

Magnetic Resonance Imaging for Staging of Primary Rectal Cancer: Imaging Prognosticators

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ABSTRACT

Accurate staging by high-resolution magnetic resonance imaging (MRI) is pivotal to the multidisciplinary management of rectal cancer. Aside from tumour and lymph node staging, high-resolution MRI can identify other imaging prognosticators to stratify patients to different prognostic groups for different treatment. These imaging prognosticators include circumferential resection margin, extramural venous invasion, extramural depth of tumour extension, vascular / tumour deposits, mucinous primary tumour, and relationship to the inter-sphincteric plane (in low-rectal tumours). This review describes the imaging features and prognostic impact of these MRI-detected biomarkers.

Key Words: Magnetic resonance imaging; Rectal neoplasms

中文摘要

磁共振成像分期原發性直腸癌：影響預後的影像學表現

洪曉義、戴毓玲、曹子文

通過高解析度磁共振成像（MRI）準確分期是多學科綜合治療直腸癌的關鍵。除了腫瘤和淋巴結分期外，高解析度MRI可以發現其他影響預後的因素，以便區分不同預後的患者進行不同的治療。這些影響預後因素的影像學表現包括周圍切除邊緣、外壁靜脈侵犯、腫瘤外展深度、腫瘤血管轉移、粘液原發性腫瘤以及低位直腸腫瘤括約肌間平面關係。這篇綜述文章描述這些預後影響的MRI成像特徵。

INTRODUCTION

Magnetic resonance imaging (MRI) is the gold standard for staging of primary rectal cancers.¹⁻⁵ To minimise local and distant recurrence, high-resolution MRI is pivotal to patient stratification for optimal therapy that

includes total mesorectal excision,⁶ local excision for early tumours, inter-sphincteric resection for sphincter preservation, neo-adjuvant therapy in patients at high risk of recurrence,^{7,8} and various radiotherapy and systemic treatment regimens. Apart from tumour (T) and lymph

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Submitted: 15 Nov 2017; Accepted: 4 Dec 2017.

Disclosure of Conflicts of Interest: All authors have disclosed no conflicts of interest.

node (N) staging, high-resolution MRI can identify other imaging prognosticators that affect local and distant recurrence and survival, and risk-stratify patients with low-risk tumour to be managed with surgery alone or patients with high-risk tumour to be managed with neo-adjuvant therapy, intensified treatment, more radical surgery, and vigilant surveillance.

This review discusses the role of MRI in the baseline evaluation of primary rectal cancer including tumour and lymph node staging, identification of high-risk features (circumferential resection margin, extramural venous invasion, extramural depth of tumour extension, vascular / tumour deposits, and mucinous primary tumour), and assessment of surgical planes (Table 1). The role of MRI in re-staging for rectal cancer patients after neo-adjuvant chemoradiotherapy is not discussed.

PROTOCOL

Rectal MRI is performed with an external phased-array surface coil, with the minimal field strength (1.0 T), but a higher field strength (1.5 T or 3 T) should be used. The use of an endorectal coil and routine use of endorectal filling are not recommended.⁵ High-resolution T2-weighted images are the key sequence in the evaluation of rectal cancer. To accurately stage the disease, specific imaging parameters should be followed to obtain high-resolution images with slice thickness of <3 mm and voxel size of <1.5.^{9,10} Three-dimensional (3D) T2-weighted sequence, fat-suppressed sequence, and contrast-enhanced T1-weighted sequence are all inappropriate and not recommended.⁵

Our MRI protocol for the evaluation of rectal cancer includes axial T2-weighted turbo spin-echo images of the pelvis, sagittal 3-mm high-resolution turbo spin-echo images of the rectum, oblique axial 3-mm high-resolution images of the rectum with the scanning plane aligned perpendicular to the tumour and covering at least 5 cm above the superior border of the primary tumour, coronal 3-mm high-resolution T2-weighted turbo spin-echo sequences aligned parallel to the long axis of tumour for mid-to-upper rectal tumour and to the anal canal for low-lying tumours, diffusion-weighted imaging with b values including 0, 1000 sec/mm² of the rectum, and reconstruction of an apparent diffusion coefficient map. An intramuscular spasmolytic agent (hyoscine butylbromide or glucagon) is routinely administered (unless contraindicated) to reduce peristaltic motion and improve image quality.^{11,12}

Table 1. Reporting template for baseline magnetic resonance imaging (MRI) assessment of rectal cancer in our hospital.

Reporting template
Primary tumour
The primary tumour is demonstrated as [annular / semi-annular / ulcerating / polypoidal / mucinous] mass with a [nodular / smooth] infiltrating border
The distal edge of the luminal tumour arises at a height of [] mm from the anal verge; [] mm [above / at / below] the top of the puborectalis sling
The tumour extends craniocaudally over a distance of [] mm
The proximal edge of tumour lies [above / at / below] the peritoneal reflection
Invading edge of the tumour extends from [to] o'clock position
Tumour is [confined to / extending through] the muscularis propria. Maximal depth of extramural invasion is [] mm
Tumour is [present / not present] at the distal levator level
The tumour invades into the [submucosal layer / partial thickness of muscularis propria / full thickness of muscularis propria / inter-sphincteric plane / external sphincter / beyond external sphincter into the ischioanal tissue]
Tumour [invades / does not invade] into prostate / seminal vesicles / uterus / vagina / urinary bladder
Lymph nodes
There is [no /] suspicious nodes at the level of tumour
There is [no /] suspicious nodes above the level of tumour
There is [no /] suspicious pelvic sidewall nodes; located at right / left / obturator / internal iliac / external iliac fossa
There is [no /] vascular deposit
Extramural venous invasion (EMVI)
There [is / is no] EMVI into the [small / medium / large] vein; [superior rectal / middle rectal / inferior rectal / non-anatomical vein]
Circumferential resection margin (CRM)
The closest CRM is at [] o'clock
The closest CRM is from [direct spread of tumour / extramural venous invasion / vascular deposit / lymph node]
Minimal tumour distance from the mesorectal fascia is [] mm
Peritoneal involvement
There [is / is no] peritoneal involvement
Additional comments
Conclusion
MRI stage: T1 / T2 / T3a / T3b / T3c / T3d / T4 peritoneal / T4 visceral; N0 / N1 / N1c / N2
CRM clear / threatened / involved
EMVI positive / negative

PROGNOSTICATORS

Tumour Staging and Extramural Depth of Tumour Invasion

T staging is a measurement of tumour extension through the rectal wall, according to the 8th edition of the American Joint Committee on Cancer (AJCC) staging system (Table 2).¹³

High-resolution MRI can clearly depict the rectal mural

layers. On T2-weighted images, the mucosal layer is a fine low-signal-intensity line with a thicker submucosal layer of higher signal intensity due to the presence of underlying fat (Figure 1). The muscularis propria is shown as two distinct layers: the inner circular layer and outer longitudinal layer. The outer longitudinal muscle coat often appears irregular and somewhat corrugated on axial images with focal areas of interruption due to vessels that penetrate the rectal wall. Perirectal fat appears as high-signal-intensity tissue surrounding the low-signal muscularis propria. The extension of the primary tumour is often shown as intermediate signal intensity relative to these tissue layers and forms the basis of T staging on MRI.

