Multiplanar MRI assists rectal cancer detection and staging

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Rectal cancer is a common cause of death in Europe and the U.S. Prognosis is directly related to the extent of extramural spread in the mesorectum at the time of diagnosis and to surgical clearance at circumferential resection margins.1

Tumor detection prior to invasion through the muscularis propria and before lymph node metastases appear offers the best prognosis and permits more limited surgery.2 Anterior or abdominoperineal resection is the standard treatment for rectal tumors, although a greater proportion of resections are now sphincter-saving or involve local excision.3,4

Despite surgical advances, local recurrence rates postresection of a primary rectal carcinoma range from 30% to 50%.5,6 Factors that predict local recurrence include tumor morphology, tumor and nodal stage (see table), surgical technique, and involvement of the lateral resection margin at the time of surgery.7,8 Two advances in therapy are reducing the frequency of local recurrence and improving survival: total mesorectal excision and preoperative neoadjuvant chemoradiation therapy, which can downstage locally advanced lesions and decrease locoregional recurrence.6,7 These advances have increased the importance of accurate preoperative assessment of a tumor's location and size and the extent of local infiltration in determining the appropriate therapeutic strategy.1,9,10 Imaging must provide reliable anatomical and spatial information to aid surgical planning. Accurate assessment of the depth of mural and extramural spread also influences selection of patients for preoperative adjuvant therapies. Precise evaluation of locally recurrent carcinoma is essential to treatment planning as well.

MR has been used to assess preoperative and recurrent rectal carcinoma. Multiplanar MRI and high tissue contrast enable noninvasive 3D definition of tumor extension and reveal depth of local wall invasion, extramural infiltration, and regional lymph node metastases.

MR OPTIONS

Initial attempts to stage rectal carcinoma with conventional body coil MR imaging proved disappointing, showing no increase in accuracy over CT.4 The problems were mainly due to poor spatial resolution and difficulties resolving rectal wall layers, which in turn hampered evaluations of the depth of wall invasion.8,9 Because wall invasion is an essential part of tumor staging and treatment planning, MR staging has not been adopted as a routine tool.

Development of phased-array flexible surface coils and rapid thin-section scanning techniques, with and without intravenous paramagnetic contrast, has improved the accuracy of MR staging. Endorectal surface coils and double-contrast techniques have further expanded MR's applications in evaluating rectal and perirectal neoplasm.

Phased-array pelvic coils and fast spin-echo sequences offer improved rectal wall spatial resolution and fewer motion artifacts than body coil imaging.5,9 Detailed visualization of the entire mesorectum and the surrounding pelvic structures permits rectal tumor staging with a high degree of accuracy.

Standard protocols should involve multiplanar high-resolution T1- and T2-weighted MR imaging. Fat saturation sequences may be added to eliminate signal from perirectal fat; they may also increase lesion conspicuity, particularly in advanced lesions invading through the muscularis propria. Some authors do not find these sequences necessary, however.1,11 Fat saturation sequences can additionally help define advanced or recurrent tumor masses and detect potential complications such as fistulae.

Oblique axial T2-weighted MR imaging through the rectal tumor and adjacent perirectal tissues, using a small field-of-view, can obtain true axial assessment of the tumor and reduce depth overestimations. The required scan time of approximately 20 minutes is acceptable even in busy departments that perform a large number of examinations.

