User's Guide for the Synoptic MRI Report for Pre-Operative Staging of Rectal Cancer

2018

- **This User's Guide accompanies the SAR synoptic MRI report and provides a rationale and detailed explanation of how to report each item on the synoptic MRI report.**
- **This manual has been adapted and modified by the Society of Abdominal Radiology Disease Focus Panel (SAR DFP) with permission from Cancer Care Ontario (CCO), Canada**

SAR DFP members:

Marc J. Gollub, MD, FACR – Chair (gollubm@MSKCC.ORG) Professor of Radiology Department of Radiology Memorial Sloan Kettering Cancer Center	**Mukesh Harisinghani, MD, FACR - Co-Chair** (mharisinghani@mgh.harvard.edu) Professor of Radiology, Harvard Medical School Massachusetts General Hospital
Supreeta Arya, MD (supreeta.arya@gmail.com) Department of Radiology Tata Memorial Centre	**Courtney Coursey Moreno, MD** (courtney.moreno@emoryhealthcare.org) Associate Professor of Radiology Department of Radiology and Imaging Sciences Emory University School of Medicine
Greg DePrisco, MD (gregdeprisco@gmail.com) Department of Radiology Baylor University	**Randy D. Ernst, MD**(randy.ernst@mdanderson.org) Professor, Diagnostic Radiology University of Texas MD Anderson Cancer Center
Dhakshina Ganeshan, **MD** (DGaneshan@mdanderson.org) Assistant Professor, Department of Diagnostic Radiology The University of Texas MD Anderson Cancer Center	**Jennifer S. Golia Pernicka, MD** (goliapej@mskcc.org) Assistant Professor of Radiology Memorial Sloan Kettering Cancer Center
Kartik S. Jhaveri, MD, FRCPC (Kartik.Jhaveri@uhn.ca) Director - Abdominal MRI, CME Director - Medical Imaging Associate Professor - University of Toronto University Health Network, Mt. Sinai and WCH	**Thomas A. Hope, MD** (thomas.hope@ucsf.edu) Assistant Professor in Residence Department of Radiology and Biomedical Imaging
Zahra Kassam, MD, FRCPC (zahra.kassam@sjhc.london.on.ca) Regional Imaging Lead, Southwest Regional Cancer Program Assistant Professor, Radiology & Nuclear Medicine Schullich School of Medicine Western University London, Ontario, Canada	**Harmeet Kaur, MD** (hkaur@mdanderson.org) Professor, Diagnostic Radiology The University of Texas MD Anderson Cancer Center
David H. Kim, MD (dkim@uwhealth.org) Professor of Radiology, Vice Chair of Education University of Wisconsin School of Medicine and Public Health Abdominal Imaging and Intervention	**Elena Korngold, MD** (Korngold@ohsu.edu) Department of Radiology
Chandana Lall, MD (clall@uci.edu) Department of Radiology	**Neeraj Lalwani, MD** (nlalwani@wakehealth.edu) Associate Professor Department of Radiology, Section of Abdominal Imaging Wake Forest University and Baptist Medical Center

Stephanie Nougaret, MD (stephanienougaret@gmail.com) Department of Radiology Montpellier Cancer Research Institute, University of Montpellier Montpellier, France	**Iva Petkovska, MD** (petkovsi@mskcc.org) Assistant Professor Memorial Sloan Kettering Cancer Center
Perry J. Pickhardt, MD (PPickhardt2@uwealth.org) Professor of Radiology Medical Director- Cancer Imaging University of Wisconsin School of Medicine & Public Health	**Gaiane (Maia) Margishvili Rauch, MD, PhD** (GMRauch@mdanderson.org) Assistant Professor Department of Diagnostic Radiology MD Anderson Cancer Center - Houston, TX
Shannon P. Sheedy, MD (Sheedy.Shannon@mayo.edu) Assistant Professor, Department of Diagnostic Radiology Mayo Clinic of Rochester, MN	**Raj Mohan Paspulati, MD, FSAR** (rajmohan.paspulati@uhhospitals.org) Professor Department of Radiology University Hospitals, Case Western Reserve University - Cleveland, OH

ACKNOWLEDGEMENTS

Regina Beets-Tan, MD, PhD **International liaison** Department of Radiology The Netherlands Cancer Institute, Amsterdam University of Maastricht, The Netherlands	**David Patrick Ryan, MD** **Medical Oncology Consultant** Massachusetts General Hospital
Bruce Minsky, MD **Radiation Oncology Consultant** The University of Texas MD Anderson Cancer Center	**Martin Weiser, MD** **Colorectal Surgical Consultant** Memorial Sloan Kettering Cancer Center

Table of Contents

1. Current Treatment Guidelines for Rectal Cancer

Rectal cancer is associated with a higher risk of local recurrence than colon cancer. Consequently the routine use of local preoperative therapies is suggested in intermediate and high risk rectal cancers

The current NCCN guidelines for rectal cancer (defined as cancer arising between the anal verge and 12 cm by proctoscopy) recommend the use of preoperative chemoradiation for the treatment of all Stage II (T3-4 N0) and Stage III (Any T stage N1-2) rectal cancer (1). A note of interest, the 12 cm definition of the rectum is unique to American societies. Most other countries define the distal 0-15 cm from the anal verge as rectum and some even extend it to 18 cm. These guidelines are based on the randomized clinical trials that show a reduced risk of local recurrence, but little impact on overall survival (OS) (2-5). The improved survival reported with preoperative short course radiation therapy without chemotherapy (SCRT) for patients with T1-3 disease in an earlier randomized Swedish trial has not been reproduced in subsequent trials (6); this is due to a number of reasons including combining stage 2 and 3 patients and asking chemotherapy to have an absolute impact of 10% or higher on overall survival.

