



Review

Current concepts in imaging for local staging of advanced rectal cancer



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Imaging of rectal cancer has an increasingly pivotal role in the diagnosis, staging, and treatment stratification of patients with the disease. This is particularly true for advanced rectal cancers where magnetic resonance imaging (MRI) findings provide essential information that can change treatment. In this review we describe the rationale for the current imaging standards in advanced rectal cancer for both morphological and functional imaging on the baseline staging and reassessment studies. In addition the clinical implications and future methods by which radiologists may improve these are outlined relative to TNM8.

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Introduction

Worldwide, colorectal cancer is the third most commonly diagnosed cancer in males and the second in females.^{1,2} In 2012 there were an estimated 1.4 million cases and 693,900 deaths.² Rectal cancer accounts for approximately one third of this incidence.³

Surgical treatment for rectal cancer was revolutionised in the 1980s and 1990s with the recognition of increased local tumour recurrence in the presence of residual tumour cells at the operative circumferential resection margin (CRM).^{4–6} This led to the widespread acceptance that

optimal surgery should follow the mesorectal fascial (MRF) planes to achieve negative resection margins.^{4–6} The use of preoperative imaging was shown to be accurate in predicting patients with, or at high-risk of, tumour CRM involvement, or other high-risk features.^{7–10} This preoperative staging and so the identification of high-risk tumours has enabled the selective use of neoadjuvant management to improve overall outcomes.^{11–14}

With the exception of very early stage tumours, where there is a role for endorectal ultrasound, pelvic magnetic resonance imaging (MRI) is firmly established as the optimal method of local staging for rectal cancer.^{7–10,15,16} This is reflected in the European Registration of Cancer Care (EURECCA), European Society for Medical Oncology (ESMO), European Society of Gastrointestinal and

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Abdominal Radiologists (ESGAR), and UK National Institute for Health and Care Excellence (NICE) statements/guidelines, which recommend pelvic MRI for local disease staging, with contrast-enhanced computed tomography (CT) of the chest, abdomen, and pelvis for distant staging and complete colonoscopy (either pre- or postoperatively) for colonic mucosal assessment.^{11–14}

There are various definitions for locally advanced rectal cancer (LARC), the main factors associated with higher risk tumours are extension beyond the muscularis propria of the rectal wall, tumour threatening or involving the mesorectal fascia (MRF), growth into adjacent organs, lymph node involvement, and extra-mural venous invasion (EMVI)^{11–14} (Table 1). UK treatment recommendations include surgery alone for the low-risk tumour group; short-course preoperative radiotherapy (SCRT) followed by surgery for the moderate-risk tumour group; and preoperative chemoradiotherapy (CRT) followed by consideration for surgery (based on the tumour response on interval MRI) in the high-risk tumour group.¹² These guidelines differ to those produced by ESMO at a pan-European level (Table 2). Irrespective of the guidelines followed, baseline pelvic MRI has a pivotal role in identifying LARC and is used to select patients for neoadjuvant treatment.

In addition to primary staging, restaging assessment MRI has an increasingly pivotal role in LARC tumours as a method

of quantifying the response to neoadjuvant treatment. Descriptions of the tumour response and/or other changes are important for subsequent medical and surgical treatment planning such as whether (standard total mesorectal excision (TME) or more extensive primary surgery is appropriate.

This review will concentrate on the importance of the morphological features of LARC using standard MRI techniques and the potential impact of functional MRI techniques. The importance of accurate radiologist reporting with specific reference to TNM8 is also discussed.

MRI for primary staging

T-stage and invasion depth beyond the rectal wall

Thin-section high spatial and tissue contrast resolution MRI allows detailed depiction of the relationship between the rectal tumour and mesorectal anatomy including the layers of the rectal wall, MRF and surrounding structures.^{8,16,17}

Traditional T-staging according to TNM involved subdivision of tumours into four discrete categories, T1–4¹⁸; however, further subdivision of these categories, with the creation of four subgroups for T3 tumours (T3a–d) and two subgroups for T4 tumours (T4a–b) recognises a more nuanced approach is needed to quantify the depth of

Table 1

Comparison of definitions for locally advanced rectal cancer generated by the UK National Institute for Health and Care Excellence (NICE) and the European Society for Medical Oncology (ESMO).

UK - NICE recommendations	Risk of local recurrence		European-ESMO recommendations
A threatened (<1 mm) or breached resection margin or low tumours encroaching onto the intersphincteric plane or any levator involvement	High	Advanced disease Locally advanced disease	cT3 with any MRF involved or cT4b or levators threatened or lateral lymph node involvement cT3c/d if very low rectal tumours, levators not threatened, MRF clear or cT3c/d mid or high rectal tumours, cN1-2 (extranodal) and EMVI positive
Any cT3b or greater, in which the potential surgical margin is not threatened or any suspicious lymph node not threatening the surgical resection margin or the presence of extramural venous invasion	Moderate	Intermediate disease	cT3a/b if low rectal tumours with no involvement of levator muscles and MRF clear or cT3a/b mid or high rectal tumours, cN1-2 (not extranodal) and no EMVI
cT1 or cT2 or cT3a and No lymph node involvement	Low	Early disease	cT1 or cT2 or cT3a/b if middle or high rectal tumours, and No lymph node involvement and Not threatening the surgical resection margin and No EMVI

Definitions: cT1–4 correspond to clinical tumour stages T1–4, with a/b and c/d referring to the tumour stage subgroups. EMVI: extra mural venous invasion.

Table 2

Associated treatments for locally advanced rectal cancer generated by the UK National Institute for Health and Care Excellence (NICE) and the European Society for Medical Oncology (ESMO).

