

MRI in local staging of rectal cancer: an update

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ABSTRACT

Preoperative imaging for staging of rectal cancer has become an important aspect of current approach to rectal cancer management, because it helps to select suitable patients for neoadjuvant chemoradiotherapy and determine the appropriate surgical technique. Imaging modalities such as endoscopic ultrasonography, computed tomography, and magnetic resonance imaging (MRI) play an important role in assessing the depth of tumor penetration, lymph node involvement, mesorectal fascia and anal sphincter invasion, and presence of distant metastatic diseases. Currently, there is no consensus on a preferred imaging technique for preoperative staging of rectal cancer. However, high-resolution phased-array MRI is recommended as a standard imaging modality for preoperative local staging of rectal cancer, with excellent soft tissue contrast, multiplanar capability, and absence of ionizing radiation. This review will mainly focus on the role of MRI in preoperative local staging of rectal cancer and discuss recent advancements in MRI technique such as diffusion-weighted imaging and dynamic contrast-enhanced MRI.

Colorectal cancer is the second most common cancer in women and the third most common cancer in men with 570 100 and 663 600 estimated new cases per year worldwide, respectively (1). Rectal cancer accounts for approximately 42% of colorectal cancers with 45 000 estimated new cases per year in the United States (2). Prognosis of rectal cancer is determined by depth of invasion, number of involved lymph nodes, and involvement of circumferential resection margin. Management of rectal cancer has evolved over the years with preoperative imaging playing an increasingly prominent role. Initial strategy of clinical diagnosis followed by surgery and postoperative chemotherapy had a high local recurrence rate (27%) and poor survival (48% 5-year survival) (3). Later studies showed that neoadjuvant chemoradiation improves survival and decreases local recurrence rates significantly (4). In addition, it reduces tumor size, facilitates curative resection (5), and may enable sphincter sparing surgery in cancers close to the anorectal junction (6). Neoadjuvant chemoradiotherapy is not indicated in stage I tumors (confined to rectal wall with no nodal involvement), but is recommended for stage II (extends beyond the rectal wall, no nodal involvement) and stage III tumors (regional lymph node involvement). Therefore, in order to avoid unnecessary chemoradiation in stage I cancers, a reliable imaging modality is crucial to precisely define depth of invasion and to identify lymph node involvement (7). Current approach in the management of rectal cancer includes preoperative staging with different imaging modalities followed by neoadjuvant chemoradiotherapy (for stage II/III cancers). This approach has lowered the local recurrence rate (11%) and improved survival (58% 5-year survival) (3).

Preoperative imaging for rectal cancer staging is also useful to determine which surgical technique would be more appropriate: recently-developed local excision method of transanal resection or traditional radical resections such as low anterior resection or abdominoperineal resection. Physical examination, endoscopic evaluation, and imaging modalities are used for preoperative staging of rectal cancer. Ideal imaging modality should accurately assess the depth of tumor penetration (T), lymph node involvement (N), presence of distant metastatic disease (M), mesorectal fascia involvement, and anal sphincter involvement. Currently, there is no consensus on a preferred imaging technique for preoperative staging of rectal cancer.

Endoscopic ultrasonography, one of the oldest and most widely used imaging modalities, is reported to assess T staging with 67%–97% accuracy and nodal involvement with 64%–88% accuracy (8–11). Although it has a role in staging of early cancers confined to the wall of the rectum,

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endoscopic ultrasonography may not assess deeper or higher nodes in the mesorectum and can misinterpret inflammatory or fibrotic changes as metastasis (12). Its value is also limited in the evaluation of near-obstructing tumors, tumors in the upper rectum, and mesorectal fascia involvement (12, 13).

Computed tomography (CT) is commonly used in rectal cancer because of its ability to assess entire pelvic anatomy and presence or absence of distant metastasis. However, CT has limited soft tissue contrast for local staging. A meta-analysis of 83 studies showed that CT has 73% accuracy for T staging and 22%–73% accuracy for nodal staging (14). In a recent study, Sinha et al. (15) showed T stage accuracy of 87.1% and N stage accuracy of 87.1%. Although newer multidetector CT technology with multiplanar reformations has improved the accuracy, soft tissue resolution of CT is still inadequate to evaluate early rectal cancers.

On the other hand, high-resolution phased-array MRI is recommended as a standard imaging modality for preoperative local staging of rectal cancer, with excellent soft tissue contrast, functional imaging ability, and multiplanar capability (Figs. 1 and 2). With these inherent proprieties, MRI fills a gap in clinical practice and helps accurate local staging of rectal cancer prior to management decisions. This review will mainly focus on the role of MRI in preoperative local staging of rectal cancer and discuss recent advancements in MRI technique.

