Local staging of rectal cancer: the current role of MRI

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Patrik Rogalla
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Abstract With the advent of powerful gradient coil systems and high-resolution surface coils, magnetic resonance imaging (MRI) has recently extended its role in the staging of rectal cancer. MRI is superior to endorectal ultrasound, the most widely used staging modality in patients with rectal tumors, in that it visualizes not only the intestinal wall but also the surrounding pelvic anatomy. The crucial advantage of MRI is not that it enables exact T-staging but precise evaluation of the topographic relationship of a tumor to the mesorectal fascia. This fascia is the most important anatomic landmark for the feasibility of total mesorectal excision, which has evolved into the standard operative procedure for the resection of cancer located in the middle or lower third of the rectum. MRI is currently the only imaging modality that is highly accurate in predicting whether or not it is likely that a tumor-free margin can be achieved and thus provides important information for planning of an effective therapeutic strategy, especially in patients with advanced rectal cancer.

Keywords Rectal cancer · Staging · MRI · Rectal carcinoma

Introduction

Colorectal cancer is the third most common cancer worldwide [1, 2]. In the United States, about 145,000 new cases and 56,000 deaths were estimated for 2005 [1]. In recent years, mortality rates have decreased due to major changes in therapeutic management, in particular the standardization of the operative procedure and the introduction of adjuvant and neoadjuvant therapy [1].

Colorectal cancer primarily develops from adenomatous polyps over a period of 10–15 years, known as the adenoma-carcinoma sequence [3]. The incidence of polyps increases with age and the risk of malignant transformation of a polyp markedly increases with its diameter. The rate of malignant transformation is about 1% for polyps less than 1 cm in diameter, but 10% for larger ones [4, 5]. Around 40–50% of colorectal cancers are located in the rectum.

Rectal cancer is defined as a tumor whose aboral margin measured with the rigid rectoscope is 16 cm or less from the anocutaneous line. This distance serves to classify rectal cancer into tumors of the upper third (12–16 cm), the middle third (6–12 cm), and the lower third (<6 cm) [6] according to the UICC.

The mesorectal fascia is an important anatomic landmark for the diagnostic evaluation of local tumor extent [7] (Fig. 1b). The fascia is a connective tissue sheath that encloses the rectum and the perirectal fatty tissue, including lymph nodes and lymphatic vessels down to the pelvic floor and acts as a natural barrier for tumor spread. The ability to visualize the mesorectal fascia on CT images has been described more than 20 years ago [8]. MRI currently is the most advanced staging modality able to depict the fascia and its relation to the tumor margins precisely. The following article will give an overview of the staging modalities currently used in rectal cancer staging, with an emphasis on the role of MRI and its significance for planning an effective therapeutical strategy for the individual patient.
Local tumor staging

Tumor staging is crucial for the prognosis and planning of therapy in the individual patient and aims at precisely determining the extent of the tumor as a basis for deciding whether surgery alone or surgery in combination with neoadjuvant therapy is the most suitable strategy. Of course, it is of great importance to avoid overtreatment or undertreatment of the patient. To reach a high level of accuracy in rectal cancer staging and to develop an adequate individual strategy for therapy, it is indispensable to establish a multidisciplinary team [24]. Rectal cancer staging is now mostly based on the TNM and UICC staging systems [6] (Tables 1, 2), which have largely replaced the older Dukes classification. The most important anatomic structure on which staging is based using these staging systems is the lamina muscularis propria. While T1 rectal carcinomas are confined to the mucosa and submucosa, T2 tumors invade the muscularis propria (Figs. 2a–c and 3). A T3 cancer is defined as a tumor extending beyond the lamina muscularis propria (Figs. 4, 5) without further subclassification. The therapeutically important topographic relationship of the lateral tumor margins to the mesorectal fascia is not taken into consideration. An adequate, state-of-the-art staging classification should be able to precisely determine this relationship and to predict whether a tumor-free CRM is likely to be achieved or not. In this way one would be able to differentiate patients with minimal mesorectal infiltration in whom neoadjuvant therapy is not mandatory from patients who would definitely benefit from neoadjuvant therapy because the mesorectal fascia is infiltrated or at risk. T4 rectal cancers are defined as tumors, that reach the peritoneal surface or adjacent organs (Figs. 6a,b, 7, 8).

Table 1  TNM classification for colorectal cancer

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>T1</td>
<td>Tumor involves submucosa</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor involves muscularis propria</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor beyond muscularis propria</td>
</tr>
<tr>
<td>T4</td>
<td>Tumor reaches peritoneal surface or invades adjacent organ</td>
</tr>
<tr>
<td>N0</td>
<td>No involved nodes</td>
</tr>
<tr>
<td>N1</td>
<td>Up to three perirectal/colic nodes</td>
</tr>
<tr>
<td>N2</td>
<td>Four or more perirectal/colic nodes</td>
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</table>

Table 2  UICC staging of rectal carcinoma

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Stage 0</td>
<td>Tis N0 M0</td>
</tr>
<tr>
<td>Stage I</td>
<td>T1 N0 M0</td>
</tr>
<tr>
<td></td>
<td>T2 N0 M0</td>
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<tr>
<td>Stage IIA</td>
<td>T3 N0 M0</td>
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<tr>
<td></td>
<td>B T4 N0 M0</td>
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<tr>
<td>Stage IIIA</td>
<td>T1, T2 N1 M0</td>
</tr>
<tr>
<td></td>
<td>B T3, T4 N1 M0</td>
</tr>
<tr>
<td></td>
<td>C Every T N2 M0</td>
</tr>
<tr>
<td>Stage IV</td>
<td>Every T Every N M1</td>
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Staging modalities

Endorectal ultrasound (EUS)

EUS is the oldest and most widely used imaging technique for evaluating the local extent of rectal cancer. EUS depicts the anatomic layers of the rectal wall with a high degree of accuracy and thus enables precise determination of the tumor extent in relation to the different wall layers. Reported accuracy rates of transrectal ultrasound in assessing the T stage are in the range of 69–97% [25–35]. EUS is most suitable for evaluating early rectal cancer while it is limited in assessing more advanced tumors. Although EUS allows the identification of transmural tumor growth, exact determination of the circumferential tumor spread and—even more important—depiction of the relation between the edges of the tumor and the mesorectal fascia is often not possible due to the limited scan depth caused by the high frequencies used. Moreover, the accuracy varies widely with the examiner’s experience [28, 36].