UK - NICE recommendations	Risk of local recurrence	European-ESMO recommendations	
CRT and interval to TME	High	Advanced disease	CRT or SCPRT plus FOLFOX (and delay) and TME
CRT and interval to TME	Borderline high/Moderate	Locally advanced disease	CRT or SCPRT and TME (or "watch-and-wait" in high-risk patients if cCR achieved)
SCPRT then immediate TME	Moderate	Intermediate disease	TME alone or SCPRT/CRT if good quality mesorectal excision cannot be achieved
TME alone in most cases	Low	Early disease	TME alone in most cases or TEM, CRT or 'watch-and-wait' for high-risk patients or those rejecting TME

CRT: chemoradiotherapy; TME: Total mesorectal excision; SCPRT: short course preoperative radiotherapy; TEM: Transanal endoscopic microsurgery; cCR: complete clinical response.

tumour penetration beyond the muscularis propria, which influences the risk of locoregional recurrence.^{19–21} Although debate remains about the depth of extramural growth beyond the muscularis propria that is significant, current evidence supports grouping tumours as having either <5 or >5 mm of extramural growth (T3a–b versus T3c–d).^{19–22} Appropriately aligned T2-weighted sequences, parallel and perpendicular to the tumour, allow precise sub-staging using measurements of the depth of invasion of tumours through the muscularis propria (Fig 1).¹⁷ With integration of these subcategories into treatment pathways, accurate baseline MRI staging is pivotal to direct neoadjuvant treatment (Table 2).

Mesorectal fascia involvement

T2-weighted sequences enable accurate depiction of tumours to within 1 mm of the MRF, a cut-off that has been validated in large series,²³ despite smaller studies suggesting alternative values, such as 0.4 or 2 mm.^{16,24} Preoperative identification of the relationship of the tumour to the MRF is

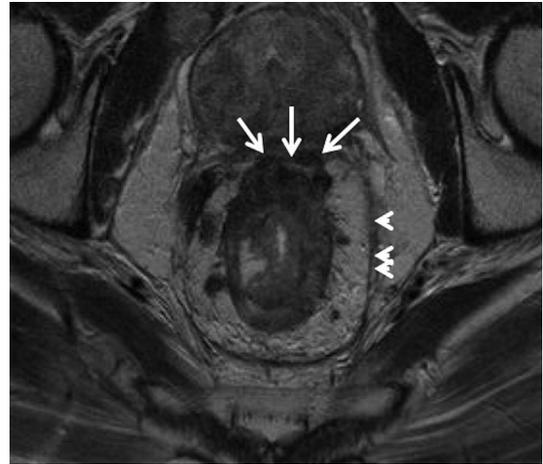


Figure 2 Axial T2W MRI image. The white arrowheads show where the mesorectal fascia is not involved or threatened by the rectal tumour. By comparison the white arrows show where there is tumour invasion through the muscularis propria and involving the mesorectal fascia.

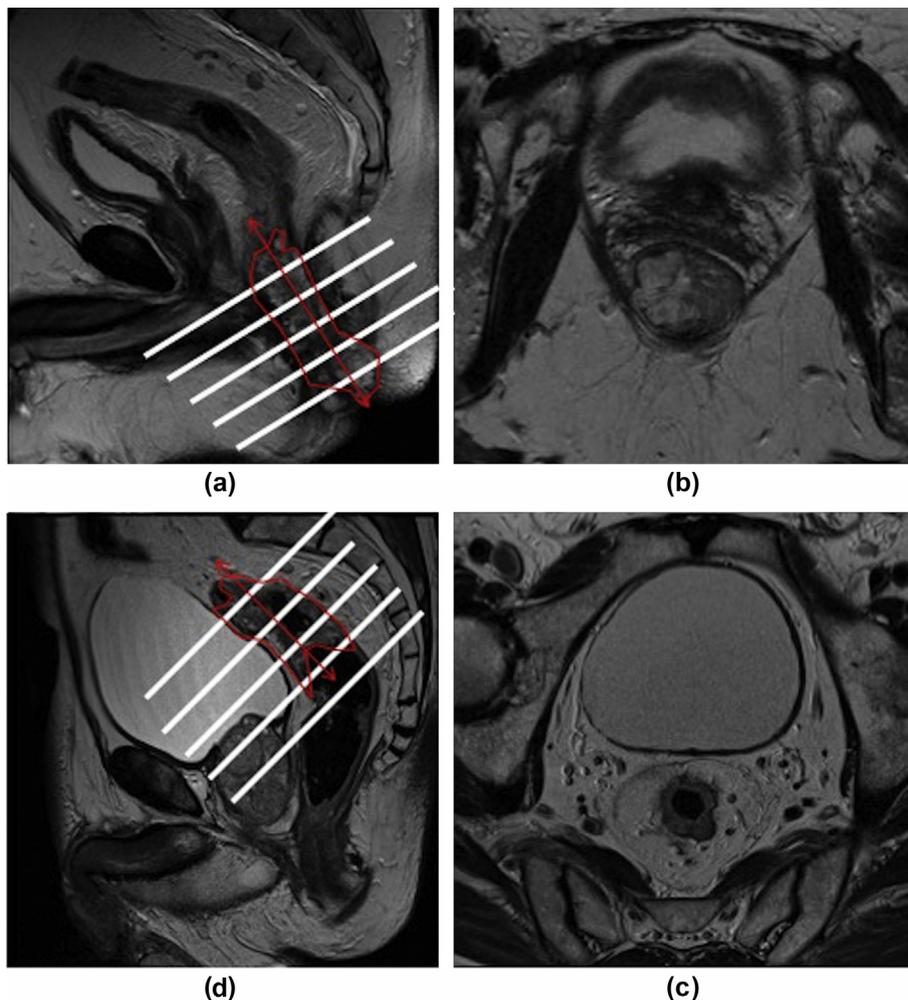


Figure 1 Sagittal (a and c) and axial (b and d) T2W MRI images demonstrating low (a and b) and high (c and d) rectal tumours (red line) and their axis (red arrow). The white lines demonstrate the planes required on MRI, orthogonal to the axis of the tumour to optimise the scan and ensure appropriate axial images of the tumour and surrounding structures are obtained (c and d).

recommended because it identifies tumours at a higher risk of local recurrence and pathological involvement of the circumferential resection margin (CRM) without neoadjuvant treatment (Fig 2).

