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Role of Magnetic Resonance Imaging in Primary Rectal Cancer—Standard Protocol and Beyond

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New-generation magnetic resonance imaging (MRI) scanners with optimal phased-array body coils have contributed to obtainment of high-resolution T2-weighted turbo spin echo images in which visualization of anatomical details such as the mesorectal fascia and the bowel wall layers is feasible. Preoperative, locoregional staging of rectal cancer with MRI, considered standard of care nowadays, relies on these images for stratification of high-risk patients for local recurrence, patients most likely to benefit from neoadjuvant therapy, as well as patients who exhibit imaging features indicative of a high risk of metastatic disease. Functional imaging, including optimized for rectal cancer diffusion-weighted imaging and more recently use of dynamic contrast-enhanced MRI, combined with radiologists' rising level of familiarity regarding the assessment of reactive changes postchemoradiation treatment, have shown to increase MRI staging accuracy after neoadjuvant treatment. Our intention is to review already established standard protocols for primary rectal cancer and go through potential additional promising imaging tools.
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Introduction

Magnetic resonance imaging (MRI) has certainly come a long way from the initial published studies introducing this modality as more accurate than computed tomography (CT) for detecting rectal cancer recurrence,[1] due to its ability to distinguish fibrosis from recurrence based on T2-weighted signal intensity characteristics, or as a useful method for determining effect of preoperative radiotherapy on rectal cancer.[2]

Magnetic Resonance Imaging and Rectal Cancer European Equivalence study (MERCURY) has demonstrated that high-resolution MRI of the rectum can accurately predict the involvement of the surgical resection margin as well as the depth of extramural tumor extension.[3] Recently published recommendations and consensus statements by expert panels namely the European Registration of Cancer Care and the European Society of Gastrointestinal and Abdominal Radiology[4,5] agree that the MRI is the first imaging choice both for primary rectal cancer locoregional staging and for restaging after neoadjuvant chemoradiation treatment (CRT).

MRI-based preoperative local staging directs neoadjuvant treatment strategies aimed primarily at the reduction of local recurrence. Short course preoperative radiotherapy and long course of CRT are used in patients presenting with T3 rectal cancer. Endorectal ultrasound (ERUS) remains the most accurate modality for assessment of tumor ingrowth into rectal wall layers and as such is highly specific for superficial tumors.[6] However, ERUS cannot adequately depict the mesorectal fascia (MF) and thus cannot stratify patients presenting with higher T3 stages according to their individual risk for local recurrence. Accurate localization and staging of rectal cancer beyond T2 stage should be performed with MRI as part of standard of care nowadays.

MRI Protocol Settings

MRI using multielement phased-array external coils (body phased-array coils or cardiac synergy phased array coils) are

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used for state-of-the-art MRI of rectal cancer at 1.5 T or 3.0 T ($\geq$1.0 T) MRI scanner.

There is no bowel preparation required for rectal MRI examination nor are spasmolytics routinely administered. However, in patients presenting with high-lying tumors and low descending small bowel loops into the dorsal pelvic cavity causing hindering motion artifacts of the posteriorly located rectal wall, spasmolytic administration may prove helpful. Intraluminal distension or opacification is not necessary, and low anterior located T2 stage rectal tumors may even lead to false-positive prediction of an involved circumferential resection margin (CRM) due to overstretching of the bowel wall and surrounding mesorectal compartment.

MRI rectum protocol comprises mainly of T2-weighted turbo spin echo (TSE) sequences that allow for good contrast between tumor, surrounding mesorectal fat, and the MF. Initially, a sagittal T2-weighted TSE sequence is obtained to detect the rectal primary, and plan further sequences accordingly.

The cardinal sequence for accurate staging and preoperative identification of poor prognostic features for local recurrence and metastatic disease is a high-resolution 2D TSE T2-weighted sequence. A considered optimal voxel size should be less or equal to $3 \times 1 \times 1\ mm^3$. High-resolution sagittal and axial oblique 2D T2-weighted sequences are mandatory for providing information regarding tumor height, T, and N stage according to TNM classification based on morphologic criteria, distance of any mesorectal fat tumor deposit to the MF, and the presence of extramural venous invasion (EMVi), allowing for patient stratification. Coronal high-resolution 2D T2-weighted sequence is especially helpful in cases of low-lying rectal cancers.