Computed tomography (CT)

Most older studies report rather low accuracy rates of only 52–70% [32, 37–41] for T-staging by CT. It is remarkable that accuracy levels reported in studies including less advanced tumors were considerably lower compared with those including only advanced tumor stages. The poor accuracy of CT in the staging of superficial tumors is mainly attributable to the fact that these studies used conventional CT protocols with low spatial and contrast resolution. The accuracy has since been improved by the advent of the multislice technique (MSCT). In a study of 92 patients by Kulminna et al. [42], T-staging using MSCT was found to have an accuracy of 86%, while Filippone et al. [43] found an accuracy of 83% in a study of 41 patients. If one takes into account that four-row CT scanners were used in these studies, it is evident that further improvement is to be expected from state-of-the-art CT scanners with up to 64 detector rows that are already in use today. Hence, the role
of MSCT in the local staging of rectal cancer remains to be defined. CT is superior to both EUS and MRI in that the scan typically covers the entire abdomen and pelvis and thus also allows evaluation of the liver, the most important target organ of hematogenic metastatic spread of rectal cancer.

MRI

It is undisputed that MRI is the imaging modality with the highest soft-tissue contrast. This is why MRI is also used for staging rectal cancer. However, initial results with MRI were disappointing, with accuracies in T-staging reported in older studies ranging between 58 and 74% [39, 44–46]. These rather poor results are primarily due to the poor spatial resolution achieved with the whole-body coil systems used in these studies. When endorectal coils are used, MRI has similar accuracies as EUS [31, 47–49]. MRI using endorectal coil systems is comparable to EUS in that it allows highly accurate differentiation of the layers of the intestinal wall. However, endorectal coils also have a number of disadvantages. As with EUS, the field of view (FOV) is rather small and only allows adequate evaluation of early stages of rectal cancer because the evaluation of surrounding pelvic anatomy is limited. In patients with advanced tumors, insertion of the coil system may be impossible or is very painful. Another disadvantage is the high cost of endorectal coils, which are usually disposable.

The advent of powerful gradient systems and, above all, the development of high-resolution phased array surface coil systems in recent years brought the breakthrough in the staging of rectal cancer by MRI. The use of these phased-array surface coils combines a very high spatial resolution with a large FOV that allows not only detailed evaluation of the intestinal wall but also depicts surrounding anatomy including the mesorectal fascia.

Imaging technique

Rectal cancer staging by MRI is rather fast and straightforward. No special patient preparation is required. Some authors recommend administration of a positive or negative enteral contrast medium, but this seems not to be necessary as suggested by current data in the literature. A
study published only recently even indicated that rectal distension significantly reduces the distance between the rectal wall and the mesorectal fascia and that this might impact on the ability of MRI to predict accurately the distance between the tumor and the potential resection margin [50].

At our department, we administer a spasmolytic agent (butylscopolamine) at a dose of 20–40 mg to prevent artifacts caused by peristalsis of the small intestine and to distend the sigmoid and rectum. The agent has a short half-life and is therefore injected intramuscularly immediately before MRI.

For efficient planning of the pulse sequences to be employed, the radiologist performing the examination should beforehand obtain information about the approximate tumor localization (distance from anocutaneous line in cm) from the referring surgeon and ask the patient about any previous surgery or diseases of the pelvic organs.

The patient is positioned comfortably on the back and a phased-array surface coil is placed on the pelvis in such a way that the lower edge of the coil comes to lie well below the pubic bone. The coil is kept in place with belts and the patient is then advanced head-first into the bore of the magnet.

Following the usual localizer scans, a sagittal T2-weighted half-Fourier single shot turbo spin-echo (SSFSE, HASTE) sequence with a large field of view (FOV) should be acquired to obtain an overview and for planning of the subsequent sequences (e.g. TR $\infty$, TE 62 ms, slice thickness 5 mm, FOV 255×340 mm, matrix size 116×256, voxel size 2.2×1.3×5 mm). Precise tumor localization is then achieved with an axial T2-weighted fast spin-echo (FSE) or turbo spin-echo (TSE) sequence with a large FOV and a slice thickness of 5 mm (e.g. TR 4,170 ms, TE 98 ms, FOV 300×220 mm, matrix 282×512, voxel size 0.8×0.6×5 mm).

At the core of the examination is a high-resolution T2-weighted TSE sequence with a small FOV and a slice thickness of 3 mm (e.g. TR 3,570 ms, TE 68 ms, FOV 180×180 mm, matrix 179×256, voxel size 1.0×0.7×3 mm). It is mandatory to place the slices perpendicular to the longitudinal axis of the tumor or the intestinal lumen in the vicinity of the tumor. With this sequence, it is possible to precisely evaluate the tumor and its relationship to the intestinal wall, mesorectal fascia, the pelvic organs, and possibly also to the peritoneal fold. Moreover, mesorectal lymph nodes in the immediate vicinity of the tumor can be evaluated. For visualization of more distant lymph nodes in our institution a T1 to proton-density-weighted two-dimensional (2D) TSE sequence with a short echo train length (e.g. 3 or 5) in axial orientation (e.g. TR 1,980 ms, TE 10 ms, slice thickness 5 mm, FOV 300×225 mm, matrix 219×512, voxel size 1×0.6×5 mm), which covers the entire area up to the aortic bifurcation is used. Alternatively, a T1-weighted 3D gradient-echo sequence can be used for this purpose, allowing for the reconstruction of thinner slices. Possible infiltration of the anal sphincter muscles in patients with low tumors is evaluated using a coronal T2-weighted FSE (TSE) sequence (e.g. TR 3,570 ms, TE 68 ms, FOV 180×180, matrix 179×256, voxel size 1.0×0.7×3 mm) positioned parallel to the longitudinal axis of the anal canal. Current data in the literature suggests that intravenous contrast medium administration does not improve staging of rectal tumors by MRI [51, 52].
Since differentiation with the T2-weighted sequences is based on the contrast between the high-signal-intensity mesorectal fatty tissue and the rather low signal intensity of the tumor, spectral fat suppression techniques are not needed. The duration of the MRI protocol as just outlined is about 25–30 min, including planning.