Despite the acknowledged influence of tumour involvement of the MRF on prognosis, the relevance of which mechanism of tumour spread threatens or involves the MRF has not been well established. A single relatively small study demonstrated lymph node–MRF involvement had no impact on local recurrence rates, unlike other tumour components that are significant (i.e., “direct” from primary tumour or “indirect” from EMVI or lymphatic vessel invasion)¹⁹; however, the US National Comprehensive Cancer Network (NCCN) and TNM v8 definition of MRF involvement do not discriminate between “direct” and “indirect” MRF involvement.^{18,25}

Low rectal tumours have higher rates of positive CRM involvement than higher rectal tumours following surgical excision.^{26,27} This is partly due to the closer anatomical relationships of structures in the lower rectal canal: the anal sphincter muscles and the lack of surrounding adipose tissue (Fig 3); however, because of its high contrast resolution, MRI has been specifically validated in low rectal cancers to adequately provide detailed preoperative descriptions of the relationships between the tumour and nearby structures.^{28,29} These descriptions therefore guide the resection required to reduce the risk of tumour involvement at the CRM. For example, MRI should be able to demonstrate tumours involving the external sphincter and levator muscles that are more suitable for a more extensive extra-levator abdominoperineal excision (ELAPE) resection than a conventional abdominoperineal (APR) resection.^{26,29,30}

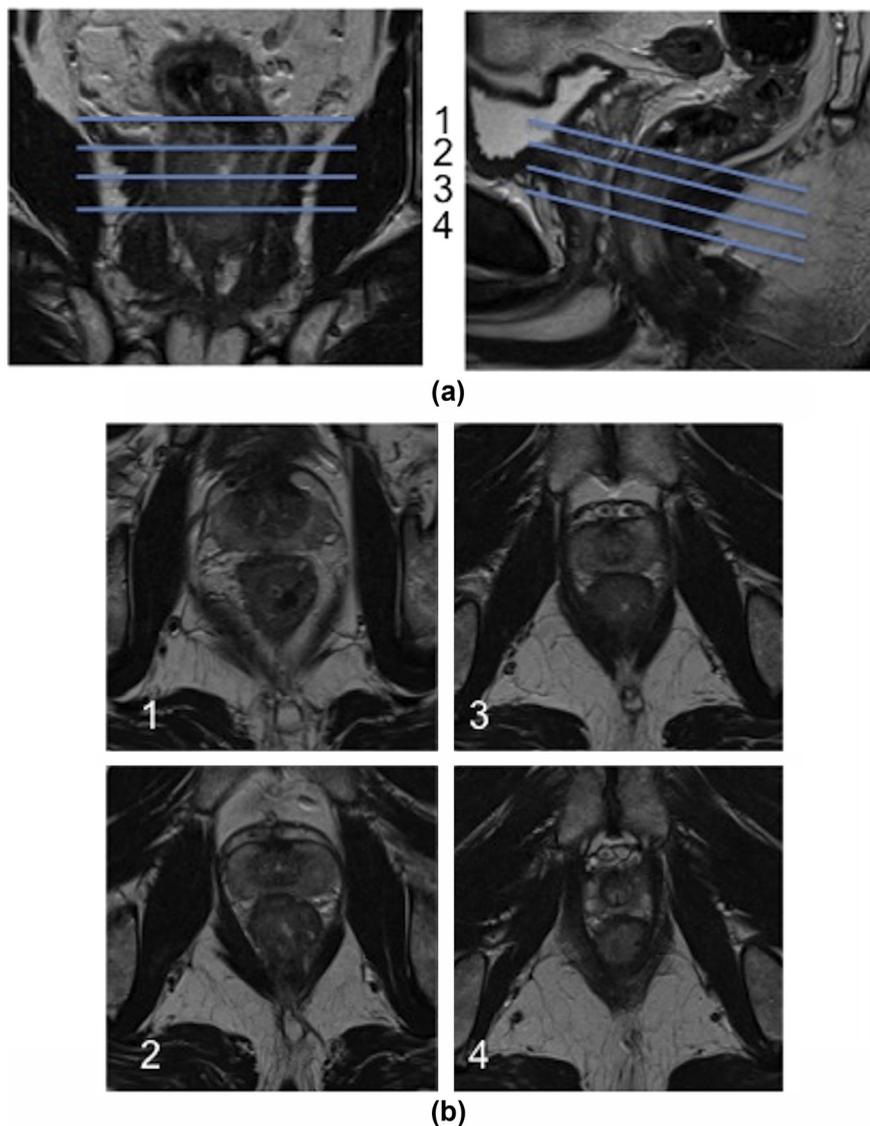


Figure 3 Coronal and sagittal (a) and axial (b) T2 weighted MRI images of a lower rectal tumour demonstrating the close relationship between the levator ani muscles and the lower rectal canal at positions 1, 2, 3, and 4 descending inferiorly. The axial image 4 is the anorectal junction at where the puborectalis muscle passes around the anorectal canal. These images demonstrate the close relationships between the lower rectal canal and the mesorectal fascia and so the increased likelihood of residual tumour involvement at the margin of these tumours following surgical resection because of the increased technical difficulty.

Lymph node involvement

Despite advances in MRI, rectal cancer lymph node metastases are difficult to determine with reported sensitivity ranging between 42% and 89%.^{43–47} It has been reported that this can result in around 25% of lymph nodes being overstaged, with a resultant increase in potentially unnecessary preoperative treatment and morbidity.⁴⁸ Given the difficulties in radiological assessment of lymph node metastatic involvement, various solutions have been suggested including lymph node size, morphological criteria, or completely discounting radiological assessment of lymph nodes.^{11,15}

Recent European and North American guidelines aim to provide a practical solution to lymph node staging with the use of combined morphological and size criteria.^{11,43,50} The three morphological criteria include a round shape, irregular lymph node contour, and mixed MRI signal with none, two, and three required for lymph nodes measuring >9, 5–8, and <5 mm, respectively.¹¹ The widespread adoption of these criteria has been poorly studied, but they provide a consensus position for practising radiologists, with the inaccuracies of this compromise clearly acknowledged by the authors of the guidelines.¹¹

When metastatic lymph node involvement is suspected, in theory the lymph node capsule provides a distinct physical boundary to surrounding structures. Extra-capsular lymph node extension describes the situation whereby tumour has breached the lymph node capsule and so directly spreads into the extra-nodal tissues. It has been investigated for its effect on prognosis with meta-analyses demonstrating that it is associated with increased rates of recurrence and all-cause mortality^{51–53}; however, it is not included in current staging criteria.

