Rectal MR Imaging

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KEYWORDS

• Rectal cancer • Rectal adenocarcinoma • Rectal tumor • MR imaging • Oncologic imaging

KEY POINTS

- Dedicated pelvic MR imaging plays a crucial role in staging and restaging patients with rectal cancer, in surveillance of patients pursuing nonoperative management, and in assessing local disease recurrence following surgery.
- Optimization of MR imaging technique is essential for accurate interpretation. High-resolution T2-weighted imaging without fat saturation in an oblique axial plane perpendicular to the tumor base is critical for accurate initial staging.
- In the initial evaluation, MR imaging is used to provide clinical staging, assess imaging biomarkers, and distinguish between patients who are best suited for primary surgery and those who might benefit from neoadjuvant treatment.
- As part of restaging, MR imaging in conjunction with digital rectal examination and endoscopy is used to determine response assessment and identify patients who may benefit from nonoperative management.
- Evaluating locoregional lymph nodes in rectal cancer based solely on size criteria has limited sensitivity and specificity. To improve performance, and particularly to enhance specificity, the application of morphologic criteria is recommended at initial staging.

INTRODUCTION

In the late 90s, colorectal cancer was the fourth-leading cause of cancer death in both men and women younger than 50 years of age. However, it has recently become the leading cause of cancer death in men and the second leading cause in women under 50 years old.[1,2] Despite rectum being only one-tenth the length of the colon, adenocarcinoma of the rectum accounts for one-third of all colorectal cancers. In addition, rectal cancer carries a higher risk of positive resection margins and local recurrence compared to colon cancer, along with a distinct pattern of distant metastasis. Fortunately, high-resolution rectal MR imaging has proven to be effective in identifying patients at high risk for positive resection margins, enabling optimized treatment plans. Due to its superior soft tissue contrast, pelvic MR imaging using a tailored rectal cancer protocol is the preferred modality for local staging, restaging, and surveillance for those following a watch-and-wait strategy.[3]

In this article, the authors aim to highlight the multidisciplinary approach, review current guidelines in staging, restaging, patterns of recurrence, posttreatment complications, pitfalls in image interpretations, and advances.

IMAGING TECHNIQUE

The bedrocks of a rectal MR imaging protocol are (1) multiplanar high-resolution T2-weighted imaging (T2WI), which provides an excellent depiction of the morphology and inter-relationship of the tumor,

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rectal wall, and adjacent mesorectal facia and (2) high b-value diffusion-weighted imaging (DWI), which helps to differentiate malignant from benign tissues and to detect residual viable tumors within the rectal wall or mesorectal facia after chemoradiation[4] (**Fig. 1**A–H). Intravenous contrast does not improve the overall diagnostic accuracy, however, postcontrast T1-weighted imaging (T1WI) is less affected by motion, and therefore can be helpful when high-resolution T2WI and DWI are of suboptimal quality. It may also help in differentiating T1 and T2 disease, and in the assessment in post-neoadjuvant treatment response.[5–8] When interpreting postcontrast images, it is important to correlate with T2WI series to minimize the risk of overestimating the disease extent (**Fig. 2**A–C).

Patient Preparation and Scan Setup

MR imaging may be performed with either 3.0 or 1.5 T scanner. The patient should be instructed to fast for a few hours and to empty the bowel and bladder right before the examination. Administration of spasmolytic agent may help to control the rectal and bladder peristalses and reduce the related image ghosting and blurriness.

Multiplanar High-Resolution T2-Weighted Imaging

High-quality multiplanar T2WI with sufficient spatial and contrast resolution and signal-to-noise ratio (SNR) as well as minimal image blurring and artifacts is essential. Typically, this sequence is acquired in the sagittal, oblique axial (perpendicular to the tumor base at the rectal wall), and coronal or oblique coronal planes, respectively.

The high-resolution T2WI series should preferably be acquired with an in-plane resolution of less than 1 mm $\times$ 1 mm and a slice thickness of 2 to 4 mm with no slice gap (**Figs. 1–3**A–F). To minimize ghosting from respiratory motion, the sagittal and oblique axial series should have the frequency encode direction set along the anterior/posterior direction. In addition, a judicious application of spatial saturation bands can be applied to further reduce the signals of any moving anatomies either outside (eg, at the anterior abdominal/pelvic wall of a sagittal series) or inside (eg, over the anterior abdominal/pelvic wall/urinary bladder for an oblique axial series) the imaging field of view (FOV). The acquisition time should be limited to 2 to 4 minutes per series to produce sufficient image SNR and minimize the potential for image degradation due to patient motion.

Small Field of View Diffusion-Weighted Imaging

DWI is most-commonly performed with a single shot echo planar imaging sequence and should be matched in FOV and slice thickness/slice

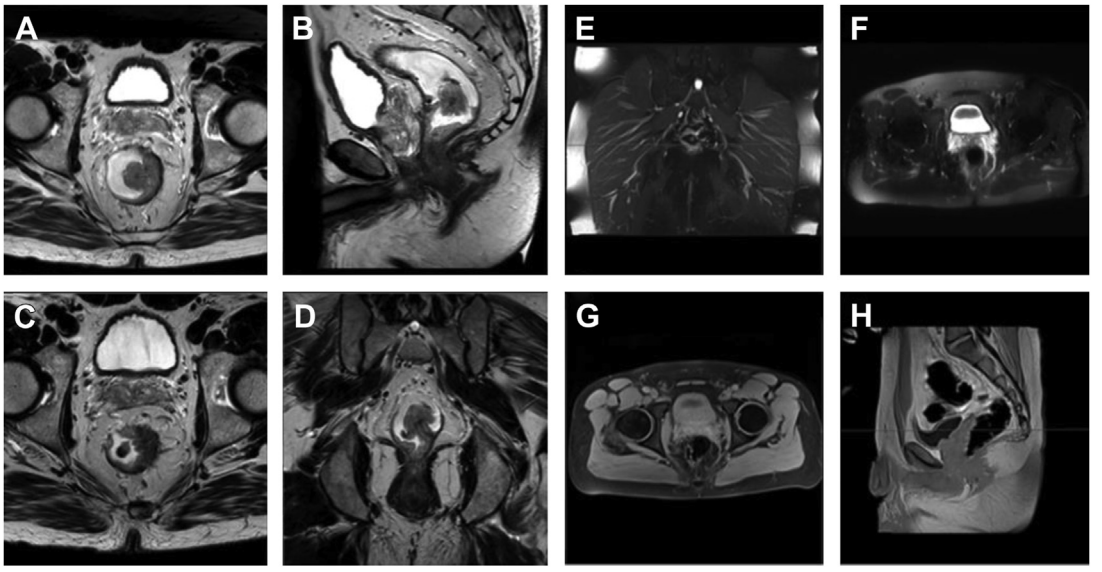


Fig. 1. MR imaging of the pelvis, with proper rectal cancer protocol sequences (*A–D*) and improper sequences (*E–H*). (*A–D*) are performed using high-resolution T2-weighted sequence without fat saturation, optimizing visualization of the T2 hypointense rectal wall, T2 intermediate tumor in the lumen, and T2 bright mesorectal fat. (*E*, *F*) are low-resolution large field of view T2 sequence performed with fat saturation, making it difficult to differentiate the rectal wall from mesorectal fat. (*G*) is an axial fat saturated T1-weighted image (T1WI) without intravenous contrast, and (*H*) is a sagittal T1WI without intravenous contrast. In both sequences, the contrast between the tumor and the rectal wall and spatial resolution are limited, resulting in no added value.