Local staging

Rectal cancer staging has three crucial components: local staging, metastatic disease evaluation, and investigation of other bowel segments for synchronous tumors. The 7th revision of TNM staging (as published by Union for Cancer Control and American Joint Committee for Cancer) is used for rectal cancer staging (16). T1 tumors are confined to mucosal/submucosal layer (Figs. 3 and 4), T2 tumors invade muscularis propria (Fig. 5), T3 tumors invade mesorectum (Fig. 6), and T4 tumors extend to visceral peritoneum (T4a) or surrounding organs (T4b) (Figs. 7–9). Low rectal tumors involving the anal sphincter are considered

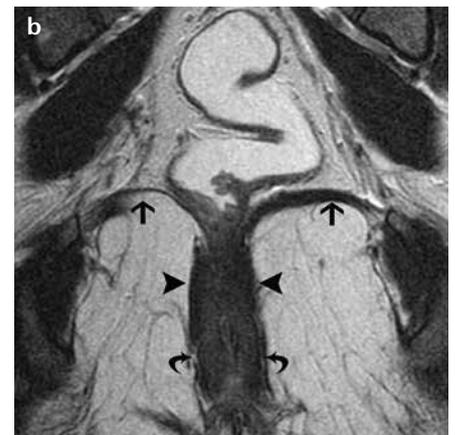
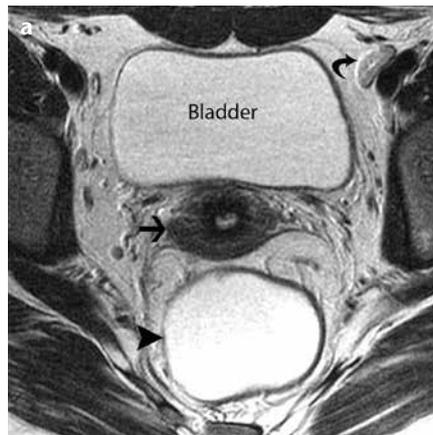


Figure 1. a, b. Axial (a) and coronal (b) fast spin-echo T2-weighted MR images obtained with a phased-array coil on a 3.0 T magnet show the normal anatomy of the pelvis. The rectum (a, arrowhead) is distended with water. Note uterus (a, arrow), and oval-shaped fatty-centered left iliac node (a, curved arrow), which is likely reactive. The iliococcygeal part of the levator ani muscle (b, arrows) extends from the pelvic sidewalls to the anus and joins with the puborectalis muscle (b, arrowheads) to form the external sphincter of the anus (b, curved arrow).

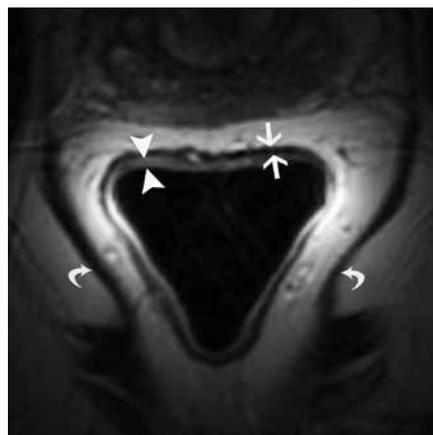


Figure 2. Axial T2-weighted MR image obtained with an endorectal coil shows the layers of the rectum. Hyperintense submucosa (curved arrows) is surrounded by hypointense muscularis propria (arrows). The mucosa cannot be differentiated from the submucosa, and both layers appear as a single hyperintense layer. Note the levator ani muscle (curved arrows).

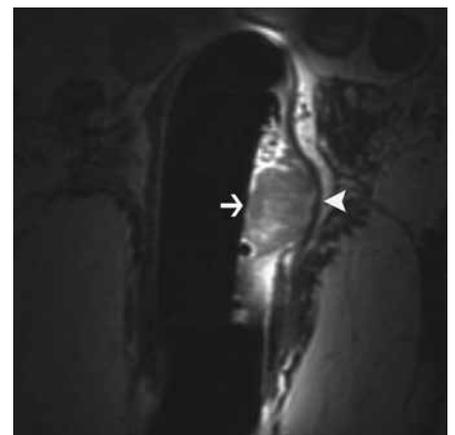


Figure 3. A 70-year-old female with pT1 rectal carcinoma. Coronal T2-weighted MR image obtained with an endorectal coil shows an intermediate signal intensity, polypoid mass arising from the left lateral rectal wall (arrow). The overlying muscularis propria (arrowhead) is smooth and demonstrates normal signal intensity without features of involvement suggestive of T1 disease.

T3 when the tumor extends into the intersphincteric plane and T4 when the external sphincter is invaded. N0 tumors have no lymph node metastasis, N1 tumors have 1–3 metastatic lymph nodes and N2 tumors have >3 metastatic mesorectal lymph nodes (Fig. 10). Staging is performed as follows: stage I, T1/T2 tumors with no nodal involvement; stage IIA, T3 tumors with no nodal involvement; stage IIB, T4 tumors with no nodal involvement; stage IIIA, T1/T2 tumors with 1–3 lymph nodes involved; stage IIIB, T3/T4 tumors with 1–3 lymph nodes involved; stage IIIC, tumors with >3 lymph nodes involved

regardless of T stage; and stage IV, tumors with distant metastasis regardless of T stage and nodal status.