Some authors advocate adding dynamic MR sequences following administration of intravenous gadolinium, although this increases scan time.4,5 The mucosa and muscularis mucosa display early
and significant enhancement, but the muscularis propria does not. This feature may help yield reliable evaluation of the integrity of the muscularis propria and can aid differentiation between T2 and T3 tumors. Rectal carcinoma also enhances on administration of gadolinium, increasing the tumor-to-muscle contrast.4 Dynamic MR sequences have a role in postradiotherapy tumor assessment. Tumors may be iso- or hypointense on T2-weighted sequences but enhance after contrast injection.5 Practitioners should remember, however, that scar tissue can remain in the inflammatory stage and show contrast enhancement for 12 months following surgery. This complicates differentiation of scar tissue from recurrent tumor.5 Images acquired using an endorectal coil can depict the rectal wall and the immediate perirectal tissues with higher resolution than those acquired using pelvic phased-array coils.9 The technique is invasive and difficult to perform if a rectal stricture or painful tumor is present, and failure rates for coil insertion are high (up to 40%).11,12 Identification of individual wall layers can be problematic if pressure from the balloon compresses the mucosa and muscularis propria together.4 The examination field is also limited, and thus the tumor may not be imaged in its entirety. Restricted views can miss pathological pelvic nodes and extension to adjacent organs.3,11 Double contrast-enhanced MR imaging offers an alternative way to improve tissue characterization and staging accuracy.11 It consists of intravenous administration of Gd-based contrast coupled with an enema containing superparamagnetic iron oxide particles. Methylcellulose has also been employed successfully as a rectal contrast agent.13 Published data have shown double contrast-enhanced subtraction imaging to be more accurate than T2-weighted spin-echo MR for differentiating fibrosis from tumor recurrence.14 A separate study of diffusion MR for rectal tumor assessment, particularly to predict response to chemotherapy, has shown promising results.15

TUMOR, NODAL STAGING

Pelvic MR imaging using phased-array coils accurately delineates the layered rectal wall and measures extramural penetration depth. These features are especially clear on T2-weighted sequences, which show the innermost mucosa and outermost muscularis propria as low signal intensity and the submucosal intermediate layer as high signal intensity.1 Tumor tissue has a relatively high water content and, therefore, exhibits high signal intensity on T2-weighted MR images—typically higher than that of circular and longitudinal muscles but lower than submucosa. Tumor tissue is less well defined on T1-weighted MR, but this sequence demonstrates extension into perirectal fat well because of high fat/tumor contrast.

MR can also differentiate between mucinous and nonmucinous tumors. Mucinous tumors, which account for up to 20% of rectal carcinomas, show high signal intensity on T2-weighted images and characteristic heterogeneous enhancement patterns following the administration of contrast.5,16 Visualizing the muscularis propria is crucial for gauging rectal wall penetration and tumor stage. T1 tumors are limited to the submucosa, while T2 tumors invade into but not through the muscularis propria. Distinguishing between these two tumor types is difficult with MR, regardless of technique,17 although this is not necessarily a problem because both types are generally treated in the same manner with local excision alone (Figure 1).

Patients with T3 tumors, which penetrate through the muscularis propria into the perirectal fat, may be selected for adjuvant treatment, making accurate staging more important. MR imaging generally distinguishes between T2 and T3 tumors accurately and consistently. Most MR staging failures occur in differentiating between T2 and borderline T3 lesions (Figure 2).1,12 but again, this is not overly problematic because surgery is usually an effective treatment for minimal T3 lesions.1 A common staging pitfall involves interpretation of spiculation in the perirectal fat as indication of advancing tumor. This finding may also be caused by fibrosis, peritumoral inflammatory response, or radiotherapy. It should be interpreted with caution when viewed alone.1,5,12 Peritumoral fibrosis and inflammation can also lead to overstaging if MR imaging is performed with an endorectal coil; this problem is common to all imaging modalities.3,4,8 T3 lesions should have a broadbased, bulging configuration through the muscularis propria and be contiguous with the intramural portion of the tumor (i.e., it should be possible to see the portion outside the muscularis propria connected to the rest of the tumor mass). Advancing tumor may have a nodular configuration and higher signal intensity than fibrous tissue.1 Misinterpretation of small interruptions of the outer muscular layer, observed in normal bowel due to penetration of small perirectal vessels, may also cause overstaging.

The direct invasion into bone or muscle that is associated with more advanced lesions is clearly seen on T2-weighted MR (Figure 3). MR techniques have proved highly accurate at predicting tumor infiltration of surrounding structures for locally advanced primary or recurrent rectal cancers.5 The
modality can stage tumors with up to 95% accuracy, depending on the specific technique.3,4,8