Table 2. American Joint Committee on Cancer 8th edition staging system for rectal cancer.

Staging	Feature
Primary tumour (T)	
TX	Primary tumour cannot be assessed
T0	No evidence of primary tumour
Tis	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 pericolorectal tissues
T4a	Tumour invades through the visceral peritoneum
T4b	Tumour directly invades or is adherent to other organs or structures
Regional lymph nodes (N)	
NX	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	Metastasis in 1-3 regional 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	Metastasis in ≥ 4 regional lymph nodes
N2a	Metastasis in 4-6 regional lymph nodes
N2b	Metastasis in ≥ 7 regional lymph nodes
Distant metastasis (M)	
M0	No distant metastasis
M1	Distant metastasis
M1a	Metastasis confined to one organ or site (liver, lung, ovary, non-regional node) without peritoneal metastasis
M1b	Metastases in >1 organ / site without peritoneal metastasis
M1c	Metastasis to the peritoneum with or without other organ involvement

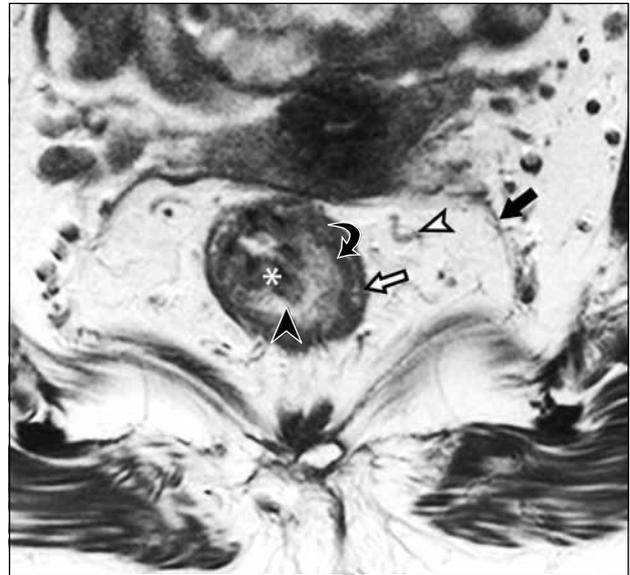


Figure 1. Axial T2-weighted image showing normal rectal mural layers. The mucosal layer is a fine low-signal-intensity line (asterisk) with a thicker outer submucosal layer of higher signal (black arrowhead). The muscularis propria is shown as two distinct layers: the inner circular layer (curved arrow) and outer longitudinal layers (white arrow). The outer longitudinal muscle coat appears irregular and somewhat corrugated. The mesorectal fat appears as high-signal-intensity tissue surrounding the low-signal muscularis propria. Serpiginous structures with flow void represent the mesorectal vessels (white arrowhead). The mesorectal fascia is a thin linear low-signal-intensity structure enveloping the mesorectum (black arrow).

A meta-analysis reported an accuracy of 85%, sensitivity of 87% and specificity of 75% for high-resolution MRI in the evaluation of T staging.¹⁴ MRI cannot reliably identify T1 disease although it is possible to distinguish a T1 tumour (Figure 2) from a T2 tumour (Figure 3) when preserved high-signal-intensity submucosa is seen.⁵ Compared with endoscopic ultrasonography, MRI is similarly accurate in identifying T2 disease and is more accurate for T3 and T4 disease.¹⁴

Spread of tumour through the muscularis propria into the perirectal soft tissue signifies T3 disease. In the United States, the National Comprehensive Cancer Network (NCCN) guidelines consider all T3 rectal cancers without metastasis as a single group and an indication for neo-adjuvant treatment.² T3 stage is sub-classified according to the extramucosal depth of tumour invasion (EMD),¹³ and these sub-stages represent a heterogeneous group with different prognostic significance. T3 disease with minimal extramucosal invasion of <1 mm (i.e. T3a) can be difficult



Figure 2. Sagittal T2-weighted image showing a T1 tumour (asterisk) in the mid rectum. Preservation of the high-signal-intensity submucosal layer (curved arrow) between the invading edge of tumour and muscularis propria excludes a T2 tumour. The muscularis propria (arrow) is fully intact.

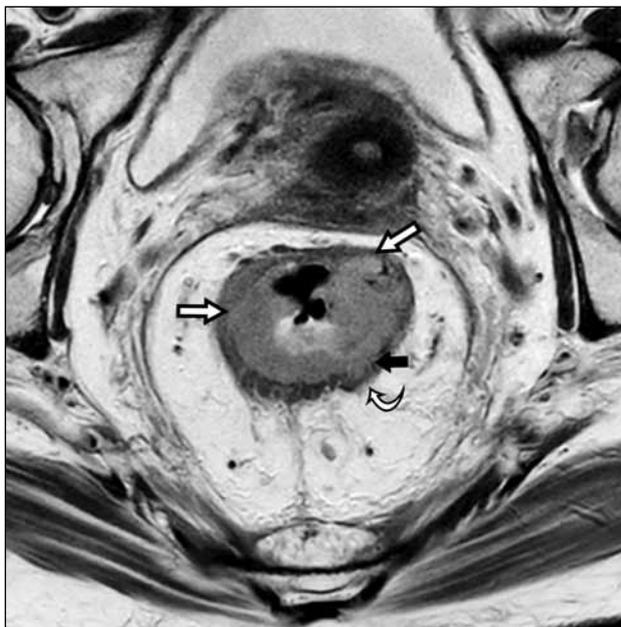


Figure 3. Axial T2-weighted image showing a T2 tumour. The semi-annular tumour is of intermediate signal intensity (outlined by white arrows) with an invading edge at 5 o'clock position. The tumour extends to but not beyond the muscle coat (black arrow), with preservation of the outer longitudinal muscle fibres (curved arrow).

