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SPECIAL SECTION: RECTAL CANCER

Rectal cancer MR staging: pearls and pitfalls at baseline examination

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Abstract
In recent years, rectal MRI has become a central diagnostic tool in rectal cancer staging. Indeed, rectal MR has the ability to accurately evaluate a number of important findings that may impact patient management, including distance of the tumor to the mesorectal fascia, presence of extramural vascular invasion (EMVI), presence of lymph nodes, and involvement of the peritoneum/anterior peritoneal reflection. Many of these findings are difficult to assess in nonexpert hands. In this review, we present a practical approach for radiologists to provide high-quality interpretations at initial baseline exams, based on recent guidelines from the Society of Abdominal Radiology, Rectal and Anal Cancer Disease Focused Panel. Practical pearls and pitfalls are discussed, focusing on optimization of technique including, patient preparation and protocol recommendations, interpretation, and essentials of reporting.

Keywords Rectal cancer · Staging · MRI · Protocol · Reporting

Introduction

Rectal MR has become an essential diagnostic tool in rectal cancer staging. In contrast to colon cancer, where surgical resection and pathology determine local staging, rectal cancer is staged clinically, with imaging serving as an important element. For locally advanced tumors, the current treatment algorithm includes neo-adjuvant chemoradiation prior to surgical resection to minimize local recurrence [1]. Rectal MR now plays a central role in determining local tumor stage. Thus, staging for rectal cancer has evolved from a pathologic-based system (i.e., determined at surgical resection) to a clinically based one to effectively stratify patients for appropriate management.

In the United States, a paradigm shift has occurred in recent years with regards to the approach to local staging for rectal cancer, whereby rectal MR has replaced endoscopic ultrasound (EUS) in most instances. Both modalities are equivalent for assessment of tumor spread beyond the muscularis propria (i.e., T2 versus T3 status), however, MR holds several advantages over EUS for locally advanced rectal cancers (LARC), which represent the majority of cancer presentations [2, 3] Rectal MR has the ability to characterize lesion size, morphology, tumor margin and other characteristics helpful to surgical planning. In addition, this modality is able to accurately characterize a number of important findings that may impact potential radiation and chemotherapeutic decisions, including proximity of the tumor to the mesorectal fascia, presence of extramural vascular invasion (EMVI), presence of extramesorectal pelvic lymph nodes, and involvement of the peritoneum/anterior peritoneal reflection. Many of these findings are either challenging to assess, or are beyond the scope of endoscopic ultrasound. Because of these advantages, MR has become the preferred modality in the initial staging of rectal cancer, particularly as part of a multi-disciplinary approach [4].

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This comprehensive review examines the performance, interpretation, and reporting of rectal MR at initial rectal cancer staging. Our intent is to present a practical resource for radiologists to provide high-quality interpretations at initial baseline exams. Specific, practical tips are discussed, focusing on optimization of technique, including patient preparation and protocol recommendations, interpretation, and essentials of reporting. Evidence-based criteria for various imaging findings will be discussed. Pearls and pitfalls will be highlighted to help optimize accurate interpretation and provide an accurate roadmap to direct subsequent management.

Multi-disciplinary approach and rectal MR: relevant clinical information to know

Rectal cancer staging and treatment has moved towards a multi-disciplinary approach in the recent years. Initiatives such as National Accreditation Program for Rectal Cancer (NAPRC) recognize that improved communication between specialties leads to better decision-making and outcomes [4] From a diagnostic perspective, the two-way communication in a multi-disciplinary conference setting leads to improved interpretations [5]. Equivocal imaging findings can be placed in the context of the other clinical information to increase confidence of a positive or negative finding.

For the radiologist, it is helpful to be aware of relevant clinical information and patient history during interpretation of the MRI examination. Typically, a patient has had a mass identified at colonoscopy (biopsy-proven as adenocarcinoma) and presents for local staging. In this case, the mass is usually easily seen for further characterization. Correlation with other clinical information such as the digital rectal exam can be helpful. For low tumors, the surgeons' perspective of the inferior margin of the tumor in relation to the anorectal ring or their assessment of fixation of the tumor to adjacent structures by exam can be helpful when interpreting the MR images.

Other common indications for rectal MR staging include post-polypectomy assessment of the rectal wall and mesorectum (particularly in the setting of malignant features at pathology); and evaluation of a large carpet lesion or suspicious mass with high-grade dysplasia, but no malignancy at pathology (here, the concern is that there is cancer which was not sampled at biopsy). In both situations, additional clinical information may be helpful. In the former, it may be difficult to determine where the polyp was located prior to resection. Information such as previous polyp location is helpful to direct attention to specific areas on the MR exam to increase confidence that an area has been well evaluated. In the latter situation, knowledge of the physical characteristics of the lesion either at endoscopy or digital rectal exam is helpful—a soft pliable nature is less likely to represent a malignant mass extending to adjacent soft tissues. In all situations, information regarding placement of an endoscopic clip (either for bleeding or localization) is helpful for the MR reader. If the clip remains, the MR may need to be temporarily deferred, as the artifact from the clip could preclude evaluation of the wall in this region.

Technique and MR protocol

Optimization of technique is critical to produce high-quality, accurate interpretations. The following section follows the Society of Abdominal Radiology (SAR) guidelines regarding the recommended patient preparation and imaging protocol [6, 7].

Patient preparation

- The administration of rectal contrast or rectal gel for staging MR remains an area of controversy with variable use among academic centers. The benefits of intra-rectal gel include a possibly improved ability to localize tumors (particularly small lesions). Pseudothickening of a nondistended, normal rectal wall can at times mimic tumor. Thus, without gel use, it may be challenging to (a) identify tumor edges and (b) determine the exact location to target when looking for tumor spread beyond the muscularis propria. On the other hand, there has been concern that rectal distension could artificially decrease the MRF distance and lead to incorrect interpretations as reported in a prior study in 2006 [8]. However, a recent study has shown that although the distance between normal rectum and the MRF can be decreased with rectal distention, where the rectal wall is more fixed, there is no significant change at the level of the tumor. This suggests that the distance can accurately predict the status of the circumference resection margin [9]. One of the other pitfalls of rectal gel is is that the high T2 signal of the gel may cause T2 shine through effects on DWI which may lead to difficult evaluation of DWI especially at 3T and after CRT. Given the lack of consensus in the literature and expert opinion, the SAR DFP position is that the use of intra-rectal gel remains up to the specific institution. Similarly, the use of enemas remains variable. Recently, the use of a microenema has shown promise in reducing susceptibility artifact related to luminal gas during diffusion-weighted imaging [10].
- The use of a spasmolytic agent (Glucagon) to prevent artifacts caused by bowel motion is also an area of disagreement. A recent SAR survey showed that slightly less

than half of the US academic centers used spasmolytics as a part of their MR staging protocol [7]. It may be more helpful in the setting of rectal gel use which may promote peristalisis. Finally, 3 h fasting in advance of the MRI also decreases small bowel movement.

- The phased-array surface coil must be placed on the pelvis in such a way that the lower edge of the coil comes to lie below the pubic bone. For low-rectal tumors, the lower edge must lie at least 10 cm below the symphysis pubis and the upper limit should be no higher than the sacral promontory. An endorectal coil is not necessary and not recommended.

Protocol

The exam should use high-resolution 2D fast spin echo T2-weighted sequences in the sagittal, axial, and coronal planes. For patients with low-rectal cancers, a high-spatial-resolution T2 coronal sequence angled to the anal canal is added to optimally image the levator muscles, the sphincter complex, the intersphincteric plane, and the relationship to the rectal wall.

DWI is usually incorporated to the standard protocol as it might improve tumor and node detection.

The use of an unenhanced large field of view T1WI sequence is recommended for node detection and bone marrow abnormalities in the pelvis.