ULTRASOUND, CT
MR compares favorably with endorectal ultrasound, the previous gold standard for local staging of colorectal lesions.3,12 Endorectal ultrasound visualizes all layers of the rectal wall, but contrast between tumor and the muscularis propria may be limited. Once the submucosa is breached, determining the depth of muscle invasion and detecting early perirectal fat infiltration can be difficult. This can affect differentiation between T2 and T3 lesions, especially following radiotherapy.4
Like endorectal MR, endorectal ultrasound imaging offers an only limited assessment of bulky, structuring, or high rectal tumors. Ultrasound at times understages these tumors and cannot detect spread outside the transducer range.1,8 Operator expertise and experience are important, as with all ultrasound techniques.
CT provides a good assessment of tumor extension into adjacent organs, but it cannot reliably determine the depth of mural or perirectal invasion. Its role in preoperative staging is therefore restricted.4,9 CT also has limited value for postoperative assessment because it cannot differentiate among fibrosis, normal tissue, and tumor recurrence.5

ROLE OF PET
PET assessment of tumor recurrence has shown greater sensitivity and specificity than MR and CT techniques.8 Lack of precise anatomical definition and orientation, however, makes correlation with cross-sectional imaging essential, especially if surgery is being considered. PET has no preoperative role at present, although it could become more relevant as scanner availability increases.18

No modality is sufficiently accurate to allow confident determination of metastatic mesorectal lymph node involvement.2,6 Most imaging techniques rely on short-axis diameter to define nodal involvement, but the high frequency of enlarged reactive nodes and small tumor-containing nodes restricts accuracy.1

Tumor-affected lymph nodes lack characteristic MR appearances. Inflammatory and metastatic lymph nodes cannot be differentiated according to size or signal characteristics.12,19
MR prediction of nodal involvement has been shown to improve if nodal border contours and signal intensity characteristics are used instead of size criteria.19 Physiologic imaging with iron oxide contrast material may also offer more accurate nodal staging in the future.3 MR nodal staging accuracy is no greater than 80%, which is comparable to that of endorectal ultrasound. Pelvic MR imaging permits detection of pelvic nodes beyond the range of ultrasound transducers, however (Figure 4).3,6

SURGICAL PLANNING
Multiplanar pelvic MR contributes significantly to surgical planning, both in staging and in predicting the distance from tumor to mesorectal resection plane and therefore the all-important resection margin.7,12 It also provides a complete preoperative view of the pelvic region surrounding the tumor.
Anatomical depiction of the extramural pattern of spread, including advanced lesions, helps practitioners select patients for presurgical therapy and provides surgeons with useful preoperative information. MR's precise visualization of sphincter infiltration and integrity in patients with low rectal cancers, especially when an endorectal coil is used, aids planning of sphincter-preserving surgery, if appropriate.3,10 Patients with widespread perirectal growth, for whom even radical surgery offers no hope of cure, can be identified.11 MR can also determine the resectability of recurrent tumor and assess complications associated with recurrence with high accuracy (Figure 5).
All modalities have limitations in staging rectal tumors and evaluating the extent of wall invasion and lymph node involvement. MR imaging provides noninvasive, accurate preoperative predictions of tumor stage and extent of extramural penetration, which correlate well with histopathological assessments. The modality's results and limitations are similar to those of endorectal ultrasound for assessing the extent of wall invasion and local lymph node involvement. Pelvic MR provides slightly lower rectal wall resolution than endorectal MR, but it allows tumor spread and nodal status to be assessed throughout the pelvis, a significant advantage over endorectal imaging techniques.

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References
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TUMOR STAGING
Primary tumor (T)
Tx: Primary tumor cannot be assessed
T0: No evidence of primary tumor
Tis: Carcinoma in situ
T1: Tumor invades submucosa. Mucosal and submucosal thickening with preservation of muscularis propria on MRI
T2: Tumor invades muscularis propria. Extension of tumor into but not through muscularis propria on MRI
T3: Tumor invades subserosa or perirectal tissues. Complete disruption of muscularis propria and indistinct border to perirectal fat on MRI
T4: Tumor directly invades peritoneum or other organs
Regional lymph nodes (N)
Nx: Regional lymph nodes cannot be assessed
N0: No regional nodal metastases
N1: Metastases in one to three perirectal lymph nodes (>5 mm on MRI)
N2: Metastases in four or more perirectal lymph nodes
N3: Metastases in any lymph node along the course of a named vascular trunk
Metastases (M)
Mx: Presence of distant metastases cannot be assessed
M0: No distant metastases
M1: Distant metastases

Disclosures:

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