T-staging

Although the introduction of phased-array coil systems has improved the accuracy of MRI in staging rectal cancer, even more recent studies report accuracies of only 67–86 % for T-staging [53–56]. These disappointing results are primarily due to the poor differentiation of T1/2 cancer from so-called borderline T3 cancer, where it is often not possible to distinguish true mesorectal tumor invasion from desmoplastic reactions (Fig. 3) [49, 54, 57]. Desmoplastic reactions are reactive tissue alterations which often occur in the immediate surrounding of tumors, most frequently resulting in fibrotic extensions that may contain tumor cells or not. The failure to differentiate between desmoplastic reactions and tumor growth is not specific to MRI but is also a well-known problem in rectal cancer staging with EUS [27]. Clinically and therapeutically, however, this differentiation is of minor importance. As already mentioned, it is much more important to precisely describe the

Fig. 6 a Paraxial T2-weighted FSE (TSE) sequence and b sagittal T2-weighted FSE (TSE) sequence of a T4 cancer located in the upper third of the rectum invading the uterus (arrows)

Fig. 7 Paraxial T2-weighted FSE (TSE) sequence of a low T4 rectal cancer with infiltration of the levator ani muscle (arrow)

Fig. 8 Recurrent rectal cancer. Paraxial T1-weighted SE sequence with fat suppression after i.v. application of gadopentetate-dimeglumine at a dosage of 0.2 mmol/kg body weight. The large extraluminal tumor shows central necrosis (arrowhead) and reaches the right pelvic wall
relationship of the tumor to the mesorectal fascia, representing the anticipated resection plane for TME in order to assess the likelihood of a tumor-free CRM. Several recent studies have confirmed that MRI is highly suited to provide this information [54, 57–60]. In a study of 43 patients, Bissett et al. [59] found good agreement between preoperative MRI and histopathology with regard to the demonstration of tumor penetration through the mesorectal fascia (accuracy: 95%). These results are underlined by the studies of Beets-Tan et al. [54, 61], who investigated 76 patients and likewise found preoperative MRI to be highly accurate in assessment of the CRM. The agreement was 100% in T4 tumors, and 97% and 93% for both readers in tumors with a histologically determined tumor-free CRM >10 mm. Regression analysis for histologically determined margins of 1–10 mm demonstrated that a tumor-free resection margin of 2 mm was predicted with an accuracy of 97% if the distance between tumor and mesorectal fascia measured by MRI was at least 6 mm. It is noteworthy that this study likewise showed only moderate results with regard to T-staging (accuracy of 83% and 67% for the two readers) [54, 61]. In a study of 98 patients published by Brown and co-workers in 2003, the agreement between MRI and histology in assessment of the CRM was 92% [60]. These figures indicate that MRI allows accurate prediction of the CRM status after resection. The expected CRM can be described as involved if tumor invasion of the mesorectal fascia is visible or the tumor has a proximity of 1 mm or less to the mesorectal fascia. A tumor-free CRM can be assumed with a high degree of accuracy if the shortest distance from the maximum tumor extension, a mesorectal tumor deposit or a suspect lymph node in the mesorectum is more than 6 mm [54]. The role of tumors that extend towards the mesorectal fascia to a distance of less than 5 mm on MR images remains controversial.

The study by Brown et al. [60] also suggests that other important prognostic factors besides the CRM are the infiltration of extramural veins and possible infiltration of the peritoneal fold and that these can also be identified by preoperative MRI.

A study by Oberholzer and co-workers published in 2005 has shown that parallel imaging techniques do not compromise diagnostic accuracy with regard to the assessment of the CRM, but can considerable shorten the examination [62].

**N-staging**

Identification of metastatic lymph nodes is the greatest challenge in preoperative staging of rectal cancer, regardless of the modality used (Figs. 9, 10, 11). Exact staging is important because the number of metastatic nodes has been shown to affect the prognosis [63]. Involvement of lymph nodes in the vicinity of the mesorectal fascia is associated with a higher risk of local recurrence [16]. In patients with metastatic nodes outside the mesorectal fascia, extended lymph node resection with additional removal of the internal iliac nodes becomes necessary [64]. This lymph node group is not removed when regular TME is performed. A special problem associated with identifying lymphatic involvement in rectal cancer is that lymph node size is not a reliable criterion for metastatic involvement because micrometastasis in normal-sized lymph nodes is common [65, 66].
The accuracy rates reported in the literature for N-staging by the different imaging modalities vary widely (EUS: 61–80% [10, 25, 26, 30–32, 34, 35, 37, 67], CT: 56–79% [32, 39, 68, 69], MRI: 57–85% [32, 39, 47, 53, 55, 60]. In a current meta-analysis including 84 studies, Lahaye et al. [70] found EUS to be slightly superior in assessing nodal status, but there were altogether no significant differences between the three staging modalities investigated. In summary, these results suggest that none of the imaging procedures currently in use enables reliable detection of metastatic lymph nodes.

In their study of MRI with histologic correlation, Brown et al. [71] identified an irregular contour and inhomogeneous signal to be the most reliable MRI criteria for lymph node metastasis (Fig. 9).

**Future perspectives**

**USPIO**

A new promising approach to detect metastatic lymph nodes by MRI is imaging in combination with ultrasmall superparamagnetic iron oxide particles (USPIO) as a contrast medium for systemic MR lymphography (Fig. 12a,b). Following intravenous administration, the particles are phagocytozed by nodal macrophages and, due to susceptibility effects, cause a signal decrease in normal or reactively changed lymph nodes on T2- and T2*-weighted images, which are usually acquired 24 h after administration of USPIO [72]. USPIO agents are currently under clinical evaluation and are not yet clinically available. Initial results of a study investigating this new approach in mesorectal lymph nodes are promising [73]. Further studies are needed to show whether USPIO can significantly improve lymph node staging by MRI.

**Whole-body MRI**

The recent introduction of powerful whole-body MRI systems enables imaging of the whole body in a single session through repeated table movement. Several studies have already demonstrated the benefit of this approach for a variety of diagnostic queries in oncologic patients [74–77]. This technique may also be used for rectal cancer staging in the future and allow local staging and whole-body staging in a single session. In this way it would become possible to also evaluate the liver as the primary target organ of hematogenic spread of rectal cancer. The potential of parallel imaging to shorten the examination...
Preoperative Staging of Rectal Cancer with MR Imaging:
Correlation with Surgical and Histopathologic Findings

Franco Iafrate, Andrea Laghi, Pasquale Paolantonio, Marco Rengo, Paolo Mercantini, Mario Ferri, Vincenzo Ziparo, Roberto Passariello

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**Introduction**

Rectal cancer is a common disease with a high rate of mortality in Western countries. Many improvements have been made over the past 20 years in the surgical, radiologic, and oncologic treatment of rectal cancer. However, this neoplasm remains associated with a poor prognosis owing to the high risk of metastases and local recurrence. After surgical treatment, local recurrence rates for rectal cancer can vary from 3% to 32% (1–5).