TIP for the High T2 axial sequence angled perpendicularly to the tumor

- Must be angled perpendicular to the tumor. The invasive center (the part of the tumor extending the most within the mesorectal fat) of the tumor must be detected on the sagittal plane. It is at this level where the sequence must be angled perpendicularly to the tumor.
- In some case, it may be necessary to obtain more than one sequence angulation for optimal assessment in bulky tumor masses.
- A slice thickness of 3 mm or less is recommended [7, 11].

Not recommended

- There is general consensus that intravenous contrast medium administration does not improve staging of rectal tumors by MRI and is not a required element [12, 13]. However, it potentially may be helpful in interpretation. In some series, intravenous contrast has been shown to improve the detection of tumors and increase the accuracy of MRI for diagnosing T3 tumors and locoregional extensions [14, 15].
- Since differentiation with the T2-weighted sequence is based on the contrast between the high-signal-intensity mesorectal fatty tissue and the rather low-signal intensity of the tumor, fat suppression sequences are not recommended.
- The use of 3D T2WI sequence is not recommended due to longer times required to acquire this sequence and the not uncommon motion artifacts.

Reporting

Multiple studies have shown the added value of structured reporting in rectal cancer [16–18]. Multiple proforma are available online [7, 11]. A mnemonic "DISTANCE" (DIS: for Distance from the *I*nferior part of the tumor to the transitional *S*kin, T: for T staging, A: for Anal complex, N: for Nodal staging, C: for Circumferential Resection Margin, E: for Extramural vascular invasion) was proposed to quickly remember each critical part of the MRI report [19]. In this following section, we detail each important feature which needs to be included in the MRI report according to the SAR guidelines [7, 11].

Primary tumor: morphology, location, and characteristics

Rectal anatomy (Fig. 1)

The rectum can be divided into three parts: the lower rectum (0–5 cm), the middle rectum (> 5–10 cm), and the upper rectum (> 10–15 cm) [20]. The anal verge begins where the skin stops and where the anal mucosa begins [21, 22]. The anorectal junction refers to the point of angulation between the lower rectum and the anal canal, and at the level of the puborectalis sling. At the anorectal junction, the muscularis propria of the rectum changes whereby the circular layer thickens and becomes the internal sphincter. The external sphincter complex is composed of the most inferior part of the levator ani muscle, the puborectalis sling, and the external sphincter muscles [21, 22] (Fig. 2).

The rectum is surrounded by fatty tissue known as mesorectal fat or mesorectum [20]. The mesorectal fascia acts as a natural barrier to tumor spread and also represents the circumferential resection margin (CRM) (Fig. 3) [20]. The mesorectal fascia represents the surgical excision plane in total mesorectal excision (TME). The CRM only applies to the non-peritonealized lower and mid-rectum. Indeed, the peritoneal reflection borders the upper third of the rectum anteriorly. On MRI, the anterior peritoneal reflection is recognized on mid-sagittal T2-weighted imaging (T2WI) as a thin hypointense line just posterior to the uterocervical junction [23]. The middle third of the rectum is partly covered by the peritoneum anteriorly. The lower third of the rectum is extra-peritonal, and it is bordered anteriorly by the

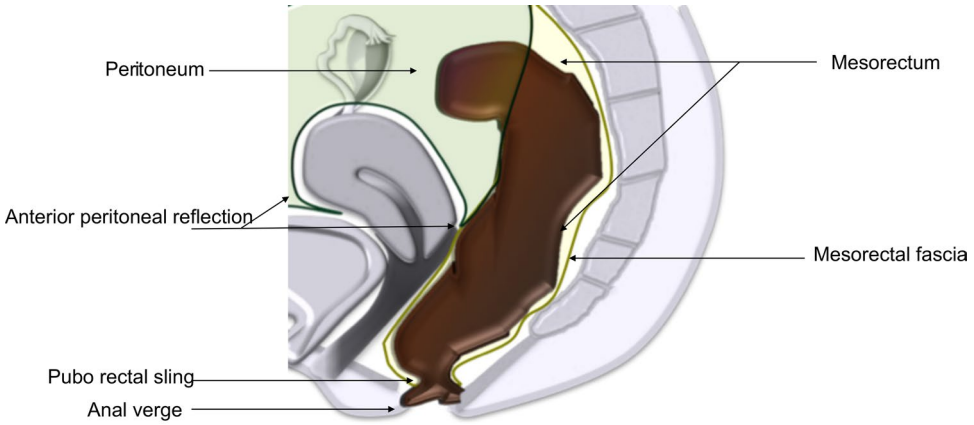

Fig. 1 Drawing describing the rectal anatomy: The anal verge begins where the skin stops and where the anal mucosa begins. The anorectal junction refers to the point of angulation between the lower rectum and the anal canal, and the point of insertion of the puborectalis sling. The mesorectal fascia acts as a natural barrier to tumor spread and also represents the circumferential resection margin (CRM). The mesorectal fascia represents the surgical excision plane in total mesorectal excision (TME). The CRM only applies to the non-peritonealized lower and mid-rectum. Indeed, the peritoneal reflection borders the upper third of the rectum anteriorly

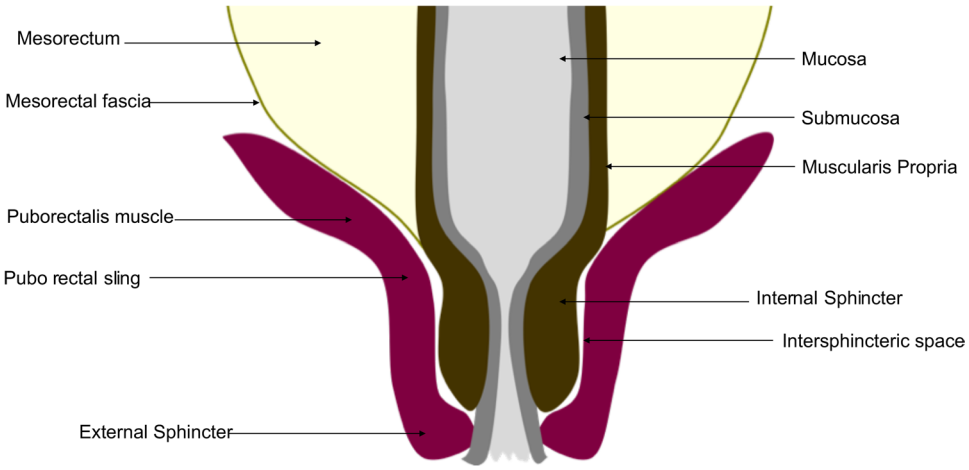

Fig. 2 Drawing describing the anal canal anatomy. The anorectal junction refers to the point of angulation between the lower rectum and the anal canal, and the point of insertion of the puborectalis sling. At the anorectal junction, the muscularis propria of the rectum changes: The circular layer thickens and becomes the internal sphincter. The external sphincter complex is composed of the most inferior part of the levator ani muscle, the puborectalis sling, and the external sphincter muscles

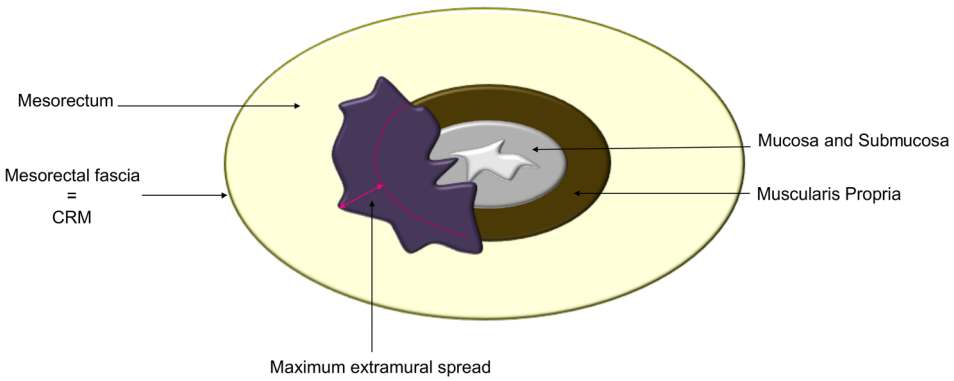

Fig. 3 Drawing showing the mesorectum and rectum relationship with a rectal tumor. The mesorectal fascia acts as a natural barrier to tumor spread and also represents the circumferential resection margin (CRM). The mesorectal fascia represents the surgical excision plane in total mesorectal excision (TME). The extramural spread is measured from the level of the supposed muscularis propria (pink dashed line) to the maximal point of mesorectal involvement (pink arrow). The tumor is represented in purple

rectoprostatic fascia in males and follows the course of the vagina in females (Fig. 1).