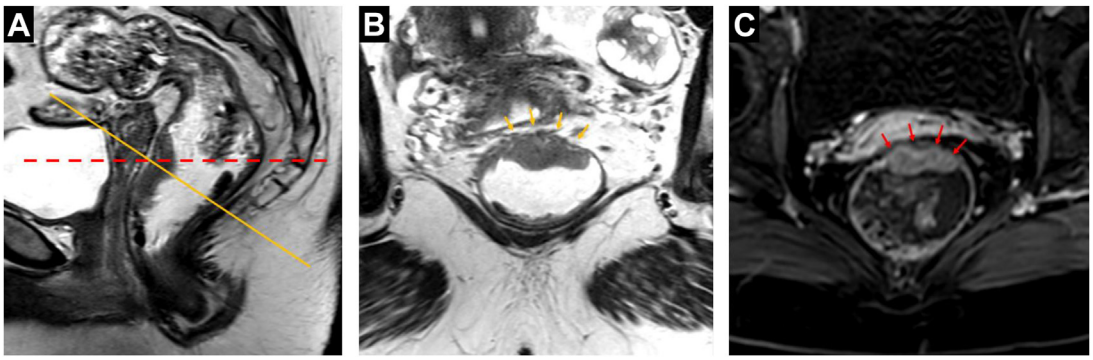


Fig. 2. A 37-year-old female patient with rectal cancer. The high-resolution T2-weighted images (T2WI) (*A, B*) without fat saturation demonstrate a tumor that does not extend beyond the outer wall of muscularis propria on sagittal plane (*A*) and oblique axial plane (*B*) (*orange arrows*). However, postcontrast axial T1WI acquired along the red dotted plane (*C*) appears highly suspicious for T3 tumor (*red arrow*). The pathology yielded T2 N0. The final determination of the T-category of the primary tumor should be made with the appropriately obliqued high-resolution T2WI as postcontrast T1WI, particularly in the straight axial plane, may over-stage.

coverage with those of the high-resolution oblique axial T2WI series. DWI with a high b-value of at least 800, preferably greater than 1500, along with apparent diffusion coefficient (ADC) map is recommended.[9] Microenema may reduce the residual stool and bowel gas, limiting image distortion and artifacts.[10]

IMAGE INTERPRETATION—ANATOMY AND PATHOLOGY, INITIAL STAGING, AND RESTAGING

Initial Staging

Primary tumor evaluation

Location Understanding the location of the rectal tumor and various anatomic relationships is

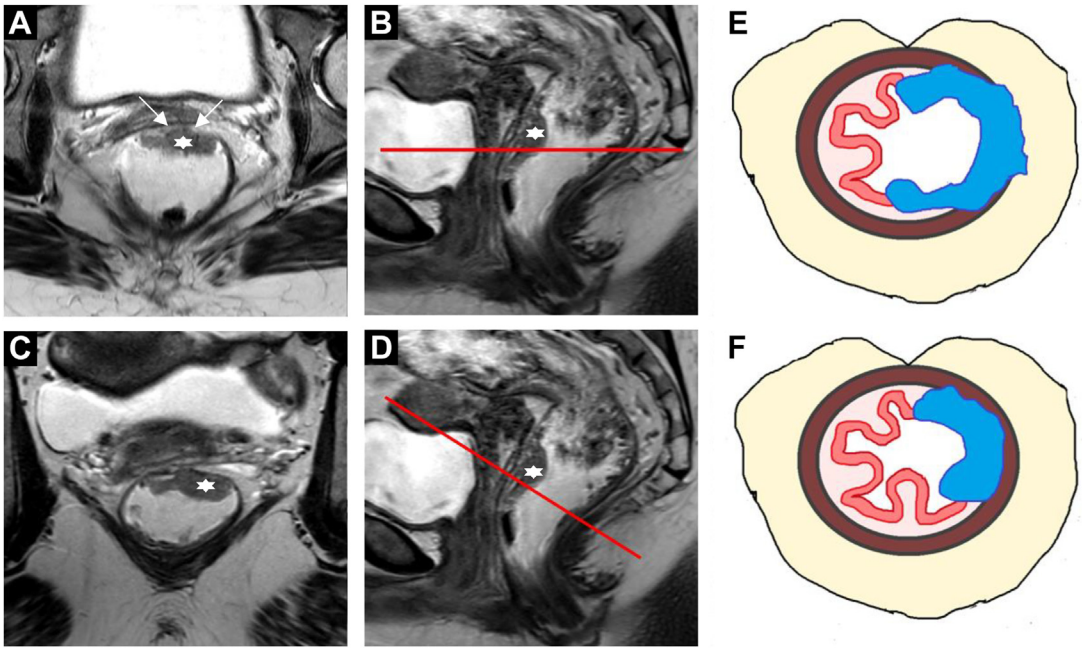


Fig. 3. Importance of acquiring an accurately obliqued axial sequence, with tumor denoted by white asterisk. Both a straight axial image (*A*) and an oblique axial image (*C*) are acquired at the tumor base, but at different angles. The correctly obliqued image (*C*) acquired at the angle outlined in (*D*), demonstrates a T2 tumor with an intact outer layer of muscularis propria (*large white arrow heads*). However, if the radiologist evaluates the straight axial image (*A*), taken at the level shown in (*B*), the tumor appears to extend through the wall (*white arrows*), suggesting a T3 tumor. This misinterpretation could lead to a recommendation for neoadjuvant treatment, which is unnecessary for a T2 tumor, unless lymph node involvement is present, according to the National Comprehensive Cancer Network guidelines. Such over-treatment could pose unnecessary risk and complications (*E-F*).

essential for selecting the optimal treatment approach. The first step is to measure the distance between the anal verge and the tumor, similar to how a rigid endoscope is used to determine the tumor location[11] (Fig. 4A–C). The anal verge is defined as the junction of the stratified squamous epithelium of the distal anal canal and the keratinized, hair-bearing squamous epithelium. It roughly corresponds to the inter-sphincteric groove, a palpable landmark for surgeons and gastroenterologist, and which appears on sagittal T2WI as a fat plane between the internal and external anal sphincters[11,12] (Fig. 4). Traditionally, this distance has been used to classify tumors as low, mid, or high rectal tumor. However, more recently, alternative anatomic landmarks have been considered to account for variations in anorectal lengths between patients.