Rectal cancer can also be divided into three groups according to the distance of distal tumor border to the anal verge: tumors located 0–6 cm away from the anal verge are low rectal; 7–11 cm, mid rectal, and 12–15 cm, high rectal.

MRI protocol

There is no consensus on MRI protocol for local staging of rectal cancer. Some authors use endorectal coil but others find pelvic phased-array coil sufficient. An endorectal coil provides a

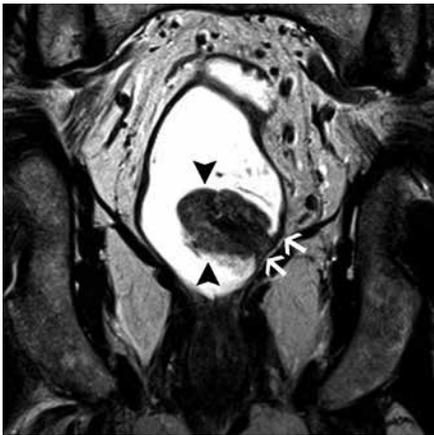


Figure 4. A 57-year-old male with pT1 rectal carcinoma. Coronal T2-weighted image shows a large polypoid mass (*arrowheads*) attached to the left lateral rectal wall. The overlying muscularis propria (*arrows*) is intact with normal signal intensity.

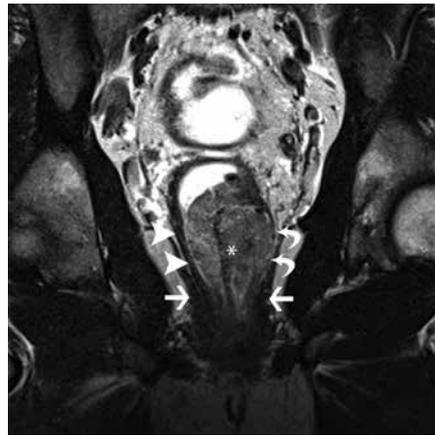


Figure 5. A 43-year-old male with pT2 rectal carcinoma. Coronal T2-weighted image demonstrates an intermediate signal intensity mass (*asterisk*) arising from the left lateral rectal wall. The muscularis propria is of normal thickness and signal intensity on the right (*arrowheads*). However, the muscularis propria overlying the mass on the left (*curved arrows*) is thinned but intact without extension of the tumor into the mesorectal fat, consistent with T2 disease. Note the normal external sphincter (*arrows*).

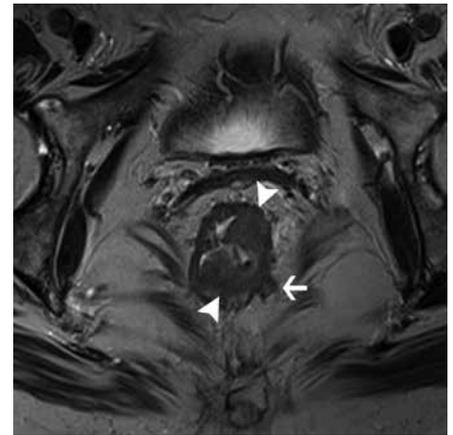


Figure 6. A 65-year-old female with pT3 rectal carcinoma. Axial T2-weighted MR images show a rectal tumor (*arrowheads*) arising from the left lateral rectal wall, disrupting the integrity of the muscularis propria, and invading the surrounding mesorectal fat (*arrow*).



Figure 7. a, b. A 57-year-old female with T4a rectal carcinoma. Axial (**a**) and coronal (**b**) T2-weighted MR image obtained with a pelvic phased-array coil shows an annular rectal mass (*arrowheads*) with extensions into the mesorectal fat (*curved arrows*) and involvement of peritoneal reflection (*arrow*) consistent with T4a disease.

high signal-to-noise ratio (SNR), which can be used to differentiate the layers of the rectal wall and is particularly helpful in the evaluation of early stage tumors (17). However, endorectal coil is expensive and its availability is limited. It cannot be placed in stenosing cancers and may not reach the tumors in the upper rectum or sigmoid colon. The evaluation of the mesorectal fascia and lymph nodes outside the mesorectum is limited because endorectal coil provides adequate signal-to-noise only within 3 cm around the coil (18). Pelvic phased-array

coils provide evaluation of the entire pelvis, but its spatial resolution may not be sufficient to differentiate rectal wall layers or identify extension of early cancers into the mesorectal fat, and its use may be limited in low-lying rectal cancers and obese patients (19). However, the resolution of pelvic phased-array at 3.0 Tesla (T) scanners is generally considered adequate to perform local staging of rectal cancer.

