplinary approach and a combination of modalities to assess response to treatment, including MRI, clinical assessment, and endoscopy. During tumor restaging, it is also important to evaluate the sphincter complex and pelvic side wall status in a similar fashion to that which is performed at primary staging.

The CRM status and the smallest distance between the remaining tumor and the MRF must also be described in the radiologic report, although this evaluation is less accurate than that of the pretreatment assessment (51). The importance of reporting EMVI at rectal cancer restaging, which can disappear after treatment and be replaced by fibrotic tissue, is still unclear (66).

The number of remaining suspicious nodes must be reported at restaging. Many irradiated lymph nodes disappear, and the majority of the remaining nodes are sterilized. After CRT, evaluating nodal size in the short axis is more reliable than evaluating borders and shape to assess for residual malignancy (33). The absence of lymph nodes at DWI, the decrease in size in at least 70% of lymph nodes, and a nodal size less than 2.5 mm in the short axis have been shown to be reliable predictors of negative node status after surgery (Fig 16) (71).

Local Recurrence at MRI

Due to the advent of neoadjuvant CRT and improvements in rectal surgery, the prevalence of recurrent rectal cancer began to decline in the past decade, occurring in approximately 4%–8% of patients who underwent surgery performed with a curative intent, especially in the first 3 years after treatment (72). Early diagnosis is fundamental to avoid progression and enable surgical resection (21).

The main risk factors for local recurrence are lack of preoperative radiation therapy, CRM