Total mesorectal excision (TME) involves resection of both the tumor and the surrounding mesorectal fat. At present, TME is the surgical treatment of choice for rectal cancer, being associated with a recurrence rate of less than 10% when used as a single-modality therapy (6). The introduction of this surgical technique reduced the mortality rate associated with rectal cancer from 16% to 9% in one study (7).

In selected patients with involvement of the mesorectal fascia at the time of diagnosis, the use of preoperative radiation therapy is advocated and has been shown to reduce the recurrence rate from 8.2% to 2.4% at 2 years (6,8). This therapeutic approach demands accurate preoperative tumor staging—namely, detection of rectal carcinoma infiltration into the mesorectal fat, involvement of the mesorectal fascia, and nodal involvement.

The goal of imaging in rectal cancer is to stratify cases on the basis of the risks of recurrence by means of accurate evaluation of the T staging. At present, there is no consensus on the role of diagnostic imaging (endorectal ultrasonography [US], computed tomography, and magnetic resonance [MR] imaging) in the preoperative T staging of rectal cancer.

In this article, we discuss the diagnosis, management, and treatment of rectal cancer and review the normal rectal anatomy. We also discuss and illustrate the correlation of MR imaging findings with pathologic findings in rectal cancer and the clinical impact of MR imaging in this setting.

<table>
<thead>
<tr>
<th>Histologic Criteria* for T Staging of Rectal Cancer</th>
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<tr>
<td><strong>Tumor Stage</strong></td>
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<tr>
<td>T1</td>
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<tr>
<td>T2</td>
</tr>
<tr>
<td>T3</td>
</tr>
<tr>
<td>T4</td>
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</table>

*2003 criteria from the International Union Against Cancer.

**Rectal Cancer**

Rectal cancer is one of the most common tumors in industrialized countries (40 cases in every 100,000 individuals) and one of the most common malignant tumors of the gastrointestinal tract (9). Rectal cancer has a slight male predilection, and its prevalence increases steadily after the age of 50 years. Adenocarcinomas account for the vast majority (98%) of rectal cancers and are the focus of this article. Other rectal tumors are relatively rare and include carcinoid tumors (0.1% of cases), lymphoma (1.3%), and gastrointestinal stromal tumors (<1%).

Imaging plays a crucial role in the preoperative management of rectal carcinoma. Indeed, the diagnosis of rectal cancer is usually made on the basis of a rectal digital examination, sigmoidoscopy or colonoscopy, a double contrast enema examination, and confirmatory histologic findings (10). However, these approaches do not adequately show the depth of tumor spread or the extent of lymph node involvement, both of which are important prognostic features (11–15). Preoperative staging techniques for rectal cancer should allow identification of (a) patients with extrarectal spread, who might benefit from preoperative radiation therapy, and (b) patients with minimal or no sphincteral involvement, who might be suitable for sphincter-sparing surgery.

For optimal patient outcome, it is crucial to stratify cases into those in which patients can benefit from local therapy (eg, transanal local
Correlation of MR Imaging Findings with Pathologic Findings

The identification and staging of rectal cancers at MR imaging is largely based on differences in T2 signal intensity between the tumor, the mucosa and submucosal layers, the muscular layer, the perirectal fat, and the mesorectal fascia. The perirectal fat has high signal intensity on turbo spin-echo T2-weighted images and surrounds the low-signal-intensity muscularis propria. The tumor itself has an intermediate signal intensity between the high signal intensity of the fat tissue and the low signal intensity of the muscular layer. Furthermore, its signal intensity is higher than that of the mucosal and submucosal layers (Fig 5). The mesorectal fascia appears as a thin, hypointense line surrounding the hyperintense perirectal fat. However, the spatial resolution of
phased-array surface coil MR imaging is not adequate to allow differentiation between the mucosal and submucosal layers of the inner layer.

At histopathologic analysis, a stage T1 tumor is characterized by infiltration of the submucosal layer and sparing of the muscularis propria (Fig 6); at phased-array MR imaging, differentiation between stage T1 and stage T2 tumors is rather difficult owing to low spatial resolution (Fig 7).

Transanal endoscopic microsurgery with a full-thickness excision represents a safe and effective treatment for adenomatous polyps, tumor in situ, and stage T1 rectal tumors.

Stage T2 tumors are generally characterized by involvement of the muscular layer with loss of the interface between this layer and the submucosa. The muscular layer is partially reduced in thickness, although the outer border between the muscularis propria and the perirectal fat remains.

Figure 7. Stage T1 rectal carcinoma. (a) Axial turbo spin-echo T2-weighted MR image shows a polypoid tumor (T) on the right lateral aspect of the rectal wall protruding into the rectal lumen. It is difficult to determine whether the muscular layer (arrow), which appears thinned, is infiltrated or spared. (b) Coronal turbo spin-echo T2-weighted MR image shows the tumor (T) invading the rectal wall without infiltrating the perirectal fat (arrow). In this imaging plane, the distance of the tumor from the plane of the levator ani muscle (L) and from the anal sphincter complex (A) can easily be evaluated. (c) Photomicrograph (original magnification, ×4; H-E stain) reveals multiple neoplastic glands (curved arrow) confined to the submucosal layer. The border between normal bowel mucosal glands (straight arrow) and the neoplastic glands is clearly visible (*). (d) Photomicrograph (original magnification, ×4; H-E stain) shows that the integrity of the muscular layer (M) and the perirectal fat (*) has not been disrupted. The boundary between the muscular layer and fat tissue is evident (arrow).
In differentiating between stage T2 and stage T3 tumors, the crucial criterion is involvement of the perirectal fat, which is characterized by the inability to visualize the interface between the muscular layer and the perirectal fat, with a rounded or nodular advancing margin. In stage T3 tumors, the muscularis propria is totally disrupted and cannot be clearly distinguished from the perirectal fat.

In the evaluation of stage T3 tumors, one parameter is particularly important: the minimum distance between the tumor and the mesorectal fascia. This measurement is important for the stratification of cases on the basis of potential recurrence after TME. Indeed, despite good-quality TME surgery, 15%–20% of TME specimens have a positive CRM (40). In such cases, the CRM consists of the mesorectal fascia itself. Even if tumor–mesorectal fascia distance has not yet been included in the TNM staging system, there is strong evidence that neoplastic involvement of the CRM is closely related to a high recurrence rate after surgery (Fig 10) (1,40–42). In patients with suspected tumoral involvement of the mesorectal fascia, neoadjuvant treatments are advocated to reduce the risk of postsurgical recurrence (7). MR imaging is a highly accurate and reliable technique for the prediction of CRM infiltration and thus represents a noninvasive tool for identifying those patients who may benefit from preoperative chemotherapy or radiation therapy and those who should undergo TME.