Tumor measurement

Measurement of tumor height is made from the anal verge up to the lowermost portion of the tumor. Measurement of tumor height is also recorded from the anorectal junction to the lowermost portion of the tumor. Tumor length is the measurement of the actual length of the tumor from the proximal to the distal ends of the tumor. The management of the tumors in the lower third of the rectum, especially those involving external sphincter, is different from the middle and upper third cancers; therefore, the precise measurement of tumor distance to anal verge and top of external sphincter/anorectal junction is critical.

Pearls for tumor height and length measurement

- Measurement of tumor height and length is usually performed on sagittal T2WI. In case of low-lying tumor, coronal sequence parallel to the anal canal enables the radiologist to accurately measure the short distance between the lower part of the tumor and the anal verge/anorectal junction.
- The relationship to the anterior peritoneal reflection (cf above) must be recorded as tumor lying above the anterior peritoneal reflection may be treated as sigmoid cancer.

On MRI, the anterior peritoneal reflection is recognized on mid-sagittal T2-weighted imaging (T2WI) as a thin hypointense line just posterior to the uterocervical junction [23] (Fig. 1).

Tumor morphology

A rectal tumor can present as annular or semiannular lesion, polypoid lesion, and flat tumor. The most common type is usually an annular or semiannular mass.

Rectal tumor may contain mucin. Mucinous tumors carry poor prognosis and a high risk of spillage during surgery [24, 25].

TIP: Mucinous tumor demonstrate T2 hyperintense signal on T2W.

T staging

Rectal cancer staging is based on the TNM (tumor, node, and metastasis) system.

In TNM classification, T1 disease shows invasion through the mucosa and submucosa with no extension into the muscularis propria. T2 disease shows invasion into the muscularis propria. T3 disease shows invasion through the muscularis propria into perirectal tissues. T3 a, b, c, and d categorize the depth of extramural invasion, as follows: < 1 mm = T3a; 1–5 mm = T3b; > 5–15 mm = T3c, and > 15 mm = T3d. T4 disease is classified into T4a if the tumor involves visceral peritoneum or anterior peritoneal reflection, and T4b if the tumor invades adjacent organ [26]. A number of histopathologic studies have shown that T3 tumors with more than 5 mm mesorectal invasion have a cancer-specific 5-year survival rate of approximately 54% [27]. On the other hand, for tumor spread of 5 mm or less, the cancer-specific survival exceeds 85% [28–34]. As such, the depth of extramural spread must be reported and divided between T3a,b,c and d stage. The overall reported accuracy for T staging using a pelvic phased-array coil ranges from 59% to 95% [28–34]. The identification and staging of rectal cancers at MR imaging is largely based on differences in T2 signal intensity between the tumor, submucosa, muscular layer, and mesorectum (Figs. 3, 4, 5 and 6).

Pearls for T staging

- T stage must be assessed on planes strictly perpendicular to the tumor. Incorrect prescription of the acquisition plane leads to blurring of the muscularis propria and may lead to overstaging (Fig. 7).
- In differentiating between stage T2 and T3 tumors, the crucial criterion is involvement of the perirectal fat. In stage T3, the T2 low-signal intensity of the muscularis propria is completely disrupted and cannot be clearly distinguished from the perirectal fat: The tumor spreads beyond the muscularis propria into the perirectal fat with a broad-based bulge or nodular appearance (Figs. 5 and 6).
- Outer longitudinal layer of the muscularis propria can be focally disrupted by small vessels penetrating the wall; this does not necessarily indicate tumor invasion.
- When the tumor is not visible on sagittal T2 WI: obtaining high-resolution images of the entire length of the rectum and adding DWI may help localize the mass.
- The depth of extramural spread must be measured in millimeters beyond the outer edge of the longitudinal muscular layer (Figs. 3, 5 and 6).

Pitfalls

Most staging failures occur in the differentiation between T2 and borderline T3 lesions (15). Indeed, it is sometimes difficult to distinguish true mesorectal tumor invasion from desmoplastic reactions [35]. Staging failures can frequently be attributed to the use of thicker sections and lower resolution techniques. Desmoplasia associated with ulcerating tumors at the invasive border is typically seen as fine

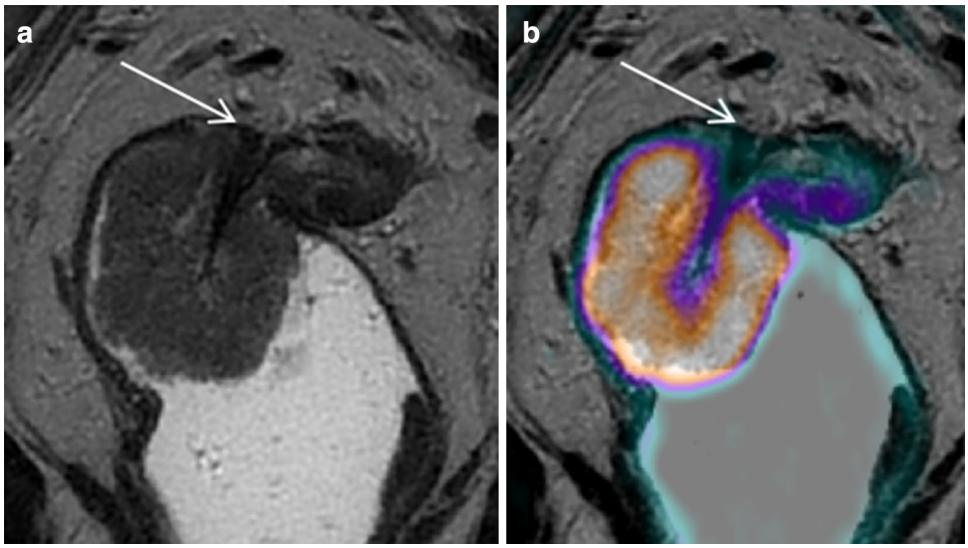

Fig. 4 Axial T2WI (**a**) shows a large polypoid tumor with the stack of the tumor lying at its superior aspect (arrow). At this level, the muscularis propria is intact in keeping with a T2 stage tumor. Note Fused DWI-T2WI nicely highlight the tumor delineation (**b**)

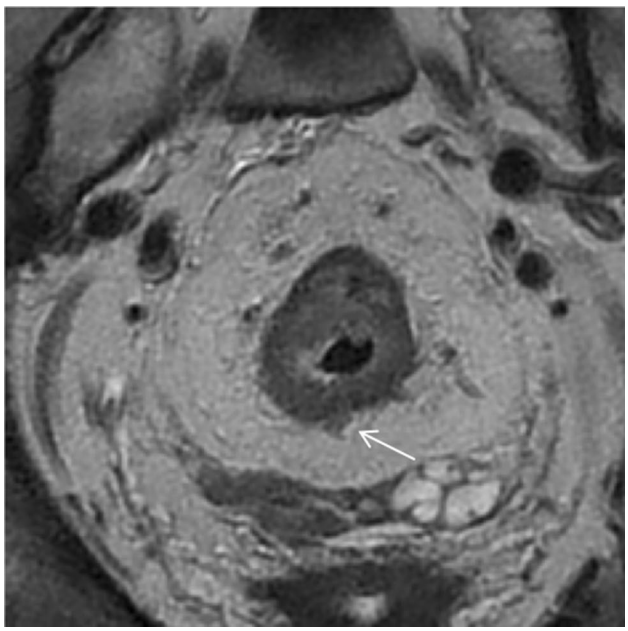

Fig. 5 Axial T2WI shows a rectal tumor disrupting the muscularis propria and extending into the mesorectal fat (arrow). The T staging was T3b

low-signal-intensity spicules on T2WI. These spicules do not show restricted diffusion. Tumor extension into the mesorectum, on the other hand, forms thicker, intermediate-signal-intensity nodular bands with restricted diffusion and disruption of muscularis propria.