Another contentious patient management issue is metastatic involvement of lateral pelvic side wall lymph nodes (LPLN) (Fig 4). Metastatic spread to LPLN is more likely to be associated with low rectal tumours, extending below the anterior peritoneal reflection, compared to high rectal tumours; involvement is reported in up to 20% of low rectal tumours compared to 8% of high rectal tumours.^{56,57} Subsequently, there has been interest in LPLN dissection to resect these malignant lymph nodes, or even as a prophylactic measure.^{58,59} Although LPLN dissection is not routine practice in the West for low rectal tumours, it is in Japan, where it has been shown to reduce the risk of intra-pelvic tumour recurrence by 50%, and improve the 5-year survival rate by 8–9%.^{58,60} As a result LPLN dissection is recommended in Japan for T3 and T4 low rectal tumours.⁶⁰ A recent comparison of the surgical techniques, demonstrated traditional TME with LPLN dissection had lower recurrence rates than TME alone.⁶¹ Although disputed by its proponents, TME with LPLN dissection has been associated with increased morbidity, specifically longer operation time, greater blood loss, impotence, and urinary bladder dysfunction.^{62,63} By comparison, in the West, neoadjuvant treatment is more widely used than LPLN dissection, having been shown within Western populations to reduce the risk of local recurrence and offer control for metastatic spread to

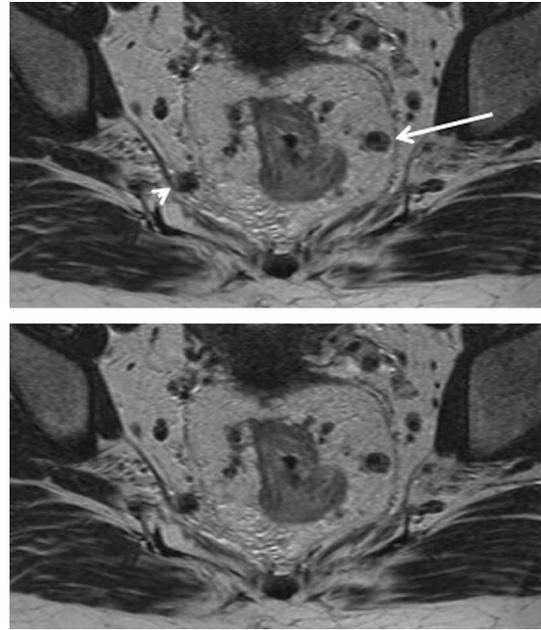


Figure 4 Axial T2W MRI image of a low rectal tumour with metastatic involvement of adjacent lymph nodes. The white arrow demonstrates an intra-mesorectal lymph node at the 3 o'clock position and the arrowhead demonstrates an extra-mesorectal lymph node on the right lateral pelvic sidewall at an 8 o'clock position. These images also demonstrate extramural venous invasion within the mesorectal fascia between the 9 and 11 o'clock positions.

LPLN,^{64–66} however, this is also not without its own controversies with increased rates of faecal incontinence and other acute or chronic radiation-induced toxicities, such as a skin ulceration and urinary bladder dysfunction.^{65,67} Recent data also suggest radiotherapy may offer inadequate treatment when LPLN involvement is suspected (in lymph nodes measuring >10 mm), with localised pelvic sidewall recurrence occurring in 33.3% (4-year rate) compared to 10.1% in patients with smaller nodes despite patients being irradiated in the lateral compartment.⁶⁸

Irrespective of the proposed treatment, radiologists should be aware of which tumours are at an increased risk of associated metastatic LPLNs, identify these, and appropriately describe the predicted sites of involvement for clinicians.

Extra-mural sites of disease beyond lymph nodes

Histopathological studies identified the prognostic significance in rectal cancer of the invasion of peri-rectal veins beyond the muscularis propria by the primary tumour in the 1980s.⁶⁹ Subsequent studies have confirmed that micro- or macroscopic EMVI is associated with local recurrence, reduced disease-free, and overall survival.^{69–73} The high spatial and contrast resolution achieved with MRI has been shown to provide high specificity and sensitivity for the detection of EMVI on baseline preoperative MRI (mrEMVI)^{74–77} (Fig 5), which allows tumours with mrEMVI to be identified and considered for neoadjuvant

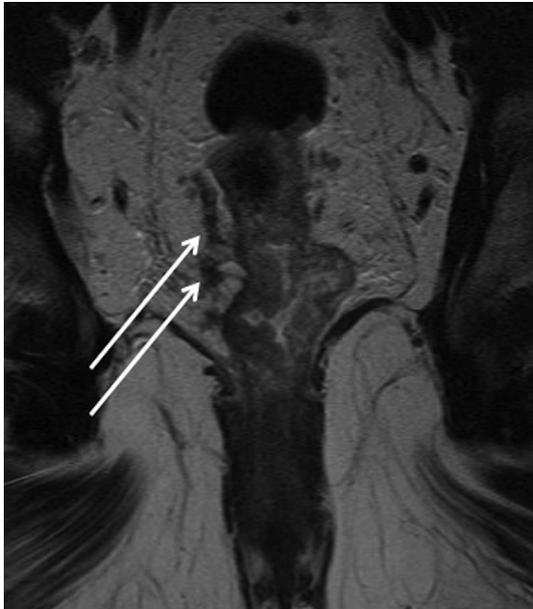


Figure 5 Sagittal T2W MRI image of a mid-rectal tumour with macroscopic extra-mural venous invasion (white arrows) extending along the mesorectal fascia.

