High-resolution T2-weighted (T2W) oblique plane turbo spin-echo (TSE) MRI for rectal adenocarcinoma staging ☆

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ABSTRACT

Purpose: The purpose of this study was to determine the frequency/significance of incorrectly planned oblique T2-weighted (T2W) MRI of rectal adenocarcinoma.
Methods: Eighty-six consecutive patients underwent MRI for rectal cancer staging. Two radiologists evaluated oblique T2W imaging and tumor stage.
Results: A total of 71% of middle/high tumors had correctly planned oblique T2W-MRI. Thirteen of 14 low tumors ($N=7$) or tumors spanning at least two rectal segments ($N=7$) had incorrectly planned oblique T2W-MRI. The sensitivity/specificity of staging on correct compared to incorrect oblique T2W was: 88.9/50% (R1)/77.8/60% (R2) and 80/100% (R1)/60/80% (R2), ($P=.54$). Agreement was substantial, $K=0.67$.
Conclusions: Oblique T2W-MRI is incorrectly performed in low tumors and those spanning multiple rectal segments. In this study, planning errors did not impact staging accuracy.

1. Introduction

Colorectal adenocarcinoma is one of the most common cancers in the world, with an estimated 447,000 new cases diagnosed in 2012 in Europe and 166,760 in North America [1,2]. The management of colorectal and specifically rectal cancer depends on the stage of disease at presentation [3,4]. Surgical resection of the primary tumor and lymph nodes (the "total mesorectal excision") is the most common treatment for stage I or II disease, while chemotherapy and radiation may be selected for more advanced stages III and IV [3–7]. Accurate staging of rectal adenocarcinoma is essential for making appropriate treatment decisions.

Magnetic resonance imaging (MRI) is widely regarded as the reference standard for preoperative local staging of rectal adenocarcinoma and is superior to both endorectal ultrasound and computed tomography [8–13]. MRI can accurately determine tumor extramural depth of invasion [13–16]. Presently, it is recommended that the staging of rectal adenocarcinoma with MRI include high-resolution T2-weighted (T2W) sequences acquired in planes perpendicular and parallel to the tumor axis, which are often oblique relative to the true axial and coronal pelvic planes [8–13,17–19]. Oblique imaging is thought to reduce overestimation of tumor extramural depth of invasion [20]. The planning of oblique plane imaging adds complexity and time, with many institutions performing rectal adenocarcinoma MRI only under the direct supervision of an experienced radiologist; studies may take as long as 45 min to perform [12,19,21].

It is unclear how often oblique MRI is incorrectly planned in clinical practice and what the impact of planning errors are on local staging with the use of modern MRI systems. The purpose of this study is to determine the frequency of incorrectly planned oblique plane imaging using high-resolution T2W turbo spin-echo (TSE) MRI for local staging of rectal adenocarcinoma, factors associated with planning errors, and whether these errors impact assessment of tumor extramural depth of invasion.

2. Material and methods

2.1. Patient population

This study was completed under a formal quality assurance waiver from our institution's ethics review board, who waived the need for formal ethics board review and informed consent. We reviewed all pelvic MRI studies performed at our institution from July 1, 2010, to June 30, 2013. This preliminary review identified 1571 MRI studies of the pelvis for all indications. Inclusion criteria included a pelvic MRI performed for the primary local staging of pathologically proven rectal adenocarcinoma and no history of neoadjuvant rectal cancer treatment prior to the MRI study. There were 93 patients who met the inclusion criteria for analysis. From these, seven patients were excluded because MRI examinations did not have oblique imaging performed ($N=5$), MRI study quality was severely limited by artifact precluding accurate staging ($N=1$), and tumor was so extensive that it involved the whole pelvis precluding oblique image planning ($N=1$).

Table 1
Pulse sequence parameters for T2W TSE sequences in rectal carcinoma staging protocol at 1.5 and 3 T[a]

	Single-shot TSE (HASTE)	TSE (BLADE)[b]	High-resolution TSE (BLADE)
Plane	Coronal	Axial, sagittal	Axial oblique, coronal oblique[c]
Coverage	Whole pelvis	Whole pelvis	At least 1 cm above and below tumor
Physiology	Breath hold	Free breathing	Free breathing
Duration	30 s	4–5 min	4–5 min
TE;TR (ms)	90;1000	120;8000	125–136;7–9000
Flip angle (°)	180	90	128
Bandwidth (Hz)	450	130	265
Number of excitations	1	1	1
Echo train length	256	35	28–35
Acceleration factor	2[d]	1–2[d]	1–2[d]
Matrix size	256×230	320×320	320×320
FOV (cm)	35	30	20
Slice thickness (mm)	6	4	3
Interslice gap (mm)	1	1.2–2	0.2

[a] Imaging was performed on clinical 1.5 or 3 T (Symphony or TRIO; Siemens Healthcare, Malvern, PA, USA).
[b] Periodically rotated overlapping parallel lines with enhanced reconstruction (BLADE; Siemens Healthcare, Malvern, PA, USA).
[c] Axial and coronal oblique planes were planned off of large-FOV sagittal and axial sequences with respect to the tumor (for high/middle cancers) or the anal canal (for low tumors) [9,19].
[d] Acceleration factor of 2 at 3 T.