The next crucial step is to evaluate the relationships between the tumor and anal sphincter/anorectal junction and the anterior peritoneal reflection (Fig. 4). The anorectal junction marks the proximal extent of the surgical anal canal and is defined by the upper margin of the puborectalis muscle (Fig. 4). If the anus is involved, reporting should describe deepest radial plane and location as depending on extent, sphincter sparing may not be possible.[13]

The anterior peritoneal reflection can usually be recognized on MR imaging.[14] The portion of the rectum below the anterior reflection drains via the systemic pathway to the pelvic side wall lymph nodes and the portal pathway, making lower rectal tumors more susceptible to lateral lymph node involvement. Additionally, rectal tumors below the reflection are at an increased risk for positive resection margins[15] (Figs. 4 and 5A–C). Tumors involving the peritonealized portion of the rectum, on the other hand, are more at risk for peritoneal spread of disease.

T-category The T-category is determined by the depth of tumor invasion into or through the bowel wall: T1 invades the submucosa, T2 invades the muscularis propria, T3 invades the mesorectal fat, T4a invades the peritoneum without other adjacent organ involvement, and T4b invades adjacent organs or structures (Fig. 6A–D). Properly oriented oblique axial T2WI without fat saturation, acquired perpendicular to the tumor base, is essential to prevent overstaging from T1/2 to T3 (Fig. 3). For polypoid and ulcerated masses, it is important to note that the most advanced invasion occurs at the tumor base or ulceration, centered between the rolled edges (Figs. 5 and 6). Polypoid tumors are generally lower in T-category compared to semi-annular or annular tumors.[16] In early T1 cases, an intact submucosal stripe sign on postcontrast imaging, or intact submucosal layer on high-resolution T2WI may be detectable.[5] However, MR imaging's ability to differentiate between T1 and T2 is limited compared to endoscopic ultrasound and it is therefore recommended to seek and consider such clinical information at MR imaging interpretation.[13] T3 substage is determined by depth of extramural penetration.

MR imaging is particularly effective in distinguishing good candidates for upfront surgery from those at high risk for positive resection margins.[17–19] Ideal candidates for upfront surgery include upper rectal tumors, rectal tumors with extramural invasion less

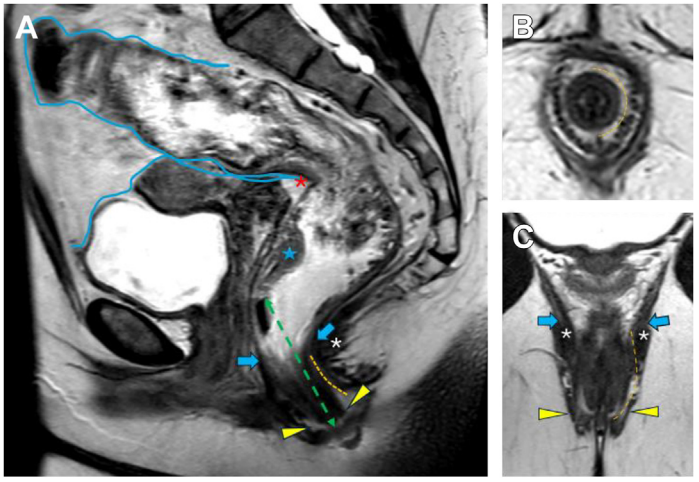


Fig. 4. Rectal cancer protocol pelvic MR imaging sagittal image (*A*), axial image (*B*), coronal image (*C*). The location of the tumor is measured from anal verge to the distal/low tumor margin (*green dotted arrow*). The anal verge can be identified by the inter-sphincteric groove, the T2 hyperintense fat plane between the distal margin of the internal sphincter and external sphincter (*yellow arrowheads*). The anorectal junction (*light blue thick arrows*) is at the level of upper border of the puborectalis muscle (*white asterisk*). The inter-sphincteric plane is denoted by orange dotted line on the posterior wall on sagittal image (*A*) and on the left wall on the axial (*B*) and coronal image (*C*). Anterior peritoneal reflection (*red asterisk*) is the lowest point of peritoneum (light *arrow* solid *line*), with an attachment to the anterior rectal wall.