treatment.^{29,71,78} Whether they are treated as moderate- or high-risk tumours remains contentious with differences between UK and European treatment guidelines.^{12,13}

Additionally, tumours with mrEMVI have been shown to be more resistant to neoadjuvant treatment;⁷⁵ however, where mrEMVI decreases on restaging MRI after neoadjuvant treatment, it has been shown to be associated with improved disease-free survival,⁷⁸ indicating that accurate quantification of mrEMVI on reassessment MRI is important when considering benefits of intensive treatment for these patients.⁷⁸

Similarly, the importance of extra-nodal tumour deposits (ENTDs) not within a lymph node, vessel, or nerve, is highly topical but poorly understood, despite being included in TNM v8 as N1c18. Their presence appears to have a more pivotal role in local recurrence and overall survival than larger lymph node metastases.^{18,54,55} A recent meta-analysis demonstrating ENTDs, shows they have a greater association with EMVI than nodal involvement.⁵⁵ ENTDs are likely, therefore, to be completely separate entities to lymph node metastases. The influence of number and size of ENTDs is poorly studied, but both have been suggested as important prognostic factors.⁵⁴ Currently, however, the presence or absence of ENTDs is all that should be incorporated within baseline rectal cancer staging, as per TNM v8.¹⁸

MRI for restaging after neoadjuvant treatment

Timing of follow-up imaging

Debate remains for the optimal timing of post-CRT surgical excision of tumour. By inference, there is also uncertainty about the best time to perform reassessment MRI

(yMRI).^{79–86} This is due the consolidation effects of neoadjuvant CRT for several weeks after treatment; the suggested range of optimal surgery is between 4 and 16 weeks after completion of neoadjuvant treatment.^{79–86} Although one study demonstrated the rate of pathological complete responders (pCR) increased from 10% to 18%, comparing an interval of <13 weeks to 15–16 weeks from the start of CRT to surgery,⁸⁰ demonstrated no benefit in pCR rate, but worse morbidity in cohorts who delayed surgery to 11 weeks compared to 7 weeks.⁸⁶ Thus, a 6–8 week interval remains most commonly recommended in UK clinical practice, with up-to-date imaging before surgery.^{11,50} Greater standardisation of the timing of imaging and the interval to surgery is imperative to improve our understanding of the radiological appearances and their pathological correlation. This is particularly relevant in imaging reassessment of patients being considered for organ preservation (“watch and wait”) treatment programmes.^{86–88}

Tumour regression grading (TRG)

Grading systems have been developed to provide a more objective assessment of the tumour to neoadjuvant treatment.^{89–93} These have been developed using pathological rather than radiological datasets.^{89–96} They predominantly rely on semi-subjective scales to quantify the replacement of tumour with fibrosis.^{94–96} Changes in the size of a tumour are incorporated into yMRI-based modified tumour regression grade (ymrTRG), however, reports of their reproducibility are mixed.^{97–99} Consequently, ymrTRG is not yet consistent enough for routine clinical use.^{93,98,100} Current reporting guidelines suggest re-staging tumours based on a three-point scale describing the residual mass without a more complex mrTRG scale; no mass with a normalised rectal wall, no mass but fibrotic wall thickening or a residual mass/focal high signal on diffusion-weighted imaging (DWI; plus yT stage [post-neoadjuvant treatment T stage]). These roughly correlate into pCR (pathological complete response), partial response and little to no response TRG categories.^{11,50} (Fig 6).

Further collaborative studies and ongoing feedback with education are required to improve concordance between radiologists ymrTRG versus histopathologists ypTRG (post-neoadjuvant treatment, preoperative MRI TRG versus postoperative pathological TRG).

Volumetry

Volumetric assessment of tumour burden has been used for primary staging, response assessment to neoadjuvant treatment, and for radiotherapy planning.^{90,91,101–104} A recent review indicated that unlike tumour volumes, standard bi/tri-dimensional (2D/3D) length measurements offered no value in reassessing tumour response.¹⁰⁵ Standard bi-dimensional quantification is more affected by movement, visceral tortuosity and tumour irregularity than gross tumour volumes.¹⁰⁶ Additionally, tumours volumes calculated using DWI image sequences (using high b-values) offer a more reliable method of delineating volume