Administration of a rectal contrast media is also controversial. Some argue that rectal contrast decreases the distance between the rectal wall and the

mesorectal fascia, and might influence the ability of MRI to predict the relationship between the tumor and the potential resection margin; therefore they do not recommend it (20). However, negative (i.e., barium sulfate solution) or positive (i.e., ultrasound gel) contrast media can be used to expand the rectum and may help to better delineate the tumor on T2-weighted images. Bowel preparation with cathartics or enema can be helpful to eliminate fecal material; however, it can be problematic and unnecessary in most patients. Intravenous or intramuscular antispasmodic agents such as glucagon or scopolamine butylbromide can help improve the image quality, but are also not mandatory (21).

T2-weighted sequences are the backbone of the MR protocol to stage rectal tumors and are typically obtained in three orthogonal planes (Table). Higher resolution (3 mm) oblique axial T2-weighted images obtained perpendicular to the rectal wall at the level of the rectal mass with smaller field-of-view (16–18 cm) are found useful to evaluate mesorectal extension of the tumors (21, 22). This high resolution sequence is recommended by the Mercury group (21), and can also be utilized in coronal orientation in low-lying tumors in order to

Table. MRI protocol to evaluate rectal cancer using pelvic phased-array coil at 1.5 or 3.0 Tesla scanner

| Sequence parameters | SSFSE | FSE | FSE | DWI | FSPGR |
|------------------------------|-----------|--------------------------|----------------------|--------------|---------------------------------------|
| Orientation | Axial | Axial, sagittal, coronal | Oblique ^a | Axial | Axial, sagittal, coronal ^b |
| Repetition time (ms) | 1000–1200 | 4000–6000 | 4000–6000 | 4700–6000 | 3.5 |
| Echo time (ms) | 100–180 | 91.0–95.0 | 91.0–95.0 | 66.0 | 1.7 |
| Dimension (2D/3D) | 2D | 2D | 2D | 2D | 3D |
| Section thickness (mm) | 6.0 | 4.0 | 3.0 | 5.0–6.0 | 3.0 |
| Interslice gap | 20% | 25% | 0 | 0 | 0 |
| Field of view (cm) | 32.0 | 24.0 | 16.0–18.0 | 36.0 | 24.0–30.0 |
| Matrix | 224×320 | 269×384 | 256×256 | 80×192 | 214×320 |
| Fat suppression | No | No | No | Yes | Yes |
| Bandwidth (Hz/Px) | 500 | 200 | 200 | 1500–1700 | 590 |
| NEX | 1 | 2 | 2 | 3 | 1 |
| b-value (mm/s ²) | NA | NA | NA | 0, 500, 1000 | NA |

SSFSE, single-shot fast spin-echo; FSE, fast spin-echo; DWI, diffusion-weighted imaging; FSPGR, fast spoiled gradient-echo; NEX, number of excitations.

^aPerpendicular to the long axis of the rectum.

^bAlthough the sequence is 3D, each orientation is obtained separately in order to achieve better in-plane resolution. All three orientations were obtained following intravenous gadolinium depending on the body weight (0.1 mmol/kg). Axial images are also obtained before gadolinium administration.

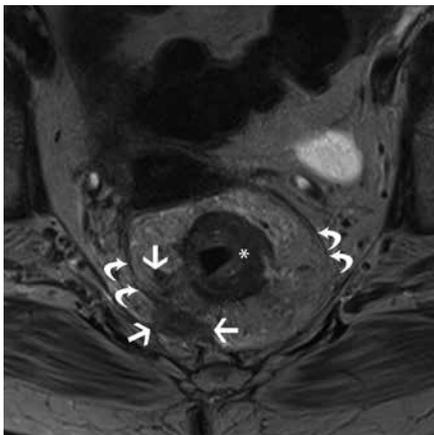


Figure 8. A 70-year-old female with T4b rectal carcinoma. Axial T2-weighted MR image shows a circumferential tumor (*asterisk*) with tumor deposits (*arrows*) within the mesorectum, involving the mesorectal fascia (*curved arrows*), and extending to the right posterolateral pelvic wall (*far right lateral arrow*) consistent with T4b disease.



Figure 9. a, b. A 55-year-old female with T4b rectal carcinoma. Axial (**a**) and sagittal (**b**) T2-weighted MR images obtained with a pelvic phased-array coil show circumferential rectal carcinoma (*arrowheads*) extending anteriorly beyond the muscularis propria (*arrows*) and infiltrating the posterior wall of the vagina consistent with T4b disease. Note intact anterior vaginal wall (*curved arrows*).

better demonstrate the relationship between the tumor and anal sphincter (21). Axial diffusion-weighted imaging (DWI) and three-dimensional fat-suppressed T1-weighted gradient-echo images before and after intravenous gadolinium can also be obtained, although the latter was found unhelpful and it is not recommended by the Mercury group (21).

