



# How Do MRI Findings Influence Rectal Cancer Management?

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## Abstract

Treatment of rectal cancer is currently guided by the need to reduce local recurrence, improve survival, reduce treatment-related toxicity, and improve the patient's quality of life (QoL). Magnetic resonance imaging (MRI) scan is now the imaging modality of choice for rectal cancer. However, the role of MRI in rectal cancer has transformed beyond describing the local stage of cancer to becoming a tool to predict the prognosis of a patient by its ability to detect features associated with a high risk of recurrence and poor survival. This greatly helps the multidisciplinary team (MDT) responsible for treating patients with rectal cancer to stratify them based on the potential for recurrence and decide on the need for and type of preoperative treatment to be offered. MRI also has the ability to assess the response to such treatments, based on which the MDT can tailor the subsequent treatment. This has the potential to spare the patient from unnecessary treatment, thus improving the QoL. MRI provides a roadmap to the surgeon while planning the surgery. In this review, we give a brief overview of the current management strategies for rectal cancer and highlight the role of MRI in the decision-making process.

## Keywords

- ▶ magnetic resonance imaging
- ▶ rectal cancer
- ▶ multidisciplinary team
- ▶ neoadjuvant treatment

## Introduction

Colorectal cancers are the third most common cancer and the second leading cause of cancer-related deaths worldwide.<sup>1</sup> The management of rectal cancer has evolved over the years from only surgery to a multimodal treatment comprising surgery, radiation, and chemotherapy, central to which is the role of the multidisciplinary team (MDT) comprising surgeons, oncologists, and radiologists besides other ancillary specialists. Implementing an MDT approach to rectal cancer management has led to improved decision-making and better delivery of evidence-based care, thus reducing local recurrence and improving overall survival (OS).<sup>2,3</sup> A high-resolution magnetic resonance imaging (MRI) scan of the pelvis is currently the recommended imaging modality for local staging of rectal cancer, while an endorectal ultrasound may be considered in early superficial lesions considered for local excision where it may score over MRI or when

an MRI is contraindicated.<sup>4-6</sup> The role of MRI in rectal cancer is not limited to assessing the local invasion of tumors into surrounding structures, but it also helps determine the presence of risk factors associated with recurrence, and in restaging after neoadjuvant treatment, all of which help the MDT to determine the treatment strategy.<sup>4-6</sup> The radiologist reporting rectal cancer MRI, therefore, needs to be familiar with the requirements and expectations of the MDT. In this review, we describe the current treatment strategies for treating rectal cancer, MRI-based risk stratification of rectal cancer, integrating the MRI-derived information into management algorithms, and the importance of a structured reporting of MRI in rectal cancer.

## Management of Rectal Cancer

The evolution of treatment for rectal cancer has been shaped not only by the need to reduce locoregional recurrence (LRR)

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and distant metastasis, thereby improving the survival, but also, more lately, by patient preference for organ preservation, the need to reduce treatment-related toxicity, and improve the quality of life of the patient. The introduction of total mesorectal excision (TME) surgery and the use of postoperative (adjuvant) or preoperative (neoadjuvant) pelvic radiation with or without chemotherapy has resulted in excellent local control rates of 90 to 95%.<sup>7-16</sup> The standard of care for most patients with locally advanced rectal cancer (clinical T3-T4 and/or node positive) in the first decade of the millennium was neoadjuvant long course chemoradiation (LCRT) or short course radiation (SCRT) followed by TME and adjuvant chemotherapy. The second decade of the millennium, however, saw a shift in the management of rectal cancer from a stage-wise to a risk-adapted approach especially in Europe.<sup>4</sup> The MDT, aided by the findings on MRI, is now able to stratify patients into those at a high risk of recurrence who would benefit from neoadjuvant treatment including total neoadjuvant treatment (TNT) and those at a low risk of recurrence who may be treated with upfront surgery.<sup>17-19</sup>

## The Role of MRI in Identifying Risk Factors in Rectal Cancer

There are many pathological factors that predict the oncological outcomes after treatment for rectal cancer for which a radiological counterpart exists. The various prognostic factors in rectal cancer, the ability to identify them on MRI, the prognostic value of identifying them on MRI, and the implications of identifying these factors on the treatment are described in the following sections.

### Tumor Stage and Depth of Invasion Beyond Muscularis Propria

The depth of extramural extension (EME) of rectal cancer is an independent prognostic indicator<sup>20,21</sup> leading to heterogeneity in the survival among patients with T3 cancer. The 5-year survival rate of patients with pathological EME greater than 5 mm compared to  $\leq 5$  mm was 54 versus 85%, respectively, after upfront surgery and 47 versus 73% after neoadjuvant LCRT.<sup>21,22</sup> The magnetic resonance imaging and rectal cancer European equivalence (MERCURY) study demonstrated that MRI and histopathologic assessments of tumor spread were considered equivalent to within 0.5 mm, thereby validating MRI as a method of accurate preoperative prognostication using depth of extramural spread.<sup>23</sup> While a T3 tumor is generally considered an indication for neoadjuvant radiation, patients with MRI-predicted T3a/T3b tumors ( $< 5$  mm spread from the muscularis propria) and MRI-predicted safe circumferential resection margin (CRM) treated with surgery alone were shown to have a positive CRM rate of only 4.9%, LRR of 1.7%, and 5-year disease-free survival (DFS) of 81%, thereby successfully avoiding radiation in this group of patients.<sup>24,25</sup> Hence, T3 tumors can now be divided into low-risk (T3a/b and uninvolved mesorectal fascia [MRF] or high-risk (T3c/d and/or involved MRF) on the MRI, which will help the MDT to decide on the need for neoadjuvant treatment.

### Mesorectal Nodal Stage

Patients with metastasis to  $\leq 3$  mesorectal nodes (N1) have a good prognosis after a TME surgery, while those with  $\geq 4$  nodes (N2) have a worse prognosis.<sup>26</sup> In addition, patients with N2 disease have other associated poor prognostic factors like extramural venous invasion (EMVI), and a higher T stage. While traditionally the accuracy of nodal staging using an MRI was low, with the use of high-resolution MRI and additional characteristics other than size, like the mixed signal intensity, shape, and irregular borders, the sensitivity and specificity of nodal staging has improved to 80 to 85%.<sup>6,27-31</sup>