to distinguish from T2 disease with a spiculated margin due to desmoplastic reaction (Figure 4). These two groups may have a similar prognosis. T3 disease with <5 mm EMD (i.e. T3a and T3b) has a better 5-year survival than T3 disease with >5 mm EMD (i.e. T3c and T3d) [85% vs. 54%].¹⁵ The local recurrence rate in advanced T3 disease is also higher.¹⁶ In the European Society for Medical Oncology (ESMO) and National Institute for Health and Care Excellence (NICE) guidelines, EMD is used as a separate parameter to select patients who need neo-adjuvant chemoradiotherapy.^{3,4} It is important to specify the distance of extramural spread (in mm) and correctly identify the high-risk group with EMD of >5 mm (i.e. T3c and T3d). MRI is accurate in the sub-classification of T3 tumours with the measured distance within 1 mm, compared with histopathology.¹⁷ EMD is measured from the outer border of the longitudinal muscle layer to the deepest portion of tumour extension beyond the muscle wall (Figure 5).

It is also important to specify the sub-stages in T4 disease because of their different management. The upper rectum is covered by visceral peritoneum anteriorly, and the coverage tapers inferiorly towards the attachment of the anterior peritoneal reflection at the mid rectum. Direct tumour invasion of the visceral peritoneum, which is often caused by anteriorly located tumour in the upper or mid rectum, signifies T4a disease (Figure 6). Local peritoneal involvement has been reported to be an independent risk factor for intraperitoneal tumour recurrence.¹⁸ Although the role of preoperative therapy in T4a disease remains undetermined,¹⁹ it is crucial to specifically report any peritoneal invasion in view of its prognostic implication and the new treatment options for peritoneal disease such as hyperthermic intraperitoneal chemotherapy.²⁰ In contrast, T4b tumour refers to the tumour that directly invades or adheres to other organs or structures (Figure 7) and requires a combined resection of the involved adjacent organ / structure for curative intent surgery; therefore the involved organ and structure should also be clearly reported.

Circumferential Resection Margin

The circumferential resection margin (CRM) is defined as the distance from the outermost edge of the tumour to the margin of the resected specimen. The mesorectal fascia denotes the resection margin of total mesorectal excision, during which the dissection follows a plane between the Denonvilliers' fascia and mesorectal fascia anteriorly, a plane between the mesorectal fascia and

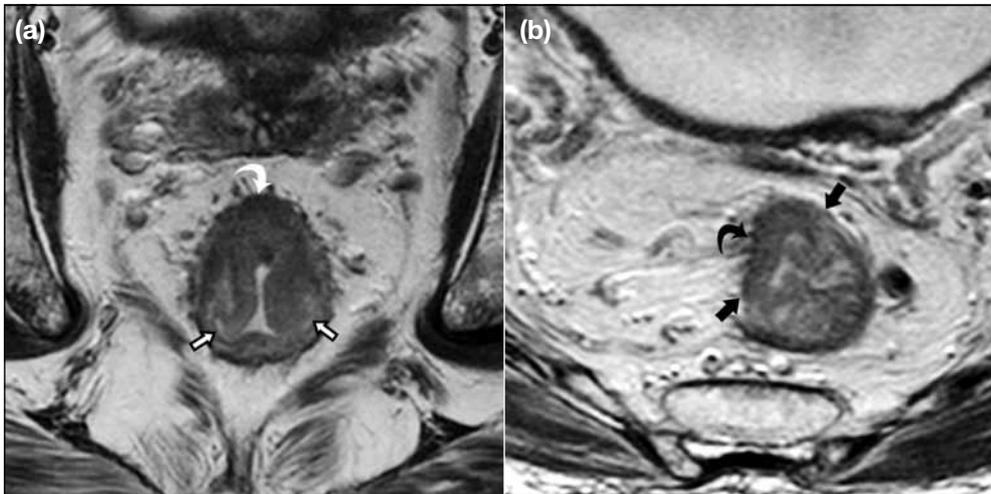


Figure 4. Axial T2-weighted images showing (a) a semi-annular T2 tumour (outlined by arrows) with full-thickness muscle involvement (curved arrow) and (b) a small T3a tumour (outlined by arrows) involving one-third of total wall circumference with early extramural extension appeared as subtle nodular undulation (curved arrow) at the tumour base. These two stages are of the same prognostic significance.

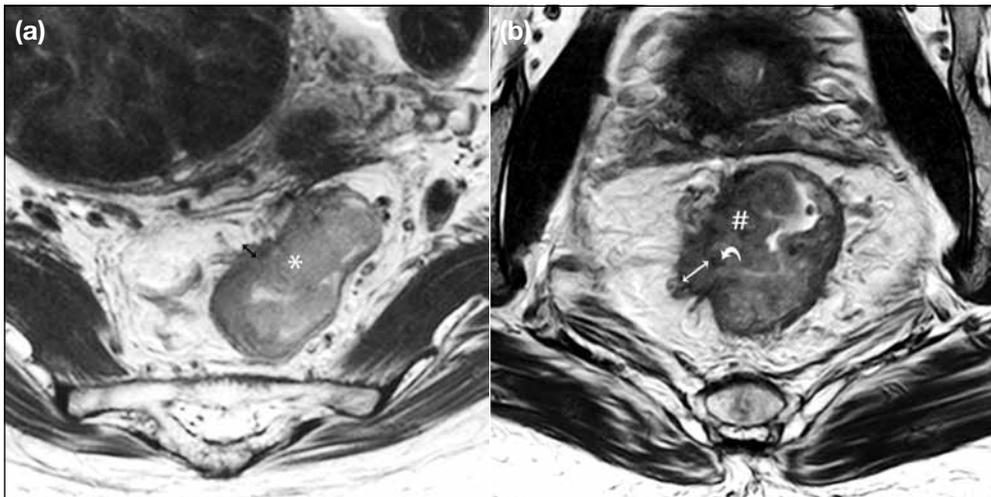


Figure 5. Axial T2-weighted images showing (a) a T3b tumour (asterisk) with extramural depth of tumour invasion of 3 mm (double arrow) and (b) a T3c tumour (hash) with extramural depth of tumour invasion of 10 mm (double arrow), with the interrupted hypointense structure at the invading edge representing the residual muscle fibres (curved arrow). The extramural depth of tumour invasion is measured from the muscularis propria to the outermost portion of the tumour.