Accuracy of MRI

Initial studies with body coil MRI were not promising (23) and the reported ac-

curacy in predicting the depth of rectal tumor penetration was around 60% (24). Introduction of endorectal coil has increased the accuracy of T staging to 71%–85% range (25, 26). Endorectal coil MRI has a high SNR for the rectal wall and provides excellent depiction of anal sphincter involvement with a reported accuracy of 92%–94% for T staging and 63% for N staging (17). Pelvic phased-array coil MRI has resulted in a higher accuracy for T staging compared to body coil with rates ranging between 55% and 86% (19, 27–28).

The depth of tumor invasion (the distance from muscularis propria to the outermost tumor edge) correlates well with survival, and this is especially important for T3 tumors (Fig. 11). Merkel et al. (29) have analyzed T3 rectal cancers and reported 5-year survival as 85% and 54% when the depth of tumor invasion was ≤ 5 mm versus >5 mm. In a study reported by Brown et al. (30), preoperative MRI was able to identify a tumor spread of ≥ 5 mm beyond the bowel wall in 21 of 24 patients. According to a more recent

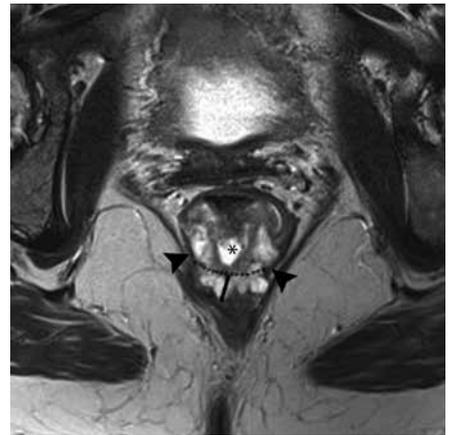
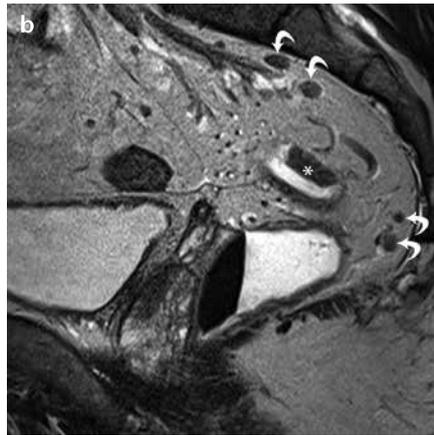


Figure 10. a, b. A 52-year-old male with T2 N2 rectal carcinoma. Axial (a) and sagittal (b) T2-weighted MR image show a left lateral tumor (asterisk) which involves the muscularis propria (arrows) but does not extend into the mesorectal fat, consistent with T2 disease. However, there are at least four larger than 5 mm nodes (curved arrows) within the mesorectal fat and along the inferior mesenteric vein consistent with N2 disease.

Figure 11. A 70-year-old female. Axial T2-weighted MR image obtained with a pelvic phased-array coil shows heterogeneous signal-intensity mass (asterisk) arising from the posterior rectal wall, invading muscularis propria (arrowheads), and extending into the mesorectal fat consistent with T3 disease. The distance (straight line) from the level of the muscularis propria (dotted line) to the outermost tumor edge correlates well with tumor recurrence and survival.

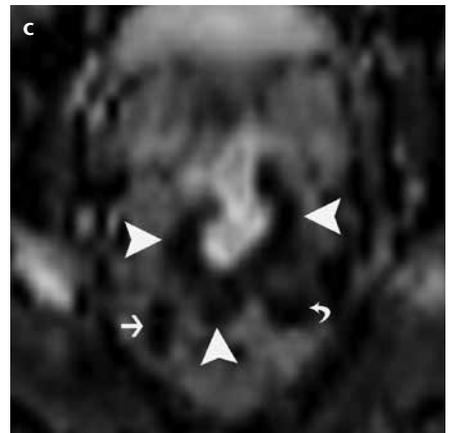
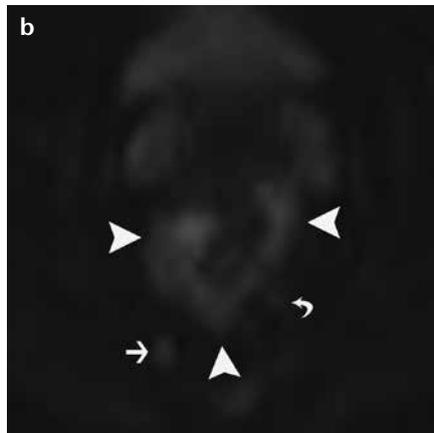
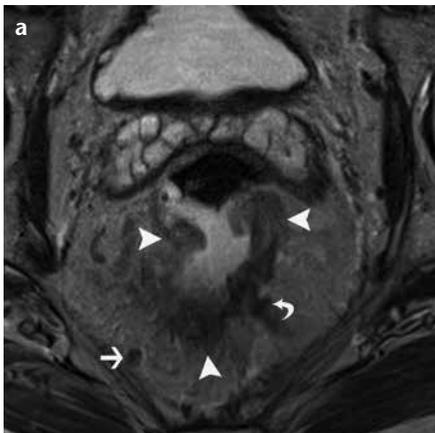