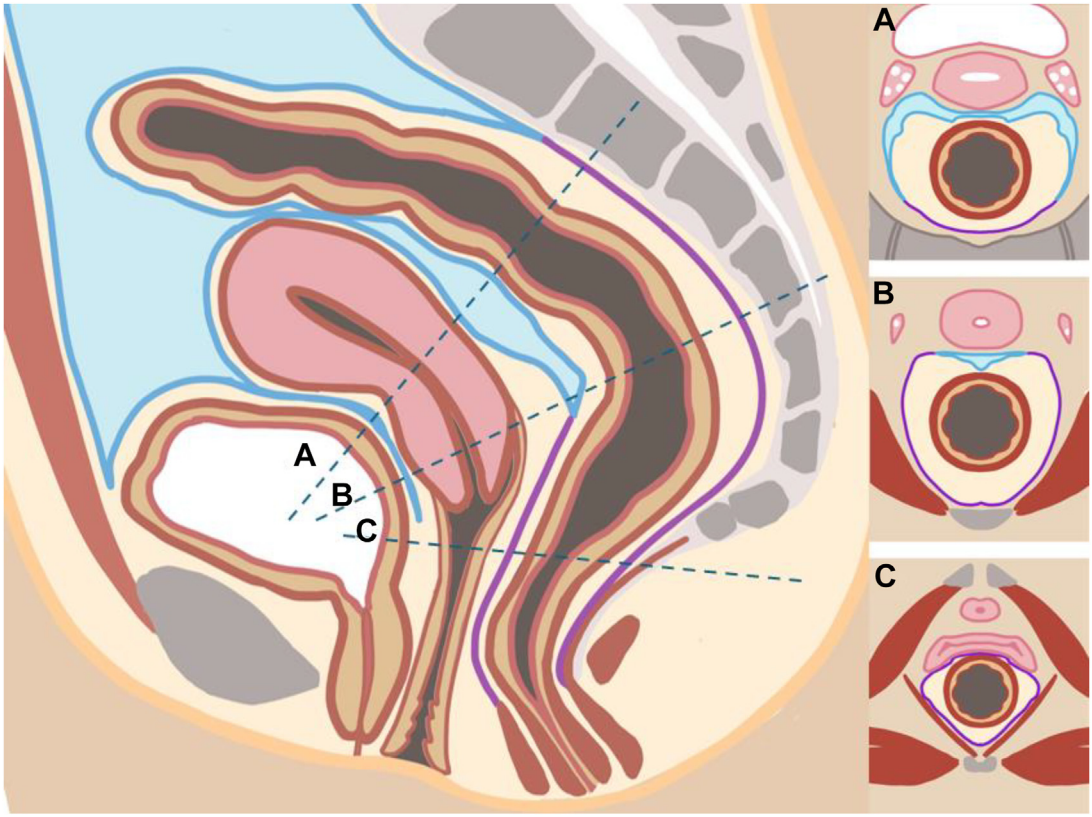


Fig. 5. The relationship between the peritoneum (*light blue solid line*), the anterior peritoneal reflection (the lowest point of peritoneum which attaches to the anterior rectum), and the mesorectal fascia (*purple solid line*), at multiple oblique axial planes, perpendicular to the rectum long axis. In the oblique axial plane A, the upper rectum is enveloped by peritoneum (*light blue*) in the anterior and lateral aspect, and mesorectal fascia (MRF) (*purple line*) posteriorly. In the oblique axial plane B (acquired at the level of the anterior peritoneal reflection), the peritoneum (*light blue line*) attaches to the anterior rectum only, and the anterolateral, lateral, and posterior rectum and mesorectum are otherwise enveloped by MRF (*purple line*). In oblique axial plane C, the low rectum and mesorectum are circumferentially enveloped by MRF (*purple line*). It is important to understand when MRF is involved by tumor, the curative resection margin (CRM) may differ from MRF, and therefore the term MRF, not CRM, should be used in radiology reporting when referring to the anatomic structure.

than 5 mm (T3a/b or lower category), and clear mesorectal fascia (MRF).

Mesorectal fascia The MRF is the plane along which a total mesorectal excision (TME), the standard oncologic surgery for rectal cancer, most typically occurs.[20,21] The MRF circumferentially envelopes the extraperitoneal rectum and the surrounding mesorectal tissue below the anterior peritoneal reflection. At the level of the anterior peritoneal reflection, the anterior aspect of the mid rectum becomes peritonealized. As the upper rectum/sigmoid ascends in the pelvis, it becomes increasingly peritonealized laterally and eventually circumferential (**Fig. 5**). If distance between tumor and MRF is 1 mm or less by MR imaging, the MRF is considered "involved"; if greater than 1 mm, it is "clear."[22] While not included in the TNM staging, MRF involvement has significant prognostic implications, as it is associated with positive resection margins and increased rates of local recurrence[23] (**Fig. 7**A, B). In radiology reports, when describing the tumor's relationship with this anatomic structure, the term of "MRF" should be used rather the "curative resection margin (CRM)." Whereas the former refers to the anatomic structure seen at MR imaging, the latter refers to the pathologic specimen. They are not always congruent as the surgeon may modify the resection plane away from the MRF in order to achieve negative CRM.[24]

Nodal involvement (N category)

Mesorectal lymph nodes Rectal cancer most often metastasizes to mesorectal lymph nodes. However, in cases of low rectal tumors, pelvic side wall or lateral lymph nodes (specifically,

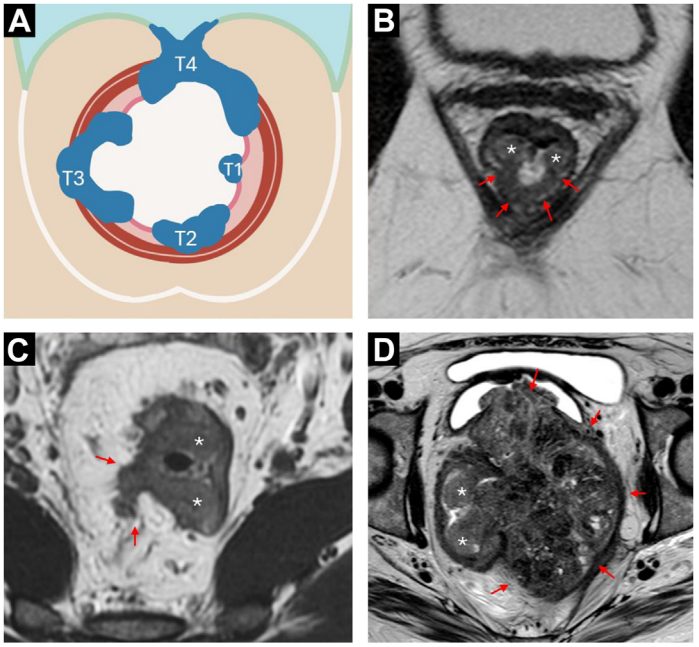


Fig. 6. Illustration of T categories (*A*) and multiple MR images with rolled edge of the tumor margin denoted with white asterisks and the deepest margin at the central tumor base denoted by red arrows. A T1 tumor invades the base of the mucosa but does not extend through the full thickness of submucosa. A T2 tumor extends through the submucosa and reaches the muscularis propria but does not extend through it (*B*). A T3 tumor extends through muscularis propria into the mesorectal fat but does not involve peritoneum or adjacent organs (*C*). A T4 tumor involves either the peritoneum (T4a) or other adjacent structures/organs such as vagina, cervix, prostate, seminal vesicle, levator ani, puborectalis muscle, or bone (D, T4b vaginal invasion). Of note, involvement of MRF is not considered T4 disease.

internal iliac and obturator nodes) may also be involved. If the primary tumor extends below the dentate line, inguinal lymph node involvement is considered locoregional. Conversely, if the tumor is above dentate line, inguinal lymph nodes are considered metastatic. External iliac, common iliac, and retroperitoneal lymph nodes are also classified as distant metastasis or "M" node.

Differentiating between benign reactive and malignant mesorectal lymph nodes on MR imaging is challenging due to overlapping appearances.[25] The size of the lymph node alone, measured in