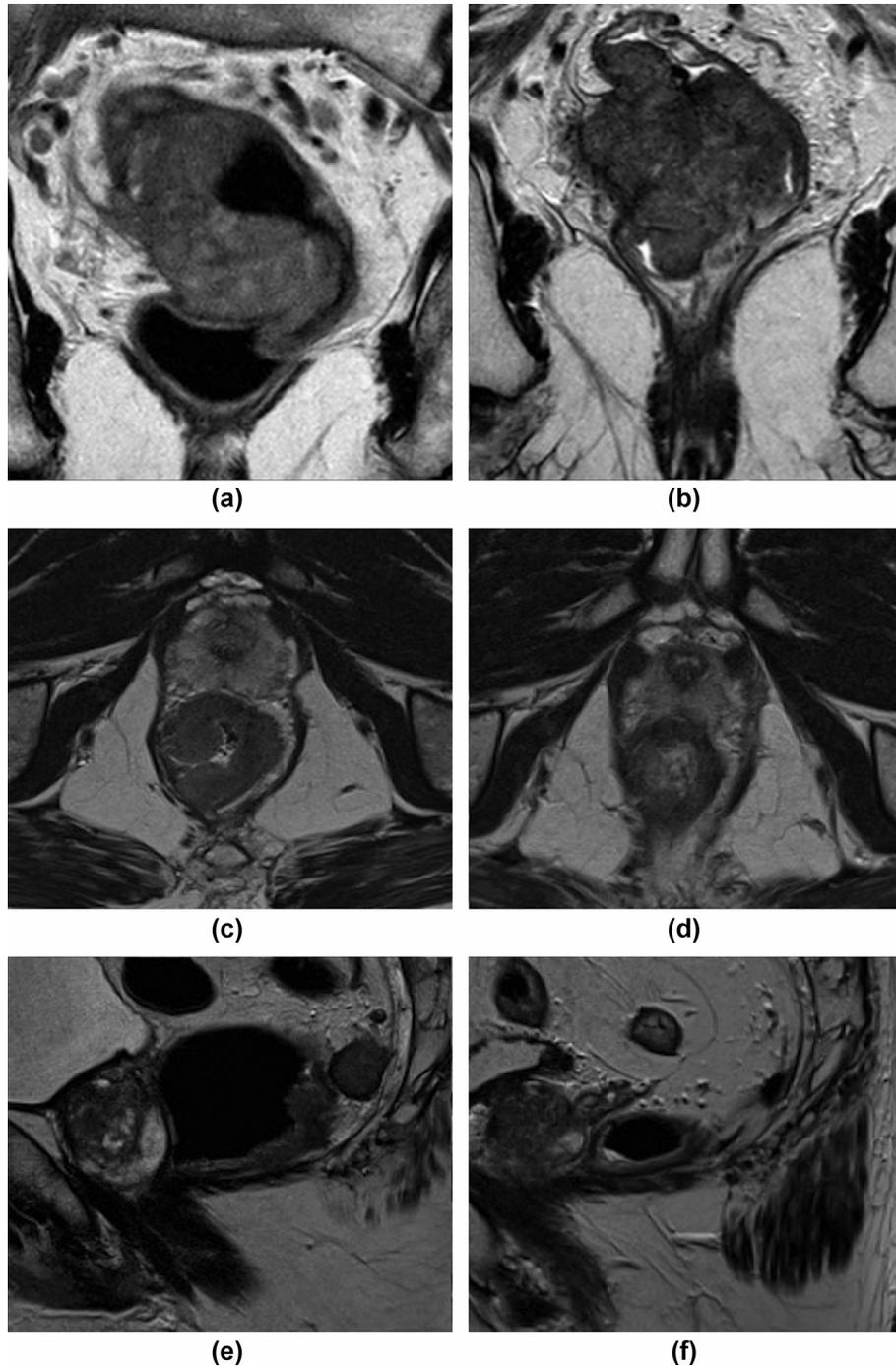


Figure 6 Coronal T2W MRI images of a mid-rectal tumour (a) pre- and (b) post-neoadjuvant treatment demonstrating progressive disease. Axial T2W MRI images of a low rectal tumour (c) pre- and (d) post-neoadjuvant treatment demonstrating partial tumour response. Coronal T2W MRI images of a mid-rectal tumour with extra-luminal disease, (e) pre- and (f) post-neoadjuvant treatment demonstrating complete tumour response and residual fibrotic tissue.

than standard T2-weighted (W) sequences, despite the higher image resolution of T2W.^{90,91,101–104,107}

The practical difficulties of implementing tumour volume assessment, however, has prevented its inclusion into clinical practice and recent ESGAR guidelines.¹¹ Advances in semi-automated tumour segmentation are promising and offer significant time-saving benefits compared to manual delineation, potentially making it a clinically useful tool.^{108,109}

Identification of complete responders

After CRT about 15–25% of patients undergo a pCR hence the growing interest in identifying these patients for recruitment into “watch and wait” treatment programmes to avoid the associated morbidity of surgery.^{88,110} The ymrTRG system has a reported sensitivity and specificity for identifying complete responders of 74% and 63%

respectively.^{98,111} The addition of functional (DWI) imaging can improve the sensitivity compared to T2W imaging alone, with a pooled meta-analysis demonstrating an improvement from 50% to 84% in the identification of a pCR.¹¹² Even the combination of these sequences is not fully sensitive, as it does not appreciate small volumes of residual viable tumour cells. The efficacy of combined 2-[¹⁸F]-fluoro-2-deoxy-D-glucose positron-emission tomography/CT (FDG-PET/CT) has been investigated to identify patients with a pCR; however, the results are also mixed with no conclusive evidence to support its use.^{113,114} At present, the most accurate non-operative recognition of a complete response relies on MRI volume reduction, fibrotic transformation of the tumour, and changes in diffusion¹¹⁵ (see later section for a more detailed discussion of appearances on DWI).

MRI assessment after surgery

Tumour recurrence and assessment following anastomotic leak

Local recurrence is more common when there has been an anastomotic leak, independent of tumour stage.¹¹⁶ Although subsequent studies have cast doubt on this, a recent meta-analysis has shown the adverse impact of an anastomotic leak in local disease control.^{117,118} The reasons for this are unclear, but the correlation between an anastomotic leak and the technical difficulty of the surgical resection and the subsequent inflammatory microenvironment have both been implicated in promoting the implantation of tumour cells.¹¹⁹ Radiologists should be aware of this risk and be extra vigilant to assess for sites of recurrence when reviewing follow-up imaging in cases where there has been an anastomotic leak, particularly as imaging is inherently more complex because of the distortion of tissues and fibrosis that forms in response to the leak. Important signs of recurrence include ill-defined or spiculate borders to a soft-tissue mass and identifying asymmetric oedema at a tumour margins, as this may indicate tumour spread rather than reactive change,⁴¹ (Fig 7).

Functional MRI

DWI

DWI is a measure of the random movement of water molecules within the extra-cellular space, which is hindered by densely packed cell membranes commonly seen in tumours. Apparent diffusion coefficient (ADC) is a more objective measure of the diffusion restriction also accounting for the background level water content.