### Mesorectal Fascia Involvement

Pathological involvement of the CRM after a TME, defined as tumor  $\leq 1$  mm from the inked lateral resection margin, is one of the strongest predictors of LRR, metastasis, and poor survival.<sup>32-35</sup> The MRI can clearly delineate and predict the involvement of the MRF, which is the radiological counterpart to the potential pathological CRM, with a negative predictive value of 93 to 98% on baseline MRI and an accuracy of 94% on restaging MRI after LCRT.<sup>36-39</sup> The prognostic value of MRI-determined involvement of the MRF on LRR and survival has been shown by many studies including the MERCURY study in which the 5-year OS in patients with uninvolved versus involved MRF was 62.2 versus 42.2%, respectively, with a three- to fourfold increase in the LRR in the latter group.<sup>40,41</sup> Preoperative assessment of CRM status using high-resolution MRI is in fact superior to the American Joint Committee on Cancer TNM-based criteria for assessing risk of LRR, DFS, and OS.<sup>40</sup> One of the most important functions of the rectal cancer MDT is to prevent a positive CRM after surgery, and therefore, knowledge of the potential for CRM involvement can help the MDT to decide on the need for neoadjuvant radiotherapy,

### Extramural Venous Invasion

Involvement of the veins beyond the muscularis propria is an independent risk factor for local and distant metastasis and poor survival.<sup>42-44</sup> MRI is an accurate and reproducible imaging modality for identifying EMVI in primary staging as well as restaging scans.<sup>45-48</sup> There is a moderate to strong correlation between MRI-identified EMVI (mrEMVI) and pathologic EMVI with mrEMVI scores of 3 to 4 in vessels  $\geq 3$  mm having a specificity of 88 to 94%.<sup>46,49,50</sup> Presence of mrEMVI is associated with worsened survival outcomes,<sup>45,49-53</sup> confers a four- to fivefold increased risk of synchronous or metachronous metastases<sup>54</sup> and supersedes clinical TNM staging in prognostic accuracy.<sup>55</sup> Moreover, the severity of mrEMVI score and the size of the involved vessels have been found to correlate with response to neoadjuvant LCRT and DFS.<sup>50,53,56,57</sup> Nearly 25 to 50% of patients with a baseline mrEMVI-positive status can be converted to mrEMVI-negative status after neoadjuvant LCRT<sup>56-58</sup> and MRI can be a useful imaging biomarker to assess the effectiveness of the neoadjuvant treatment. An improved 3-year DFS and lower recurrence rates have been observed in patients who, after neoadjuvant LCRT, show greater than

50% fibrosis in a previously detected EMVI compared to those with less than 50% fibrosis (88 vs. 46% and 9 vs. 44%, respectively).<sup>57</sup> Regression of mrEMVI post neoadjuvant CRT confers a similar low rate of distant metastasis as that of a baseline mrEMVI negative status while a persistent positive mrEMVI has a worse prognosis.<sup>48,58</sup> In light of its prognostic significance, EMVI identification in a primary staging MRI or its persistence after neoadjuvant radiation CRT may necessitate aggressive neoadjuvant treatment protocols.

**Tumor Deposits**

Extranodal tumor deposits (TD) are nodules of tumor cells within the mesorectum discontinuous from the primary tumor and its presence portend a poor prognosis with increasing size (>12 mm) and number (≥3) having the worst prognosis.<sup>59</sup> Seen in around 20% of patients with rectal cancer, the negative effects of TDs on survival are stronger than those of both lymph node metastasis (LNM) and EMVI.<sup>59</sup> MRI can reliably identify TDs, which are seen as nodules with irregular margins often located along the vessels.<sup>60</sup> Positive mrTD/mrEMVI has been shown to have a greater prognostic accuracy than the current clinical TNM staging in rectal cancer.<sup>55</sup> Patients with baseline mrTD-positive status who respond to neoadjuvant LCRT and become ymrTD negative have similar outcomes to baseline mrTD-negative patients.<sup>55</sup> This suggests that identifying TD in the primary staging MRI can help the MDT to decide on an aggressive neoadjuvant treatment protocol to induce regression of the TD and EMVI.

**Lateral Pelvic Node**

Metastasis to the lateral pelvic nodes (LPNs) can occur in 16 to 23% of T3–T4 low rectal cancer<sup>61,62</sup> and account for at least 50% of lateral local recurrences (LLRs), which are the most common form of LRR after surgery for rectal cancer.<sup>63–65</sup> Nearly 30 to 40% of patients with an LPN with short-axis diameter (SAD) greater than 10 mm on baseline MRI have an LLR within 5 years after neoadjuvant radiation and TME.<sup>64,66</sup> Internal iliac node enlargement is associated with an increased risk of LLR, whereas obturator nodes are associated with increased risk of distant metastasis and reduced survival.<sup>66</sup>

Clinically suspicious LPNs, defined as those located in the internal iliac or obturator compartment with SAD ≥7 mm on MRI, are seen in around 16% of patients with rectal cancer.<sup>65,67,68</sup> The Lateral Lymph Node Consortium study showed that in the presence of an LPN with ≥7 mm SAD on primary MRI, if after (chemo)radiotherapy a lateral pelvic node dissection (LPND) was performed along with TME, the LLR was 5.7% compared to 19.5% if the LPND was omitted.<sup>65</sup> This consortium later reported that following neoadjuvant (chemo)radiation. The 5-year LLR was 0, 53, and 8% in patients in whom the LPN had shrunk to ≤4 mm on restaging MRI and underwent TME alone, those with persistent LPN greater than 4 mm who underwent only TME, and those with persistent LPN greater than 4 mm but underwent TME with LPND, respectively.<sup>69</sup> This has been shown by others as well.<sup>66</sup> Hence, in patients with rectal cancer, the presence

or absence of a clinically suspicious LPN should always be reported.<sup>67</sup> In low rectal cancers and a pretreatment MRI showing a clinically suspicious LPN, the MDT can decide on neoadjuvant (chemo)radiation. If these nodes respond by shrinking to ≤4 mm on the restaging MRI, LPND can be avoided but if they persist to greater than 4 mm in size especially in the internal iliac compartment or 6 mm in the obturator compartment, an LPND will be indicated.

**Role of Restaging MRI**

Restaging MRI, especially with diffusion weighted imaging (DWI), has proven to be valuable in assessing response to neoadjuvant treatment along with clinical examination.<sup>70–72</sup> A tumor regression grading system based on MRI reassessment (mrTRG) has been suggested to characterize the response to neoadjuvant treatment.<sup>73</sup> The 5-point mrTRG was shown to be an independent prognostic factor for oncological outcomes with a 5-year survival of 72 versus 27% for good versus poor mrTRG scores.<sup>74</sup> Combination of DWI patterns and T2 high-resolution MRI based MR-TRG can improve diagnostic performance of MRI for predicting complete pathological response.<sup>75</sup>

Restaging MRI can also be used not only to prognosticate patients but also to direct further therapy based on the response, as discussed in the following section. If a tumor with initial high-risk features on baseline MRI as discussed in the previous sections is downstaged to low risk on restaging MRI after neoadjuvant chemoradiotherapy, then the initial poor prognosis is altered to the prognosis of the final downstaged disease,<sup>37,48,76</sup> whereas if the high-risk features persist, the prognosis is poor and such patients may be candidates for a more intensive treatment like chemotherapy before surgery or a more radical surgery.