Two randomized trials of SCRT and long course chemoradiation offer comparable oncological outcomes (5,7). The NCCN guidelines however do not suggest SCRT in the setting of T4 tumors or those requiring preoperative therapy for sphincter preservation (1). Preoperative chemo-radiation is generally less strongly recommended for tumors>12cm and those above the anterior peritoneal reflection for a variety of reasons, however regional variations do exist, and in the USA, many bulky tumors at this height will receive neoadjuvant therapy. The RAPIDO randomized trial from the Netherlands is examining SCRT + induction chemotherapy vs. long course chemoRT. Results will be available in 2019.

Table 1

Trial	N	Description	Local Recurrence (%)		Overall Survival (%)	
			Pre-op RT	No RT	Pre-op RT	No RT
Dutch (NEJM, 2001)	1861	Clinical Stage I-III Pre-op RT vs No Pre-op RT 2 yr follow up	2*	8*	82	82
			Pre-op RT	Selective Post-op CRT	Pre-op RT	Selective Post-op CRT
MRC CR07 NCIC-CTG C016 (Lancet, 2009)	1350	Clinical Stage 1-III Pre-op RT vs selective Post op CRT 5 yr follow up	5.0*	12.0*	70	68
			Pre-op CRT	Post-op CRT	Pre-op CRT	Post-op CRT
German (NEJM, 2004)	823	Stage II and III Pre-op CRT vs Post-op CRT 5 yr follow up	6*	13*	76	74
			Pre-op RT	Pre-op CRT	Pre-op RT	Pre-op CRT
Polish (BJS, 2006)	312	Stage II and III Pre-op RT vs Pre-op CRT 4 yr follow up	9	14	67	66
Swedish (NEJM, 1997)	1168	Stage I-III Pre-op RT vs No Pre-op RT 5 yr follow up	11*	27*	58*	48*

Pre-op RT = preoperative radiation = 25 Gy = 5 fractions X 5 Gy
Pre-op CRT = preoperative chemoradiation = 50.4 Gy = 28 fractions X 1.8 Gy + continuous 5-FU infusion
* denotes $p<0.05$

Use of Induction Chemotherapy in the Rectal Cancer

The 2016 NCCN guidelines have incorporated the option of induction chemotherapy in the treatment of Stage II and Stage III tumors. This is related to a randomized trial that found less toxicity, and better completion rates for chemotherapy administered preoperatively (8). In addition smaller prospective studies have found higher rates of complete pathologic response with induction chemotherapy (9-10). This approach is being tested in a Phase II NRG trial.

Watch and Wait Non-operative Approach for Complete Clinical Response

This approach suggests that patients with a complete clinical response to chemo-radiation may be spared the morbidity of surgery with comparable OS and DFS rates to patients undergoing surgical resection. Although this approach has been validated in prospective studies, the current NCCN guidelines do not support this approach in the routine management of patients with localized rectal cancer (11,12).

2. Synoptic MRI Report

A. Clinical Information

Synoptic MRI report for rectal cancer should include a section for clinical information. This is an important part of the document and radiologists may use free text to include any specific details from the referring physicians, as deemed necessary. In particular, it may be useful to include details from the endoscopy report detailing the location of rectal tumor in this section, which can be helpful in the rectal MR interpretation.

B. Technique/ MRI Protocol

In this section of the synoptic report, the radiologist should comment on the specific protocol used for performing the rectal MR, including details on the adequacy of the study. It would be acceptable to simply state "The institutional standard rectal cancer staging protocol was used on a 1.5 T or 3 T magnet." Alternatively, a full description of the various different sequences obtained may be reported in this section.

The rectal cancer protocol recommended by the SAR Rectal Cancer DFP is available here (http://c.ymcdn.com/sites/www.abdominalradiology.org/resource/resmgr/education_dfp/rectal_cancer/MR_Protocols.pdf)

Hardware

Either 1.5 T or 3 T MR may be used for imaging rectal cancer but imaging parameters would need to be altered according to the magnet strength used, in order to obtain optimal signal-to-noise ratio. Although endorectal coils had been used in the past for obtaining high resolution MR imaging of the rectal cancer (1), this is not widely used due to several disadvantages associated with this practice, including patient discomfort, increased cost and inability to fully image the entire mesorectum . Currently, phased-array surface coils are used for rectal MRI (2) and the coil is positioned such that its lower edge lies below the pubic bone. Specifically for the low rectal cancers, the coil should be placed low enough so that that the pubic symphysis remains in the center of the field of view, which would ensure that all the relevant anatomical details are included in the study.