Figure 12. a–c. An 83-year-old male with pT3 rectal carcinoma. Axial, T2-weighted (a), diffusion-weighted (DWI) with b-value of 1000 mm²/s² (b), and apparent diffusion coefficient (ADC) (c) images show a rectal mass (arrowheads) arising from the posterior rectal wall and extending into the mesorectal fat. Note an involved node (arrow) on the right and an adjacent vessel (curved arrow) on the left, which is expanded with abnormal signal intensity consistent with extramural vascular invasion. The tumor, involved node, and vessel show high (b) and low (c) signal on DWI and ADC map, respectively, suggestive of restricted diffusion.

study, extramural depth of spread was predicted accurately with thin-section MRI (within 0.5 mm error compared to histopathologic extramural depth of spread) (31).

Extramural vascular invasion (EMVI) is another prognostic factor in rectal cancer, which is associated with high risk of local and distant recurrence (32) and poor overall survival (33). Smith et al. (34) showed that T2-weighted MRI was able to identify EMVI with a positive predictive value of 86%. In this study, recurrence-free survival rates were comparable in patients who had

documented EMVI by MRI versus histopathologic examination. Extramural vascular invasion (Fig. 12) is manifested by changes in a vessel adjacent to T3 tumor, including abnormal tumoral signal intensity within normal-sized or expanded vessel or irregular contour due to extension of tumor beyond a vessel (32–34).

Tumor to mesorectal fascia distance, which is called as circumferential resection margin (CRM), is another prognostic indicator and an independent predictor of local recurrence (Fig. 13). A positive margin is described as a

presence of tumor within 1 mm of the mesorectal fascia and can be secondary to tumor extension, tumor deposit, lymph node involvement, or extramural vascular invasion. Wibe et al. (35) have reported the impact of negative CRM in 686 patients who underwent total mesorectal excision. Local recurrence rate was 22% in patients with positive CRM (<1 mm), while 5% in patients with negative CRM (>1 mm). Role of MRI in assessing relationship of tumor to the mesorectal fascia and predicting CRM involvement has been well studied. Karatag et al. (36) showed

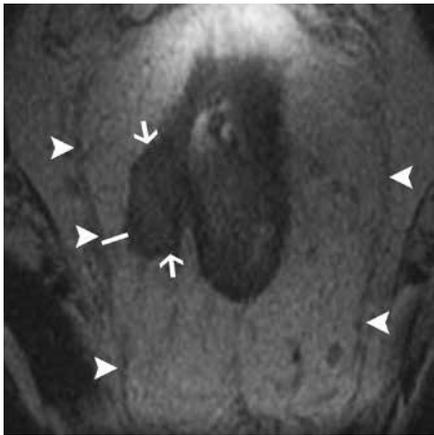


Figure 13. A 52-year-old male with pT3 rectal carcinoma. Axial, T2-weighted MR image obtained with an endorectal coil (not seen) shows rectal carcinoma (arrows) extending into the mesorectal fat, but not invading the mesorectal fascia (arrowheads). Tumor to mesorectal fascia distance (straight line) is another prognostic indicator; a short tumor to mesorectal fascia distance is the most important predictor of local recurrence.

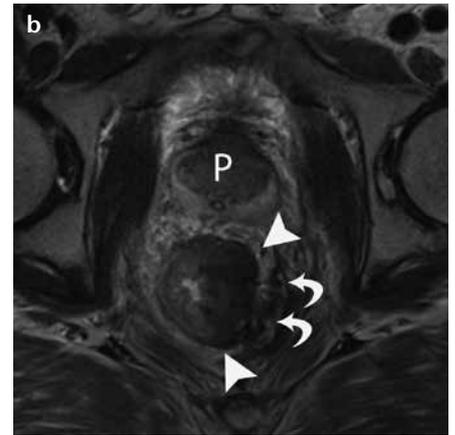
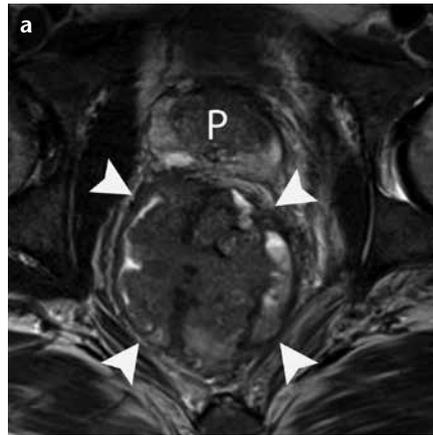


Figure 14. a, b. A 50-year-old male with rectal carcinoma. Axial T2-weighted image (a) shows a large, heterogeneous, rectal mass (arrowheads) invading the mesorectal fascia and peritoneal reflection consistent with T4 disease. Axial T2-weighted image (b) following chemoradiation shows that the tumor is markedly smaller (arrowheads) in size and low in signal intensity. Diffuse high signal intensities (curved arrows) in the perirectal soft tissues are due to edema, and low signal intensity foci adjacent to the rectum likely represents fibrosis. Note prostate gland (P) anteriorly.