A valid criterion for predicting CRM infiltration is thought to be a cutoff distance of 6 mm between a tumor and the mesorectal fascia. This criterion was established by Beets-Tan et al (43), who observed that it was highly accurate in predicting CRM involvement. In their experience, a distance of at least 5 mm between a tumor and the mesorectal fascia at MR imaging helped predict an uninvolved CRM of 1 mm at histologic analysis with 97% confidence. Although not fully discussed in the literature, the usefulness of MR imaging in the evaluation of the CRM may be limited in (a) thin patients with little perirectal fat and (b) tumors of the anterior wall of the rectum, due to the poor visualization of the mesorectal fat.

In stage T4 tumors, the signal intensity of the tumor is seen infiltrating surrounding structures (ie, other organs and muscular structures of the pelvic wall) (Fig 11).
A Systematic Approach to the Interpretation of Preoperative Staging MRI for Rectal Cancer

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Lennart Blomqvist²
Gina Brown³

Objective. The purpose of this article is to provide an aid to the systematic evaluation of MRI in staging rectal cancer.

Conclusion. MRI has been shown to be an effective tool for the accurate preoperative staging of rectal cancer. In the Magnetic Resonance Imaging and Rectal Cancer European Equivalence Study (MERCURY), imaging workshops were held for participating radiologists to ensure standardization of scan acquisition techniques and interpretation of the images. In this article, we report how the information was obtained and give examples of the images and how they are interpreted, with the aim of providing a systematic approach to the reporting process.

Over the past few years, significant progress has been made in the management of rectal cancer. Advances in surgical technique and adjuvant therapies have led to significant improvements in outcome for some patients. The advances in preoperative therapies have led to the need for an accurate preoperative staging technique to select those patients who are most likely to benefit from these interventions without subjecting others to unnecessary treatment.

Several studies have been published showing the ability of MRI to accurately stage rectal cancer and to clearly identify the relevant anatomy [1–5]. Although we accept that endoscopic sonography can show comparable accuracy with regard to T and N staging of rectal tumors, sonography has inherent problems. It is operator-dependent, and problems arise when scanning high or stricturing lesions. The limited field of view makes assessment of structures beyond the field of view difficult to interpret. Endoscopic sonography cannot accurately assess the circumferential resection margin or identify other prognostic features such as extramural venous invasion. Similarly, CT has shown poor results for the local staging of rectal lesions.

The Magnetic Resonance Imaging and Rectal Cancer European Equivalence Study (MERCURY) study showed that high-resolution MRI can accurately predict involvement of the surgical resection margin (≤1 mm) and extramural tumor invasion. The study showed that MRI is reproducible and allows patients to be selected on this basis for preoperative treatment. As a result, this form of preoperative staging is more widespread and is becoming mandatory in certain countries (the United Kingdom, Denmark, Norway, and Sweden) in the management of rectal cancer [6–8].

In this article we describe a systematic approach to the interpretation of MR images that enables all clinically relevant structures to be adequately assessed.

Technique

We perform this examination for all patients with histologically proven rectal cancer as part of their staging process before initiating treatment. We recommend no bowel preparation, filling of the rectum with contrast agents, or air insufflation. IV or intramuscular antispasmodic agents are also not mandatory but can be helpful in improving image quality. IV contrast enhancement with gadolinium is not recommended for the staging of rectal cancer [9–11].

The technique for acquisition of the scans has previously been described [9], and the parameters are numerated in Table 1. A 1- or 1.5-T system is used with phased-array coils. These coils maintain the high signal required but will obtain greater coverage than endorectal coils. Our experience with 3 T using the present protocol is still limited, but it is likely that there is a benefit from the higher

Keywords: MRI, preoperative staging, rectal cancer

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thirds because outcomes appear to relate to the height of the tumor.

Upper Third

The tumor is in the upper third when its lowest edge is more than 10 cm from the anal verge. The anterior wall of the upper rectum is covered by the peritoneal reflection; the point of attachment occurs at a variable height, particularly in women, and can be as low as 5 cm from the anal verge. Knowledge that the tumor is at this site in relation to the peritoneal reflection must facilitate a careful search for peritoneal perforation of these tumors because of the importance of transcoelomic spread [14, 15].

Middle Third

The middle third of the rectum is the area between 5 and 10 cm from the anal verge. At this point the rectum is entirely encircled by mesorectal fat; most patients with tumors at this level will undergo a total mesorectal excision with sphincter-sparing surgery [3].

Lower Third

The lower third of the rectum is the area below 5 cm from the anal verge, the area of the rectum and mesorectum below the origin of the levators where the mesorectum tapers sharply. Interpretation at this level is more challenging.

T Staging the Tumor

The process of T staging is shown in Table 2. A morphologic description of the tumor can be helpful in identifying its invasive portion and will indicate the area that causes the most concern.

MRI can help in interpreting the relationship of the tumor to the surrounding structures and the bowel wall; these layers can usually be clearly identified (Figs. 1–7). On T2-weighted images, the muscularis mucosal layer is shown as a fine low-signal-intensity line with the thicker, high-signal submucosal layer seen beneath. The muscularis propria can often be depicted as two distinct layers, the inner circular layer and the outer longitudinal layer. The outer muscle layer has an irregular grooved appearance with interruptions due to vessels entering the rectal wall.

The perirectal fat appears as a high signal surrounding the low signal of the muscularis propria and contains signal void vessels (i.e., vessels that do not show any signal). The mesorectal fascia is seen as a fine, low-signal layer enveloping the perirectal fat and rectum; it is this layer that defines the surgical excision plane in anterior total mesorectal resections [3].