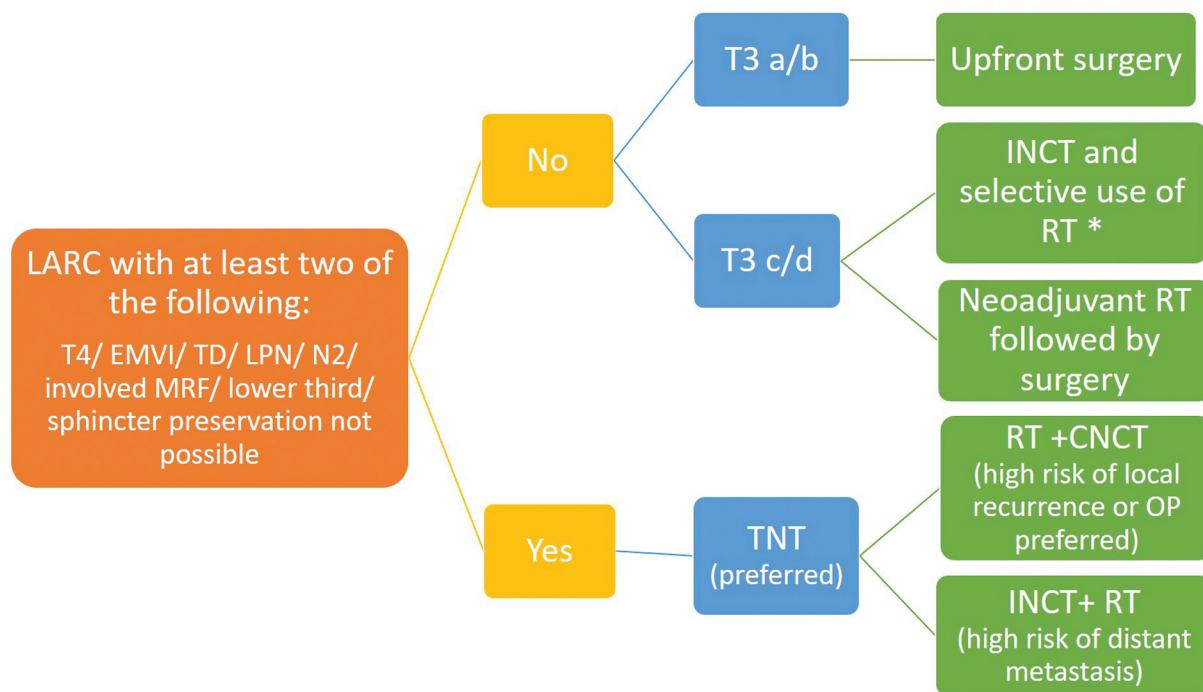
**MRI-Guided Treatment Planning in Locally Advanced Rectal Cancer**

MRI-determined risk factors have been enumerated in ► **Table 1**. In the absence of these risk factors on the MRI, patients with T3c/d could be offered neoadjuvant (chemo) radiation followed by TME, whereas those with T3a/b could be offered upfront surgery.<sup>4,5,77</sup> The presence of one or more of these risk factors on MRI is a strong indication for the MDT to

**Table 1** Risk factors for recurrence in rectal cancer on the MRI

| High risk of local recurrence   | High risk of distant metastasis |
|---|---------------------------------|
| Involvement of the MRF by either the primary tumor, EMVI, or tumor deposits | EMVI                            |
| T4b disease   | Tumor deposits                  |
| Clinically suspicious lateral pelvic nodes                                  | Any T4 disease                  |
| Low rectal cancers  | N2 disease                      |

Abbreviations: EMVI, extramural venous invasion; MRF, mesorectal fascia; MRI, magnetic resonance imaging.



**Fig. 1** Treatment algorithm for locally advanced rectal cancer based on MRI-assessed risk factors. CNCT, consolidation chemotherapy; EMVI, extramural venous invasion; INCT, induction chemotherapy; LARC, locally advanced rectal cancer; LPN, lateral pelvic node; MRF, mesorectal fascia; OP, organ preservation; RT, radiation therapy; TD, tumor deposit; TNT, total neoadjuvant treatment. \*If response to chemotherapy is greater than 20%, then the patient can undergo surgery, but if the response is less than 20%, then the patient requires radiation therapy prior to surgery.

consider TNT (►Fig. 1). Radiation (LCRT or SCRT) followed by consolidation chemotherapy is preferred when risk factors for pelvic recurrence predominate or when organ preservation is to be attempted, whereas induction chemotherapy followed by LCRT or SCRT followed by consolidation chemotherapy is offered when there is a high risk for distant metastasis.

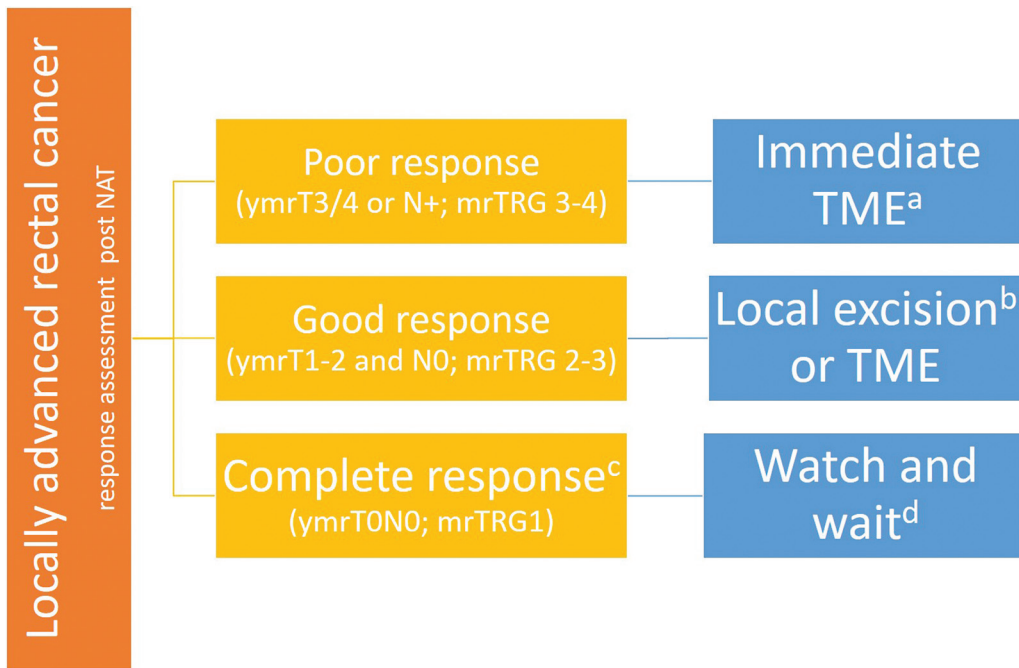
Further treatment can then be tailored based on one of three types of clinical response to the neoadjuvant treatment: poor response (y<sub>mr</sub>T3–4 or N +), a good response (y<sub>mr</sub>T1–2 and N0), or a complete clinical response (y<sub>mr</sub>TON0; ►Fig. 2). Patients with a poor response are advised immediate TME surgery, whereas those with a good response may be candidates for an organ-sparing local excision.<sup>5</sup> The PROSPECT trial showed that following induction chemotherapy in patients with T2 node positive or any T3 tumor, if the primary tumor reduced in size by greater than 20%, the patients could proceed directly to surgery without the need for radiotherapy and without compromising the oncological outcomes.<sup>78</sup> Patients who achieve a complete clinical response after neoadjuvant therapy, especially after TNT, can now be offered an option of watch and wait where no surgery is performed and the patient is placed on intensive surveillance.<sup>19,79,80</sup> This approach has shown to be successful in preserving the rectum in up to 50% of patients with locally advanced rectal cancers with good long-term oncological and functional outcomes.<sup>19,81,82</sup>