Patient Preparation

Use of rectal contrast and intravenous contrast is not recommended as they do not provide any added benefit in rectal cancer staging (2-4). It may be helpful to empty the bladder as a full bladder may lead to patient discomfort, resulting in suboptimal images. Use of anterior saturation bands may also be useful to reduce motion artifacts related to abdominal wall. Use of bowel preparation, enemas and anti-peristaltic agents, has not been shown to improve staging accuracy significantly. These maneuvers are considered optional and may be used, according to the preferences of the individual imaging center.

Sequences

Four fast-spin echo, T2-weighted sequences without fat saturation are recommended (2, 5), as summarized in the SAR Rectal cancer DFP recommended protocol.

(http://c.ymcdn.com/sites/www.abdominalradiology.org/resource/resmgr/education_dfp/rectal_cancer/MR_Protocols.pdf).

Sagittal T2 weighted images (using slice thickness of 3 to 4 mm) and large field of view axial T2 weighted images sequence (using slice thickness of 5 mm) is initially obtained to assess the site of rectal cancer, and pelvic nodal involvement. Information obtained from these 2 sequences is used for planning the high resolution sequences in the oblique axial and coronal plane. The high resolution oblique axial images of the rectum should be performed perpendicular to the long axis of the rectum. High resolution coronal images are especially important for low rectal tumors to ascertain the relationship between the tumor and the anal sphincter complex. Axial diffusion weighted images using b values including b0-20 and b800-1000 may be helpful. T1-weighted sequences are not recommended as they prolong the study and do not provide additional information.

C. Local Tumor Staging

(1) Primary Tumor: Morphology, Location and Characteristics

(i) Distance from the Anal Verge

Tumor location is assessed using the anal verge as a landmark. The anal verge is the distal most portion of the anal canal, and serves as the transition point between the anal mucosa and perianal skin. It can be most easily identified on sagittal T2 weighted images, as the lowest portion of the anal sphincter complex at the level of the intergluteal cleft. Distance from the verge to the lowest rolled edge of the tumor is measured and reported (Fig. 1). Craniocaudal length may be measured on sagittal or coronal images (Fig 1).

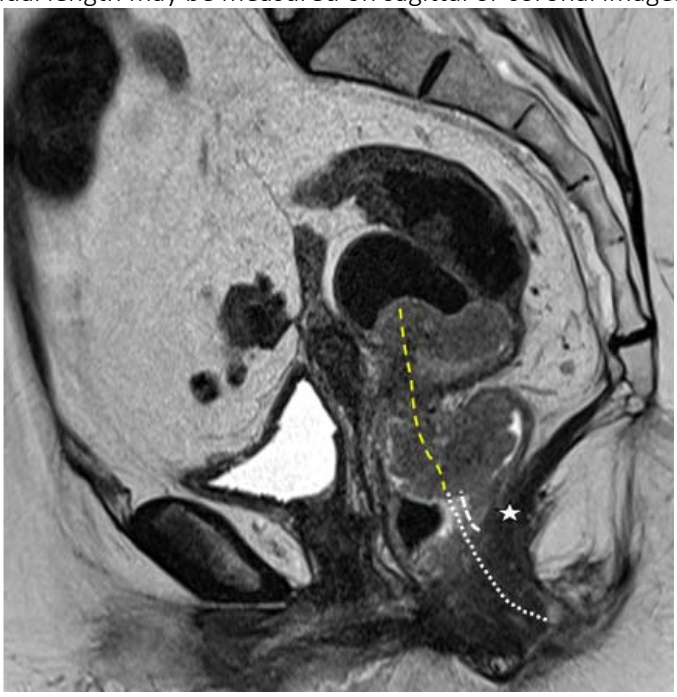


Figure 1: Measurement of craniocaudal length, distance from anal verge, and distance to top of sphincter complex (starred) on a sagittal T2WI image. The craniocaudal tumor length is indicated by the dashed yellow line. As the tumor lies above the sphincter complex, there is a short distance between the caudal tumor edge and the top of the sphincter complex (dashed white line). The distance of the caudal tumor edge to anal verge is indicated by the dotted white line.

(ii) Distance to the top of sphincter complex/anorectal junction:

This measurement is best obtained by examining sagittal T2 weighted images, obtained parallel to the long axis of the anal sphincter. The puborectalis muscles converge inferiorly to become the external sphincter muscles. The top of the sphincter complex is identified at the apex of this curvature, when the puborectalis curves inferiorly and vertically, paralleling the anal canal (Fig. 1).

(iii) Relationship to the Anterior Peritoneal Reflection:

Interpretation of the anterior peritoneal reflection can be challenging. Proper evaluation requires careful review of T2 weighted axial and sagittal images. The anterior peritoneal reflection can be identified in most

cases on sagittal T2 weighted images, appearing as a thin, low signal line extending approximately from the posterior aspect of the dome of the bladder to the ventral aspect of the rectum (Figure 2).