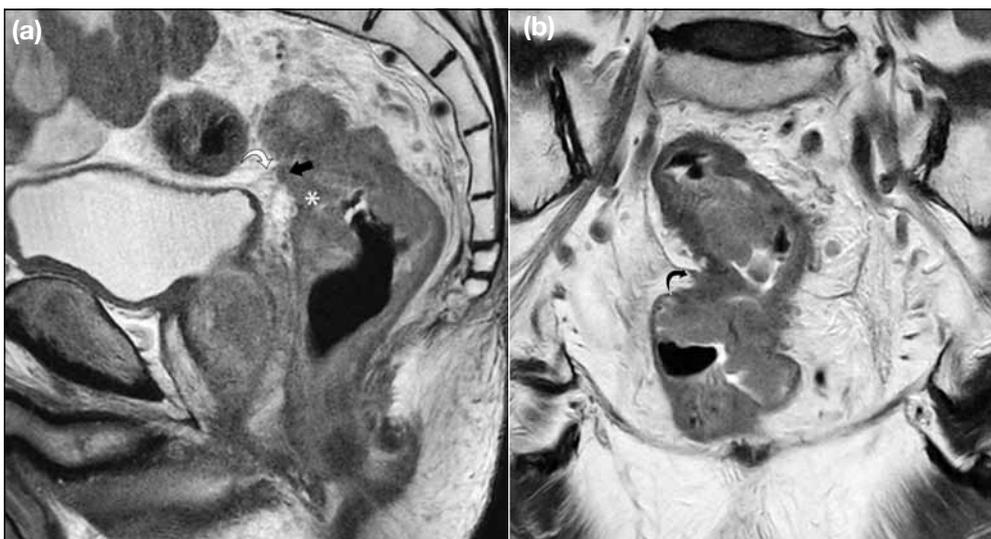


Figure 6. (a) Sagittal T2-weighted image showing an annular tumour (asterisk) in the mid rectum, with the tumour extension (arrow) at the attachment of the peritoneal reflection (curved arrow). (b) Coronal T2-weighted image showing nodular tumour infiltration (curved arrow) along the peritoneal reflection.

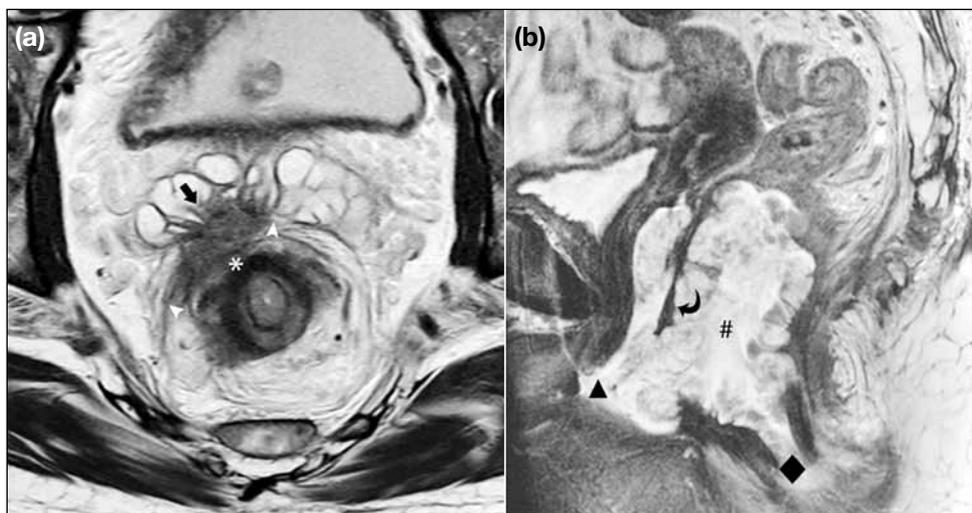


Figure 7. (a) Axial T2-weighted image showing a T4 tumour (asterisk) with extensive extramural depth of tumour invasion of the mesorectal fascia (arrowheads) and right seminal vesicle (arrow). (b) Sagittal T2-weighted image showing a large mucinous tumour (hash) with high-signal tumour stroma in low rectum with tumour extension through the posterior vaginal wall (curved arrow) into the vaginal cavity. The tumour extends inferiorly to the introitus (triangle) and anal canal (diamond). Exenteration procedure is required for tumour clearance for both cases.

endo-pelvic fascia laterally and posteriorly through the retrorectal space between the mesorectal fascia and the presacral fascia. The mesorectal fascia is identified as a thin, low-signal-intensity structure on MRI that envelops the high-signal mesorectum containing signal void vessels (Figure 1).

The pathological circumferential resection margin (pCRM) is defined as the presence of tumour within 1 mm of the resection margin.^{21,22} It is associated with a worse prognosis, high local recurrence rate, distant metastasis, and decreased survival.²³⁻²⁵ The MERCURY trial has shown that a positive pCRM is the most reliable prognostic factor for 5-year survival and is more important than T and N stage.^{26,27} Therefore, the plane of surgical resection should be routinely assessed by preoperative MRI, and patients with CRM threatened by tumour should undergo neo-adjuvant chemoradiotherapy according to the NCCN, NICE, and ESMO guidelines.²⁻⁴ In MRI-defined tumour-involved CRM, the cut-off distances of 1, 2, and 5 mm are used to predict positive pCRM.^{23,28-30} In the MERCURY study group, a distance of ≤ 1 mm from the mesorectal fascia had a high specificity of 94% in predicting a positive pCRM.²³ Relative to the shortest tumour distance of >5 mm from the mesorectal fascia on MRI, the risk of local recurrence was comparable in the 1-2 mm and 2-5 mm groups but was significantly higher in the ≤ 1 mm group.²⁸ In a meta-analysis of thresholds of 1, 2, and 5 mm for the shortest tumour distance from mesorectal fascia on MRI, using ≤ 1 mm to define CRM involvement had the highest overall accuracy, with 76% pooled sensitivity,

88% pooled specificity, and diagnostic odds ratio of 22.4.³¹ The European Society of Gastrointestinal and Abdominal Radiology and the Korean Society of Abdominal Radiology also recommend a cut-off of ≤ 1 mm to define tumour-involved CRM on MRI,^{5,32} and a cut-off of ≤ 2 mm to define a threatened CRM on MRI.⁵ Apart from direct extension from the primary tumour, other high-risk features in the mesorectum (such as extramural venous invasion, vascular / tumour deposits, and less likely metastatic nodes) can also cause tumour-involved CRM (Figure 8). For low-rectal tumours, assessment of CRM differs slightly and will be discussed in the low-rectal tumour section.