MRI diagnosis of a stage T3 lesion is based on the presence of tumor signal extending into the perirectal fat with a broad-based bulging or nodular configuration in continu-

---

**TABLE 2: T Staging on MRI**

<table>
<thead>
<tr>
<th>Tx</th>
<th>Primary tumor cannot be assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>No evidence of primary tumor</td>
</tr>
<tr>
<td>T1</td>
<td>Tumor invades submucosa: low signal in submucosal layer, replacement of submucosal layer by abnormal signal not extending into circular muscle layer (Fig. 2)</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor invades but does not penetrate muscularis propria: intermediate signal intensity (higher signal than muscle, lower signal than submucosa) in muscularis propria; outer muscle coat replaced by tumor of intermediate signal intensity that does not extend beyond outer rectal muscle into rectal fat (Fig. 3)</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor invades subserosa through muscularis propria: broad-based bulge or nodular projection (not fine spiculation) of intermediate signal intensity projecting beyond outer muscle coat (Figs. 4 and 5)</td>
</tr>
<tr>
<td>T3a</td>
<td>Tumor extends &lt; 1 mm beyond muscularis propria</td>
</tr>
<tr>
<td>T3b</td>
<td>Tumor extends 1–5 mm beyond muscularis propria</td>
</tr>
<tr>
<td>T3c</td>
<td>Tumor extends &gt; 5–15 mm beyond muscularis propria</td>
</tr>
<tr>
<td>T3d</td>
<td>Tumor extends &gt; 15 mm beyond muscularis propria</td>
</tr>
<tr>
<td>T4</td>
<td>Tumor invades other organs: extension of abnormal signal into adjacent organ, extension of tumor signal through peritoneal reflection (Fig. 6)</td>
</tr>
</tbody>
</table>

---
Worthy for the surgeon in planning the distal diagnosis (and ill-defined border will have a worse prognosis important. Tumors with a widely infiltrative pattern of malignancy [24–26].

...shown that these tend to have a lower grade of an ulcerating lesion with a central indentation and raised, rolled edges. These cancers usually grow circumferentially; most will ultimately cause an annular stenosis of 1 cm [30–32].

...accurate interpretation of several important prognostic features in rectal cancer.

The ability of MRI to accurately image the relevant structures of the mesorectum in rectal cancer has become increasingly evident. Advances in imaging technique, together with development of dedicated methods for performing the MRI examination in rectal cancer, have resulted in improved image acquisition. Standardized imaging criteria using thin-section MRI, 3-mm slices, and a small field of view (160–200 mm) allow accurate interpretation of several important prognostic features in rectal cancer.

A thorough evaluation of the images can be a daunting task. The aim of this article is to provide an aid to the systematic evaluation of scans to ensure that all clinically relevant structures are adequately assessed. We have also provided some examples to aid in interpretation of these scans.

**General Description**

The most common description of a tumor is of an ulcerating lesion with a central indentation and raised, rolled edges. These cancers usually grow circumferentially; most will ultimately cause an annular stenosis of the bowel wall. Polypoid tumors are those that protrude into the lumen; studies have shown that these tend to have a lower grade of malignancy [24–26].

The pattern of invasion by rectal tumors is important. Tumors with a widely infiltrative and ill-defined border will have a worse prognosis (= 25% of cases) [20, 27, 28]. However, an inflammatory response at the advancing margin is likely to indicate a more favorable prognosis [20, 29]. It is rare for rectal tumors to show intramural spread, a fact that is noteworthy for the surgeon in planning the distal resection margin. Current recommendation allows a distal clearance of 1 cm [30–32].

**Images After Chemoradiotherapy**

For patients who receive preoperative chemoradiotherapy, we use a tumor regression grade analysis, grades 1–5, modified from Dworak et al. [22] (Table 4). Grade analysis is known to be a better predictor of outcome after treatment than T stage [23].

**Discussion**

The use of preoperative therapy and the selection of patients vary widely and range from routine use of preoperative therapy for all stage T3 and T4 tumors, which form most rectal cancers, to the more selective use of chemoradiotherapy, depending on the risk of both local and distant failure. A more selective approach has been suggested because better patient selection using MRI may be a more effective future strategy that will enable targeted selection of high-risk tumors [41, 42]. This is particularly relevant when considering the morbidity that is associated with chemoradiotherapy [43, 44].

**T Staging and Nodal Status**

The international TNM staging system [35] is the most widely used pathologic staging system. It is based on the depth of tumor into and beyond the bowel wall, the number of nodal metastases, and the presence of distant metastases. At this time, T staging and margin status give us much of the preoperative information that allows clinical decision making. In the Dutch rectal cancer trial, patients were randomized to preoperative radiation therapy or surgery alone (all underwent total mesorectal excision). That study of mobile operable cancers showed a benefit from radiation therapy, but the degree of benefit depended on the stage of the primary tumor [36]. That study was performed without preoperative staging; accurate identification of the preoperative stage can allow greater patient selection.

Previous studies have described staging failures due to overstaging of T2 lesions [37, 38], with difficulty in the distinction of spiculation in the perirectal fat caused by fibrosis alone compared with that caused by fibrosis that contains tumor cells. The difficulties of overstaging of T3 tumors by endoscopic sonography have been documented [39]. In that study, 18% of patients with stage T3 or T4 node-positive tumors by endoscopic sonography were shown to be stage T1 or T2 node-negative tumors at pathology. In our experience, perirectal fibrosis can be seen as spiculation with lower signal intensity compared with the broad-based or nodular appearance of an advancing tumor margin [40].

**Margin Status**

Many studies have shown that depth of extramural invasion, nodal involvement, and involvement of the circumferential resection margin are independent markers for poor prognosis [45–48]. Indeed, circumferential...
3-T MRI of Rectal Carcinoma: Preoperative Diagnosis, Staging, and Planning of Sphincter-Sparing Surgery

Xiao Ming Zhang1,2
Hong Lei Zhang2
Dexin Yu1
Yong Dai3
Dongsong Bi3
Martin R. Prince2
Chuanfu Li1

OBJECTIVE. The purpose of this study was to assess the accuracy of 3-T MRI in the preoperative diagnosis, staging, and planning of surgical management of rectal carcinoma.

SUBJECTS AND METHODS. Thirty-eight patients (23 men, 15 women) with clinically suspected rectal carcinoma underwent 3-T MRI. Coronal, axial, and sagittal T2-weighted sequences with and without fat suppression; axial T1-weighted spin-echo sequences; axial T1-weighted gradient-echo sequences with and without fat suppression; oblique 2D MR hydrography; and 3D fat-suppressed dynamic contrast-enhanced MRI were performed. Image quality with these sequences was evaluated by three radiologists experienced in body MRI. The significance of difference in results with the sequences was tested. The manner in which MRI staging and feasibility of sphincter-sparing surgery agreed with operative and pathologic findings was evaluated with kappa statistics.