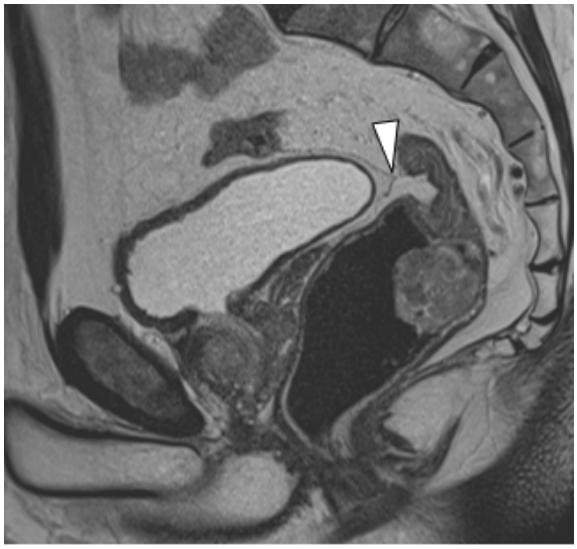


Figure 2: Anterior peritoneal reflection (arrowhead) appearing as a thin, low signal line extending from the posterior bladder dome to ventral rectum.

Based on this assessment, the radiologist determines whether the tumor is “above”, “below”, or “straddles” (extends both above and below) the anterior peritoneal reflection.

On axial imaging, the apex of the peritoneum attaches to the anterior rectal wall in a V-shaped configuration (Figure 3). In men, this is generally at a point just above the tip of the seminal vesicles; in women, the attachment is more variable. The point at which the peritoneal reflection commences can also be recognized on axial MRI images through the mesorectum. Serial axial images show the anterior mesorectal fat becoming progressively thinner. The point where no anterior mesorectal fat is seen is generally where the peritoneal reflection begins (Figure 4).

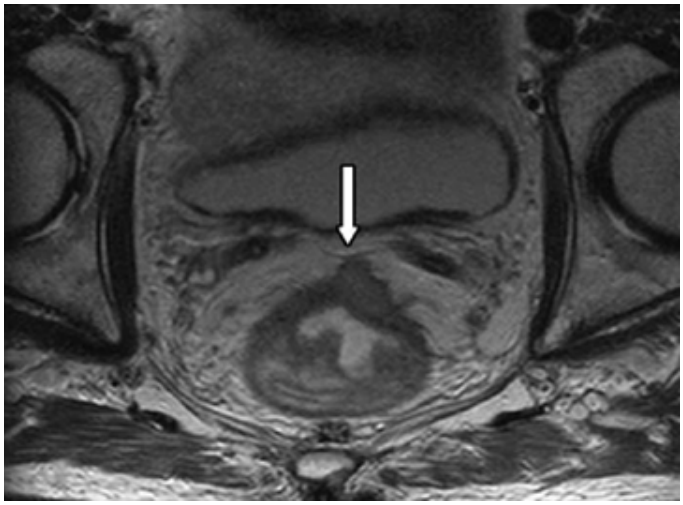


Figure 3: With permission from Elsevier Salerno G, Daniels IR, Moran BJ, Wotherspoon A, Brown G. Clarifying margins in the multidisciplinary management of rectal cancer: the MERCURY experience. Clin Radiol. Nov 2006; 61(11):916-923.