2.2. MRI technique

All patients in this study were imaged on one of two clinical MR systems at 1.5 or 3 T (Symphony or TRIO TIM; Siemens Healthcare, Malvern, PA, USA). All patients underwent the same MRI protocol, which consisted of preliminary pulse sequences of the whole pelvis including a large-field-of-view (FOV) coronal T2W half-Fourier single-shot TSE localizer sequence and large-FOV sagittal/axial T2W TSE sequences. Planning of the high-resolution axial and coronal oblique T2W TSE sequences relative to the tumor (for high and middle rectal tumors) or relative to the anal canal for low rectal tumors [8–13,17–19] was based off of the large-FOV T2W TSE sequences. Although only axial oblique (for high/middle tumors) and coronal oblique (for low tumors) are currently considered compulsory for rectal cancer staging with MRI [8–10,22], our institutional protocol requires oblique imaging
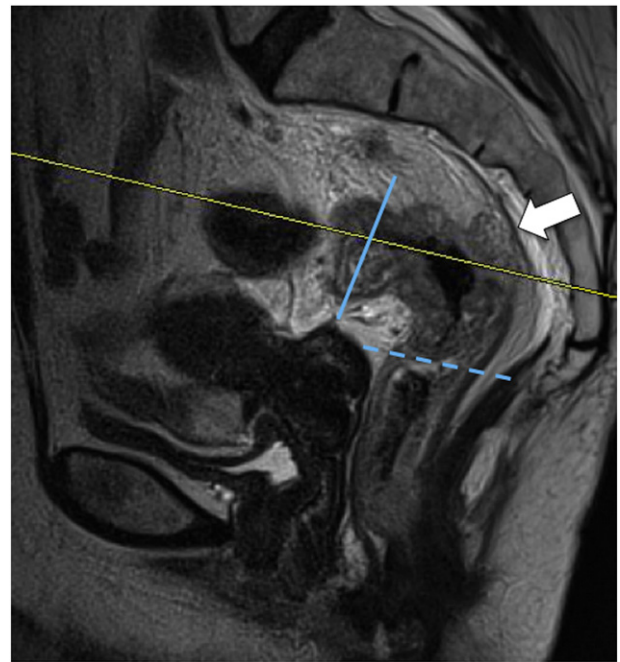

Fig. 2. Large-FOV sagittal T2W TSE image in a 55-year-old female with extensive rectal adenocarcinoma which is straddling a curved rectal segment involving both the high and middle rectum, requiring two separate axial oblique planes to adequately image the entirety of the tumor (solid and dashed blue lines). The axial oblique imaging plane (yellow line) is correctly planned (within 5°) for the middle portion of the tumor (relative to the dashed blue line) but incorrectly planned (>5° difference) for assessment of the high portion of the tumor (relative to the solid blue line). In this example, there was clearly greater than 1 mm of extramural extension. The tumor was abutting the potential circumferential resection margin posteriorly (white arrow).

in both planes for every tumor. MR pulse sequence parameters are provided in Table 1. A supervising radiologist was available for all rectal cancer staging examinations performed during the study period.

Throughout the study period, additional pulse sequences including axial T1-weighted (T1W), dual-echo T1W gradient recalled echo (GRE), axial fat-suppressed T1W GRE, gadolinium-enhanced fat-suppressed T1W GRE, and diffusion-weighted imaging were variably performed; for the purposes of this study, only the T2W TSE sequences were reviewed. All patients were instructed to undergo a cleansing enema (Fleet enema, Lynchburg, VA, USA) the morning of the
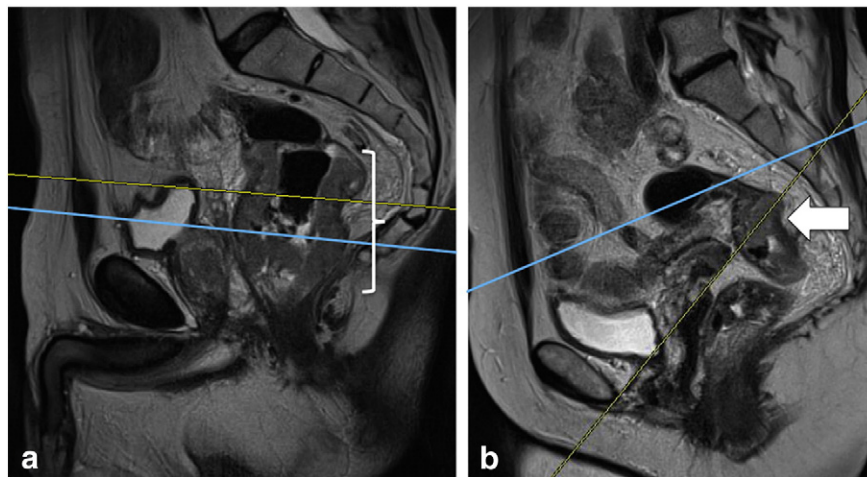

Fig. 1. Sagittal large-FOV T2W TSE image (A) in a 64-year-old male undergoing local staging MRI of the pelvis for extensive annular rectal adenocarcinoma involving the middle rectum (tumor bracketed in A). The axial oblique imaging plane, depicted by a yellow cross-reference line (automatically generated in PACS), was determined to be correctly planned (in this study, defined as within 5° of the ideal plane determined by two abdominal radiologists). The ideal plane (as selected by two radiologists) is depicted by the blue line in A. Sagittal large-FOV T2W TSE image (B) in a 57-year-old female undergoing MRI for local staging of a more focal rectal adenocarcinoma (white arrow) in the high rectum demonstrates an example of incorrect axial oblique plane imaging (yellow line), as it differed by more than 5° compared to the ideal plane (blue line).