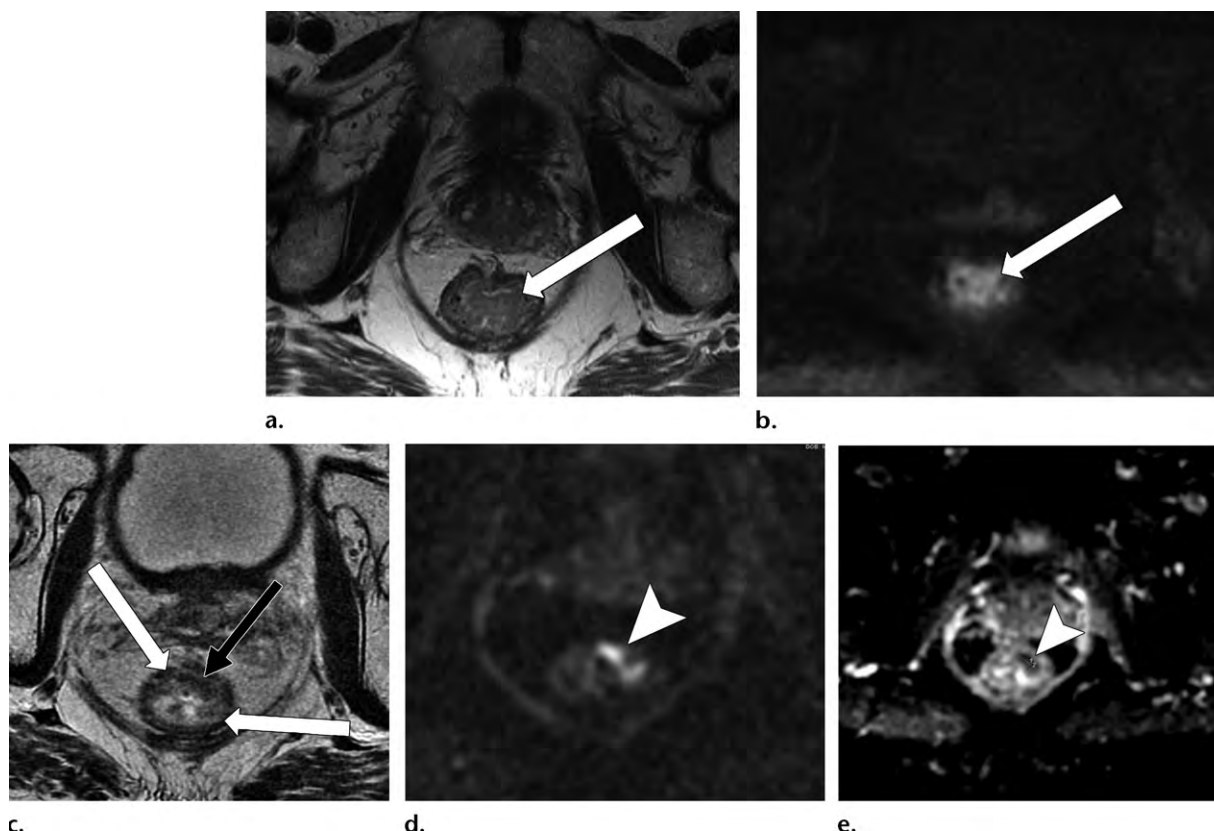


Figure 15. Partial response after neoadjuvant CRT. (a, b) Oblique axial T2-weighted MR image (a) and diffusion-weighted image (b) obtained during primary staging shows a tumor (arrow) in the lower rectum, with intermediate signal intensity in a and restricted diffusion in b. (c) Oblique axial T2-weighted MR image obtained after neoadjuvant CRT at restaging shows areas of low signal intensity (black arrow) in the tumor bed and residual tumor (white arrows) with intermediate signal intensity. (d, e) Axial diffusion-weighted image (d) shows restricted diffusion within the areas of the residual tumor (arrowhead), which was confirmed on the corresponding ADC map (e).

positivity, EMVI, close proximity of the tumor to the anal verge, perforation of the tumor at surgery, anastomotic leak, higher pathologic TNM stage, and lower tumor differentiation (73). Although 30% of patients can be asymptomatic, the majority of patients with local recurrence manifest with symptoms and an increased carcinoembryonic antigen level.

Local recurrence can occur in four locations: (a) axial, with recurrence in the anastomotic, residual mesorectum, or perirectal soft tissue in the center of the pelvis or perineum, including the pelvic floor; (b) anterior, with recurrence in the bladder, vagina, uterus, seminal vesicles, or prostate; (c) posterior, with recurrence in the presacral fascia, sacrum, coccyx, or sacral root sheaths; and (d) lateral, with recurrence in the pelvic ureters, iliac vessels, lateral lymph nodes, pelvic nerves, sidewall muscles, or lateral pelvic bones.

Most local recurrences are anastomotic and therefore are easily identified at clinical evaluation and/or endoscopy. However, other recurrence sites can be difficult to diagnose by these methods. In this context, imaging is an important tool in early diagnosis, especially in asymptomatic

Table 4: Tumor Regression Grade Features at MRI

TRG 1

Complete radiologic response: no evidence of treated tumor

TRG 2

Good response: dense fibrosis (>75%); no obvious residual tumor, signifying minimal residual disease, or no tumor

TRG 3

Moderate response: >50% fibrosis or mucin* and visible intermediate signal intensity

TRG 4

Slight response: little areas of fibrosis or mucin,* but mostly tumor

TRG 5

No response: intermediate signal intensity; same appearance as that of the original tumor

Note.—TRG = tumor regression grade.

*Data are from references 20 and 25.

patients. The main role of imaging is to verify the extent and precise localization of the disease, as well as the presence of metastases.