Lymph Node Staging

Based on the number of metastatic nodes, the N stages are classified as N0, N1, and N2.¹³ In the pre-total mesorectal excision era, locoregional nodal spread was regarded as a significant risk factor for local recurrence and distant metastasis after surgery. The current NCCN guidelines recommend that patients with node-involved rectal cancer should undergo preoperative neoadjuvant therapy.² After total mesorectal excision for rectal cancer, the local recurrence risk increased only when pathology had ≥ 4 metastatic regional nodes.³³ In the MERCURY study group, the local recurrence rate was very low (3.3%) regardless of MRI-predicted N stage as long as the MRI-predicted T stage was T3b or lower (i.e. EMD <5 mm); the MRI-predicted CRM was safe and there was no demonstrable extramural venous invasion (EMVI) on MRI.²⁶ MRI has fair accuracy in diagnosing nodal metastases, with sensitivity of 66-77%



Figure 8. Axial T2-weighted images showing (a) an annular tumour with extensive extramural tumour extension, a maximal extramural depth of tumour invasion at 3-5 o'clock position with adequate distance to the mesorectal fascia (black double arrow), and a closest circumferential resection margin at 11 o'clock with a distance of <1 mm (white double arrow) to the mesorectal fascia, (b) a T3d tumour with extension beyond the mesorectal fascia (curved arrow) into the left pelvic side wall (arrow), and involvement of the total mesorectal excision circumferential resection margin, and (c) tumour deposit (arrowhead) at the posterior circumferential resection margin.

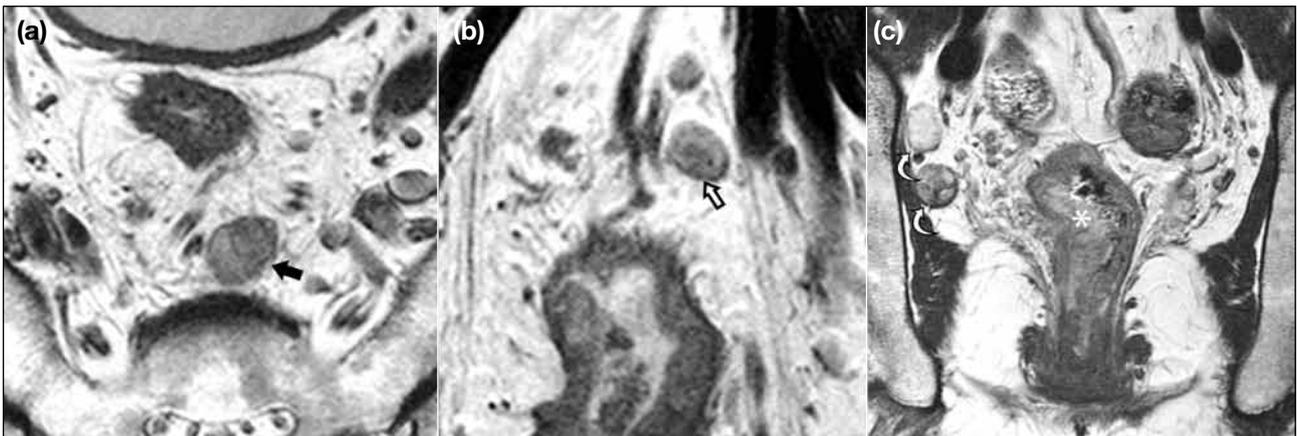


Figure 9. (a) Axial T2-weighted image showing a lymph node (arrow) with irregular contour and heterogeneous internal signal due to metastatic infiltration and extracapsular spread. Coronal T2-weighted images showing (b) a lymph node (arrow) with a well-encapsulated border but internal heterogeneous signal due to metastasis, and (c) lymph nodes (curved arrows) with abnormal morphology in the right pelvic side wall. The primary tumour (asterisk) is in the low rectum with some mucinous differentiation. These extra-mesorectal lymph nodes may necessitate extended radiotherapy or surgery and should be specifically reported.

and specificity of 71-76%. Thus, the MRI-predicted N stage is not as strong as the pathological N stage as a prognostic factor. When total mesorectal excision of good quality is performed, the nodes less commonly cause tumour-involved CRM on final pathology.

Metastatic spread within the nodes can be predicted by the presence of abnormal nodal morphology such as heterogeneous signal intensity and irregular nodal border.^{34,35} The optimal cut-off size for predicting nodal status remains unknown.³⁴ Histologically, the size of

a lymph node poorly correlates with the likelihood of malignancy (Figure 9).³⁶

The AJCC nodal staging depends on the number of abnormal nodes in the vicinity of the tumour, irrespective of the nodal location. Nonetheless, the presence of pelvic side wall nodes along the internal iliac and obturator vessels should be specifically reported (Figure 9). These nodes are outside the confines of the mesorectum and affect surgical and radiation field planning. Small nodes can often be adequately treated

with preoperative radiotherapy alone,³⁷ whereas larger nodes may require extension of the surgical field as they cannot be removed by total mesorectal excision.^{38,39}

Nodules in the mesorectum may indicate vascular deposits or extra-nodal tumour (rather than lymph node) deposits, and are classified as N1c.¹³ They are difficult to assess on final histology as the absence of a preserved nodal capsule precludes the differentiation between a malignant lymph node completely replaced by tumour and an extra-nodal tumour deposit. In a meta-analysis of 20,000 patients, extra-nodal tumour deposits were associated with a poorer prognosis (overall survival and disease-free survival), and differed from lymph node or extramural venous invasion in terms of biology and outcome.^{40,41} High-resolution MRI allows differentiation of nodal metastasis (alongside the vessels) from extra-nodal tumour deposits (along the infiltrative vein and area of internal flow void) [Figure 10].⁴²