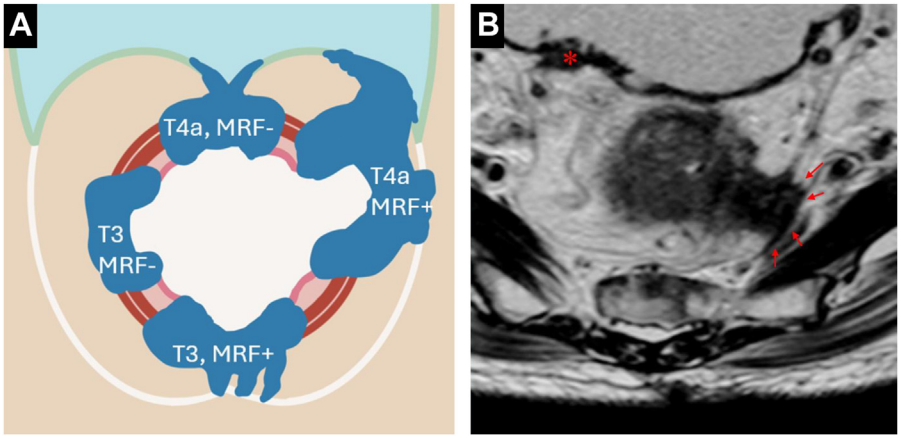


Fig. 7. (*A*) demonstrates 4 examples of rectal cancer with different relationships with peritoneum and MRF. The right rectal wall tumor is an example of a T3 tumor with no peritoneal or MRF involvement (T3 MRF-). The posterior rectal wall tumor invasion extends to the MRF (T3, MRF+; *white solid line*). The left rectal wall tumor extends left lateral wall to involve the MRF, and anteriorly to involve the peritoneum (T4a, MRF+). Anteriorly, the tumor involves only the peritoneum (T4a, MRF not applicable as the tumor only involves the peritonealized portion of the rectal wall). (*B*) T2WI MR oblique axial image with a circumferential rectal cancer with invasion into the mesorectal fat, involving the left posterolateral MRF (*red arrows*). The tumor also extends to the peritoneum (direct tumor extension not visualized on this image), resulting in thickening and nodularity along the peritoneum (*red asterisk*). Ascites is present as well. This tumor is classified as T4a, MRF+.

short axis (SA) diameter, is not a reliable indicator of malignancy. To improve specificity and avoid overtreatment from overestimation of lymph node involvement, morphologic criteria are used alongside size.[25] One commonly applied standard is the Dutch criteria which classified lymph nodes as suspicious if they meet any of the following: SA diameter greater than 9 mm; SA 5 to 9 mm with at least 2 suspicious morphologic features; or SA diameter less than 5 mm with 3 morphologic features. These suspicious morphologic features include irregular borders, a round shape, and abnormal/heterogeneous signal intensity[26] (**Table 1**). Of note, DWI/ADC maps cannot differentiate between metastatic and inflammatory lymph nodes at initial staging.[27] However, in restaging, if all diffusion restriction signal associated with previously suspicious lymph nodes disappear, the lymph nodes are likely sterile, or show a complete response.[28] According to the National Comprehensive Cancer Network (NCCN) guidelines, suspicious locoregional lymph nodes warrant neoadjuvant therapy regardless of the primary tumor's T stage. This differs from the European Society for Medical Oncology (ESMO) guidelines, where TME is recommended for T1/T2/early T3 mid or high rectal tumors without MRF involvement, even with suspected mesorectal lymph node involvement.[29]

Lateral pelvic lymph nodes, locoregional Lateral lymph node (LLN) metastasis should be considered in T3/4 tumors located less than 8 cm from the anal verge.[30] In these tumors, the risk of local recurrence after neoadjuvant treatment is stratified by LLN size: if at pre-treatment, LLN SA size is greater than 10 mm SA, the rate of lateral compartment local recurrences after neoadjuvant chemoradiotherapy is 33% to 36.7%, if 5 to 10 mm, 10.1% to 20%, and if less than 5 mm, 6.4%.[31–34] The LLN consortium, a multicenter international collaboration, showed that an LLN (internal iliac or obturator) measuring $\geq$ 7 mm SA at initial staging leads to a 5-year lateral local recurrence (LLR) rate of 17.9%.[30]

Because of the differences in prognosis between internal iliac and obturator lymph node metastases (i.e., internal iliac associated with local recurrence, obturator with distant metastasis), Kaur and Gabriel recently proposed a simple anatomic mapping strategy based on the Lateral Node Study Consortium data to aid in accurate categorization of lateral lymph nodes (**Fig. 8**A–D).[31] Internal iliac lymph nodes are located around the internal iliac artery and its branches, from its origin to the infra-piriformis foramen. Obturator lymph nodes are situated posterior to the external iliac vessels at mid pelvis, anterior and lateral to the internal iliac region. The pelvic side wall lymph nodes below the internal iliac vessel exit at the infra-piriformis foramen are classified as obturator lymph nodes (**Fig. 8**).

Lateral lymph nodes (LLN) are a significant source of recurrence in locally advanced low rectal tumors because they are not routinely removed during total mesorectal excision (TME). In most US and many European institutions, LLNs are treated with radiation therapy in combination with systemic therapy and lateral lymph nodes dissection is performed selectively. However, Japanese data indicate that lateral lymph node dissection in high-risk patients reduces local recurrence and improves overall outcomes.

Extramural venous invasion

Although not included in the TNM staging system, extramural venous invasion (EMVI) is a stronger predictor of poor prognosis than T or N category, as it is associated with a higher risk of local recurrence and a greater likelihood of distant metastases.[35] On MR imaging, EMVI is identified as tumor invasion into extramural vessels, characterized by irregular thickening, a triangular shape, and intermediate T2 tumor signal within the affected vessel, confirmed in at least 2 planes. Most often EMVI is contiguous from the primary tumor, but it can be discontiguous. When contiguous, it is important to note that EMVI extends from the tumor base and vessels not originating from this area are unlikely to be involved. The presence of EMVI influences treatment decisions, particularly regarding neoadjuvant therapy and surgical planning (**Fig. 9**A, B).

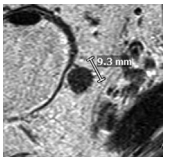
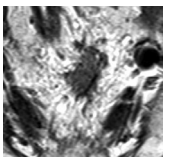
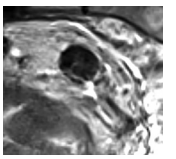
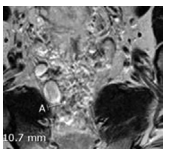
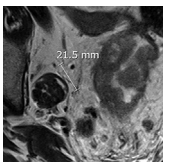
Tumor deposits

Tumor deposits (TD) are tumor masses in the mesorectum that are separate from the primary tumor and that are not associated with lymphoid tissue on microscopic evaluation. TDs are strongly associated with EMVI. Studies suggest that contiguity with vein in multiple planes, tumor tapering into the vein ("comet tail sign"), and marked contour irregularity are more suggestive of TD than of lymph node.[36] However, more studies are needed to determine the accuracy of MR imaging to differentiate between the TD and lymph node metastasis. Like EMVI, TDs are associated with poor prognosis.[36]

Restaging: Assessment of Response to Neoadjuvant Treatment

After initial staging, curative resection, either through local excision or TME, may be attempted if the rectal cancer is early stage and considered

Table 1
At initial staging, mesorectal lymph node assessment cannot rely solely on size criteria as benign reactive lymph node can also be enlarged and very small lymph nodes can harbor metastasis