### Role of MRI in Guiding Surgical Strategy

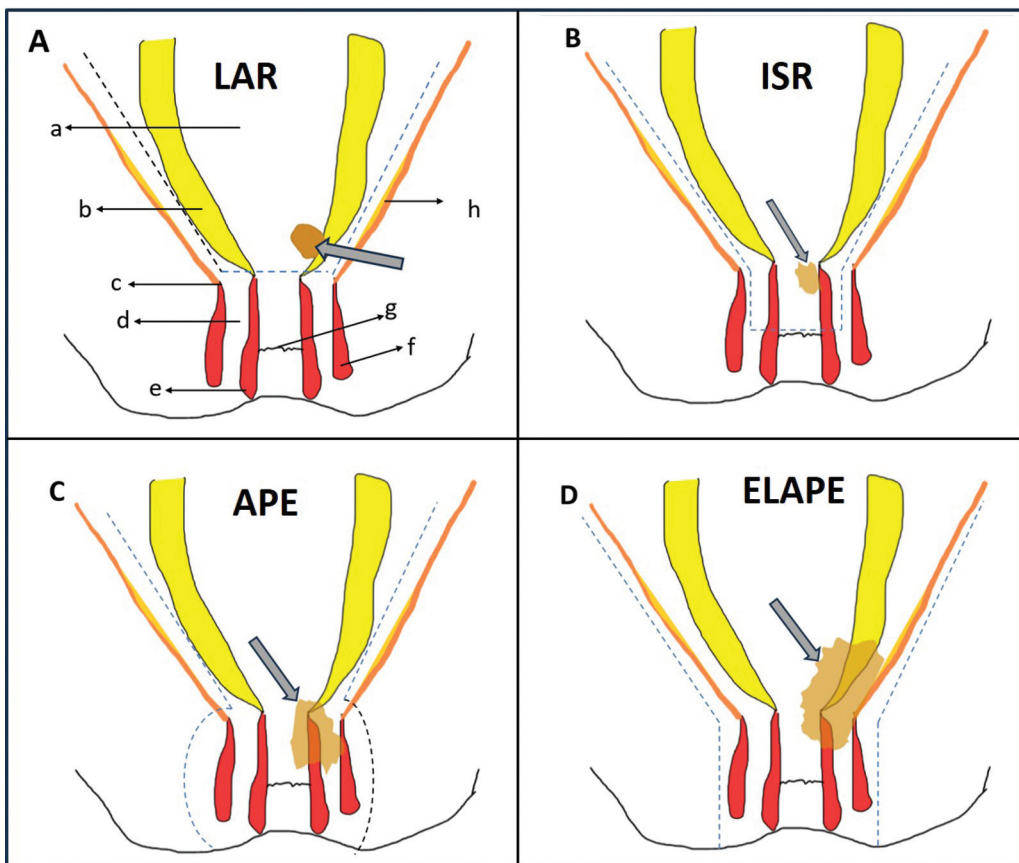
Low rectal cancers are often a challenge to the surgeon as they are associated with a higher rate of local recurrence

and reduced DFS compared to mid/upper third tumors.<sup>83–85</sup> The options of surgery in low rectal cancers include sphincter-preserving surgeries like low anterior resection or intersphincteric resection and sphincter resecting surgeries like a conventional or extralevator abdominoperineal excision (APE; ►Fig. 3). The choice of surgery for low rectal cancer depends on, besides other factors, the ability to achieve a negative CRM for which the surgeon must know the relation of the tumor to the levator ani, puborectalis, and the sphincter complex. MRI is an invaluable tool for the surgeon to plan surgery, especially in low rectal cancers.<sup>86</sup> Various MRI-based staging systems have been developed for low rectal cancers based on which the radiologist can clearly demonstrate tumor-free planes for surgical excision and the possibility of sphincter preservation.<sup>87,88</sup> In one such system, tumors at or below the puborectal sling are classified as stage 1 to 2 (tumor within the intersphincteric plane) where the intersphincteric plane is clear of tumor and a conventional APE can be performed safely or stage 3 to 4 (tumor extending into the intersphincteric plane and beyond) where the APE needs to be more radical to include the levator sling in the specimen (extralevator APE).<sup>88</sup>

The prospective MERCURY II trial successfully validated an MRI-determined low rectal cancer surgical resection plane (mrLRP) with a fivefold increase in the pathological CRM rate for an “unsafe” compared with “safe” preoperative mrLRP.<sup>89</sup> Involvement of the MRF on the immediate presurgical MRI should alert the surgeon to the need for a surgical approach going outside the conventional TME planes



**Fig. 2** Tailoring treatment after neoadjuvant therapy based on magnetic resonance imaging (MRI) assessed response to treatment. NAT, neoadjuvant therapy; TME, total mesorectal excision; TRG, tumor regression grade. <sup>a</sup>If the patient has not received TNT, there is an option of adding consolidation chemotherapy. <sup>b</sup>The residual scar/lesion should be less than 2 cm to perform local excision. <sup>c</sup>A complete clinical response also needs a finding of no palpable tumor on digital rectal examination and no visible residual tumor, nodule, or ulcer on white light endoscopy. <sup>d</sup>Based on patient preference to avoid surgery and willing to comply with an intensive surveillance schedule.



**Fig. 3** Types of surgery for low rectal cancer. (A) Low anterior resection (LAR). (B) Intersphincteric resection (ISR). (C) Conventional abdominoperineal excision (APE). (D) Extralevator abdominoperineal excision (ELAPE). The *dotted line* indicates the plane of dissection for each type of surgery. a, rectum; b, mesorectum; c, puborectalis sling; d, intersphincteric space; e, internal sphincter; f, external sphincter; g, dentate line; h, levator ani; *thick arrow* indicates the location of the tumor in the rectum.