RESULTS. Rectal carcinoma was identified on MRI and confirmed histologically in all 38 patients. MRI findings were correctly predictive of T category in 35 cases (accuracy, 92.1%). In 31 (96.9%) of 32 resectable cases, sphincter-sparing surgical approaches were accurately chosen on the basis of MRI findings. Among the 11 sequences, 3D fat-suppressed dynamic contrast-enhanced MRI best delineated tumor margins. Coronal and axial T2-weighted images also well depicted tumor margins with minimal artifact. T2-weighted images were superior to unenhanced T1-weighted images.

CONCLUSION. MRI of rectal cancer at 3 T is accurate for prediction of T category and the feasibility of sphincter-sparing surgery. The best images were obtained with coronal, sagittal, and axial T2-weighted sequences and 3D fat-suppressed dynamic contrast-enhanced MRI.

colorectal carcinoma is the second most common cancer in Western society with 148,620 new cases and 55,170 deaths in the United States each year [1], and the worldwide incidence is rapidly increasing as diet and lifestyles change. Accurate preoperative diagnosis and staging of rectal carcinoma, which are essential for treatment planning and prognosis, can be achieved with endorectal sonography [2–5] and CT [6, 7]. Because of its superior soft-tissue contrast and multiplanar capability, MRI is becoming increasingly accepted by radiologists, surgeons, and patients for imaging of the rectum. Use of MRI also eliminates the risks of ionizing radiation and nephrotoxicity from iodinated contrast material.

Most studies of rectal MRI have been performed with a field strength of 1.5 T or lower [8–11] because susceptibility artifacts from bowel gas increase at higher field strength. This artifact, however, can be reduced with the use of spin-echo sequences and distention of the rectum with warm water. In a preliminary study, Chun et al. [12] found that 3-T high-field-strength MRI with only four MR sequences and without gadolinium enhancement or MR hydrography was almost as accurate as endorectal sonography for staging rectal carcinoma. Another study [13] of the use of 3-T MRI with a four-channel phased-array coil in the diagnosis of rectal cancer also showed promising results with T2-weighted fast spin-echo sequences in the axial and sagittal planes and 2D T1-weighted sequences with fat saturation before and after gadolinium enhancement. There remains uncertainty, however, about the optimal pulse sequences, and there are limited data on the diagnostic accuracy of rectal MRI at 3 T. The lack of a standard protocol causes inconsistent diagnostic accuracy among institutions. The purpose of this study was to...
MRI of Rectal Carcinoma

MRI of Rectal Carcinoma

Fig. 2—57-year-old man with T1 well-differentiated rectal adenocarcinoma (arrow). Coronal T2-weighted MR image shows distance from lower margin of rectal cancer to upper margin of external sphincter, where levator ani muscle (arrowheads) attached to rectum, was 5 cm (double arrow). Patient underwent sphincter-sparing resection of rectum.

Fig. 3—58-year-old man with T2 moderately differentiated rectal adenocarcinoma (arrow). Coronal T2-weighted MR image shows distance from lower margin of rectal tumor to point where levator ani muscle (arrowheads) attaches to rectum is 1.5 cm (double arrow). Patient underwent internal sphincter resection with prolapsing technique to save external sphincter and anus.

Fig. 4—75-year-old man with T3 rectal carcinoma. Axial T2-weighted MR image shows rectal tumor (arrow) and local lymph node metastasis (arrowhead).

Fig. 5—72-year-old man with T4 rectal adenocarcinoma. Axial T2-weighted MR image shows tumor (arrow) with invasion into prostate gland (arrowhead).

TABLE 2: Mean Ridit Value of Image Quality Scores for Each 3-T MRI Sequence

<table>
<thead>
<tr>
<th>Sequence</th>
<th>No. of Patients</th>
<th>Ridit</th>
<th>Artifact</th>
<th>Depiction of Border Between Rectal Tumor and Normal Rectum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal T2-weighted</td>
<td>38</td>
<td>0.59</td>
<td>0.56</td>
<td>0.58</td>
</tr>
<tr>
<td>Coronal T2-weighted with fat suppression</td>
<td>9</td>
<td>0.59</td>
<td>0.53</td>
<td>0.51</td>
</tr>
<tr>
<td>Sagittal T2-weighted</td>
<td>38</td>
<td>0.54</td>
<td>0.46</td>
<td>0.53</td>
</tr>
<tr>
<td>Sagittal T2-weighted with fat suppression</td>
<td>5</td>
<td>0.47</td>
<td>0.44</td>
<td>0.51</td>
</tr>
<tr>
<td>Axial T2-weighted</td>
<td>38</td>
<td>0.59</td>
<td>0.54</td>
<td>0.56</td>
</tr>
<tr>
<td>Axial T2-weighted with fat suppression</td>
<td>38</td>
<td>0.58</td>
<td>0.53</td>
<td>0.41</td>
</tr>
<tr>
<td>Axial T1-weighted SPGR</td>
<td>38</td>
<td>0.24</td>
<td>0.28</td>
<td>0.20</td>
</tr>
<tr>
<td>Axial T1-weighted SPGR with fat suppression</td>
<td>38</td>
<td>0.47</td>
<td>0.34</td>
<td>0.27</td>
</tr>
<tr>
<td>Axial T1-weighted FSE</td>
<td>14</td>
<td>0.49</td>
<td>0.43</td>
<td>0.29</td>
</tr>
<tr>
<td>Hydrographic single-shot FSE</td>
<td>38</td>
<td>0.44</td>
<td>0.43</td>
<td>—</td>
</tr>
<tr>
<td>Axial 3D T1-weighted dynamic gadolinium enhancement</td>
<td>38</td>
<td>0.53</td>
<td>0.47</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Note—Dash (—) indicates not available. SPGR = spoiled gradient-recalled echo, FSE = fast spin echo.

A statistical method used to describe differences between groups on an ordered categoric basis.

Number of patients in whom sequence was performed.

Discussion

The anatomic location, fixation in the pelvic fat, and lack of peristalsis make the rectum an ideal organ for imaging with MRI [14]. Although rectal tumors can be diagnosed with digital examination, barium enema, and colonoscopy or sigmoidoscopy, these endoluminal techniques do not provide sufficient information about the extraluminal spread of tumor for preoperative planning. Rectal MRI has the benefits of multiplanar imaging and excellent contrast between tumor and perirectal fat, which helps precisely show the tumor and its extent for surgical planning and staging. Some authors [11] recommend MRI for imaging low-lying rectal cancer because MRI has better accuracy for detecting lymph node metastasis. Of 17 patients with lymph node metastasis and 19 of 21 patients without nodal metastasis were correctly identified (accuracy, 79.0%; \( \kappa = 0.56; p < 0.001 \) ) (Table 4).