DWI for baseline staging

There is limited evidence that DWI has a role in baseline staging of advanced tumours compared to T2W sequences; particularly with reference to the T-staging, MRF and EMVI evaluation. The value of DWI for the detection of metastatic lymph node involvement is more contentious; some studies

show improved lymph node staging by using DWI and ADC alongside conventional T2W sequences^{120–124}; however, both benign and malignant lymph nodes can display high DWI signal, so DWI is insufficient alone to discriminate these.¹²⁰ Hence, although DWI is often included by radiologists in primary staging assessment MRI, it does not feature in staging criteria. It can, however, subsequently be used for retrospective comparisons to assess tumour response at the time of yMRI.¹¹

DWI for restaging

Restaging DWI and ADC imaging have a greater role in comparing neoadjuvant treatment response in the primary tumour, MRF involvement, and lymph nodes containing metastatic disease, when compared to pre-CRT diffusion appearances;^{102,120,124–128} however, the utility of DWI/ADC is improved in combination with standard morphological T2W imaging.¹¹² Combining morphological and functional imaging improves the accuracy of an ymrCR representing a true pCR,^{11,92,102,112,128} (Fig 8). Furthermore, an automated version of predicting pCR can be achieved using a combination of T2W derived volumetry with DWI, but this remains a pre-clinical tool.⁹² DWI, however, is not a panacea as it will tend to over-diagnose pCR. Just as with morphological imaging, small numbers of viable tumour cells will not be seen and there is limited evidence for reassessment of nodal involvement.^{124,129–131} Given the reduced spatial resolution inherent to DWI, it is important that radiologists appreciate its specific technical limitations, which include: misinterpretation of low signal fibrosis on ADC map, susceptibility effects, T2W shine-through of fluid in the rectal lumen, suboptimal sequence angulation, and collapsed rectal wall.¹²⁸

Dynamic contrast enhancement (DCE)/perfusion

MRI DCE/perfusion is a technically challenging MRI technique that combines anatomical detail with semi-quantification of vascular parameters as an indirect measure of angiogenesis. More angiogenic tumours are associated with a worse prognosis, because of their disorganised vasculature and associated increased vascular permeability, which should be quantifiable using a contrast agent;¹³² however, despite some results supporting the utility of MRI DCE, others have been more equivocal regarding its added value.^{132–138} In spite of the lower contrast resolution, CT perfusion imaging is also being assessed in colorectal cancer, as the technical practicalities of CT perfusion are easier to overcome than MRI DCE, with studies suggesting poor perfusion is associated with worse clinical outcomes.^{139–141}

In addition to risk-stratifying primary tumours, MRI DCE has been used to aid the prediction of tumour response to neoadjuvant treatment (from pre- and post-neoadjuvant treatment scans), often using semi-quantification of changes in perfusion, but results are inconsistent.^{132,133,136,142,143} DCE remains limited to clinical trials with no recommendation for routine clinical use.

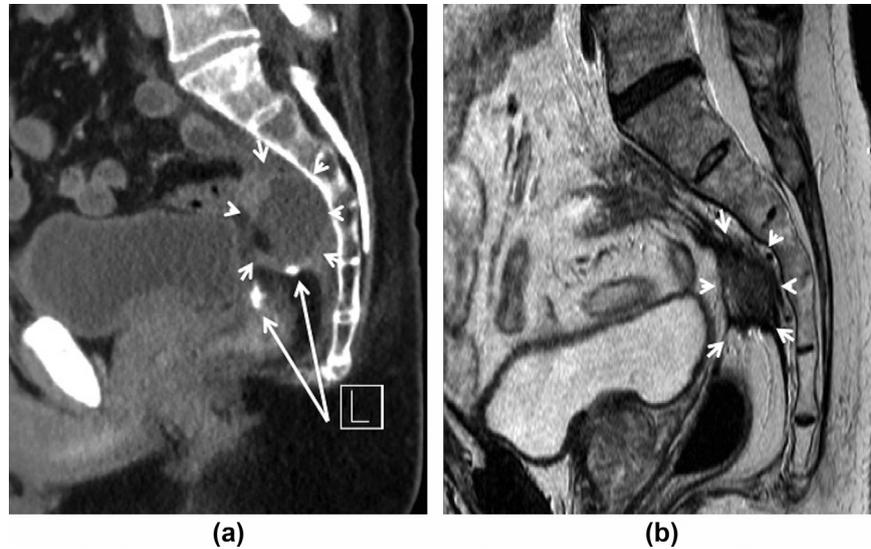


Figure 7 Tumour recurrence in the pre-sacral space following a leak from the colorectal anastomosis. Sagittal CT (a) and subsequent T2W sagittal MRI (b) obtained 12 months later. The CT demonstrates a pre-sacral fluid collection that has formed as a consequence of an anastomotic leak (within the arrowheads). The metallic surgical clips are identified by the long arrows. The MRI demonstrates tumour recurrence at this same site (within the arrowheads) demonstrated by the intermediate T2 signal.

Other MRI techniques

Lymph node-specific contrast agents, such as ultra-small super paramagnetic particles of iron oxide (uSPIO) and gadofosveset trisodium, have shown potential for identifying metastatic lymph node involvement, but none are clinically available and so they have no routine clinical role.^{144–147}

There have been a limited number of small studies assessing susceptibility-weight imaging (SWI) and dynamic-susceptibility contrast (DSC) MRI in rectal cancer. Although these show the feasibility of SWI the relationship to prognosis is less clear.^{148,149}

Reporting for advanced rectal cancer

Pros and cons of pro-forma reports

Structured reporting in radiology and pathology has been shown to improve communication of imaging findings and

consistency of reports for both clarity and content.^{160–163} This is particularly true in rectal cancer, given the number of tumour descriptors that are of prognostic significance.¹⁶³ Recent consensus statements published by ESGAR and SAR both recommend using structured report templates for primary staging and restaging of rectal cancer.^{11,50} These provide a minimum dataset of key tumour descriptors that should be documented for every case, to allow retrospective audit of standards. In LARC or low rectal tumours further key tumour descriptors are recommended; however, to date there is no agreed template to satisfy these requirements. Template reporting also allows greater opportunity for radiological–histopathological correlation and consequently individual and departmental/hospital feedback for service standardisation and quality improvement.