(beyond TME approach) in order to achieve an R0 resection.<sup>90</sup> In patients with locally invasive primary or recurrent rectal cancers requiring pelvic exenteration, an MRI is the preferred imaging since it is able to predict involvement of the pelvic compartments with a high accuracy and also the risk of a positive resection margin and prognosis based on the compartment involved.<sup>91,92</sup> This knowledge can guide the surgeon in planning the surgical strategy to achieve an R0 resection, which is the most important predictive factor for survival following such surgeries.<sup>93–95</sup>

## Structured Reporting

Reporting staging and restaging MRI of the rectum using proformas or in a structured or synoptic format significantly helps improve the quality and completeness of the reports.<sup>96–98</sup> In a comparative study, structured reports (SR) significantly improved the adequacy of information for surgical planning (94% in SRs vs. only 38% in free text) as well as definite clinical decision-making (surgery vs. neoadjuvant therapy; 96% of SRs vs. 60% of free text reports;  $p < 0.001$ ).<sup>97</sup> Template report usage has been shown to significantly increase reporting of important prognostic indicators like EMVI status and CRM status compared to nontemplate reports.<sup>99</sup> Several reporting templates exist for primary as well as restaging MRI,<sup>100–102</sup> which incorporates all the essential elements required for the MDT to make appropriate treatment plans for patients with rectal cancer.

## Conclusion

MRI is an invaluable tool for local staging of rectal cancer. It not only guides the surgeons in planning the surgical strategy but also has the potential to identify important prognostic features, which helps the MDT to plan appropriate risk-stratified treatment pathways and tailor the treatment based on its ability to assess the response to neoadjuvant treatment. Use of a structured reporting format ensures that all important information needed for planning treatment is available to the MDT.

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### Conflict of Interest

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## References

- Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2024;74(03): 229–263
- Burton S, Brown G, Daniels IR, Norman AR, Mason B, Cunningham DRoyal Marsden Hospital, Colorectal Cancer Network. MRI directed multidisciplinary team preoperative treatment strategy: the way to eliminate positive circumferential margins? *Br J Cancer* 2006;94(03):351–357
- Palmer G, Martling A, Cedermark B, Holm T. Preoperative tumour staging with multidisciplinary team assessment improves the outcome in locally advanced primary rectal cancer. *Colorectal Dis* 2011;13(12):1361–1369
- Glynn-Jones R, Wyrwicz L, Tiret E, et al; ESMO Guidelines Committee. Rectal cancer: ESMO clinical practice guidelines for diagnosis, treatment and follow-up. *Ann Oncol* 2017;28(suppl\_4):iv22–iv40
- National Comprehensive Cancer Network. National Comprehensive Cancer Network Guidelines, version 4.2024. Rectal cancer. Accessed September 18, 2024 at: [https://www.nccn.org/professionals/physician\\_gls/pdf/rectal.pdf](https://www.nccn.org/professionals/physician_gls/pdf/rectal.pdf)
- Brown G, Davies S, Williams GT, et al. Effectiveness of preoperative staging in rectal cancer: digital rectal examination, endoluminal ultrasound or magnetic resonance imaging? *Br J Cancer* 2004;91(01):23–29
- Phillips RK, Hittinger R, Blesovsky L, Fry JS, Fielding LP. Local recurrence following “curative” surgery for large bowel cancer: II. The rectum and rectosigmoid. *Br J Surg* 1984;71(01):17–20
- McDermott FT, Hughes ES, Pihl EA, Milne BJ. Changing survival prospects in carcinoma of the rectum. *Br J Surg* 1980;67(11): 775–780
- Pollett WG, Nicholls RJ. The relationship between the extent of distal clearance and survival and local recurrence rates after curative anterior resection for carcinoma of the rectum. *Ann Surg* 1983;198(02):159–163
- Heald RJ, Ryall RD. Recurrence and survival after total mesorectal excision for rectal cancer. *Lancet* 1986;1(8496):1479–1482
- Sauer R, Becker H, Hohenberger W, et al; German Rectal Cancer Study Group. Preoperative versus postoperative chemoradiotherapy for rectal cancer. *N Engl J Med* 2004;351(17):1731–1740
- Kapiteijn E, Marijnen CA, Nagtegaal ID, et al; Dutch Colorectal Cancer Group. Preoperative radiotherapy combined with total mesorectal excision for resectable rectal cancer. *N Engl J Med* 2001;345(09):638–646
- Bosset JF, Collette L, Calais G, et al; EORTC Radiotherapy Group Trial 22921. Chemotherapy with preoperative radiotherapy in rectal cancer. *N Engl J Med* 2006;355(11):1114–1123
- Thomas PR, Lindblad AS. Adjuvant postoperative radiotherapy and chemotherapy in rectal carcinoma: a review of the Gastrointestinal Tumor Study Group experience. *Radiother Oncol* 1988; 13(04):245–252
- Ngan SY, Burmeister B, Fisher RJ, et al. Randomized trial of short-course radiotherapy versus long-course chemoradiation comparing rates of local recurrence in patients with T3 rectal cancer: Trans-Tasman Radiation Oncology Group trial 01.04. *J Clin Oncol* 2012;30(31):3827–3833
- Erlandsson J, Holm T, Pettersson D, et al. Optimal fractionation of preoperative radiotherapy and timing to surgery for rectal cancer (Stockholm III): a multicentre, randomised, non-blinded, phase 3, non-inferiority trial. *Lancet Oncol* 2017;18(03): 336–346
- Bahadoer RR, Dijkstra EA, van Etten B, et al; RAPIDO collaborative investigators. Short-course radiotherapy followed by chemotherapy before total mesorectal excision (TME) versus preoperative chemoradiotherapy, TME, and optional adjuvant chemotherapy in locally advanced rectal cancer (RAPIDO): a randomised, open-label, phase 3 trial. *Lancet Oncol* 2021;22(01):29–42
- Conroy T, Bosset JF, Etienne PL, et al; Unicancer Gastrointestinal Group and Partenariat de Recherche en Oncologie Digestive (PRODIGE) Group. Neoadjuvant chemotherapy with FOLFIRINOX and preoperative chemoradiotherapy for patients with locally advanced rectal cancer (UNICANCER-PRODIGE 23): a multicentre, randomised, open-label, phase 3 trial. *Lancet Oncol* 2021;22(05):702–715