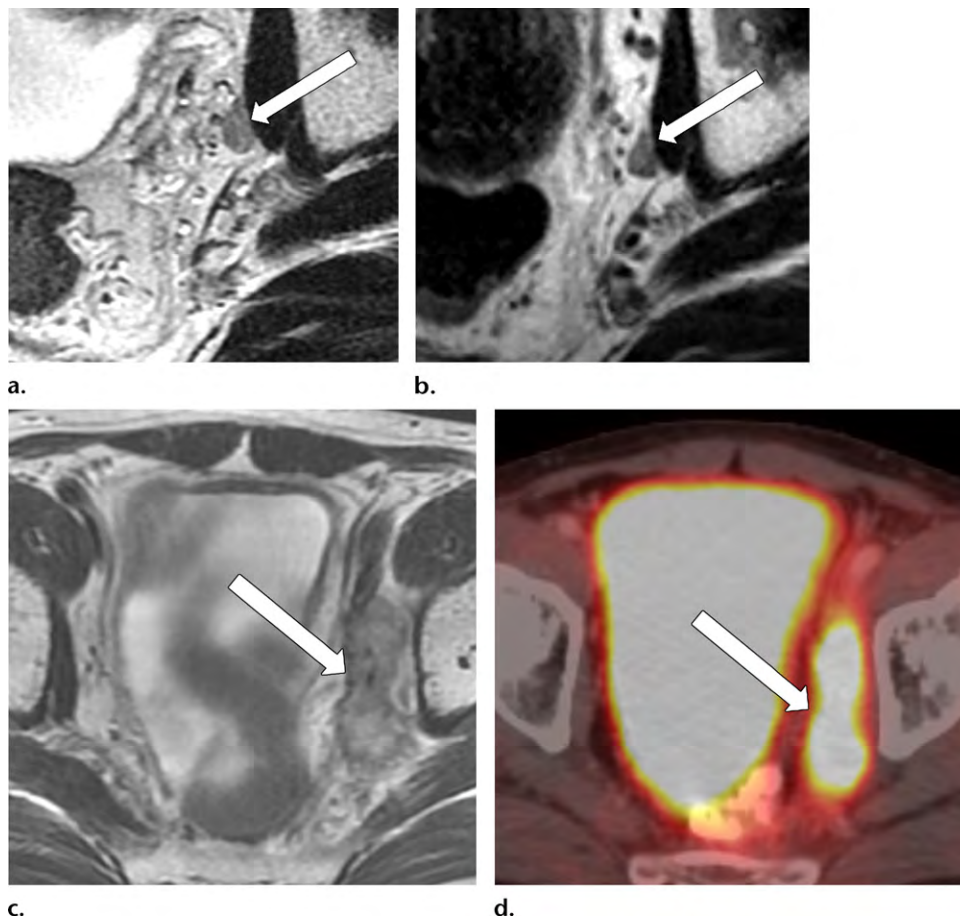


Figure 16. No significant change in lymph node size after CRT. (a) Axial T2-weighted MR image obtained during primary staging shows a suspicious left lateral node (arrow). (b) Axial T2-weighted MR image obtained after CRT shows the lymph node (arrow), which did not reduce in size. (c, d) Axial T2-weighted MR image (c) and axial positron emission tomography (PET)/CT image (d) obtained 10 months after TME without lateral pelvic lymph node dissection shows the metastatic node with marked enlargement (arrow in c) and FDG uptake (arrow in d).

Table 5: Contraindications for Pelvic Exenteration and Features to Report in Patients with Local Recurrence

Unresectable distant metastasis
Infiltration of the proximal sacrum (S2 or higher causes pelvic instability)
Invasion of the proximal lumbosacral plexus and sciatic nerves
Encasement of the external or common iliac vessels
Medical comorbidities

MRI is the most accurate imaging modality for local staging, while CT and PET/CT are more useful in detecting distant recurrence. However, posttreatment (surgery or CRT) changes may be difficult to differentiate from local recurrence, as they can share similar imaging features and may also appear fluorodeoxyglucose avid at PET. An increase in size and early, heterogeneous, marked contrast enhancement, invasive behavior, and asymmetric appearance are suspicious for local

recurrence (21,47,74). The contraindications for pelvic exenteration are shown in Table 5 (75,76) and should be described in the radiologic report.

Schematic Approach to Reporting Rectal Cancer at MRI

Figure 17 summarizes a schematic step-by-step approach to facilitate comprehension of the key features that should be addressed and described in a rectal cancer MRI report. The key features are also represented by the mnemonic RECTAL CANCER.

Future Directions and Research

Some novel MRI techniques, which are not currently used in routine clinical practice, have been studied to overcome some limitations of MRI in the evaluation of rectal cancer during primary staging and restaging. The main novel techniques that have been studied in the evaluation of response after CRT are DCE MRI, magnetization transfer ratio (MTR), and textural analysis (eg, radiomics).

PRIMARY STAGING AND RESTAGING	R	Medical <u>R</u> ECORDS of the patient
	E	<u>E</u> VALUATE MRI sequences
	C	<u>C</u> - SHAPE appearance (invasive border)
	T	<u>T</u> -STAGE
	A	<u>A</u> PPPEARANCE of the tumor
	L	<u>L</u> OCATION of the tumor
	C	<u>C</u> RM status
	A	<u>A</u> NALYZE prior MR images
	N	<u>N</u> - STAGE
	C	Sphincter <u>C</u> OMPLEX status
RESTAGING	E	<u>E</u> MVI status
	R	Tumor <u>R</u> EGRESSION

FIRST STEP - Check the patient's medical records

- Digital rectal examination
- Endoscopic evaluation: localization, size, morphology
- Previous treatment/procedure: biopsy, local resection, chemotherapy, radiation therapy, surgery
- Previous pathologic report

SECOND STEP - Identify the tumor and its most invasive border

- Identify the tumor: elevated borders and luminal mucoid material
- Most invasive border: halfway in sagittal; C shape in the oblique axial, usually located in the center of the C curvature