Specific issues related to low-lying tumors

Low-rectal tumors are associated with higher rates of positive resection margins, higher local recurrence rates, and poorer survival [36–40]. This is largely due to anatomic considerations and the fact that the mesorectal envelope tapers and narrows at this level. Preoperative CRT in locally advanced low-rectal tumors has been shown to increase the sphincter preservation rate and disease-free survival [41–43]. A tumor that would have previously required an abdominoperineal excision may instead be treated with ultralow resection and coloanal anastomosis. [44].

The pre-treatment MRI must be able to define the location of the tumor relative to the sphincter complex to determine which patients need to receive CRT before surgery.

Pearls for staging low-lying tumors

- High-spatial-resolution T2W FSE coronal imaging must be added to optimally depict the tumor relationship with the levator and puborectal muscles, sphincter complex, and intersphincteric plane.
- The first question to answer in low-lying tumors is where the lower edge of the tumor is located in relation to the puborectalis sling: if the tumor is located above the puborectalis sling, sphincter involvement can be easily excluded.
- When the tumor extends below the puborectalis sling: three areas have to be evaluated and reported on [45] (Fig. 2):

  1. The internal sphincter
  2. The intersphincteric plane
  3. The external sphincter

- Levator, puborectalis muscles or external sphincter involvement are considered as Stage T4 (Fig. 8).

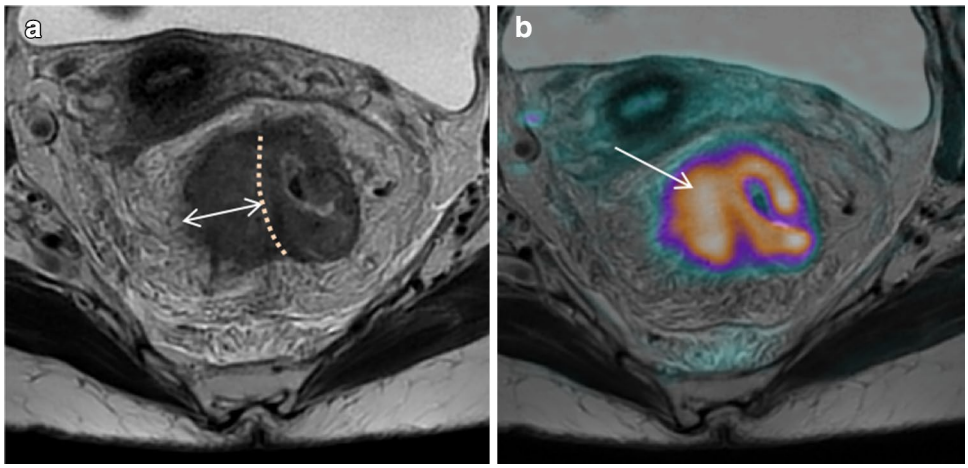

Fig. 6 Axial T2WI (**a**) shows a rectal tumor with a large extramural spread. The extramural spread is measured from the level of the supposed muscularis propria (dashed line) to the maximal point of mesorectal involvement (arrow). In this case, the tumor is staged T3d. Fused DWI-T2WI (**b**) shows high b1000 signal intensity within the tumor and its extramural spread (arrow)

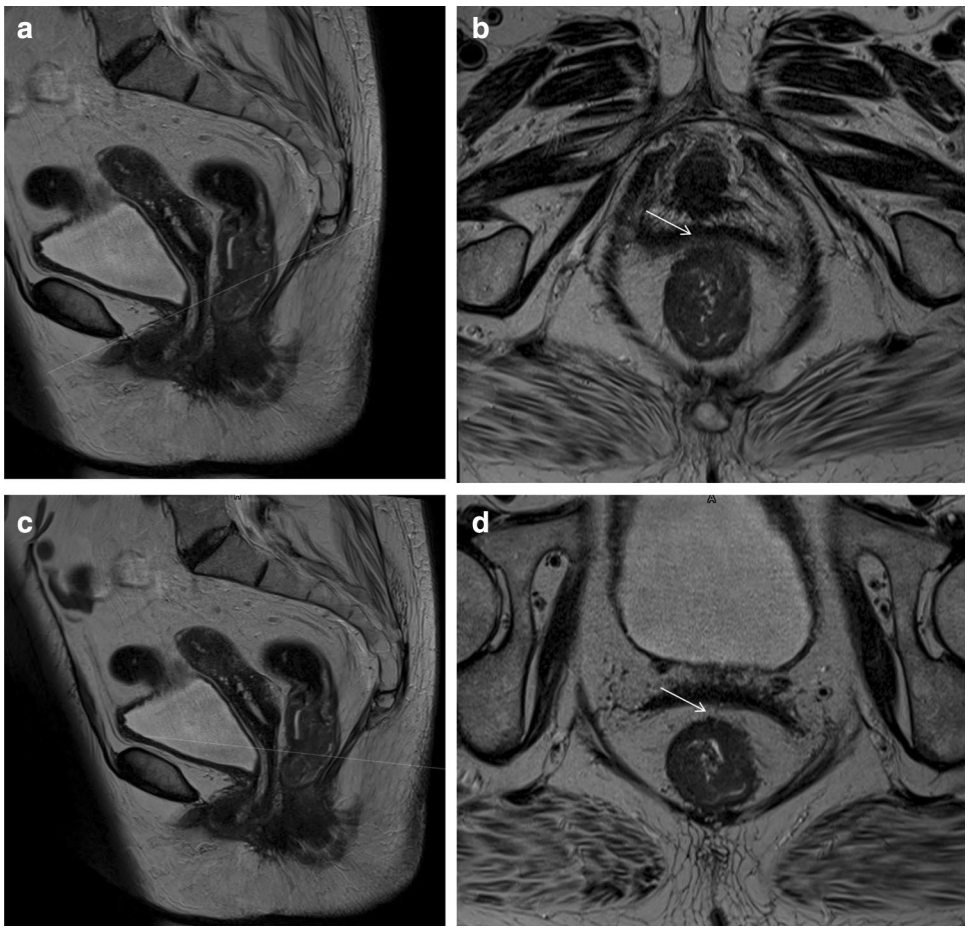

Fig. 7 Sagittal T2WI (**a**) with localizer shows that the images were incorrectly angled and the tumor was reported to be involving the posterior wall of the vagina on the axial T2WI (**b**, arrow). A repeat study with appropriate angle (sagittal T2WI with white line as localizer **c**), shows on axial T2WI (**d**, arrow) no invasion of the vaginal wall

Extramural venous invasion (EMVI)

EMVI is defined as tumoral invasion of the venous structures beyond the muscularis propria [19]. This adverse feature of rectal cancer was first described by Talbot et al. in 1981 in post-mortem pathology. However, it remained largely unaddressed by MRI until 2003, when it was first described by Brown et al. as a serpiginous extension of tumor signal within a vascular structure [46]. A 5-point model of classification of EMVI was subsequently developed by Smith et al. to determine possibility of EMVI based on a comprehensive assessment of four essential elements including the pattern of tumor margin, location of the tumor relative to major vessels, caliber and border of the vessel, and signal intensity