- 19 Garcia-Aguilar J, Patil S, Gollub MJ, et al. Organ preservation in patients with rectal adenocarcinoma treated with total neoadjuvant therapy. *J Clin Oncol* 2022;40(23):2546–2556
- 20 Cawthorn SJ, Parums DV, Gibbs NM, et al. Extent of mesorectal spread and involvement of lateral resection margin as prognostic factors after surgery for rectal cancer. *Lancet* 1990;335(8697):1055–1059
- 21 Merkel S, Mansmann U, Siassi M, Papadopoulos T, Hohenberger W, Hermanek P. The prognostic inhomogeneity in pT3 rectal carcinomas. *Int J Colorectal Dis* 2001;16(05):298–304
- 22 Merkel S, Weber K, Schellerer V, et al. Prognostic subdivision of ypT3 rectal tumours according to extension beyond the muscularis propria. *Br J Surg* 2014;101(05):566–572
- 23 MERCURY Study Group. Extramural depth of tumor invasion at thin-section MR in patients with rectal cancer: results of the MERCURY study. *Radiology* 2007;243(01):132–139
- 24 Taylor FG, Quirke P, Heald RJ, et al; MERCURY study group. Preoperative high-resolution magnetic resonance imaging can identify good prognosis stage I, II, and III rectal cancer best managed by surgery alone: a prospective, multicenter, European study. *Ann Surg* 2011;253(04):711–719
- 25 Kennedy ED, Simunovic M, Jhaveri K, et al. Safety and feasibility of using magnetic resonance imaging criteria to identify patients with “good prognosis” rectal cancer eligible for primary surgery: the phase 2 nonrandomized quicksilver clinical trial. *JAMA Oncol* 2019;5(07):961–966
- 26 Hermanek P, Merkel S, Fietkau R, Rödel C, Hohenberger W. Regional lymph node metastasis and locoregional recurrence of rectal cancer in the era of TNM surgery. Implications for treatment decisions. *Int J Colorectal Dis* 2010;25:359368
- 27 Li XT, Sun YS, Tang L, Cao K, Zhang XY. Evaluating local lymph node metastasis with magnetic resonance imaging, endoluminal ultrasound and computed tomography in rectal cancer: a meta-analysis. *Colorectal Dis* 2015;17(06):O129–O135
- 28 Kim JH, Beets GL, Kim MJ, Kessels AG, Beets-Tan RG. High-resolution MR imaging for nodal staging in rectal cancer: are there any criteria in addition to the size? *Eur J Radiol* 2004;52(01):78–83
- 29 Beets-Tan RGH, Lambregts DMJ, Maas M, et al. Magnetic resonance imaging for clinical management of rectal cancer: updated recommendations from the 2016 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. *Eur Radiol* 2018;28(04):1465–1475
- 30 Smith N, Brown G. Preoperative staging of rectal cancer. *Acta Oncol* 2008;47(01):20–31
- 31 Brown G, Radcliffe AG, Newcombe RG, Dallimore NS, Bourne MW, Williams GT. Preoperative assessment of prognostic factors in rectal cancer using high-resolution magnetic resonance imaging. *Br J Surg* 2003;90(03):355–364
- 32 Quirke P, Durley P, Dixon MF, Williams NS. Local recurrence of rectal adenocarcinoma due to inadequate surgical resection. Histopathological study of lateral tumour spread and surgical excision. *Lancet* 1986;2(8514):996–999
- 33 Birbeck KF, Macklin CP, Tiffin NJ, et al. Rates of circumferential resection margin involvement vary between surgeons and predict outcomes in rectal cancer surgery. *Ann Surg* 2002;235(04):449–457
- 34 Wibe A, Rendedal PR, Svensson E, et al. Prognostic significance of the circumferential resection margin following total mesorectal excision for rectal cancer. *Br J Surg* 2002;89(03):327–334
- 35 Hall NR, Finan PJ, al-Jaberi T, et al. Circumferential margin involvement after mesorectal excision of rectal cancer with curative intent. Predictor of survival but not local recurrence? *Dis Colon Rectum* 1998;41(08):979–983
- 36 Beets-Tan RG, Beets GL, Vliegen RF, et al. Accuracy of magnetic resonance imaging in prediction of tumour-free resection margin in rectal cancer surgery. *Lancet* 2001;357(9255):497–504
- 37 MERCURY Study Group. Diagnostic accuracy of preoperative magnetic resonance imaging in predicting curative resection of rectal cancer: prospective observational study. *BMJ* 2006;333(7572):779
- 38 Kim SH, Lee JM, Park HS, Eun HW, Han JK, Choi BI. Accuracy of MRI for predicting the circumferential resection margin, mesorectal fascia invasion, and tumor response to neoadjuvant chemoradiotherapy for locally advanced rectal cancer. *J Magn Reson Imaging* 2009;29(05):1093–1101
- 39 Al-Sukhni E, Milot L, Fruitman M, et al. Diagnostic accuracy of MRI for assessment of T category, lymph node metastases, and circumferential resection margin involvement in patients with rectal cancer: a systematic review and meta-analysis. *Ann Surg Oncol* 2012;19(07):2212–2223
- 40 Taylor FG, Quirke P, Heald RJ, et al; Magnetic Resonance Imaging in Rectal Cancer European Equivalence Study Study Group. Preoperative magnetic resonance imaging assessment of circumferential resection margin predicts disease-free survival and local recurrence: 5-year follow-up results of the MERCURY study. *J Clin Oncol* 2014;32(01):34–43
- 41 Martling A, Holm T, Bremner S, Lindholm J, Cedermark B, Blomqvist L. Prognostic value of preoperative magnetic resonance imaging of the pelvis in rectal cancer. *Br J Surg* 2003;90(11):1422–1428
- 42 Horn A, Dahl O, Morild I. The role of venous and neural invasion on survival in rectal adenocarcinoma. *Dis Colon Rectum* 1990;33(07):598–601
- 43 Rich T, Gunderson LL, Lew R, Galdibini JJ, Cohen AM, Donaldson G. Patterns of recurrence of rectal cancer after potentially curative surgery. *Cancer* 1983;52(07):1317–1329
- 44 Krasna MJ, Flancbaum L, Cody RP, Shneibaum S, Ben Ari G. Vascular and neural invasion in colorectal carcinoma. Incidence and prognostic significance. *Cancer* 1988;61(05):1018–1023
- 45 Smith NJ, Shihab O, Arnaout A, Swift RI, Brown G. MRI for detection of extramural vascular invasion in rectal cancer. *AJR Am J Roentgenol* 2008;191(05):1517–1522
- 46 Jhaveri KS, Hosseini-Nik H, Thippavong S, et al. MRI detection of extramural venous invasion in rectal cancer: correlation with histopathology using elastin stain. *AJR Am J Roentgenol* 2016;206(04):747–755
- 47 Patel UB, Brown G, Rutten H, et al. Comparison of magnetic resonance imaging and histopathological response to chemoradiotherapy in locally advanced rectal cancer. *Ann Surg Oncol* 2012;19(09):2842–2852
- 48 Chand M, Evans J, Swift RI, et al. The prognostic significance of postchemoradiotherapy high-resolution MRI and histopathology detected extramural venous invasion in rectal cancer. *Ann Surg* 2015;261(03):473–479
- 49 Sohn B, Lim JS, Kim H, et al. MRI-detected extramural vascular invasion is an independent prognostic factor for synchronous metastasis in patients with rectal cancer. *Eur Radiol* 2015;25(05):1347–1355
- 50 Smith NJ, Barbachano Y, Norman AR, Swift RI, Abulafi AM, Brown G. Prognostic significance of magnetic resonance imaging-detected extramural vascular invasion in rectal cancer. *Br J Surg* 2008;95(02):229–236
- 51 Tan JJ, Carten RV, Babiker A, Abulafi M, Lord AC, Brown G. Prognostic importance of MRI-detected extramural venous invasion in rectal cancer: a literature review and systematic meta-analysis. *Int J Radiat Oncol Biol Phys* 2021;111(02):385–394
- 52 Liu L, Liu M, Yang Z, He W, Wang Z, Jin E. Correlation of MRI-detected extramural vascular invasion with regional lymph node metastasis in rectal cancer. *Clin Imaging* 2016;40(03):456–460
- 53 Bugg WG, Andreou AK, Biswas D, Toms AP, Williams SM. The prognostic significance of MRI-detected extramural venous invasion in rectal carcinoma. *Clin Radiol* 2014;69(06):619–623
- 54 Siddiqui MRS, Simillis C, Hunter C, et al. A meta-analysis comparing the risk of metastases in patients with rectal cancer and