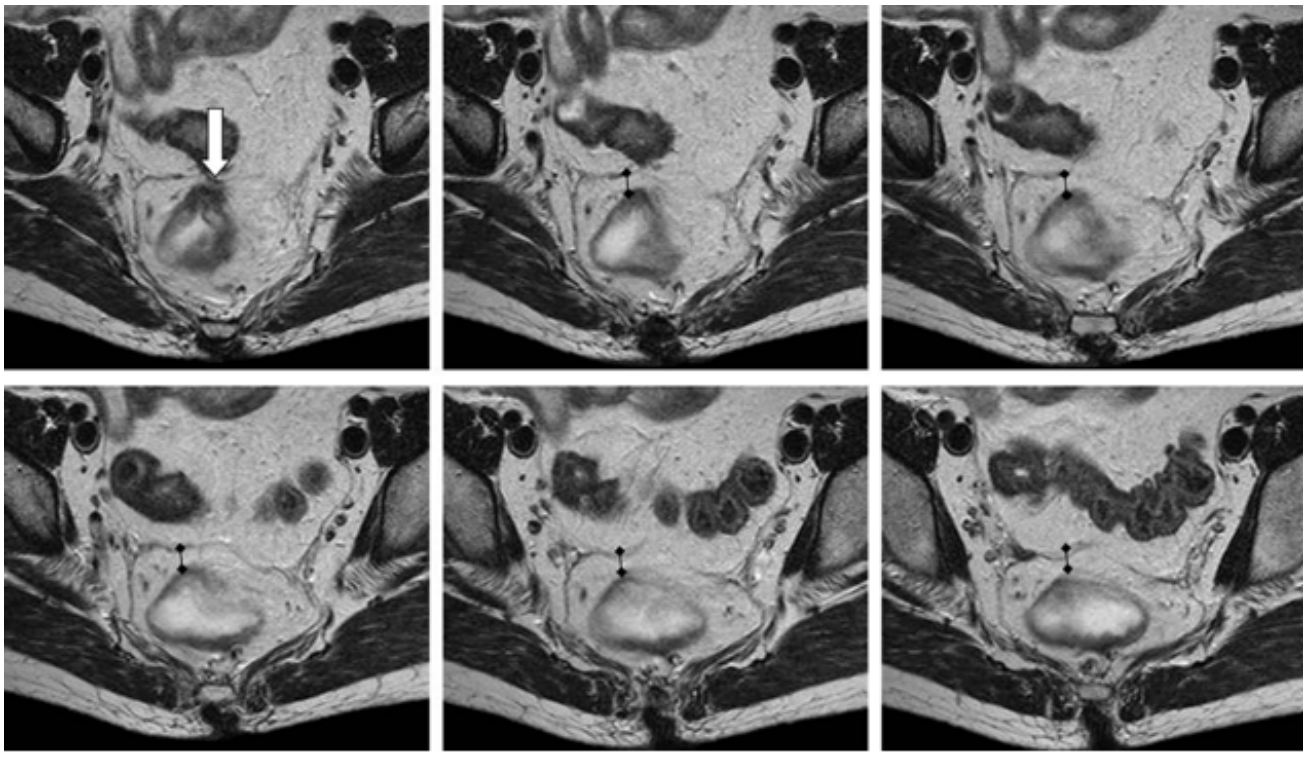


Figure 4: The point at which the peritoneal reflection commences can also be recognized on serial axial MRI through the mesorectum showing the anterior mesorectal fat becoming thinner and thinner. The point where no anterior mesorectal fat is seen is generally where the peritoneal reflection begins.

(iv) Tumor Morphology and Signal Intensity

Rectal adenocarcinoma typically has the configuration of a solid, often centrally ulcerated mass, usually with rolled edges. The configuration may be classified as “annular”, “semiannular”, or “polypoid”. Polypoid lesions may have a discernable stalk (Figure 5).

Rectal adenocarcinoma is commonly intermediate signal on T2 weighted images (slightly higher than skeletal muscle; moderately higher signal compared to the muscularis propria).

Mucinous rectal adenocarcinoma can be recognized by markedly hyperintense T2 signal (like fluid). The degree of mucin is variable; some lesions are almost entirely mucinous, while others may contain small pockets of mucin (Figure 6). Description of suspected mucinous composition is important for prognostic reasons. A rectal lesion is reported as “mucinous” when >50% of the tumor/stroma has very high T2 signal intensity compared to perirectal fat/muscle.

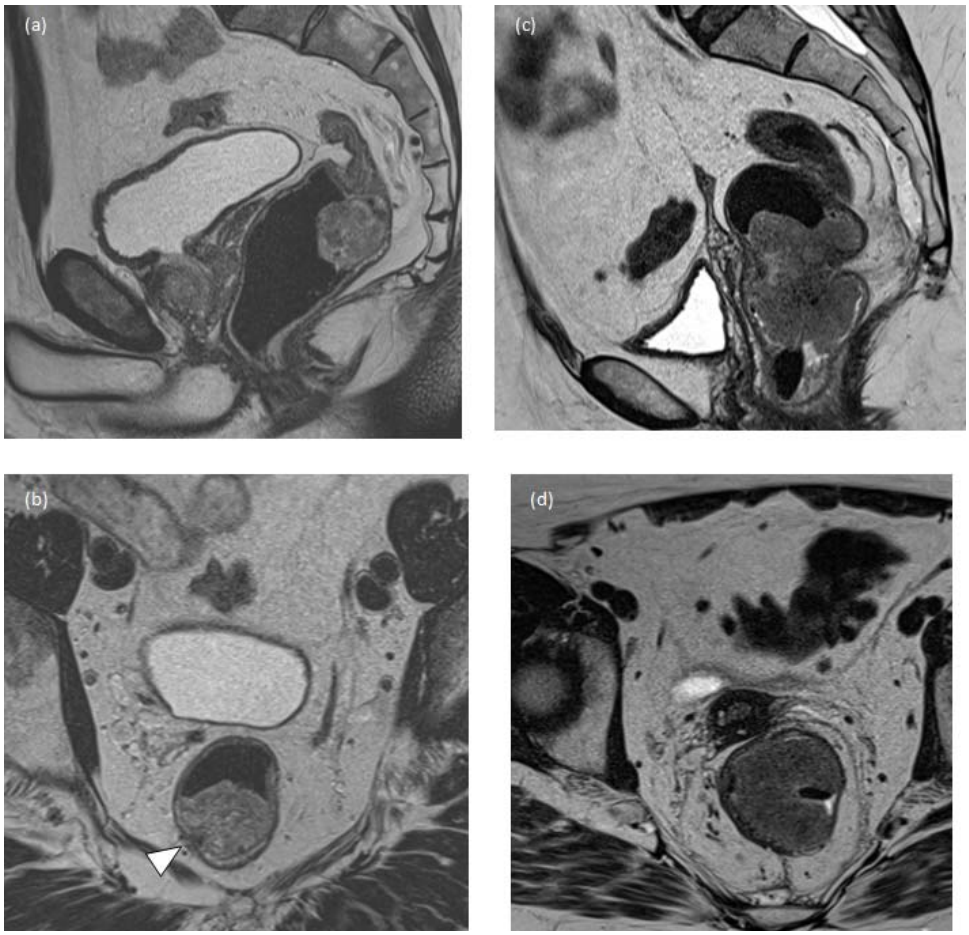


Figure 5: Variability in Tumor Morphology. (a) Polypoid lesion in mid rectum. (b) Axial oblique images demonstrate a stalk arising from the posterior right wall (arrowhead). Images (c) and (d): Sagittal and axial views of an annular lesion.