Initial Stage Lymph Node Evaluation Criteria				
Mesorectal Lymph Node	*Size, Short Axis (SA)*	*Morphologic Criteria*	*MR Imaging Example of Suspicious Lymph Node Involvement*	*Description*
	9 mm or larger	None required		T2-weighted axial imaging shows a 9.3 mm SA mesorectal lymph node, suspicious by size criteria. The lymph node also demonstrates 1 morphologic criterion, round
	5–9 mm	At least 2 out of 3 criteria 1. Irregular border 2. heterogenous signal 3. round		Axial T2WI shows a mesorectal node with irregular border. Sagittal T2WI demonstrates a mesorectal node with heterogenous signal intensity
	5 mm or less	All 3 criteria		
	Any size	Mucin containing		Axial T2WI shows multiple mucin-containing T2 hyperintense lymph nodes are present, largest 10.7 cm in SA. All lymph nodes that contain mucin in initial stage are considered suspicious
Lateral lymph node (Internal iliac and obturator lymph nodes)	7 mm or larger	Involvement at risk if the primary tumor is 1. T3/4 and < 8 cm from the anal verge		Axial T2WI shows a right enlarged heterogeneous signal suspicious 21.5 mm SA right internal iliac lymph node, in a T3 tumor 6.6 cm from the anal verge

To increase specificity of MR imaging evaluation, other morphologic criteria are also considered. The Dutch criteria, widely adopted for evaluation of mesorectal lymph nodes, combine both size and morphology to define which lymph nodes should be regarded "suspicious" for metastasis. Although data are limited, locoregional lymph node assessment is more heavily reliant upon size.

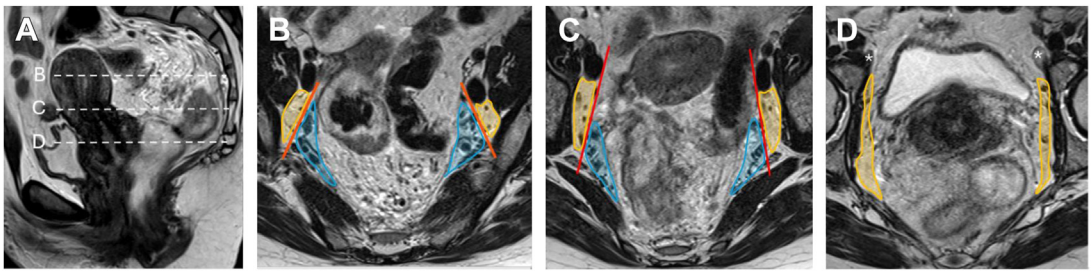


Fig. 8. MR sagittal (*A*) and axial T2WI at upper (*B*), mid (*C*), and lower (*D*) pelvis demonstrate the distribution of lateral lymph nodes at different axial levels, highlighting the obturator region (*light orange*) and internal iliac region (*light blue*). In the upper pelvis (*B*), the obturator region (*light orange*) lies posterior to the external iliac vessels and lateral to the solid red line, which marks the lateral aspect of the internal iliac region (*light blue*). In the mid pelvis (*C*), the obturator region (*light orange*) is lateral to the red line drawn from the obliterated umbilical artery (*dark red arrows*) to the internal iliac vessels, while the internal iliac region is medial to this line. In the lower pelvis (*D*), where the internal iliac vessels have exited the pelvis via the infra-piriformis foramen, the pelvic sidewall is entirely within the obturator region[31,34] A lymph node located posterior to the distal external iliac vein (*white asterisk*) is often prominent in size, but is usually long and slender rather than round, and it is almost never involved in disease. Consequently, this node was not considered in the lateral lymph node consortium study. Radiologists should be cautious not to overcall lateral lymph node involvement based on this specific lymph node (C, *white asterisk*).[34]

a good candidate for primary surgery. For locally advanced cancers, neoadjuvant treatment is typically administered to decrease the risk of positive resection margins and improve the likelihood of sphincter preservation. Nonoperative management ("watch-and-wait") is becoming an increasingly common strategy for patients who have achieved complete clinical response.

During the last decade, total neoadjuvant therapy (TNT) has emerged as an alternative to the traditional course of neoadjuvant chemoradiation followed by surgery. TNT involves administering the chemotherapy upfront, either as induction or consolidation, and has been found to increase the rate of clinical complete response (up to 50%) and to improve 3-year survival rates.[37] For patients undergoing traditional neoadjuvant treatment, TNT, or chemotherapy alone, restaging MR imaging is performed to assess the treatment response.

In preparation for reporting

For accurate restaging, the initial staging MR imaging should be used for comparison when available. This helps identify the tumor's original location and extent, as treatment changes such as edema and/or hyperemia in nontumor bowel segments and volume loss in tumor-involved areas can complicate the posttreatment appearance[38] (**Fig. 10**A–C). The treatment history—whether short or long course chemoradiation, chemotherapy, or TNT—and date of treatment completion should all be considered when evaluating treatment response.[39]

MR imaging treatment response reporting

The Society of Abdominal Radiology colorectal and anal cancer Disease Focus Panel previously

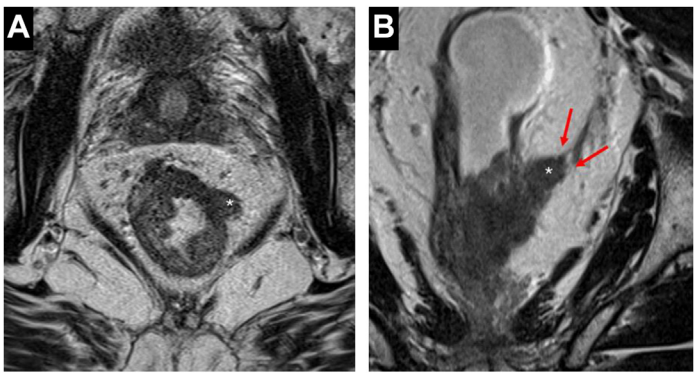


Fig. 9. Axial (*A*) and coronal (*B*) T2WI of a 51-year-old male with low rectal cancer. Tumor invasion into mesorectal fat is noted at the left lateral wall on axial image (*A*, *white asterisk*), and when followed cranially, elongated finger-like extension into vessels is noted on coronal image (*B*, *white asterisk* denoting tumor invasion, red arrow denoting vessels), consistent with extramural venous invasion (EMVI). There is often an abrupt caliber change and signal intensity change of the vein at the margin of the EMVI. The patient later developed liver and lung metastasis.