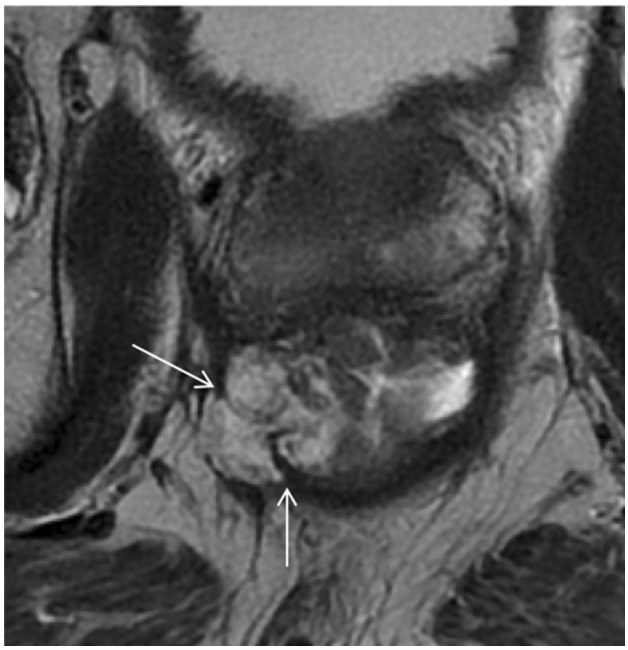

Fig. 8 Axial T2WI shows a low-lying mucinous tumor (bright T2 hypersignal) disrupting the puborectal muscle on the right (arrows) and extending within the ischioanal fossa

changes in a vein [47–49]. A modified version of this system was introduced by Jhaveri et al. afterwards, which is explicitly described in Figs. 9 and 10 [50]. Based on this classification, lower scores (0 and 1) are unlikely to be associated with pathologic EMVI (pEMVI), whereas higher scores (3 and 4) are interpreted as definite MRI-depicted EMVI (mrEMVI). Venous structures classified as score 2 mrEMVI are considered equivocal [47–51], and contrast injection may further assist radiologists in more precise categorization of these uncertain cases by recognizing whether or not a filling defect is present in the vessel [50].

EMVI detected either preoperatively in MRI (mrEMVI) or postoperatively in pathologic specimens (pEMVI) is an independent prognostic predictor of adverse outcomes in rectal cancer such as local tumor recurrence, synchronous and metachronous distant metastases and overall mortality [19, 48]. For this reason, many of the international guidelines suggest that detection of definite EMVI before any intervention or persistence of the tumor inside vessels after chemoradiotherapy (CRT) should be considered as an indication for neoadjuvant CRT for the former and further intensified courses of the treatment for the latter [47, 50, 52]. This approach could eventually mitigate the risk of unfavorable events, specifically in stage II of rectal cancers, in which other high-risk features of the cancer are normally absent.

Pearls for EMVI detection

- Signs suggestive for EMVI are as follows: (a) Presence of tumor signal intensity within a vascular structure, (b) Expanded vessels, and (c) Tumoral expansion through and beyond the vessel wall, disrupting the vessel border.
- EMVI may be contiguous (adjacent to the tumor), or discontiguous (separated from the tumor).
- EMVI must be associated with tumors that are at least category T3. A stage T1 or T2 has no potential for invading extramural vessels.
- If EMVI is present, assessment of the relationship between the involved veins and the mesorectal fascia (i.e., whether the EMVI is within 1 mm of the fascia) needs to be made.

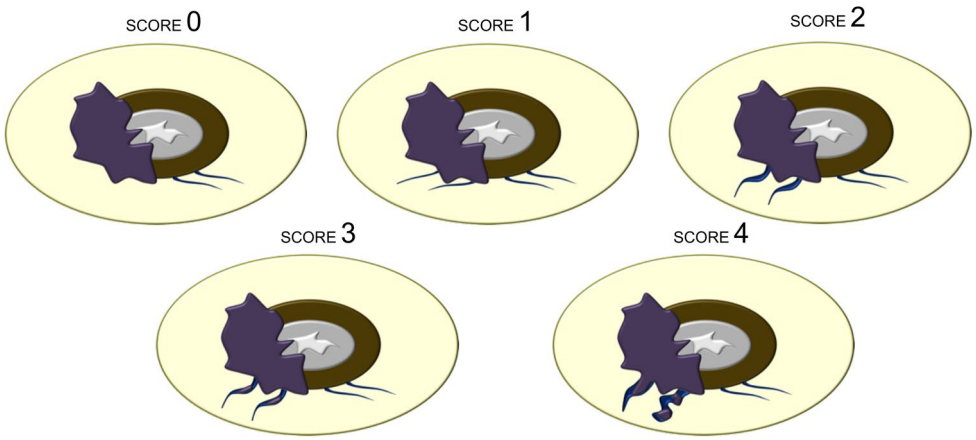

Fig. 9 Extramural venous invasion (EMVI) scoring system for MRI from Jahveri et al. EMVI status is negative for score 0–1, equivocal for score 2, and positive for score 3–4. **a** Score 0 denotes no vessel in vicinity of extramural tumor penetration. **b** Score 1 denotes vessels with normal caliber and without definite tumor signal intensity. **c** Score 2 denotes slightly expanded vessels without definite tumor signal intensity. **d** Score 3 denotes intermediate tumor signal intensity within expanded vessels. **e** Score 4 denotes obvious irregular vessel contour or nodular expansion of vessel by definite tumor signal

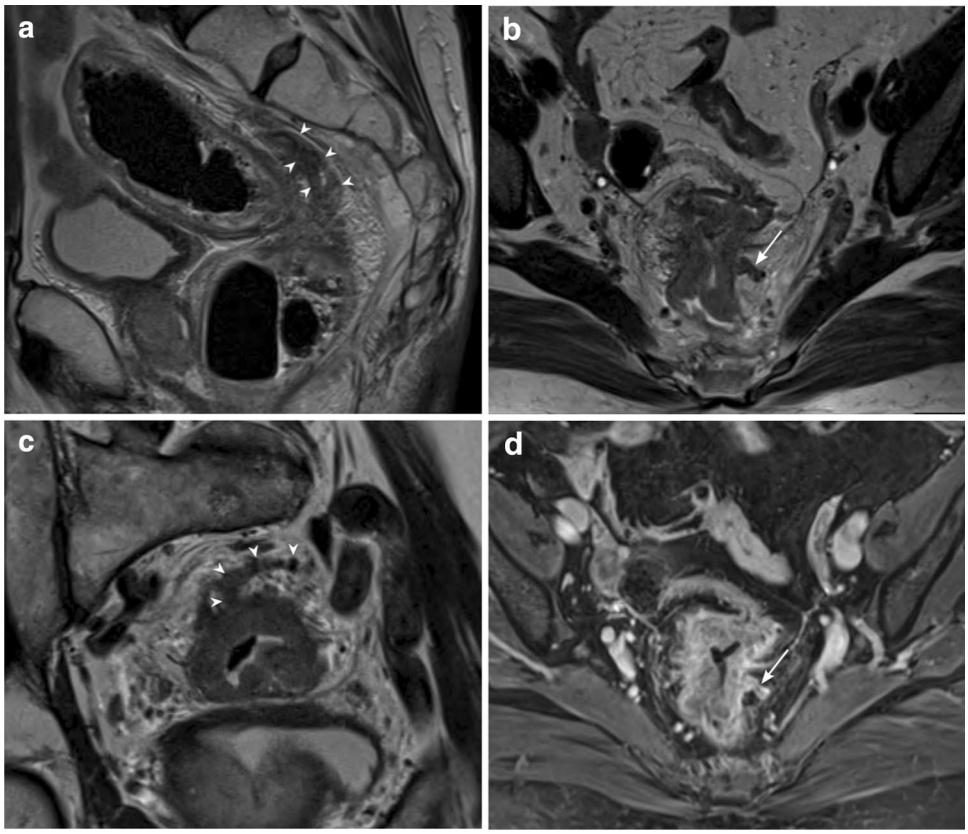

Fig. 10 Sagittal (**a**) and axial T2WI (**b**) shows an irregular expanded vessel with intermediate tumor signal intensity in keeping with definite extramural venous invasion (arrowhead and arrow). Axial oblique T2WI (**c**) show another irregular expanded vessel with intermediate tumor signal intensity feeding the tumor consistent with extramural venous invasion (arrowhead). Contrast injection may further assist radiologists in more precise categorization of these uncertain cases by recognizing whether or not a filling defect is present in the vessel (post contrast T1FS image) (**d**)