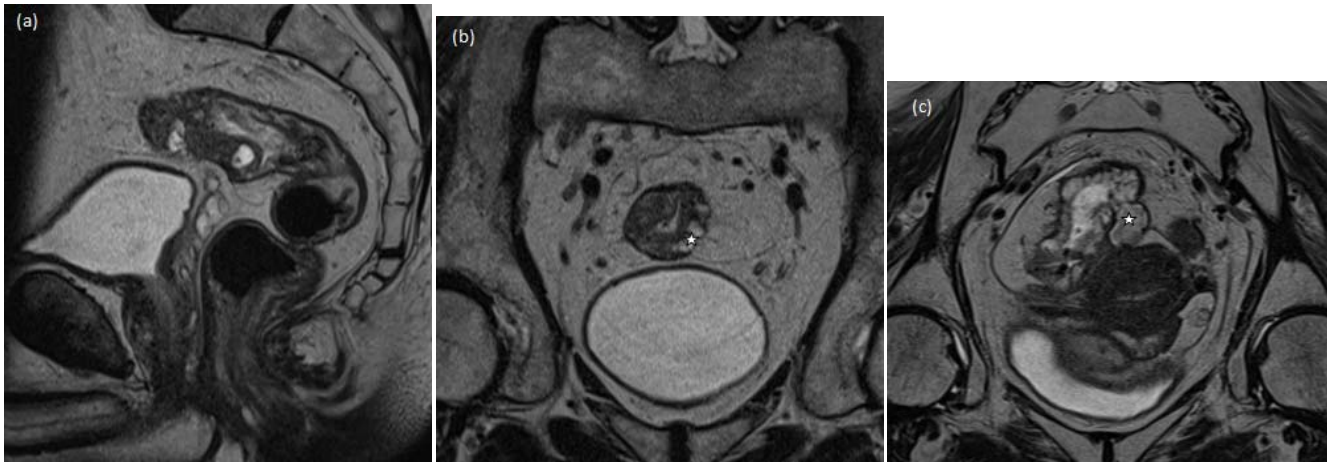


Figure 6: Variability in Mucin Expression. Images (a) and (b) demonstrate "pockets" of mucin within the tumor (starred). In (c), the majority of the lesion contains mucin. A rectal lesion is reported as "mucinous" when >50% of the tumor/stroma has very high T2 signal intensity compared to perirectal fat/muscles.

(2) MR T-Category

T category is based on depth of tumor invasion. Rectal cancer begins as a mucosal process and as it advances can invade into deeper layers of the bowel wall and beyond the wall into the mesorectal fat.

On T2 weighted images, the layers of the rectal wall can be identified (Figure 7 and 8):

- The ***mucosal layer*** is the fine innermost low signal intensity layer (not always seen separately)
- The ***submucosal layer*** is just deep to the mucosa, is thicker, and higher signal intensity
- The ***muscularis propria*** (MP) is the outer, darkest layer
    - This usually appears as a single layer, but is made up of two distinct layers: the inner circular layer and the outer longitudinal layer
    - Blood vessels can be seen interrupting the otherwise smooth outer MP and should not be mistaken for tumor [1]. If the vessel is expanded and/or intermediate signal intensity rather than signal void, consider EMVI.

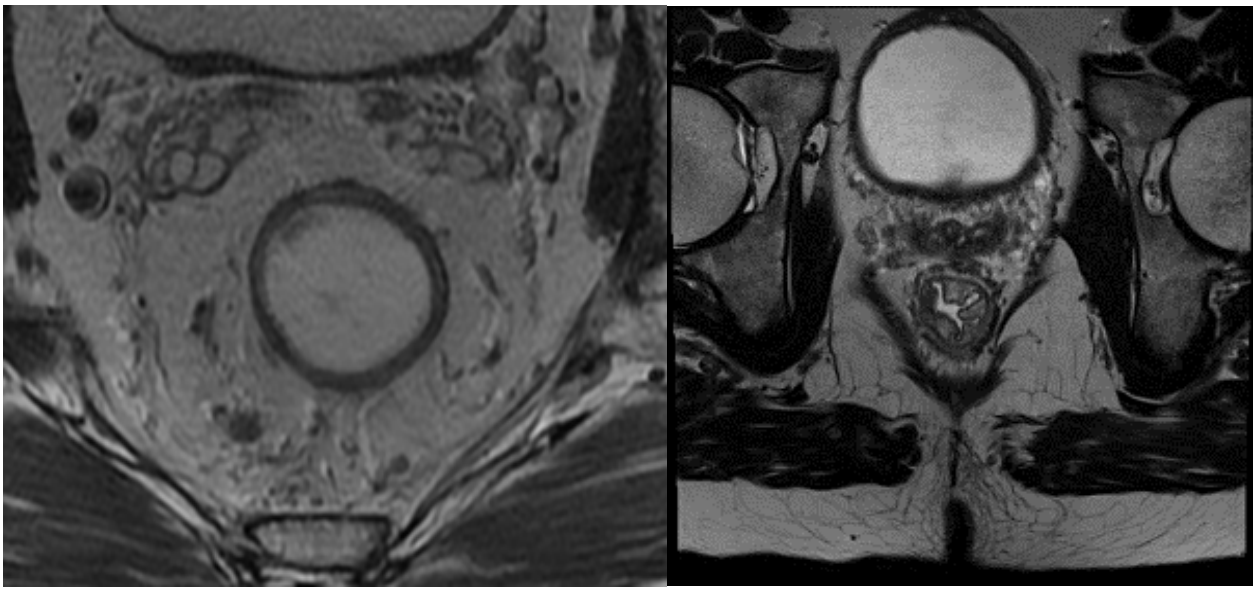


Figure 7: Two high resolution axial T2W images of the rectum with and without rectal gel demonstrate the rectal wall layers and the surrounding mesorectal fat. On the left image, notice the abnormal lymph node in the mesorectal fat posterolaterally on the right, above the level of the tumor (not shown). On the right image, notice how there is less mesorectal fat about the lower rectum, between the rectum and levator pelvic floor musculature.