TNM8 overview

TNM v8 has recently been implemented for colorectal cancer staging.¹⁸ This has several minor modifications from

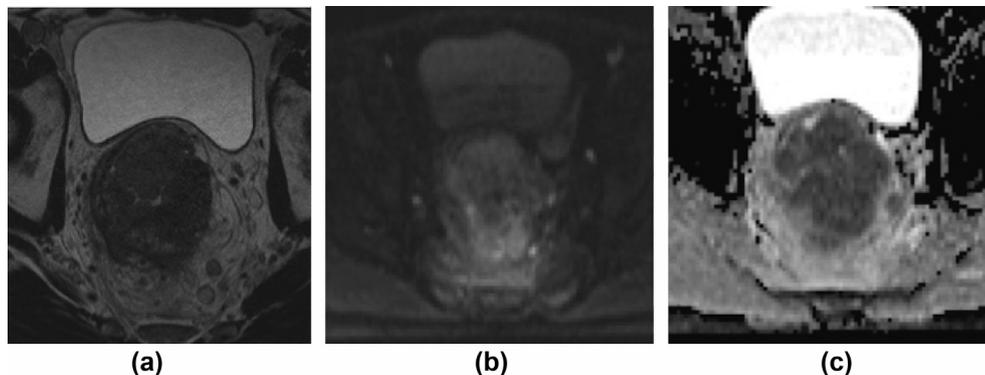


Figure 8 Axial T2W (a), DWI image (b, acquired with a b-value of 750) and apparent diffusion coefficient image (c). These demonstrate a large mid-rectal tumour with minor and heterogeneous diffusion restriction.

earlier versions (see Table 3 for the latest version). Although developed from pathological datasets, it is routinely adapted to baseline MRI staging.

Important changes in TNM8 include: (1) primary tumour staging: T1 tumours invade beyond the submucosa; T2 tumours invade into the muscularis propria; T3 tumours invade beyond muscularis propria; and T4 tumours invade directly into other organs or structures and/or perforate the visceral peritoneum. Although not part of TNM8, the T3 subdivisions measure the depth of tumour invasion through the muscularis propria and $<5/>5$ mm has shown to be of prognostic significance: T3a <1 mm, T3b 1–5 mm, T3c 5–15 mm, and T3d >15 mm. The definitions of T4a and T4b have switched from TNM v5, now pT4a tumour cells have breached the peritoneal surface and pT4b tumour invades adjacent organs. (2) Nodal staging: subdivision of pN1 (N1a; 1 involved node, N1b; 2–3 involved lymph nodes) and pN2 (≥ 4 involved lymph nodes) and a new category of extra-

nodal tumour deposits (ENTDs, without regional lymph node metastases) has been created, pN1c. There are no minimum size criteria and tiny subserosal deposits will not be seen radiologically. Isolated tumour cells in nodes are no longer counted as pathologically involved, although these could never be seen radiologically, which should increase the correlation with pathology for N status. (3) Metastatic staging: further subdivisions into pM1a–c and abolition of pM0/pMx. (4) Venous, perineural and lymphatic channel invasion are included and are sub-classified into intramural or extramural at their deepest extent, whereas radiological assessment may only detect extramural spread in large veins.

Conclusion

MRI remains the best in vivo method for rectal cancer staging and response assessment, but despite recent imaging advances including DWI, contrast-enhanced MRI, and FDG-PET/CT, accurate categorisation of key tumour variables remains challenging for radiologists. Template reporting can improve completeness of data collection. Further technical developments and education are required to maximise the potential for patient risk stratification and personalised therapies based on baseline and re-assessment imaging. Future prospective work is required to improve the accuracy of rectal cancer staging in routine clinical practice, including better discrimination of malignant lymph nodes. Additionally, studies should assess using the tumour phenotype as a prognostic marker and a predictor of response to neoadjuvant therapies, which might include texture analysis when obstacles around MRI texture analysis have been overcome.

Conflicts of interest

None declared.

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Table 3

Current AJCC TNM8 criteria used for staging of colorectal cancers with additional criteria of prognostic significance included.

TNM v 8: rectal cancer	
T0	No evidence of primary tumour
Tis ^a	carcinoma in situ: intraepithelial or invasion of lamina propria
T1	tumour invades submucosa
T2	tumour invades muscularis propria
T3	tumour invades through the muscularis propria into the subserosa or into non-peritonealised perirectal tissues
T3a ^b	tumour extends <1 mm beyond muscularis propria
T3b ^b	tumour extends 1–5 mm beyond muscularis propria
T3c ^b	tumour extends 5–15 mm beyond muscularis propria
T3d ^b	tumour extends 15 mm beyond muscularis propria
T4	tumour invades directly into other organs or structures and/or perforates visceral peritoneum
T4a	tumour penetrates to the surface of the visceral peritoneum
T4b	tumour directly invades or is adherent to other organs or structures
N0	no regional lymph node metastases
N1 ^c	metastasis in 1–3 regional (perirectal) lymph nodes
N1a	metastasis in 1 regional lymph node
N1b	metastasis in 2–3 regional lymph nodes
N1c	tumour deposit(s) in the subserosa, mesentery, or non-peritonealised pericolic or perirectal tissues without regional nodal metastasis
N2 ^c	metastasis in ≥ 4 regional lymph nodes
N2a	metastasis in 4–6 regional lymph nodes
N2b	metastasis in ≥ 7 regional lymph nodes
M0	no distant metastasis
M1	distant metastasis
M1a	metastasis confined to one organ or site (for example, liver, lung, ovary, non-regional node) without peritoneal metastases
M1b	metastases in more than one organ
M1c	metastasis to the peritoneum with or without other organ involvement

^a The term intramucosal carcinoma is not used in the UK, instead these lesions are termed high grade dysplasia in UK practice.

^b Not in TNM8 staging criteria but of prognostic significance.

^c Current guidelines suggest the addition of morphological criteria in addition to nodal size to determine metastatic lymph node involvement; these are not included in TNM8 but are in ESGAR and SAR reporting guidelines and include: [1] round shape, [2] irregular border, [3] heterogeneous signal.

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