Extramural Venous Invasion

EMVI is defined as the presence of tumour within vessels outside the muscular wall in the mesorectum. It is an independent predictor of local recurrence, distal metastasis, and poorer overall survival.^{43,44} MRI-detected EMVI correlates with histopathological findings and survival outcome. On MRI, EMVI is seen as intermediate T2 signal intensity within extramural vessels contiguous to the primary tumour.⁴⁵ Contour and calibre of the involved vessels can be expanded slightly or markedly, depending on the size and extent of intravascular tumour extension (Figure 11). MRI has

a sensitivity of 54% and specificity of 96% in detecting EMVI in veins of ≥ 3 mm in diameter, compared with histopathology with elastin stain.⁴⁶

MRI-detected EMVI is prevalent in about one-third of patients and is a strong predictor of poor prognosis and local and distant recurrence.⁴⁷ The 3-year disease-free survival for patients with MRI-positive EMVI has been reported to be 35%, compared with 74% in patients without EMVI on MRI.⁴⁸ MRI-detected EMVI is a predictor of synchronous and metachronous tumour metastases, especially to the liver (Figure 11).^{47,49,50} In a meta-analysis of 1262 patients, MRI-detected EMVI was associated with a five-fold increased rate of synchronous metastases, and almost four-fold risk of developing metastases during follow-up after surgery.⁴⁷ In low- and mid-rectal tumours, the presence of EMVI is associated with an increased risk of positive pCRM and pelvic side wall disease (Figure 11). The presence of EMVI on clinical staging is considered a moderate-risk and high-risk feature in the NICE and ESMO guidelines, respectively, and is an indication for neoadjuvant therapy.^{3,4}

Low-rectal Tumours

A low-rectal tumour is defined as adenocarcinoma of < 6 cm from the anal verge and accounts for one-third of all rectal cancers.⁵¹ On MRI, the position of the lower margin of the tumour in relation to the anal verge and puborectalis are best assessed on sagittal images and the actual distances are routinely reported (Figure 12). The anal sphincter complex, inter-sphincteric plane, and levator ani are important anatomical landmarks to

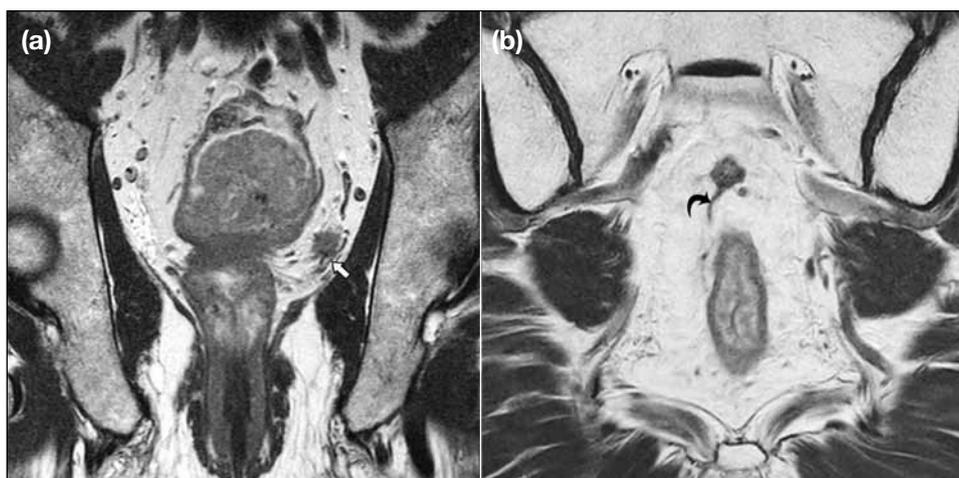


Figure 10. Coronal T2-weighted images showing (a) an irregular nodule infiltrating a non-anatomical vein and abutting the mesorectal fascia (arrow), and (b) a tumour deposit infiltrating a branch of the superior rectal vein (curved arrow). Tumour deposits are associated with higher risk of tumour-involved circumferential resection margin than lymph nodes.