THIRD STEP - Identify tumor location

- Craniocaudal direction (low, middle, upper rectum)
- Circumferential plane (o'clock position)
- Length of tumor
- Relationship to anterior peritoneal reflection (above, below, or at)
- Distance from its inferior border to anorectal junction and anal verge

FOURTH STEP - Tumor appearance: mucinous vs nonmucinous

- Mucinous: high signal intensity on T2-weighted images (poor prognosis)
- Non-mucinous: intermediate signal intensity on T2-weighted images

FIFTH STEP - T Staging and CRM Status

- T staging: oblique T2 at the level of the most invasive border of the tumor
- CRM status: shortest distance between the tumor and MRF
Tumor-MRF distance < 1mm: positive CRM
Tumor-MRF distance 1-2 mm: threatened CRM

SIXTH STEP - Sphincter complex status (low rectal tumors) for treatment and surgical planning

Evaluate if the tumor involves:

- Internal sphincter
- Intersphincteric plane
- External sphincter
- Levator ani

Figure 17. Chart shows a step-by-step approach to imaging and staging rectal cancer. The mnemonic RECTAL CANCER facilitates the comprehension of the key features that should be addressed in a rectal MRI report. Red areas = features to identify and steps to complete at restaging.

In regard to lymph node assessment, novel contrast material and PET/MRI have been described as possible means of improving the evaluation of nodal status. Furthermore, some of these techniques have been assessed as imaging biomarkers to predict clinical outcomes.

DCE MRI assesses tumor vascularization, which can help in tumor identification and may correlate with the degree of angiogenesis and tumor aggressiveness and may predict response to neoadjuvant CRT. Volume transfer content (K^{trans}) is the volume transfer coefficient that reflects vascular permeability of gadolinium from blood into the extravascular extracellular space. Dijkhoff et al (77) published a systematic review revealing that high K^{trans} values at primary staging and a decrease in K^{trans} values after CRT are significant predictors of response (77).

MTR is a technique that evaluates differences in magnetization interaction between the protons bound to macromolecules and those in free water, which corresponds to the efficiency of this exchange. Tissues that are rich in macromolecules (such as those in collagen that occur in fibrosis) will express a high MTR. Studies have demonstrated the potential of MTR in the assessment of tumor response after CRT (78,79).

Radiomics consists of computer-aided extraction of many quantitative features from large imaging datasets ("big data") derived from CT,

MRI, and PET, with the potential to correlate these image phenotypes that are otherwise not detectable by conventional radiologic human interpretation with disease outcomes (80). In rectal cancer, radiomics using MRI has demonstrated promising pilot results in the prediction of complete response after CRT (81–83) and using PET/CT as a predictor of survival (84).

The use of lymph node MRI contrast material, such as ultrasmall superparamagnetic iron oxide (USPIO) and gadofosveset, is promising for differentiating benign from metastatic lymph nodes, but availability and safety concerns have mostly prevented their use (85,86). USPIO is an iron-based nanoparticle that is taken up by normal cells, decreasing their signal intensity at T2-weighted imaging. Malignant nodes do not take up USPIO particles and have a higher signal intensity relative to that of benign nodes and are enhanced relative to that of normal tissue. Gadofosveset is an albumin-bound gadolinium chelate that is taken up by normal and reactive lymph nodes, which enhance like vessels. Thus, malignant nodes show less enhancement.

PET/MRI has demonstrated higher accuracy in T staging and at least comparable accuracy in N and M staging compared with those of PET/CT owing to the high soft-tissue contrast enhancement depicted at MRI (87). This strength may optimize local and distant staging and

potentially improve the diagnostic performance of MRI by adding the functional capabilities of PET. However, studies with larger sample sizes are required to evaluate the importance of this modality in rectal cancer evaluation.

FDG PET/CT and PET/MRI may also be helpful for restaging (67). In a meta-analysis with a total of 538 patients with locally advanced rectal cancer, Rymer et al (88) found that post-CRT PET/CT showed a statistically significant reduction in the maximum standardized uptake value in histopathologic responders and higher response index values. The sensitivities of PET/CT in the prediction of pathologic complete response and identification of distant metastases were 75% and 97%, respectively (89).

Although these techniques are promising and may add value in patient care, further research is still required to provide consistent results and standardized technical parameters before PET/MRI can be implemented into clinical practice for patients with rectal cancer.

Conclusion

Currently, rectal MRI plays a key role in management of patients with rectal cancer in local staging, identifying risk factors for local and distant recurrence to help tailor treatment, and improving patient outcome. A systematic analysis allows for a uniform and reproducible interpretation.

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