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# High-Resolution T2-Weighted MRI to Evaluate Rectal Cancer: Why Variations Matter

Kirsten L Gormly[1, 2]

[1]Dr Jones and Partners Medical Imaging, Adelaide, Australia; [2]The University of Adelaide, Adelaide, Australia

## INTRODUCTION

MRI has been used to image rectal cancer for over two decades and there is extensive research on this imaging technique. The 1999 seminal paper by Brown et al. [1] demonstrated the accuracy of thin-slice MRI in identifying the depth of extramural tumor in 28 patients with rectal cancer. MRI has also been shown to predict involvement of the circumferential resection margin in total mesorectal excision surgery, which is extremely useful to surgeons who may otherwise have produced an R2 resection [2,3]. MRI has enabled the stratification of patients into high- and low-risk and the selection of appropriate patients for neoadjuvant chemoradiotherapy. It has previously been demonstrated that the thin section, or high-resolution (HR) T2 imaging provided promising results in the assessment of lymph nodes, detection of extramural venous invasion, and differentiation of tumors from fibrosis on post-treatment imaging, which continue to be extensively studied [4-6].

The majority of publications assessing MRI in rectal cancer describe the use of HR T2 sequences, and the term 'HR T2' has been generally accepted to represent HR imaging. There have been a variety of results regarding the accuracy of rectal MRI, particularly the T2 sequence alone, and it has been regularly assessed against other techniques including diffusion, post-contrast, and radiomics. On more in-depth methodological assessment, there is significant heterogeneity in the resolution of the HR T2 sequences across many publications, and this may have an impact on the results.

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**Corresponding author:** Kirsten L Gormly, MBBS FRANZCR, Dr Jones and Partners Medical Imaging, 226 Greenhill Road, Eastwood SA 5063, Australia.
• E-mail: Kirsten.gormly@drjones.com.au


## What Is High-Resolution T2?

The original thin slice HR T2 sequence was defined very clearly by Brown et al. [1], and is used in the MERCURY study protocols and many others [1,3,6-9]. It has an in-plane resolution of 0.6 x 0.6 mm and 3 mm slice thickness, providing a voxel size of 1.08 $mm^3$. The field of view is 160 mm, matrix 256 x 256, with four signal averages. In the year 2000, these scans took over 6 minutes using 1.5T MRI scanners. The resultant scans achieved a high spatial resolution and image quality, which is remarkably similar to that obtained today with the same parameters.

Variations in the parameters producing a larger voxel size, and therefore a lower spatial resolution, have a visible difference on the T2 sequence, as illustrated in Figure 1. These comparative images were obtained on a 1.5T scanner (Aera, Siemens) following intramuscular injection of 20 mg hyoscine butylbromide during the same examination sitting. The sequence parameters are listed in Table 1. A relatively mild increase of the in-plane resolution to 0.8 x 0.8 mm, with a slice thickness of 3 mm, gives a voxel of 1.92 $mm^3$. Hence, this does not meet the MERCURY definition of a HR T2 sequence for rectal MRI. There is a visible reduction in clarity of the rectal wall layers, the internal structure and outline of the lymph nodes and tumor deposits, and a difference in T staging.

On reviewing a selection of publications from the past two decades on MRI in rectal cancer, I note that the parameters of the HR T2 sequence have voxels ranging from 0.75 $mm^3$ to 5.4 $mm^3$. In particular, many publications