that phased-array coil MRI had 95.8% accuracy for determining CRM involvement and negative predictive value was 100%. Al-Sukhni et al. (37) recently reported a meta-analysis of 21 studies where MRI with phased-array coil was found to have 94% specificity (range, 88%–97%) for predicting CRM involvement. According to Beets-Tan et al. (38) tumor-free margin of ≥ 1 mm can be predicted when tumor to CRM distance is ≥ 5 mm on the phased-array coil MRI. In a more recent prospective multicenter study, tumor to CRM distance of ≥ 1 mm in high-resolution MRI was in agreement with the pathological examination in 94% of patients (39). Similarly, Taylor et al. (40) suggested that using a greater cutoff would not increase the accuracy of MRI to predict CRM involvement.

Accuracy of MRI for predicting CRM involvement might differ according to the tumor location. According to Peschard et al. (41), MRI was in agreement with pathological CRM involvement in 22% of patients with low anterior rectal tumors, 83% of patients with low posterior rectal tumors, and 100% of patients with mid-rectal tumors. When patients with low anterior rectal cancer were excluded, the overall agreement was 90%, with 100% sensitivity and 86% specificity. The authors postulated that the presence of

rather thin perirectal fat anterior to the rectum might limit the ability of MRI to detect anterior mesorectal fascia. Also the proximity of low anterior rectal wall to seminal vesicle in men and posterior vaginal wall in women might contribute to the poor performance of MRI in detection of CRM involvement in low anterior tumors (41).

Preoperative detection of metastatic lymph nodes is highly challenging for radiologists, and there is no ideal imaging method for this purpose. Presence or absence of involved lymph nodes and number and location of metastatic nodes affect prognosis (42) and have become an important factor to determine whether patients will require neoadjuvant chemoradiation and to decide the type of surgery (43). Mesorectal nodes are often first to be involved (44), however, rarely skip metastases to obturator or iliac chain can occur (45). In normal individuals, there should be no nodes within the mesorectal fascia and any node larger than 5 mm is considered to be involved, although size is not a good criterion to identify involvement as smaller nodes can be involved with metastatic disease (27, 46–48). In addition to size, borders and signal intensity of nodes should be evaluated, and nodes with irregular borders and mixed signal intensity should be considered

suspicious (46–48). Current literature reveals a wide range of accuracy (39%–95%) in detection of metastatic lymph nodes by MRI (14, 49–51). Bipat et al. (51) reported a meta-analysis of ninety studies where MRI was found to have 66% sensitivity (range, 54%–76%) and 76% specificity (range, 59%–87%) for detecting lymph node involvement. Some authors have looked into combined endorectal and phased-array coil MRI for detection of nodal metastasis. Blomqvist et al. (52) reported 83% sensitivity and 74% specificity with combined MRI in a study of 19 patients. In a more recent study Tatli et al. (7) reported 85% sensitivity and 69% specificity with combined endorectal and phased-array coil MRI.

Restaging after neoadjuvant chemotherapy

Studies utilizing MRI following chemoradiation have not shown very promising results because of lower accuracy. Fibrosis, desmoplastic reaction, edema, and inflammation are factors leading to downstaging or overstaging of rectal cancers following chemoradiotherapy (Fig. 14) (53). In a recent study by Chen et al. (54) MRI accuracy was 52% in T staging and 68% in N staging. Tumors may significantly decrease in size and signal intensity and may not be visible on T2-weighted images fol-

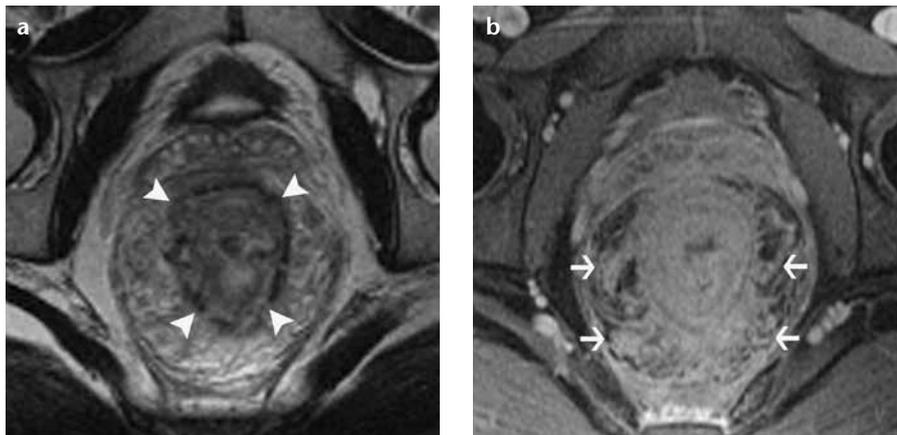


Figure 15. a, b. A 32-year-old male with mucinous type invasive adenocarcinoma. Axial, T2-weighted MR image (a) obtained with pelvic phased-array coil shows a circumferential rectal cancer (arrowheads). Note numerous lineonodular, intermediate signal intensities in the mesorectal fat. Axial T1-weighted image (b) following intravenous gadolinium clearly shows enhancement suggestive of tumor extensions (arrows).

lowing chemoradiation. A tumor volume reduction of more than 75% was significantly associated with pathologic complete response and higher disease-free survival rate (55). Both residual tumor and fibrosis may appear as decreased signal intensity areas, and DWI may help to differentiate residual viable tumor from fibrosis (56, 57).