- MRI-detected extramural vascular invasion (mrEMVI) vs mrEMVI-negative cases. *Br J Cancer* 2017;116(12):1513–1519
- 55 Lord AC, D'Souza N, Shaw A, et al. MRI-diagnosed tumor deposits and EMVI status have superior prognostic accuracy to current clinical TNM staging in rectal cancer. *Ann Surg* 2022;276(02):334–344
  - 56 Chand M, Bhangu A, Wotherspoon A, et al. EMVI-positive stage II rectal cancer has similar clinical outcomes as stage III disease following pre-operative chemoradiotherapy. *Ann Oncol* 2014;25(04):858–863
  - 57 Chand M, Swift RI, Tekkis PP, Chau I, Brown G. Extramural venous invasion is a potential imaging predictive biomarker of neoadjuvant treatment in rectal cancer. *Br J Cancer* 2014;110(01):19–25
  - 58 Schaap DP, Voogt ELK, Burger JWA, et al. Prognostic implications of MRI-detected EMVI and tumor deposits and their response to neoadjuvant therapy in cT3 and cT4 rectal cancer. *Int J Radiat Oncol Biol Phys* 2021;111(03):816–825
  - 59 Nagtegaal ID, Kniijn N, Huguenin N, et al. Tumor deposits in colorectal cancer: improving the value of modern staging: a systematic review and meta-analysis. *J Clin Oncol* 2017;35(10):1119–1127
  - 60 Lord AC, D'Souza N, Pucher PH, et al. Significance of extranodal tumour deposits in colorectal cancer: a systematic review and meta-analysis. *Eur J Cancer* 2017;82:92–102
  - 61 Sugihara K, Kobayashi H, Kato T, et al. Indication and benefit of pelvic sidewall dissection for rectal cancer. *Dis Colon Rectum* 2006;49(11):1663–1672
  - 62 Hazen SJA, Sluckin TC, Konishi T, Kusters M. Lateral lymph node dissection in rectal cancer: state of the art review. *Eur J Surg Oncol* 2022;48(11):2315–2322
  - 63 Iversen H, Martling A, Johansson H, Nilsson PJ, Holm T. Pelvic local recurrence from colorectal cancer: surgical challenge with changing preconditions. *Colorectal Dis* 2018;20(05):399–406
  - 64 Kim TH, Jeong SY, Choi DH, et al. Lateral lymph node metastasis is a major cause of locoregional recurrence in rectal cancer treated with preoperative chemoradiotherapy and curative resection. *Ann Surg Oncol* 2008;15(03):729–737
  - 65 Ogura A, Konishi T, Cunningham C, et al; Lateral Node Study Consortium. Neoadjuvant (chemo)radiotherapy with total mesorectal excision only is not sufficient to prevent lateral local recurrence in enlarged nodes: results of the multicenter lateral node study of patients with low cT3/4 rectal cancer. *J Clin Oncol* 2019;37(01):33–43
  - 66 Schaap DP, Boogerd LSF, Konishi T, et al; Lateral Node Study Consortium. Rectal cancer lateral lymph nodes: multicentre study of the impact of obturator and internal iliac nodes on oncological outcomes. *Br J Surg* 2021;108(02):205–213
  - 67 Sluckin TC, Couwenberg AM, Lambregts DMJ, et al. Lateral lymph nodes in rectal cancer: do we all think the same? A review of multidisciplinary obstacles and treatment recommendations. *Clin Colorectal Cancer* 2022;21(02):80–88
  - 68 Lambregts DMJ, Bogveradze N, Blomqvist LK, et al. Current controversies in TNM for the radiological staging of rectal cancer and how to deal with them: results of a global online survey and multidisciplinary expert consensus. *Eur Radiol* 2022;32(07):4991–5003
  - 69 Ogura A, Konishi T, Beets GL, et al; Lateral Node Study Consortium. Lateral nodal features on restaging magnetic resonance imaging associated with lateral local recurrence in low rectal cancer after neoadjuvant chemoradiotherapy or radiotherapy. *JAMA Surg* 2019;154(09):e192172
  - 70 Lambregts DM, Vandecaveye V, Barbaro B, et al. Diffusion-weighted MRI for selection of complete responders after chemoradiation for locally advanced rectal cancer: a multicenter study. *Ann Surg Oncol* 2011;18(08):2224–2231
  - 71 Lambregts DMJ, Delli Pizzi A, Lahaye MJ, et al. A pattern-based approach combining tumor morphology on MRI with distinct signal patterns on diffusion-weighted imaging to assess response of rectal tumors after chemoradiotherapy. *Dis Colon Rectum* 2018;61(03):328–337
  - 72 Thompson HM, Omer DM, Lin S, et al; OPRA Consortium. Organ preservation and survival by clinical response grade in patients with rectal cancer treated with total neoadjuvant therapy: a secondary analysis of the OPRA randomized clinical trial. *JAMA Netw Open* 2024;7(01):e2350903
  - 73 Patel UB, Taylor F, Blomqvist L, et al. Magnetic resonance imaging-detected tumor response for locally advanced rectal cancer predicts survival outcomes: MERCURY experience. *J Clin Oncol* 2011;29(28):3753–3760
  - 74 Patel UB, Blomqvist LK, Taylor F, et al. MRI after treatment of locally advanced rectal cancer: how to report tumor response: the MERCURY experience. *AJR Am J Roentgenol* 2012;199(04):W486–95
  - 75 Chandramohan A, Siddiqi UM, Mittal R, et al. Diffusion weighted imaging improves diagnostic ability of MRI for determining complete response to neoadjuvant therapy in locally advanced rectal cancer. *Eur J Radiol Open* 2020;7:100223
  - 76 Yu SKT, Tait D, Chau I, Brown G. MRI predictive factors for tumor response in rectal cancer following neoadjuvant chemoradiation therapy: implications for induction chemotherapy? *Int J Radiat Oncol Biol Phys* 2013;87(03):505–511
  - 77 Schrag D, Shi Q, Weiser MR, et al. Preoperative treatment of locally advanced rectal cancer. *N Engl J Med* 2023;389(04):322–334
  - 78 Scott AJ, Kennedy EB, Berlin J, et al. Management of locally advanced rectal cancer: ASCO guideline. *J Clin Oncol* 2024;42(28):3355–3375
  - 79 Martens MH, Maas M, Heijnen LA, et al. Long-term outcome of an organ preservation program after neoadjuvant treatment for rectal cancer. *J Natl Cancer Inst* 2016;108(12):djw171
  - 80 Bercz A, Park BK, Pappou E, et al. Organ preservation after neoadjuvant long-course chemoradiotherapy versus short-course radiotherapy. *Ann Oncol* 2024;35(11):1003–1014
  - 81 van der Valk MJM, Hilling DE, Bastiaannet E, et al; IWWD Consortium. Long-term outcomes of clinical complete responders after neoadjuvant treatment for rectal cancer in the International Watch & Wait Database (IWWD): an international multicentre registry study. *Lancet* 2018;391(10139):2537–2545
  - 82 Verheij FS, Omer DM, Williams H, et al. Long-term results of organ preservation in patients with rectal adenocarcinoma treated with total neoadjuvant therapy: the randomized phase II OPRA trial. *J Clin Oncol* 2024;42(05):500–506
  - 83 Marr R, Birbeck K, Garvican J, et al. The modern abdominoperineal excision: the next challenge after total mesorectal excision. *Ann Surg* 2005;242(01):74–82
  - 84 Nagtegaal ID, van de Velde CJH, Marijnen CAM, van Krieken JHJM, Quirke P. Dutch Colorectal Cancer Group Pathology Review Committee. Low rectal cancer: a call for a change of approach in abdominoperineal resection. *J Clin Oncol* 2005;23(36):9257–9264
  - 85 Faerden AE, Naimy N, Wiik P, et al. Total mesorectal excision for rectal cancer: difference in outcome for low and high rectal cancer. *Dis Colon Rectum* 2005;48(12):2224–2231
  - 86 Brown G, Kirkham A, Williams GT, et al. High-resolution MRI of the anatomy important in total mesorectal excision of the rectum. *AJR Am J Roentgenol* 2004;182(02):431–439
  - 87 Salerno GV, Daniels IR, Moran BJ, Heald RJ, Thomas K, Brown G. Magnetic resonance imaging prediction of an involved surgical resection margin in low rectal cancer. *Dis Colon Rectum* 2009;52(04):632–639
  - 88 Shihab OC, Moran BJ, Heald RJ, Quirke P, Brown G. MRI staging of low rectal cancer. *Eur Radiol* 2009;19(03):643–650
  - 89 Battersby NJ, How P, Moran B, et al; MERCURY II Study Group. Prospective validation of a low rectal cancer magnetic resonance imaging staging system and development of a local recurrence