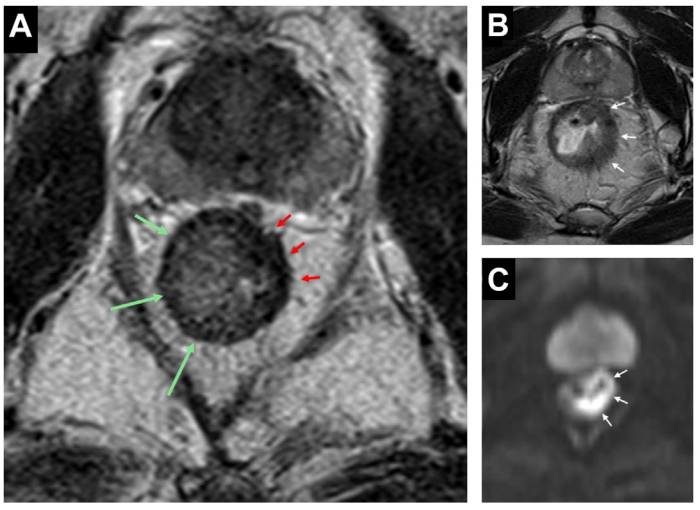


Fig. 10. T2WI high-resolution axial image at restaging (*A*) shows asymmetric thickening of the right rectal wall (*long narrow light green arrows*), which might be suspicious for residual tumor. However, comparison with initial staging MR images (*B* and *C*) shows an intermediate T2 signal ulcerated mass (*B*) with diffusion restriction (*C*) in the left wall (*white arrows*), confirming the location of the original tumor. On the restaging MR imaging (*A*), the tumor bed demonstrates volume loss and fibrosis (*short red arrows*), indicating a positive response to neoadjuvant therapy. The asymmetrically thickened right wall seen in (*A*) is benign posttreatment change in an area not previously involved by the tumor.

suggested a 3-tiered grading system of response: (1) complete/near complete, (2) incomplete, and (3) minimal/no response or progression (https://abdominalradiology.org/wp-content/uploads/2021/03/Updated-MRI-pelvis-Rectal-Cancer-RESTAGING.pdf). More recently, the 3-tier system was updated to (1) complete response (no residual tumor), (2) near complete response (possible/equivocal for residual tumor), (3) incomplete response (definite residual tumor), (4) No response (stable or increased in size), and (5) mucinous change (cannot distinguish between cellular and acellular mucin). Different tiers in the treatment response provide valuable guidance on the subsequent step in their management[40] (**Table 2**).

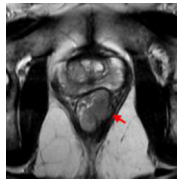
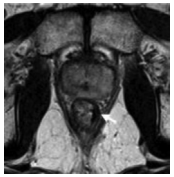
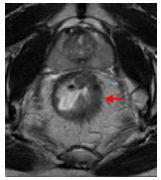
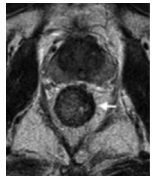
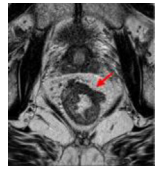
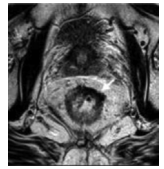
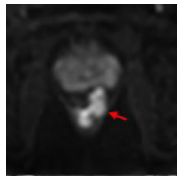
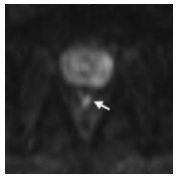
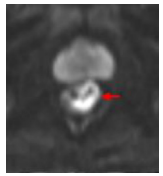
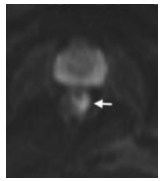
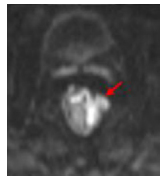
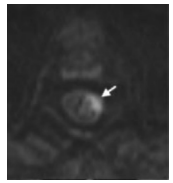
For patients with a complete response, "watch-and-wait" and organ preservation may be a viable alternative to resection. In cases of near complete response, short-term follow-up can be considered to assess whether the tumor regresses further or if surgical resection is warranted. However, if there is clear residual tumor, the "watch-and-wait" strategy is not considered a safe option, and surgery should be considered.

A complete response of the primary tumor on rectal MR imaging is characterized by a normalized rectal wall appearance or entirely dark T2 signal indicating scar/fibrosis, with no associated diffusion restriction. The "split-scar" sign is reported as a specific indicator of complete response, but it is not sensitive, not validated, and rarely observed.[41] A near-complete response of the primary tumor may appear as near-total T2 hypointense fibrosis of the tumor with small area(s) of intermediate signal allowable (which could be treated nonviable or viable tumor). On DWI/ADC, tiny foci of restricted diffusion or equivocal diffusion restriction are permissible. Incomplete response is identified as intermediate tumor signal on T2WIs, and residual diffusion restriction. Evaluation of EMVI and TDs follows the same criteria as for the primary tumor: complete response is indicated by significant size regression and the resolution of intermediate T2 tumor signal (which may be replaced by T2 hypointense fibrosis) and diffusion restriction.

Imaging evaluation of treatment response in lymph node is limited in its accuracy; however, there are a few clues that aid interpretation. Lack of any detectable lymph node and lack of any diffusion restriction within lymph nodes are consistent with complete response.[28] If restricted diffusion is present, it may be emanating from residual viable tumor or lymphoid tissue, and differentiation is difficult; for these nodes, the use of size criteria is recommended. In mesorectal lymph nodes with diffusion restriction, the size criteria of 5 mm SA are recommended as a cut off. However, the sensitivity and specificity of this threshold is limited. The performance of radiographic evaluation of lateral sidewall lymph nodes is also limited. For an internal iliac lymph node greater than 7 mm SA at initial staging in a patient with a low T3/4 rectal tumor, if that lymph node remains greater than 4 mm SA at restaging, it is considered suspicious, with a reported 5-year LLR rate of 52.3%. For obturator lymph nodes $\geq$ 7 mm SA on initial staging and still > 4 mm after neoadjuvant treatment, the 5-year local recurrence risk was much lower, at 9.5%.[30] No LLR was seen on those where lateral node SA was decreased in size to less than 4 mm.[30]

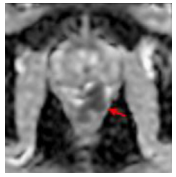
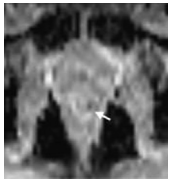
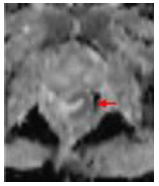
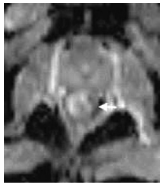
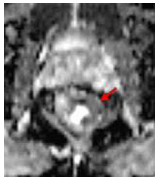
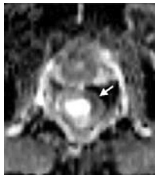
Pretreatment mucin in lymph node associated with mucin-containing rectal tumor allows clear indication of lymph node involvement. However, even after a complete response, residual acellular