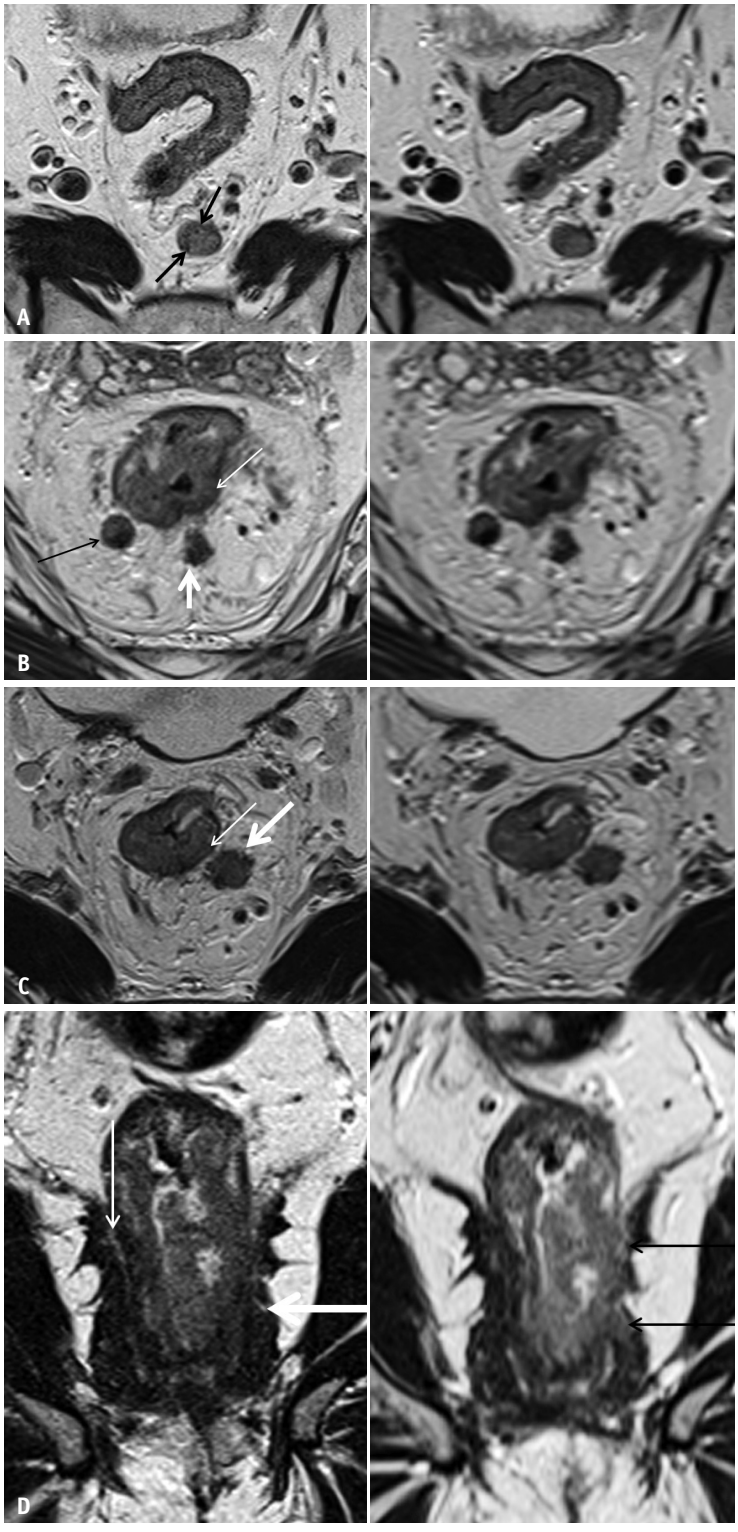


**Fig. 1. T2 axial oblique images with visible differences in scan quality.** The images have different voxel sizes: 1.08 $mm^3$ (left) and 1.92 $mm^3$ (right). See Table 1 for the sequence parameters.
**A.** Visible internal heterogeneity of the lymph node (arrows) on higher spatial resolution. **B.** Increased sharpness of the rectal wall (thin white arrow), internal signal of the lymph node (black arrow), and border of the tumor deposit (thick white arrow). **C.** Increased visibility of the submucosa in the rectal wall (thin white arrow) and lymph node border irregularity (thick white arrow). **D.** Differences in the interpretation of an anal sphincter invasion. The scan with voxel 1.08 $mm^3$ shows preservation of the external sphincter low T2 signal (T3) (thick white arrow), but with voxel 1.92 $mm^3$ appears to show tumor signal extending into the external sphincter (T4a) (black arrows). Increased visibility of the intersphincteric plane is evident on the non-involved side (thin white arrow).