For the 32 resectable tumors, with a 2 cm or greater distance between the lower margin of rectal cancer to the point at which the levator ani muscle attached to the rectum as the criterion for predicting the feasibility of sphincter-sparing surgery, MRI was accurate for determining the surgical approach in 31 cases (accuracy, 96.9%; \( \kappa = 0.9; p < 0.0001 \) ). The only patient with less than 2 cm between the tumor and the levator ani muscle had T2 well-differentiated rectal adenocarcinoma. This patient underwent internal sphincter resection with prolapsing technique to save at least the external sphincter and anus, although the distance was only 1.5 cm on MRI.
sequences, albeit with a longer acquisition time than for the axial T1-weighted gradient-echo sequence, but was still substantially inferior to that of the T2-weighted images. Coronal and sagittal images were especially useful for showing the relations among the tumor, levator ani muscle, and sphincter.

All three reviewers identified dynamic contrast-enhanced MRI as the best sequence for depicting tumor margins even through respiratory motion artifact was present. All reviewers considered this sequence essential in the rectal MRI protocol. This finding was consistent with those of a study by Wallengren et al. [24]. In the detection of rectal cancer, those investigators reported 100% sensitivity and 70% specificity of MRI performed with contrast enhancement by superparamagnetic ferrioxalate. This double-contrast method also was clinically valuable for staging and determining the depth of tumor invasion into the rectal wall, which was not possible in this study because of our goal of assessing MR hydrography performed with saline enema.

MR hydrography has been used successfully to visualize the lumens of biliary ducts, pancreatic ducts, the ureters, and the bladder through depiction of static fluid. In this study, sodium chloride was introduced into the rectum to show the rectal lumen distended with water in a manner similar to that used for 2D single-shot fast spin-echo MR hydrography performed radially to view the endoluminal features from different angles. Depiction of the rectal lumen was similar to that on images from barium enemas.

Bowel preparation is crucial to avoid interference from feces and to reduce susceptibility artifact from air–tissue borders. In this study, a simplified 20-mL glycerin enema 1 hour before the examination was adequate for patients with rectal cancer in the middle and lower sections who had not yet undergone magnesium sulfate bowel cleansing for surgery. Distention of the rectum is useful but often is not possible owing to encasement by tumor; at least one group of authors [25] has suggested that bowel preparation and distention are unnecessary. Lauenstein et al. [26] suggested oral administration of multiple doses of gadolinium or barium sulfate beginning 3 days before MRI examination to label feces, entirely avoiding enemas. Many contrast materials have been used to distend the rectum, including air [27], water [28], dilute gadolinium, and other paramagnetic agents [24, 29]. In our study, warm sodium chloride was used mainly because of its low cost, absence of toxicity, and acceptance by patients.

In addition to facilitating the diagnosis and staging of rectal tumors, MRI contributes to surgical planning by showing the relations among the tumor, the sphincter, and the levator ani muscle. Sphincter invasion is identified with an accuracy of 87% [30, 31]. Complete tumor resection and sphincter sparing are important goals of rectal surgery to improve quality of life and have fewer complications than abdominoperineal excision. A rectal cancer distal resection margin greater than 2 cm is considered optimal for avoiding recurrence [32]. Thus the length of normal rectum above the levator ani muscle is the key to determining whether sphincter-sparing surgery can be performed. In this study, the distance from the lower margin of rectal cancer to the upper margin of the external sphincter (the point at which the levator ani muscle attaches to the rectum) was measured on good-quality coronal and sagittal images to assess the feasibility of sphincter-sparing surgery with adequate tumor margins. Data on 32 patients with surgical confirmation showed that findings on 3-T MRI were accurate predictors of the feasibility of sphincter-sparing surgery in 31 (96.9%) of the patients. In one patient with a 1.5-cm distance between the tumor and the levator ani muscle, MRI helped the surgeons to plan a modified procedure that spared the external sphincter and anus.

### TABLE 3: Accuracy of 3-T MRI in TNM Staging of Rectal Cancer

<table>
<thead>
<tr>
<th>MRI Finding (n)</th>
<th>True Positive</th>
<th>True Negative</th>
<th>False Positive</th>
<th>False Negative</th>
<th>Accuracy (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Negative Predictive Value (%)</th>
<th>Positive Predictive Value (%)</th>
<th>( \kappa )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>T category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>92.1</td>
<td>88</td>
<td>100</td>
<td>81.3</td>
<td>100</td>
<td>0.83</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Invasion to fat surrounding rectum</td>
<td>22</td>
<td>13</td>
<td>0</td>
<td>3</td>
<td>92.1</td>
<td>88</td>
<td>100</td>
<td>81.3</td>
<td>100</td>
<td>0.83</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Invasion to adjacent organs</td>
<td>4</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>1.00</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lymph node metastasis</td>
<td>11</td>
<td>19</td>
<td>2</td>
<td>6</td>
<td>79.0</td>
<td>64.7</td>
<td>90.5</td>
<td>76</td>
<td>84.6</td>
<td>0.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sphincter sparing possible</td>
<td>25</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>96.9</td>
<td>96.2</td>
<td>100</td>
<td>85.7</td>
<td>100</td>
<td>0.90</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
The importance of rectal cancer MRI protocols on interpretation accuracy

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Abstract

Background: Magnetic resonance imaging (MRI) is used for preoperative local staging in patients with rectal cancer. Our aim was to retrospectively study the effects of the imaging protocol on the staging accuracy.

Patients and methods: MR-examinations of 37 patients with locally advanced disease were divided into two groups; compliant and noncompliant, based on the imaging protocol, without knowledge of the histopathological results. A compliant rectal cancer imaging protocol was defined as including T2-weighted imaging in the sagittal and axial planes with supplementary coronal in low rectal tumors, alongside a high-resolution plane perpendicular to the rectum at the level of the primary tumor. Protocols not complying with these criteria were defined as noncompliant. Histopathological results were used as gold standard.

Results: Compliant rectal imaging protocols showed significantly better correlation with histopathological results regardless of anterior organ involvement (sensitivity and specificity rates in compliant group were 86% and 94%, respectively vs. 50% and 33% in the noncompliant group). Compliant imaging protocols also used statistically significantly smaller voxel sizes and fewer number of MR sequences than the noncompliant protocols.

Conclusion: Appropriate MR imaging protocols enable more accurate local staging of locally advanced rectal tumors with less number of sequences and without intravenous gadolinium contrast agents.