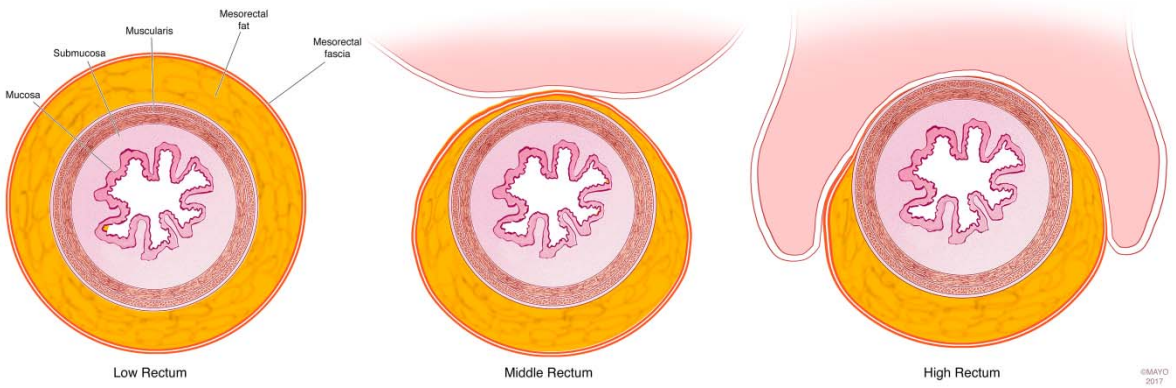


Figure 8: Schematic illustration demonstrating rectal wall layers, mesorectal fat and mesorectal fascia in the lower rectum. In the mid rectum, the mesorectal fat thins anteriorly as it approaches the peritoneal reflection. In the upper rectum, the peritoneal reflection drapes over the anterior and lateral aspects of the rectum.

The current method for describing the depth of tumor invasion on MRI is based on the AJCC T staging system [2]. According to the 7th edition of this system,

Tx: primary tumor cannot be assessed
T0: no evidence of primary tumor
T1: tumor invades submucosa
T2: tumor invades muscularis propria
T3: tumor invades through the MP into the perirectal tissues
T4a: tumor invades through the visceral peritoneum
T4b: tumor directly invades or is adherent to other organs or structures

Examples of MRI T categories are provided in Figures 9-13.