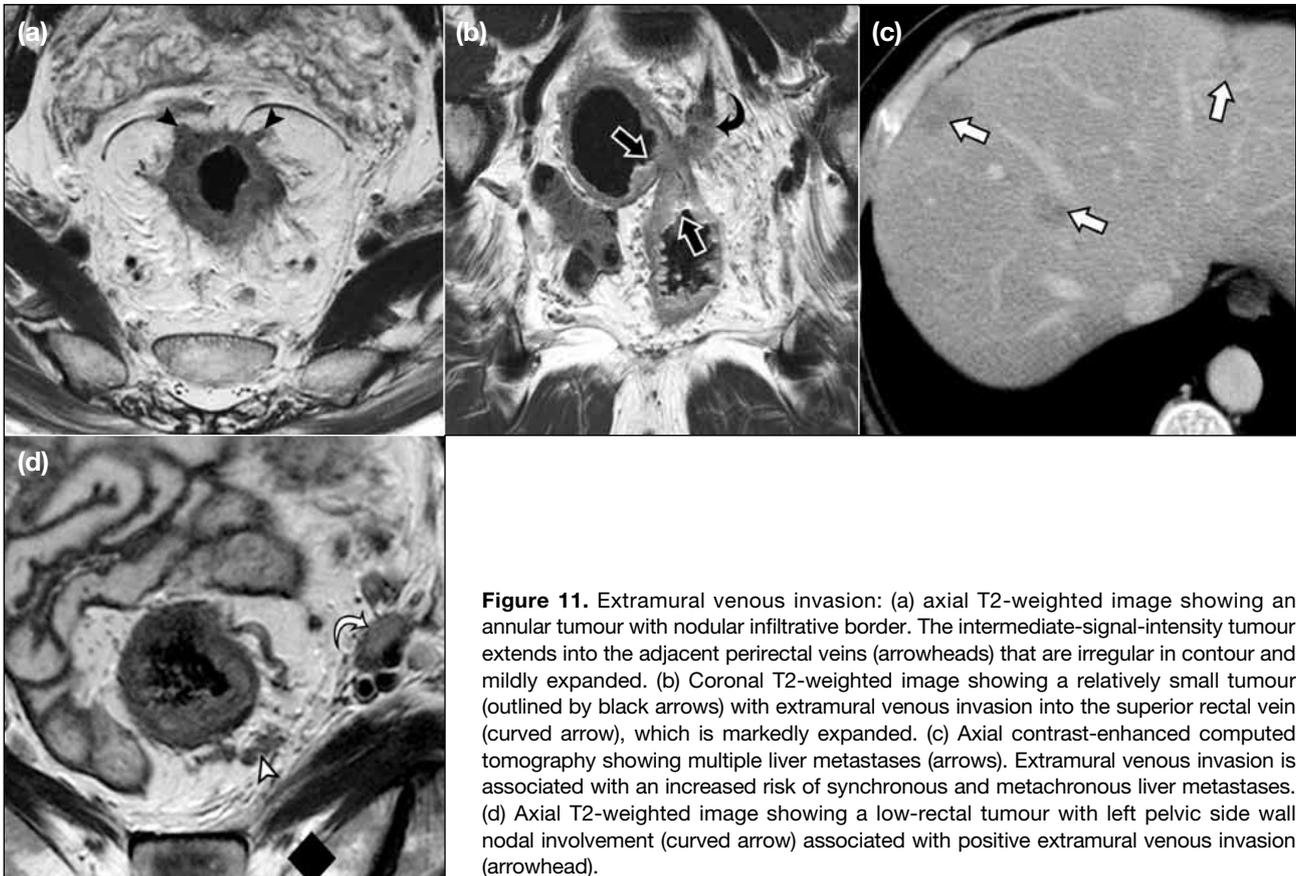


Figure 11. Extramural venous invasion: (a) axial T2-weighted image showing an annular tumour with nodular infiltrative border. The intermediate-signal-intensity tumour extends into the adjacent perirectal veins (arrowheads) that are irregular in contour and mildly expanded. (b) Coronal T2-weighted image showing a relatively small tumour (outlined by black arrows) with extramural venous invasion into the superior rectal vein (curved arrow), which is markedly expanded. (c) Axial contrast-enhanced computed tomography showing multiple liver metastases (arrows). Extramural venous invasion is associated with an increased risk of synchronous and metachronous liver metastases. (d) Axial T2-weighted image showing a low-rectal tumour with left pelvic side wall nodal involvement (curved arrow) associated with positive extramural venous invasion (arrowhead).

be assessed (Figure 13). These structures are clearly visualised on MRI, and the relationship of tumour to these structures is important for surgical planning such as inter-sphincteric resection, conventional abdominoperineal resection, or extralevator abdominoperineal resection to achieve histological clearance (Figure 14).

The outcome after surgery is worse and the local recurrence rate is higher in low-rectal tumours (than mid- and upper-rectal tumours), with a positive pCRM rate of 20-36%.⁵²⁻⁵⁴ The mesorectum tapers inferiorly below the origin of the levator ani, and tumours located in the far distal rectal region are associated with a higher chance of tumour spread into the perirectal tissues, and therefore a higher chance of tumour perforation during surgery and positive pCRM, regardless of whether the procedure is a low anterior resection or abdominoperineal resection (Figure 13).⁵⁵ According to the NICE and ESMO guidelines, patients with low-rectal tumours that encroach the inter-sphincteric plane or that are stage T2 or above should undergo neo-

adjuvant therapy to reduce the chance of recurrence.^{3,4}

The mesorectal fascia is the plane of assessment for the prediction of tumour-involved CRM. Nonetheless, the mesorectal fascia does not form the entire boundary in abdominoperineal resection; the margin status for low-rectal tumours at the distal levator level where the rectum is devoid of mesorectal fascia needs to be assessed differently. The presence of tumour within 1 mm of the levator ani muscles on MRI is a criterion for tumour-involved CRM.^{56,57} At the level of the puborectalis, the surrounding fatty tissue is usually very sparse, resulting in an insufficient safety boundary between the tumour and levator and / or sphincter complex. Thus, even a T2 tumour with full-thickness invasion of the muscularis propria may potentially threaten the resection margin.

Tumour invasion into or beyond the inter-sphincteric plane is a predictor for tumour-involved CRM after abdominoperineal resection.⁵⁶ A novel MRI staging system for low-rectal cancer is proposed to assess the



Figure 12. Sagittal T2-weighted image showing longitudinal location of the rectal tumour. The lowest border of the low-rectal tumour (curved arrow) must be clearly documented with reference to the top of puborectalis (black arrow) and anal verge (white arrow).

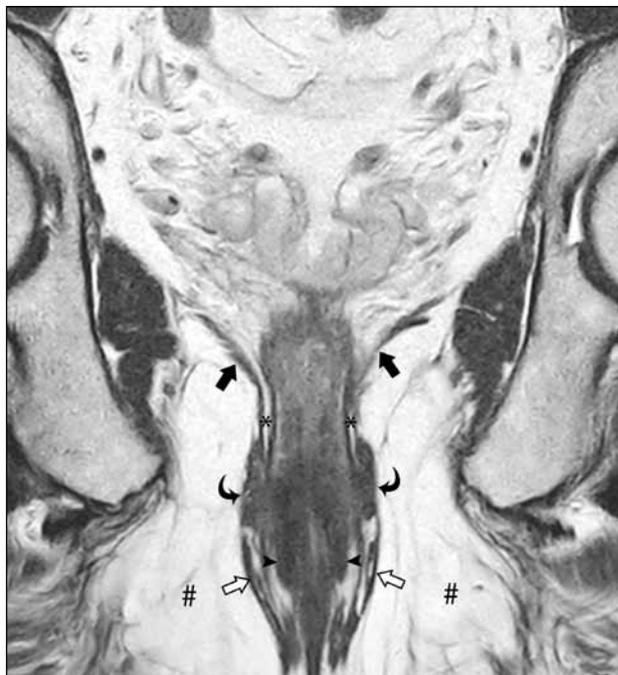


Figure 13. Coronal T2-weighted image parallel to the long axis of the anal canal showing anatomy for low-rectal tumour with distal tapering of the mesorectum and minimal fat tissue surrounding the muscles of the low rectum (the inter-sphincteric fat) at the level of distal levator / puborectalis. The important anatomical landmarks for low-rectal tumours are levator ani (black arrows), puborectalis (curved arrows), external anal sphincter (white arrows), internal anal sphincter (arrowheads), inter-sphincteric fat (asterisks), and ischiorectal fossae (hashes).

safety of surgical planes and to aid decisions about the optimal surgical approach to achieve radial histological clearance,⁵⁶ and results in decreased positive pCRM.^{51,58} In low-rectal tumours confined to the submucosal layer or partial thickness of muscularis propria, the inter-sphincteric or mesorectal planes are safe and inter-sphincteric abdominoperineal resection or ultra-low total mesorectal excision is possible. When the tumour extends through the full thickness of the muscularis propria into the inter-sphincteric plane or into the external sphincter, extralevator abdominoperineal resection is indicated (Figure 15).