How to report MRI

The tumor variables that should be included in a radiological report are the three-dimensional size, appearance (circular, polypoid, or ulcerated), signal intensity (T1- and T2-weighted), and location (distance between the lower edge of the tumor and the anorectal junction-superior aspect of the anal sphincter) of the tumor, T staging (T1, T2, T3, T4), lymph node involvement (N1, N2), depth of tumor invasion, CRM and EMVI (for T3 tumors), pelvic organ invasion, as well as distant metastases.

Recent advances in MRI

Recent introduction of 3.0 T MRI has increased SNR, increased resolution, and decreased alternating current time compared to 1.5 T MRI (58). There is a growing literature on use of 3.0 T MRI in the local staging of rectal carcinoma (56–58). Winter et al. (59) analyzed 23 patients who underwent 3.0 T MRI and reported 100% accuracy for determining sphincter-saving resectability, 95% and 91% accuracy for T and N staging, respectively. Kim et al. (60) revealed

similar results on 42 rectal cancer patients who were evaluated with 3.0 T MRI (84%–90% accuracy for N staging, 85%–86% accuracy for mesorectal extension). Zhang et al. (61) reported 92% accuracy for T staging and 96.9% accuracy for determining sphincter-saving resectability. Currently, pelvic phased-array coil MR imaging at 3.0 T using high-resolution imaging protocol is generally considered the most accurate tool in local staging of rectal cancer.

Invention of DWI has also improved utility of MRI in patients with rectal cancer (Fig. 12). Rao et al. (62) showed that addition of DWI to T2-weighted imaging improved accuracy of rectal cancer detection. Ichikawa et al. (63) studied high-b-value DWI in 33 colorectal cancer patients (14 of these had rectal cancer) and reported 91% sensitivity and 100% specificity. DWI has also been utilized for detection of metastatic lymph nodes in rectal cancer. Ono et al. (64) reported 80% sensitivity, 76.9% specificity, and 78.3% accuracy in a series of 27 colorectal cancer patients (10 of these had rectal cancer). A more recent study on 129 patients showed 93% sensitivity, 81% specificity, and 87% accuracy in metastatic lymph node detection with combination of DWI and conventional MRI (65). DWI MRI has also been used to predict pathologic response after chemoradiation. Engin et al. (57) showed that increase in apparent diffusion coefficient can predict therapy

response. In many centers, DWI is now being used in routine MRI protocol as an adjunctive to T2-weighted images.

Dynamic contrast-enhanced MRI has been used in rectal cancer patients both for predicting response to therapy and for evaluation after neoadjuvant treatment (Fig. 15). Kremser et al. (66) applied dynamic T1 mapping as a predictor of post-chemoradiotherapy outcome. Gollub et al. (67) showed that dynamic contrast-enhanced MRI is reliable in predicting pathological complete response after chemotherapy; the authors suggested that this could help identify patients with favorable risk in whom a more conservative approach could be preferred to radical resection. However, the benefit of using intravenous gadolinium in the staging of rectal cancer is still debated, and gadolinium use is not recommended by some groups (20, 21).

A promising technique has been incorporated into MRI to help detection of lymph node metastasis. This technique uses a unique contrast agent, ultrasmall superparamagnetic iron oxide (USPIO), which undergoes phagocytosis by macrophages in normal lymph nodes. T2* images are obtained 24 hours after USPIO injection and reduced signal is accepted as normal whereas loss of signal indicates involvement of the lymph node. Koh et al. (68) studied this technique on 25 patients and reported improved accuracy with 65% sensitivity and 93% specificity. Although preliminary studies suggested better sensitivity and specificity with USPIO, further studies with larger patient population are required in order to elucidate the exact role of this technique. In addition, USPIO has not been approved by Food and Drug Administration for clinical use in the USA.

Conclusion

Current management of rectal cancer includes preoperative imaging for staging, followed by presurgical chemoradiotherapy for appropriate patients. This approach has lowered local recurrence rate and improved survival. MRI can be reliably used in local staging of rectal cancers to help select the appropriate patients for preoperative chemoradiotherapy and decide the ap-

appropriate surgical method. However, in order to achieve the desired accuracy and clinical benefit, an appropriately tailored imaging protocol must be utilized and prognostic factors must be carefully assessed and reported in detail.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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