Pitfalls of EMVI in MRI

A potential pitfall of MRI is its limited accuracy in the identification of extramural and intramural vascular invasion in vessels smaller than 3 mm, in which tumor signal may not be identifiable. These vessels lack the normal signal void appearance of larger vessels; therefore, tumor invasion can only be detected in the presence of vessel expansion or irregularity [53]. In addition, misinterpretation of an EMVI as an enlarged lymph node and vice versa is a potential source of error, yet the multiplanar capability of MRI should enable radiologists to follow the suspicious lesion in different planes, resulting in more accurate distinction. Compared to post-operative pathologic detection of EMVI in routine H&E specimens, mrEMVI has comparable accuracy, and also has the advantage of detecting this feature of the tumor preoperatively. Identification of EMVI prior to surgery can assist in triaging patients towards preoperative neoadjuvant CRT [48, 49], thereby reducing the risk of tumor cell dissemination during surgery. Moreover, MRI benefits from being more consistent and reproducible which is clearly demonstrated by Siddiqui et al's meta-analysis in which mrEMVI detection prevalence has shown to be 34.6% (23.7% to 47.6%) compared to pEMVI (9% to 90%). Nevertheless, compared with novel elastin-stained pathologic assessment of specimen, MRI offers high specificity (96%) but limited sensitivity of 54% in the detection of EMVI more than 3 mm diameter [50].

Circumferential resection margin

The mesorectal fascia represents the potential circumferential resection margin (CRM) in patients undergoing TME surgery (Fig. 3). CRM involvement is an important independent prognostic factor for local recurrence and poor survival [54–56]. A potentially positive margin is defined as tumor within 1 mm of the mesorectal fascia. This applies to the main tumor, extramural vascular invasion and tumor deposit(s).

Pearls for CRM reporting

- A positive margin is defined as tumor lying within 1 mm of the mesorectal fascia.
- Anteriorly the mesorectal fat can be thin, and the rectum can be close to the CRM. In cases in which the rectum abuts the mesorectal fascia anteriorly, the tumor must be at least a stage T3 before discussing CRM involvement, as this is not relevant in T1 or T2 tumors.
- In tumor lying above the peritoneal reflection, anterior and lateral CRM involvement cannot be discussed as there is no mesorectum at this level. For example, a

tumor located at the upper rectum with peritoneal reflection involvement will be defined as T4a stage with negative CRM (Fig. 1).

Lymph node staging in rectal cancer

MRI is the gold standard for detecting potentially metastatic lymph nodes in patients with rectal cancer however, the specificity of MRI for detection of nodal metastasis in rectal cancer is only moderately accurate at this time. This is a significant shortcoming considering implications regarding treatment selection and prognosis.

The presence of nodal metastases in rectal cancer implies stage III disease and the need of intensified therapy. However, differences in overall survival have been noted when patients are stratified by the extent of nodal metastasis [16]. More detailed information about the number of nodal metastases was subsequently incorporated into further iterations of the TNM staging system for rectal cancer. Previously, three N stratifications were utilized; absence of nodal metastasis (N0), presence of 1-3 nodal metastases (N1), and presence of > 3 nodal metastases (N2). The N1 classification was further stratified into N1a, (metastasis in 1 regional lymph node), N1b (metastasis in 2–3 regional lymph nodes), and N1c (no regional lymph nodes are positive but there are tumor deposits in the subserosa, mesentery or non-peritonealized pericolic or perirectal/mesorectal tissues). N2 status was further stratified into N2a (metastasis in 4–6 regional lymph nodes), and N2b (metastasis in 7 or more regional lymph nodes). Preoperative identification and characterization of nodal metastases is critical for surgical planning, prognosis after treatment, and the decision to administer adjuvant/neoadjuvant chemoradiation [57] (Fig. 11).

Pearls for nodes reporting

- Uniform nodes smaller than 9 mm with homogeneous signal intensity are not suspicious.
- Criteria for malignant nodes includes

1. Short axis diameter ≥ 9 mm.
2. Short axis diameter 5–8 mm and ≥ 2 morphologically suspicious characteristics.
3. Short axis diameter < 5 mm and 3 morphologically suspicious characteristics Suspicious characteristics includes: Round shape, irregular border, heterogeneous signal.
4. All mucinous lymph nodes (any size).

- It is also critical to report extramesorectal lymph nodes as it may change the radiotherapy field and surgical management. This lymph node group is not removed when a regular TME is performed.

Potential pitfall 1

Sensitivity of MRI for detection of lymphatic metastases in rectal cancer is low based on size and typical appearance. Although an individual lymph node > 10 mm adjacent to a rectal cancer almost certainly represents metastatic disease, more than 50% of metastatic lymph nodes are < 5 mm in diameter. Other concerning MRI findings, including spiculated appearance and heterogeneous contrast enhancement, also have a low sensitivity [58]. This may lead to understaging of rectal cancer by MRI, and withholding of chemoradiation from patients who could benefit from it.

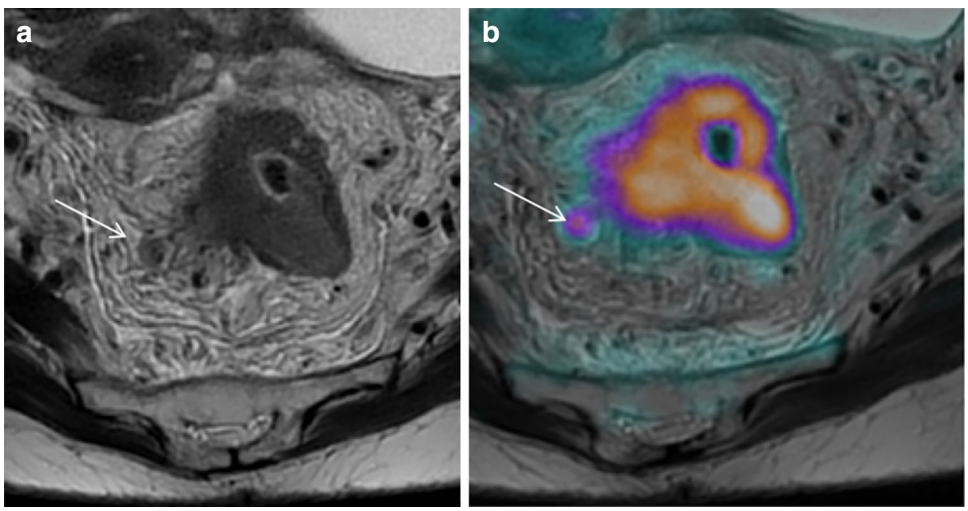

Fig. 11 Axial T2WI (**a**) shows an irregular nodes (arrow) with the same signal as adjacent tumor suspicious for nodal involvement. Fused DWI-T2WI (**b**) shows high b1000 signal intensity within the nodes (arrow) as well as the adjacent tumor. *Note* DWI helps with nodal detection but does not assess nodal malignancy

Potential pitfall 2

DWI is routinely used to increase sensitivity of lymph node staging of rectal cancer [59]. Although DWI is highly sensitive for lymph nodes detection in rectal cancer, DWI is unable to characterize lymph nodes as benign or malignant [60]. Using DWI to assess patients for lymphatic metastases in rectal cancer may, therefore, lead to overstaging and unnecessary administration of adjuvant chemoradiation.