For low-rectal tumours, identification of tumour involvement in specific mural layers of the rectum, inter-sphincteric plane, and sphincter complex are important in determining the optimal surgical approach and the need for neo-adjuvant therapy.

Mucinous Tumour

A mucinous tumour is one of the distinct histological subtypes in rectal cancer, and is characterised by the presence of abundant extracellular mucin that exceeds

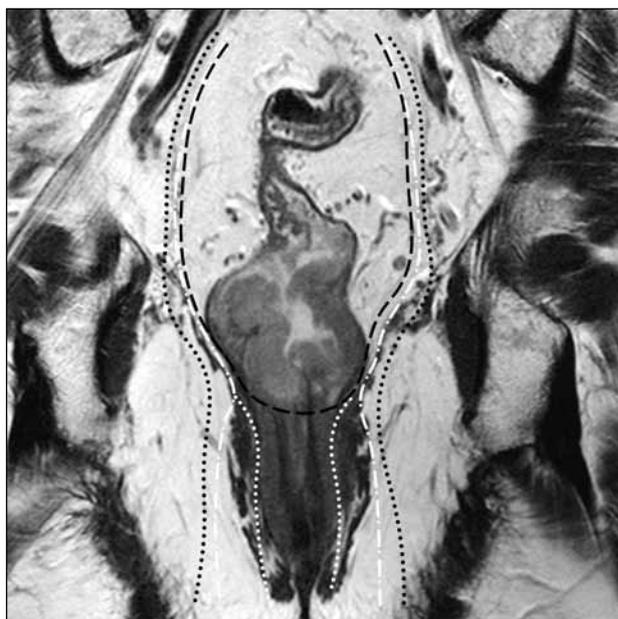


Figure 14. Coronal T2-weighted image showing various dissection planes for low-rectal tumour: ultra-low anterior resection (outlined by black dashed line), conventional abdominoperineal resection (outlined by white dashed line), inter-sphincteric resection (outlined by white dotted line), and extralevator abdominoperineal resection (outlined by black dotted line).

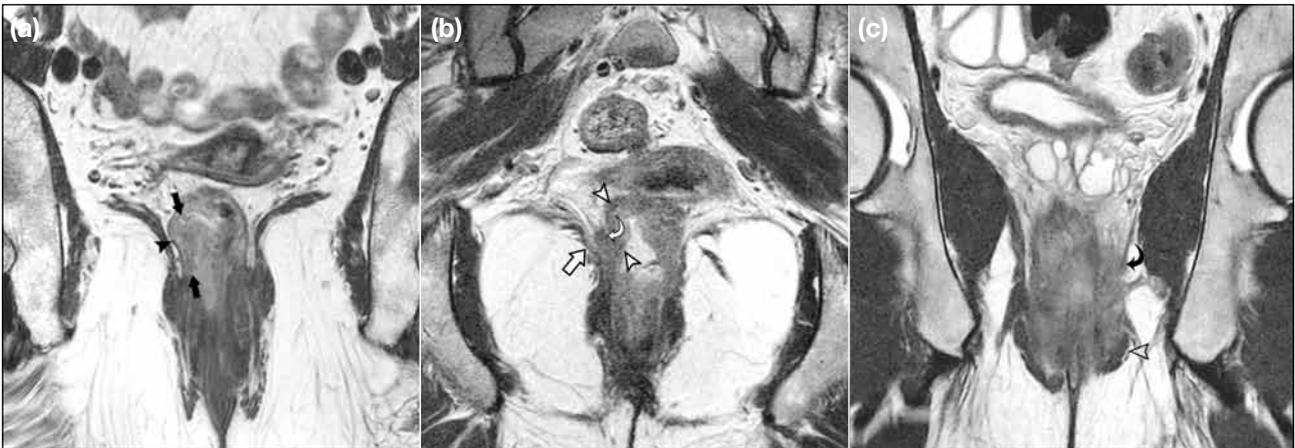


Figure 15. Coronal T2-weighted images for low-rectal tumour staging: (a) a tumour (outlined by arrows) is confined to the bowel wall but not through the full thickness and with intact outer muscle coat (arrowhead). The inter-sphincteric plane is intact indicating conventional abdominoperineal resection is safe for tumour clearance. (b) A tumour (outlined by arrowheads) is invading through the muscle coat and into the inter-sphincteric plane (curved arrow), lying within 1 mm of the levator muscle (arrow), indicating conventional abdominoperineal resection is unsafe for tumour clearance. (c) A tumour is invading into the external anal sphincter (arrowhead) and levator (curved arrow) on the left side, indicating extralevator abdominoperineal resection is needed for tumour clearance. The levator ani and external anal sphincters on the right side are intact.



Figure 16. Axial T2-weighted image showing a large mucinous tumour (asterisk) with >50% tumour stroma consisting of hyperintense mucinous component. The tumour extends into the vagina (outlined by black arrows) and is in contact with urethra (white arrow).

50% of the tumour stroma on histology.⁵⁹ It accounts for 5% to 20% of all colorectal cancers and has a worse prognosis than non-mucinous tumours.⁶⁰ On MRI, the presence of mucinous tumour is defined as tumour with

>50% high-signal intensity mucinous stroma in the primary tumour (Figure 16). MRI is highly accurate (97%) in identifying mucinous tumour,⁶¹ compared with biopsy (<20%).⁶² It has a 100% accuracy in detecting mucin-containing tumours.⁶³ Compared with non-mucinous tumours, mucinous adenocarcinomas are less sensitive to preoperative chemoradiotherapy and are associated with worse disease-free and overall survival.^{64,65} Preoperative diagnosis of this distinct morphological subtype, which is an independent imaging biomarker for poor prognosis, can aid management planning and prognosis counselling.

CONCLUSION

High-resolution MRI is pivotal in guiding the management of patients with rectal cancer. It facilitates selection of high-risk patients for more intensive treatment, without subjecting low-risk patients to unnecessary treatment and morbidity. Apart from T and N staging, imaging prognosticators on MRI (T-stage sub-classification, circumferential resection margin, N stage and extra-mesorectal node, extramural venous invasion, presence of low-rectal tumour, and presence of mucinous tumour) are useful to guide management. The role of radiologists in the multidisciplinary team has become more important.

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