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**Table 1. MRI Parameters for Comparative HR T2 Scans in Figure 1 Using 1.5T Siemens Aera**

| | TR/TE (ms) | FOV (mm) | Matrix (%) | Signal Averages | In Plane Resolution | Slice Thickness (mm) | Voxel Size ($mm^3$) | Time (Min:Sec) |
|---|---|---|---|---|---|---|---|---|
| HR | 4750/95 | 180 | 320 x 256 (80) | 4 | 0.6 x 0.6 | 3 | 1.08 | 5:10 |
| "HR" | 4750/95 | 200 | 256 x 179 (70) | 4 | 0.8 x 0.8 | 3 | 1.92 | 4:59 |

FOV = field of view, HR = high-resolution, TE = echo time, TR = repetition time

**Table 2. 1.5T Siemens Aera MR Rectum Protocol**

| Parameter | TR/TE (ms) | FOV (mm) | Matrix (%) | Signal Averages | In Plane Resolution | Slice Thickness/ Gap (mm) | Time (Min:Sec) |
|---|---|---|---|---|---|---|---|
| Axial T2WI (TSE) | 4000/110 | 360 | 448 x 358 (80) | 1 | 1.0 x 0.8 | 5.5/1.1 | 1:38 |
| Sagittal T2WI (TSE) | 4380/99 | 200 | 320 x 266 (83) | 2 | 0.66 x 0.63 | 3.0/0.3 | 4:37 |
| HR oblique axial T2WI (TSE) | 4750/95 | 180 | 320 x 256 (80) | 4 | 0.56 x 0.56 | 3.0/0.3 | 5:10 |
| HR oblique coronal T2WI | 6420/106 | 180 | 320 x 256 (80) | 4 | 0.56 x 0.56 | 3.0/0.3 | 5:16 |
| Diffusion b0, 500, 800 | 4500/66 | 230 | 128 x 109 (85) | b0-1 b400-6 b800-8 | 1.8 x 1.8 | 3.5/0 | 3:47 |

FOV = field of view, HR = high-resolution, TE = echo time, TR = repetition time, TSE = turbo spin echo, T2WI = T2 weighted imaging

have reported voxels of > 2 $mm^3$, which is greater than the lower-resolution image examples, that demonstrate visible differences. Several papers do not provide sufficient information to calculate the in-plane resolution [10-23]. However, all these sequences are usually referred to as HR, and have been accepted in the literature as representing HR T2, with no questions or discussion about the resolution of the sequence and resultant conclusions.

This has implications for the interpretation of individual articles and meta-analyses. In a meta-analysis of MRI assessment of complete response by the Korean Society of Abdominal Radiology, there is a large study heterogeneity for both T2 sensitivity and specificity for diagnosing pathological complete response [24]. The authors commented on the heterogeneity of the criteria adopted by studies to diagnose complete tumor response on T2, but they did not comment on the heterogeneity of the T2 technique assessed. Most of the 17 papers that assessed the T2 technique described the use of a HR T2 technique. However, four did not provide information on the in-plane resolution or voxel size, another four reported voxel sizes of between 1.6 $mm^3$ and 3.5 $mm^3$, and two described ranges that extended significantly above 1.1 $mm^3$. This leaves only seven papers that actually described the HR technique as defined by the MERCURY trials [7-9,16-23,25-30]. When looking at the published images of one study, which concluded that MRI was not useful and did not define their parameters, the field of view appeared quite large, and the image quality was less than expected for HR T2 images. When assessing the forest plot of T2 sensitivity for diagnosing pathological complete response, almost all those to the right of the line met the definition of the HR technique, but only one to the left of the line did. The others reported large voxels or had undefined parameters. Therefore, variation in the technique may impact the results.