The need for increased detail in nodal staging has spurred the development of innovative new imaging strategies to detect malignant nodes. Novel nodal contrast agents, assessment of node perfusion [61, 62], and computerized algorithms [63] are a few of the strategies currently being explored to improve accuracy. The need to obtain detailed information about the status of the mesentery and mesorectal tissues for N1c classification has also encouraged innovation such as utilization of high-resolution MRI [64] and dynamic contrast-enhanced MRI [65]. Additional sequences such fat-suppressed, gadolinium-enhanced, high-resolution 3D-GRE-T1WI showed promise for identifying metastatic nodes less than 5 mm in diameter [66]. A deeper analysis of the lymph node contrast enhancement characteristics over time and the heterogeneity observed by diffusion kurtosis imaging may yield valuable diagnostic information regarding nodal metastasis. Angiogenesis in metastatic nodes may be identified by the contrast enhancement pattern, malignant nodes are more likely to exhibit persistent enhancement, and benign nodes are more likely to demonstrate washout [67].

Conclusion

Optimal treatment of rectal cancer involves a multi-disciplinary approach with collaboration between radiologists, oncologists, surgeons and pathologists to achieve local control and decrease recurrence. MRI is currently the imaging modality that demonstrates highly accurate evaluation of patient's tumor prognosis. Standardized scanning techniques and structured reporting increase consistency and help treatment decision.

Compliance with ethical standards

Conflict of interest Disclosures for David H Kim: Shareholder for Elucent and Cellectar. The authors Stephanie Nougaret, Kartik Jhaveri, Zahra Kassam, Chandana Lall have declare that they have no conflict of interest.

References

1. Sauer R, Becker H, Hohenberger W et al (2004) Preoperative versus postoperative chemoradiotherapy for rectal cancer. N Eng J JMed 351:1731-1740
2. Horvat N, Petkovska I, Gollub MJ (2018) MR Imaging of Rectal Cancer. Radiol Clin N Am 56:75
3. Gollub MJ, Arya S, Beets-Tan RGH et al (2018) Use of magnetic resonance imaging in rectal cancer patients: Society of Abdominal Radiology (SAR) rectal cancer disease-focused panel (DFP) recommendations 2017. Abdom Radiol 43:2893-2902
4. (2017) Commision on Cancer. National Accreditation Program for Rectal Cancer Standards Manual. Am Coll Surg, https://www.facs.org/quality-programs/cancer/naprc/standards, pp 1-61
5. Ioannidis A, Konstantinidis M, Apostolakis S, Koutserimpas C, Machairas N, Konstantinidis KM (2018) Impact of multidisciplinary tumor boards on patients with rectal cancer. Mol Clin Oncol 9:135-137
6. Beets-Tan RG, Lambregts DM, Maas M et al (2013) Magnetic resonance imaging for the clinical management of rectal cancer patients: recommendations from the 2012 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. Eur Radiol 23:2522-2531
7. Gollub MJ, Arya S, Beets-Tan RG et al (2018) Use of magnetic resonance imaging in rectal cancer patients: Society of Abdominal Radiology (SAR) rectal cancer disease-focused panel (DFP) recommendations 2017. Abdom Radiol (NY) 43:2893-2902
8. Slater A, Halligan S, Taylor SA, Marshall M (2006) Distance between the rectal wall and mesorectal fascia measured by MRI: Effect of rectal distension and implications for preoperative prediction of a tumour-free circumferential resection margin. Clin Radiol 61:65-70
9. Ye F, Zhang H, Liang X, Ouyang H, Zhao X, Zhou C (2016) JOURNAL CLUB: Preoperative MRI Evaluation of Primary Rectal Cancer: Intrasubject Comparison With and Without Rectal Distention. AJR Am J Roentgenol 207:32-39
10. van Griethuysen JJM, Bus EM, Hauptmann M et al (2018) Gas-induced susceptibility artefacts on diffusion-weighted MRI of the rectum at 1.5T - Effect of applying a micro-enema to improve image quality. Eur J Radiol 99:131-137
11. Beets-Tan RGH, Lambregts DMJ, Maas M et al (2018) Magnetic resonance imaging for clinical management of rectal cancer: Updated recommendations from the 2016 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. Eur Radiol 28:1465-1475
12. Okizuka H, Sugimura K, Yoshizako T, Kaji Y, Wada A (1996) Rectal carcinoma: prospective comparison of conventional and gadopentetate dimeglumine enhanced fat-suppressed MR imaging. J Magn Reson Imaging 6:465-471
13. Vliegen RF, Beets GL, von Meyenfeldt MF et al (2005) Rectal cancer: MR imaging in local staging–is gadolinium-based contrast material helpful? Radiology 234:179-188
14. Alberda WJ, Dassen HP, Dwarkasing RS et al (2013) Prediction of tumor stage and lymph node involvement with dynamic contrast-enhanced MRI after chemoradiotherapy for locally advanced rectal cancer. Int J Colorectal Dis 28:573-580
15. Rudisch A, Kremser C, Judmaier W, Zunterer H, DeVries AF (2005) Dynamic contrast-enhanced magnetic resonance imaging: a non-invasive method to evaluate significant differences between malignant and normal tissue. Eur J Radiol 53:514-519
16. Greene FL, Stewart AK, Norton HJ (2004) New tumor-node-metastasis staging strategy for node-positive (stage III) rectal cancer: an analysis. J Clin Oncol 22:1778-1784
17. Taylor F, Mangat N, Swift IR, Brown G (2010) Proforma-based reporting in rectal cancer. Cancer Imaging 10 Spec no A:S142-150
18. Al-Sukhni E, Messenger DE, Charles Victor J, McLeod RS, Kennedy ED (2013) Do MRI reports contain adequate preoperative staging information for end users to make appropriate treatment decisions for rectal cancer? Ann Surg Oncol 20:1148-1155
19. Nougaret S, Reinhold C, Mikhael HW, Rouanet P, Bibeau F, Brown G (2013) The use of MR imaging in treatment planning