- risk stratification model: the MERCURY II study. *Ann Surg* 2016; 263(04):751–760
- 90 Beyond TME Collaborative. Consensus statement on the multidisciplinary management of patients with recurrent and primary rectal cancer beyond total mesorectal excision planes. *Br J Surg* 2013;100(08):E1–E33
  - 91 Georgiou PA, Tekkis PP, Constantinides VA, et al. Diagnostic accuracy and value of magnetic resonance imaging (MRI) in planning exenterative pelvic surgery for advanced colorectal cancer. *Eur J Cancer* 2013;49(01):72–81
  - 92 Brown WE, Koh CE, Badgery-Parker T, Solomon MJ. Validation of MRI and surgical decision making to predict a complete resection in pelvic exenteration for recurrent rectal cancer. *Dis Colon Rectum* 2017;60(02):144–151
  - 93 Stelzner S, Kittner T, Schneider M, et al. Beyond total mesorectal excision (TME): results of MRI-guided multivisceral resections in T4 rectal carcinoma and local recurrence. *Cancers (Basel)* 2023; 15(22):5328
  - 94 PelvEx Collaborative. Surgical and survival outcomes following pelvic exenteration for locally advanced primary rectal cancer: results from an international collaboration. *Ann Surg* 2019;269 (02):315–321
  - 95 PelvEx Collaborative. Factors affecting outcomes following pelvic exenteration for locally recurrent rectal cancer. *Br J Surg* 2018; 105(06):650–657
  - 96 Sahni VA, Silveira PC, Sainani NI, Khorasani R. Impact of a structured report template on the quality of MRI reports for rectal cancer staging. *AJR Am J Roentgenol* 2015;205(03): 584–588
  - 97 Nörenberg D, Sommer WH, Thasler W, et al. Structured reporting of rectal magnetic resonance imaging in suspected primary rectal cancer: potential benefits for surgical planning and interdisciplinary communication. *Invest Radiol* 2017;52(04):232–239
  - 98 Tersteeg JJC, Gobardhan PD, Crolla RMPH, et al. Improving the quality of MRI reports of preoperative patients with rectal cancer: effect of national guidelines and structured reporting. *AJR Am J Roentgenol* 2018;210(06):1240–1244
  - 99 Brown PJ, Rossington H, Taylor J, et al; YCR BCIP Study Group. Standardised reports with a template format are superior to free text reports: the case for rectal cancer reporting in clinical practice. *Eur Radiol* 2019;29(09):5121–5128
  - 100 Gollub MJ, Arya S, Beets-Tan RG, et al. Use of magnetic resonance imaging in rectal cancer patients: Society of Abdominal Radiology (SAR) rectal cancer disease-focused panel (DFP) recommendations 2017. *Abdom Radiol (NY)* 2018;43(11):2893–2902
  - 101 Kassam Z, Lang R, Arya S, et al. Update to the structured MRI report for primary staging of rectal cancer: perspective from the SAR disease focused panel on rectal and anal cancer. *Abdom Radiol (NY)* 2022;47(10):3364–3374
  - 102 Nougaret S, Rousset P, Gormly K, et al. Structured and shared MRI staging lexicon and report of rectal cancer: a consensus proposal by the French Radiology Group (GRECAR) and Surgical Group (GRECCAR) for rectal cancer. *Diagn Interv Imaging* 2022;103 (03):127–141