Special attention should be paid to angulation when planning these sequences, as the high-resolution axial oblique T2 w images should be obtained perpendicular to the rectal tumor axis (Fig. 1), whereas coronal T2 w images should be acquired parallel to the anal canal or tumor axis to delineate better the distal MF and anorectum for accurate distance measurement. In addition, an axial T1-weighted fast spin echo sequence over the entire pelvis is obtained, for visualization of nodes along the iliac regions, for which a slice thickness of 4 mm is considered adequate.

According to the recommendations, use of diffusion-weighted imaging (DWI) is not obligatory for primary baseline staging. DWI sequences, however, are implemented in routine rectal cancer MRI protocols nowadays. DWI depicts the random motion of water molecules in the body. In tissues presenting with high cellular content and intact cell membranes, such as rectal tumor tissue, water motion is restricted. This does not apply to the tissue from which tumor originates, in our case rectal wall, and thus DWI is very helpful in tumor detection.[7-10] DWI sequences for clinical purposes are relatively quick to perform, do not require the administration of contrast medium, and can be integrated to the existing rectal tumor imaging protocol without significant delay in the overall examination time. Optimally, DWI images have to be obtained with the same slice thickness and orientation as the high-resolution axial oblique T2-weighted images. For quantitative analysis or measurements for assessment of therapy response, at least 3 *b* values should be obtained.[10] It is advised as there is no standardization regarding the use of DWI in the abdomen, and more specifically for rectal cancer imaging, each center should test the apparent diffusion coefficient (ADC) values produced by their sequence or scanner and have own references.

Contrast administration is not required for primary rectal cancer identification and staging as the addition of a gadolinium-enhanced sequence does not improve diagnostic performance for prediction of T stage and CRM,[3] unless a lymph node–specific contrast can be administered for better conspicuity of involved lymph nodes. Examination time without contrast administration does not exceed 25 minutes.

Baseline MRI Assessment

If the MRI protocol published on recent recommendation or consensus statement articles[4,5] is followed then rectal cancer

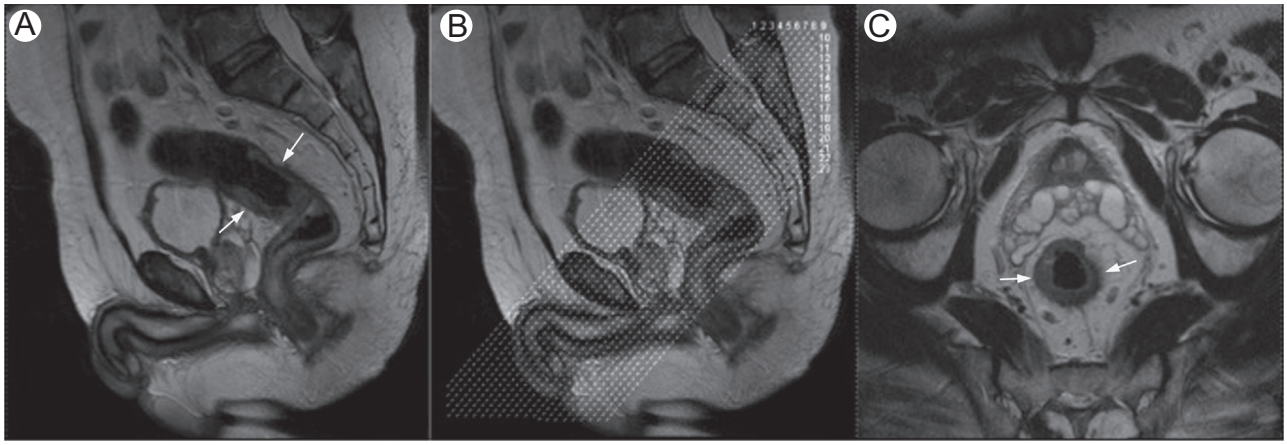

Figure 1 Tumor (arrows) is identified in the sagittal plane T2 w images, in this case circumferential mid rectal adenocarcinoma (A), and special attention should be paid to the angulation when planning the axial oblique high-resolution T2 w sequence. Plane should be perpendicular to the rectal tumor axis as this is identified on the sagittal plane T2 w images (B) so that "true axial" images are obtained (C).