for patients with rectal carcinoma: have you checked the "DISTANCE"? Radiology 268:330-344
20. Akasu T, Iinuma G, Fujita T et al (2005) Thin-section MRI with a phased-array coil for preoperative evaluation of pelvic anatomy and tumor extent in patients with rectal cancer. AJR Am J Roentgenol 184:531-538
21. Stelzner S, Holm T, Moran BJ et al (2011) Deep pelvic anatomy revisited for a description of crucial steps in extralevator abdominoperineal excision for rectal cancer. Dis Colon Rectum 54:947-957
22. Tsukada Y, Ito M, Watanabe K et al (2016) Topographic Anatomy of the Anal Sphincter Complex and Levator Ani Muscle as It Relates to Intersphincteric Resection for Very Low Rectal Disease. Dis Colon Rectum 59:426-433
23. Gollub MJ, Maas M, Weiser M et al (2013) Recognition of the anterior peritoneal reflection at rectal MRI. AJR Am J Roentgenol 200:97-101
24. McCawley N, Clancy C, O'Neill BD, Deasy J, McNamara DA, Burke JP (2016) Mucinous Rectal Adenocarcinoma Is Associated with a Poor Response to Neoadjuvant Chemoradiotherapy: A Systematic Review and Meta-analysis. Dis Colon Rectum 59:1200-1208
25. Oberholzer K, Menig M, Kreft A et al (2012) Rectal cancer: mucinous carcinoma on magnetic resonance imaging indicates poor response to neoadjuvant chemoradiation. Int J Radiat Oncol Biol Phys 82:842-848
26. Moran B, Brown G, Cunningham D et al (2008) Clarifying the TNM staging of rectal cancer in the context of modern imaging and neo-adjuvant treatment: 'y''u' and 'p' need 'mr' and 'ct'. Colorectal Dis 10:242-243
27. Rao SX, Zeng MS, Xu JM et al (2007) Assessment of T staging and mesorectal fascia status using high-resolution MRI in rectal cancer with rectal distention. World J Gastroenterol 13:4141-4146
28. Low RN, McCue M, Barone R, Saleh F, Song T (2003) MR staging of primary colorectal carcinoma: comparison with surgical and histopathologic findings. Abdom Imaging 28:784-793
29. Maas M, Lambregts DM, Lahaye MJ et al (2012) T-staging of rectal cancer: accuracy of 3.0 Tesla MRI compared with 1.5 Tesla. Abdom Imaging 37:475-481
30. Smith N, Brown G (2008) Preoperative staging of rectal cancer. Acta Oncol 47:20-31
31. Taylor FG, Swift RI, Blomqvist L, Brown G (2008) A systematic approach to the interpretation of preoperative staging MRI for rectal cancer. AJR Am J Roentgenol 191:1827-1835
32. Brown G (2004) Local radiological staging of rectal cancer. Clin Radiol 59:213-214
33. Klessen C, Rogalla P, Taupitz M (2007) Local staging of rectal cancer: the current role of MRI. Eur Radiol 17:379-389
34. Yeung JM, Ferris NJ, Lynch AC, Heriot AG (2009) Preoperative staging of rectal cancer. Future Oncol 5:1295-1306
35. Beets-Tan RG, Beets GL, Vliegen RF et al (2001) Accuracy of magnetic resonance imaging in prediction of tumour-free resection margin in rectal cancer surgery. Lancet 357:497-504
36. Nagtegaal ID, van de Velde CJ, Marijnen CA, van Krieken JH, Quirke P (2005) Low rectal cancer: a call for a change of approach in abdominoperineal resection. J Clin Oncol 23:9257-9264
37. Chamlou R, Parc Y, Simon T et al (2007) Long-term results of intersphincteric resection for low rectal cancer. Ann Surg 246:916-921; discussion 921-912
38. Anderin C, Martling A, Hellborg H, Holm T A population-based study on outcome in relation to the type of resection in low rectal cancer. Dis Colon Rectum 53:753-760
39. Habr-Gama A, de Souza PM, Ribeiro U, Jr. et al (1998) Low rectal cancer: impact of radiation and chemotherapy on surgical treatment. Dis Colon Rectum 41:1087-1096
40. Shihab OC, Brown G, Daniels IR, Heald RJ, Quirke P, Moran BJ Patients with low rectal cancer treated by abdominoperineal excision have worse tumors and higher involved margin rates compared with patients treated by anterior resection. Dis Colon Rectum 53:53-56
41. Gerard JP, Chapet O, Nemoz C et al (2004) Improved sphincter preservation in low rectal cancer with high-dose preoperative radiotherapy: the lyon R96-02 randomized trial. J Clin Oncol 22:2404-2409
42. Kao PS, Chang SC, Wang LW et al The impact of preoperative chemoradiotherapy on advanced low rectal cancer. J Surg Oncol 102:771-777
43. Weiser MR, Quah HM, Shia J et al (2009) Sphincter preservation in low rectal cancer is facilitated by preoperative chemoradiation and intersphincteric dissection. Ann Surg 249:236-242
44. Rouanet P, Saint-Aubert B, Lemanski C et al (2002) Restorative and nonrestorative surgery for low rectal cancer after high-dose radiation: long-term oncologic and functional results. Dis Colon Rectum 45:305-313; discussion 313-305
45. Shihab OC, Moran BJ, Heald RJ, Quirke P, Brown G (2009) MRI staging of low rectal cancer. Eur Radiol 19:643-650
46. Brown G, Radcliffe AG, Newcombe RG, Dallimore NS, Bourne MW, Williams GT (2003) Preoperative assessment of prognostic factors in rectal cancer using high-resolution magnetic resonance imaging. Br J Surg 90:355-364
47. Smith NJ, Shihab O, Arnaout A, Swift RI, Brown G (2008) MRI for detection of extramural vascular invasion in rectal cancer. AJR Am J Roentgenol 191:1517-1522
48. Smith NJ, Barbachano Y, Norman AR, Swift RI, Abulafi AM, Brown G (2008) Prognostic significance of magnetic resonance imaging-detected extramural vascular invasion in rectal cancer. Br J Surg 95:229-236
49. Ale Ali H, Kirsch R, Razaz S et al (2018) Extramural venous invasion in rectal cancer: overview of imaging, histopathology, and clinical implications. Abdom Radiol (NY). https://doi.org/10.1007/s00261-018-1673-2
50. Jhaveri KS, Hosseini-Nik H, Thipphavong S et al (2016) MRI Detection of Extramural Venous Invasion in Rectal Cancer: Correlation With Histopathology Using Elastin Stain. AJR Am J Roentgenol 206:747-755
51. Siddiqui MRS, Simillis C, Hunter C et al (2017) A meta-analysis comparing the risk of metastases in patients with rectal cancer and MRI-detected extramural vascular invasion (mrEMVI) vs mrEMVI-negative cases. Br J Cancer 116:1513-1519
52. Group MS (2006) Diagnostic accuracy of preoperative magnetic resonance imaging in predicting curative resection of rectal cancer: prospective observational study. BMJ 333:779
53. Chand M, Palmer T, Blomqvist L, Nagtegaal I, West N, Brown G (2015) Evidence for radiological and histopathological prognostic importance of detecting extramural venous invasion in rectal cancer: recommendations for radiology and histopathology reporting. Colorectal Dis 17:468-473
54. Quirke P, Durdey P, Dixon MF, Williams NS (1986) Local recurrence of rectal adenocarcinoma due to inadequate surgical resection. Histopathological study of lateral tumour spread and surgical excision. Lancet 2:996-999
55. Wibe A, Rendedal PR, Svensson E et al (2002) Prognostic significance of the circumferential resection margin following total mesorectal excision for rectal cancer. Br J Surg 89:327-334
56. Adam IJ, Mohamdee MO, Martin IG et al (1994) Role of circumferential margin involvement in the local recurrence of rectal cancer. Lancet 344:707-711
57. Fritzmann J, Contin P, Reissfelder C et al (2018) Comparison of three classifications for lymph node evaluation in patients undergoing total mesorectal excision for rectal cancer. Langenbecks Arch Surg 403:451-462

58. Grone J, Loch FN, Taupitz M, Schmidt C, Kreis ME (2018) Accuracy of Various Lymph Node Staging Criteria in Rectal Cancer with Magnetic Resonance Imaging. J Gastrointest Surg 22:146-153
59. Schurink N, Lambregts D, Beets-Tan R (2018) Diffusion-weighted imaging in rectal cancer: current applications and future perspectives. Br J Radiol. https://doi.org/10.1259/bjr.20180655
60. Mizukami Y, Ueda S, Mizumoto A et al (2011) Diffusion-weighted magnetic resonance imaging for detecting lymph node metastasis of rectal cancer. World J Surg 35:895-899
61. Lahaye MJ, Engelen SM, Kessels AG et al (2008) USPIO-enhanced MR imaging for nodal staging in patients with primary rectal cancer: predictive criteria. Radiology 246:804-811
62. Heijnen LA, Lambregts DM, Martens MH et al (2014) Performance of gadofosveset-enhanced MRI for staging rectal cancer nodes: can the initial promising results be reproduced? Eur Radiol 24:371-379
63. Tse DM, Joshi N, Anderson EM, Brady M, Gleeson FV (2012) A computer-aided algorithm to quantitatively predict lymph node status on MRI in rectal cancer. Br J Radiol 85:1272-1278
64. Chen Y, Yang X, Lu B, Xiao X, Zhuang X, Yu S (2018) [Diagnostic accuracy of 3.0T high-resolution MRI for assessment mesorectal lymph node metastases in patients with rectal cancer]. Zhonghua Wei Chang Wai Ke Za Zhi 21:786-792
65. Armbruster M, D'Anastasi M, Holzner V et al (2018) Improved detection of a tumorous involvement of the mesorectal fascia and locoregional lymph nodes in locally advanced rectal cancer using DCE-MRI. Int J Colorectal Dis 33:901-909
66. Chen Y, Yang X, Wen Z et al (2018) Fat-suppressed gadolinium-enhanced isotropic high-resolution 3D-GRE-T1WI for predicting small node metastases in patients with rectal cancer. Cancer Imaging 18:21
67. Yu J, Dai X, Zou HH et al (2018) Diffusion kurtosis imaging in identifying the malignancy of lymph nodes during the primary staging of rectal cancer. Colorectal Dis 20:116-125