Table 2
High-resolution T2-weighted imaging and diffusion-weighted imaging/apparent diffusion coefficient are used to assess treatment response

	Complete Response		Near Complete Response		Incomplete Response	
	Initial Staging	Restaging	Initial Staging	Restaging	Initial Staging	Restaging
T2WI						
	Interval resolution of T2 intermediate tumor signal (red arrow). Thin completely dark T2 signal (white arrow, fibrosis) may be seen post radiation.		Internediate T2 signal mass of the left wall (red arrow) show marked tumor volume decrease with predominantly dark T2 signal at tumor bed (white arrow)l.		Intermediate T2 signal tumor (red arrow) has decreased in volume at restaging (white arrow). However, residual tumor signal is present.	
High b-value DWI sequence						
	Interval resolution of restricted diffusion signal associated with tumor (red arrow) at restaging. Only trace increased signal (white arrow) in mucosa adjacent to tumor bed at restaging.		Near complete resolution of the diffusion restriction associated with tumor (red arrow).Trace residual diffusion restriction similar or minimally increased compared to background mucosal was interpreted as equivalence for residual tumor.		Despite decrease in volume and signal intensity, residual diffision restriction definitely above background level is present at the tumor bed (white arrow).	

(*continued on next page*)

Table 2
(continued)

	Complete Response		Near Complete Response		Incomplete Response	
	Initial Staging	Restaging	Initial Staging	Restaging	Initial Staging	Restaging
Apparent diffusion coefficient (ADC) map						
	Interval resolution of low signal mass (red arrow) at the tumor bed (white arrow).		Low ADC signal at the tumor (red arrow) has almost completely resolved (white arrow).		Tumor bed low ADC signal, correlating with high signal seen on high b value sequence consistent with definite residual tumor (white arrow).	

If the patient demonstrates clinical complete response based on MR imaging, endoscopy, and digital rectal examination, a watch-and-wait approach with organ preservation may be considered. In cases of near-complete response, short-term follow-up of 3 to 6 months may be recommended if other factors suggest the possibility of achieving a complete response. However, if at follow-up, suspicion for residual disease is present, the patient converts to incomplete response and organ preservation is no longer considered a safe option.

mucin may be seen in a lymph node on restaging MR imaging, and differentiation between acellular from low-cellular mucin is limited.

In addition to the response categories discussed earlier, some advocate for the use of a 5-tier MR imaging-based tumor response grading system (mrTRG) using only on T2 weighted imaging. mrTRG1 suggests complete response and on MR imaging is seen as an absence of tumor with no or minimal scar. mrTRG2 denotes a good response, with a thick, dense scar, but no obvious macroscopic tumor. mrTRG3 suggests moderate response, with fibrosis predominating but measurable tumor still present. mrTRG4 indicates slight response, with some fibrosis but mostly viable tumor. mrTRG5 is for no response, when there is no fibrosis and when tumor is unchanged or has increased in size.[42] The mrTRG system is adapted from a pathology-based TRG system, although agreement between the 2 systems is low, and its adoption has been variable.[43,44]

The optimal timing for restaging MR imaging is 4 to 12 weeks after completion of neoadjuvant treatment. Extending the time interval from less than 6 weeks to 7 to 12 weeks, or to 13 weeks or longer has been shown to increase complete remission rates from 12.6%, 23%, and 31.3%, respectively.[39] However, a prolonged delay can lead to increased fibrosis, raising the risk of surgical complications.

For patients who achieve a clinical complete response and opt for nonoperative management, rectal MR imaging is recommended every 6 months for the first 3 years. In addition, chest and abdomen CT should be performed every 6 to 12 months for a total of 5 years, with pelvic CT to be included after rectal MR imaging is discontinued (NCCN v3.2024). Digital rectal examination, proctoscopy, or flexible sigmoidoscopy is recommended every 3 to 4 months for the first 2 years, and then 6 months for a total of 5 years.[45]

If tumor is detected in the original scar/tumor bed during surveillance of a patient on "watch-and-wait", it should be classified as “regrowth” rather than recurrence, reflecting the idea that it may never have been completely eradicated.[46] Close monitoring of these patients is crucial, as 22% will experience regrowth in the first 3 years, and approximately 10% will develop distant metastases.[47,48]

Patterns of recurrence

Recurrence refers to the detection of tumor after a patient has undergone a surgical excision aimed at cure, whether through local excision, TME, or pelvic exenteration. Over the past few decades, rectal cancer local recurrence rates have significantly decreased, especially following the adoption of TME as the standard surgical technique and the routine use of rectal MR imaging for optimal treatment guidance.[49]

Most recurrences occur within the first few years after surgery, with the annual incidence falling to less than 1.5%/y after 5 years. Local recurrence is more common in patients with low rectal tumors, positive resection margin, peritoneum involvement, lymphovascular invasion, EMVI/tumor deposits, high-grade histology, and in those who underwent abdominoperineal resection.[50] The recurrence locations can be categorized into central/axial (anastomosis, residual meso-perirectal soft tissue, 13%–37%), anterior (genitourinary or reproductive organs, 16%–30%), lateral (pelvis side wall, 18%–25%), and posterior (presacral fascia, sacrum 10%–41%).[51,52] While endoscopic evaluation can detect anastomotic recurrence with an endoluminal component, other locoregional metastases require cross-sectional imaging (magnetic resonance [MR], computed tomography [CT], and PET) for localization. Prognosis for local recurrence is generally poor, with lateral and posterior recurrences faring worse than axial or anterior recurrence, especially if perineural involvement is present.

Distant recurrence most commonly affects the liver and lungs. In patients with locally advanced rectal cancer who underwent TNT, the 5-year cumulative probability of distant recurrence was 23%, compared to 30% in those receiving standard long-course chemoradiation with optional adjuvant chemotherapy based on the RAPIDO trial.[53] Liver metastasis occurred more frequently in the control group than TNT group (15%, vs 9%), while lung metastasis rates were similar (12% in the TNT group and 13% in the control group).[53]

CLINICS CARE POINTS

- Rectal MRI allows improved treatment guidance by allowing identification of rectal adenocarcinoma at high risk for positive resection margin, and poor prognostic indicators such as extramural vascular invasion/tumor deposits.
- For accurate T categorization high resolution T2 WI acquired in angle to optimize tumor base evaluation is critical.
- MRI is limited in discerning N category, and therefore consideration of nodal morphologic features such as signal or border abnormality, tumor location and its anatomic

drainage pathway, and the risk of lymph node involvement based on T stage is recommended, in addition to size, to improve specificity.

- For neoadjuvant treatment response evaluation, smaller field of view high B value diffusion weighted imaging is helpful.

DISCLOSURE

The authors have nothing to disclose.

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