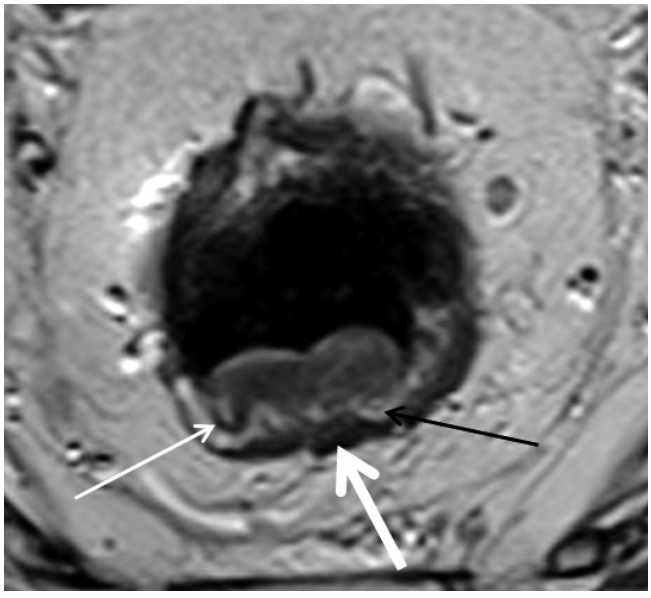

**Fig. 2. T1 tumour with well-defined wall layers on an high-resolution T2 image.** Muscularis mucosae (thin white arrow), submucosa (black arrow), and muscularis propria (thick white arrow) are shown.

## International Guidelines and Journals

The variation in the rectal MRI HR T2 technique is


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contributed to by the lack of standardization among international guidelines. The European Society of Gastrointestinal and Abdominal Radiology (ESGAR) and Society of Abdominal Radiology (SAR) consensus guidelines specify a recommended slice thickness of 3 mm but the in-plane resolution is undefined. The United Kingdom, Canadian, and Australian guidelines specify slice thickness and in-plane resolution. The Korean Society of Abdominal Radiology (KSAR) rectal reporting guidelines do not include a technical section [31-36]. These variations and the lack of a complete definition in all guidelines means that centers commencing a rectal MRI service may set up lower spatial resolution sequences without realizing that it will affect their ability to achieve a high standard of results. This has an impact on direct clinical care and research excellence.

Editors and reviewers of journals need to be aware of this issue and request the inclusion of the technical parameters so that readers can adequately assess the resolution of the T2 sequences. Many publications do include sequence parameters but do not highlight that the HR T2 definition is not met. The publishers still allow these publications to use the term, HR sequences. Groups performing meta-analyses should also consider the possible effects of lower-resolution parameters on the results. Some articles previously published in the *Korean Journal of Radiology* did not include the imaging parameters. While these were likely performed with an appropriate HR technique, it is not possible to be certain [12,15]. I suggest that it is inappropriate to call a sequence HR T2 if it does not meet the specified parameters.

## HR T2 in Practice

It is possible to achieve a small voxel and high spatial resolution scan for most magnets. The author commenced a service in Adelaide, Australia in 2004, on an older 1.5T scanner (MAGNETOM Vision, Siemens). While the HR T2 sequences took over 6 minutes to acquire, they were of high diagnostic quality because the MERCURY parameters, including four acquisitions, were applied. We currently perform the majority of our rectal MRI on 1.5T scanners with the sequence parameters listed in Table 2. While the HR T2 sequences are slightly faster on 3T scanners, they still take time. It is important to invest this time as they are the cornerstone of the rectal MRI examination and provide key information about the tumor and mesorectal structures. Using a small voxel HR technique, we can have good visualization of early tumors (Fig. 2), assess the heterogeneity of lymph nodes, and differentiate fibrosis signal from tumor signal on post-treatment scans. With the use of a spasmolytic agent, the HR T2 sequence does not routinely experience significant artifacts and is a reliable, easy-to-use sequence.

## CONCLUSION

HR T2 images are a key part of rectal MRI examination and useful for guiding patient management. It is important to be aware of the true definition of HR T2 and variations in resolution of the HR T2 sequence in the literature. To achieve the best results in day-to-day clinical practice, small voxel, HR parameters should be used. As we seek to improve rectal MRI by testing new sequences and reporting criteria, it is also important to ensure uniformity of the HR T2 sequence, so that the results are meaningful. International guidelines and editors can assist by ensuring that there is a comprehensive definition of the HR T2 sequence within guidelines, and that the parameters are included in all publications.

### Conflicts of Interest

The author has no potential conflicts of interest to disclose.

### ORCID iD

Kirsten L Gormly
https://orcid.org/0000-0002-9794-5507

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