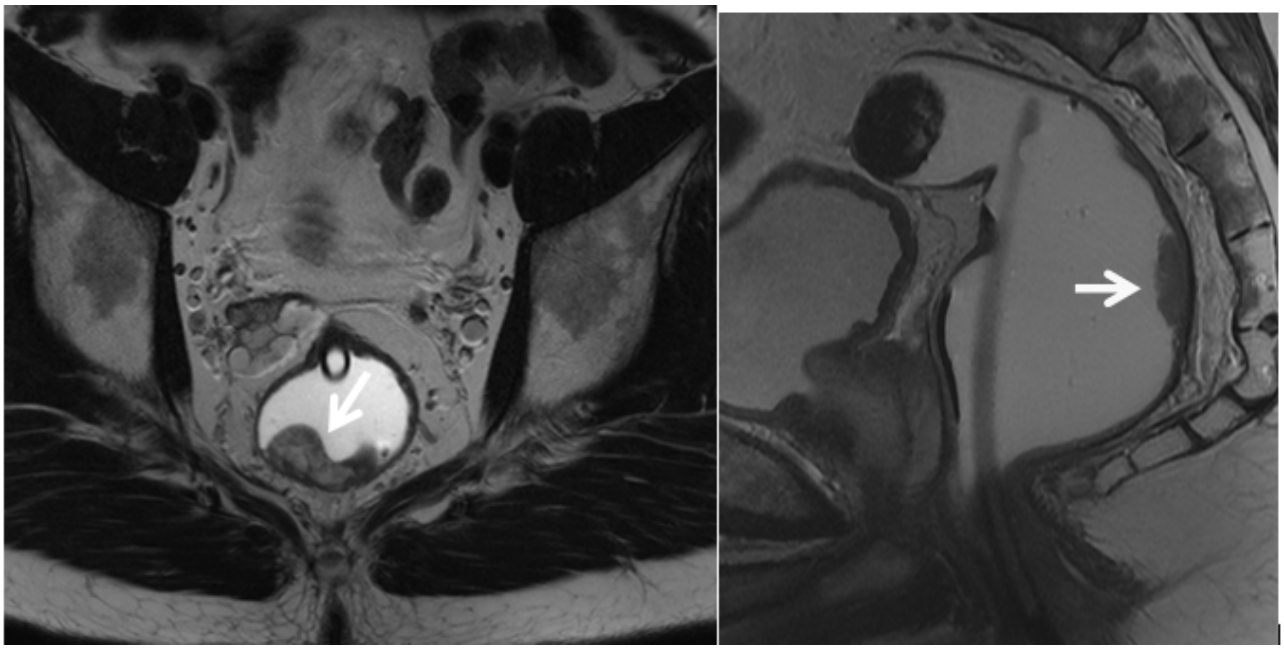


Figure 9: MRI Category T1/T2 – High resolution oblique axial and sagittal T2W images through the rectal cancer demonstrate T1/T2 tumors confined to the rectal wall in two different patients (arrows). The low signal intensity outer muscularis propria is preserved in both cases.

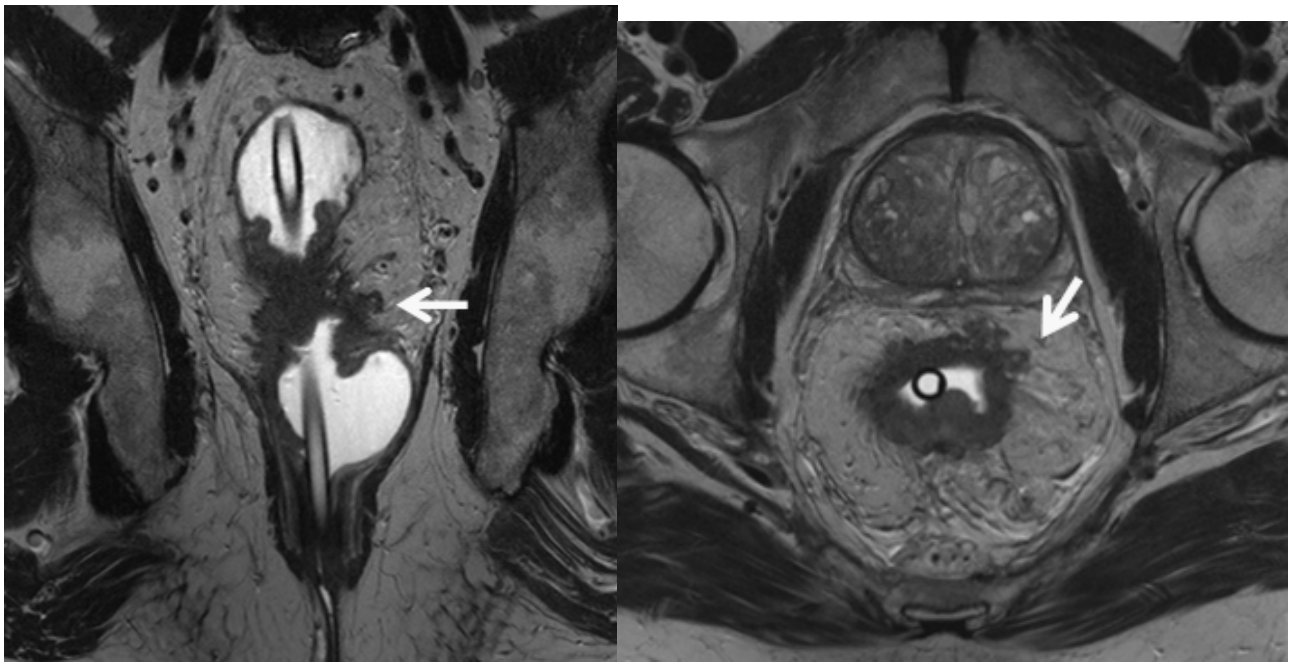


Figure 10: MRI Category T3 – Coronal and axial oblique high resolution T2W images demonstrate T3 rectal tumor penetrating through the rectal wall into the mesorectal fat in two different patients (white arrow). In the second image, the tumor penetrates through the wall at multiple locations and the white arrow points to the area with the greatest extramural depth of invasion (EMD), discussed below.

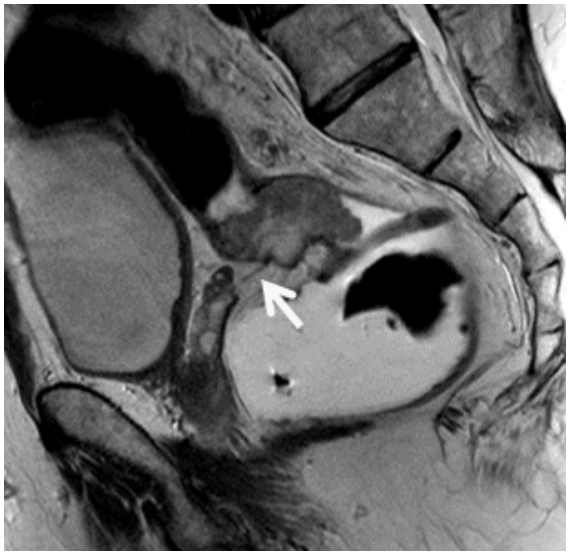


Figure 11: MRI Category T4a – Sagittal T2W image demonstrates a T4a rectal tumor penetrating through the rectal wall and involving the peritoneal reflection (white arrow).

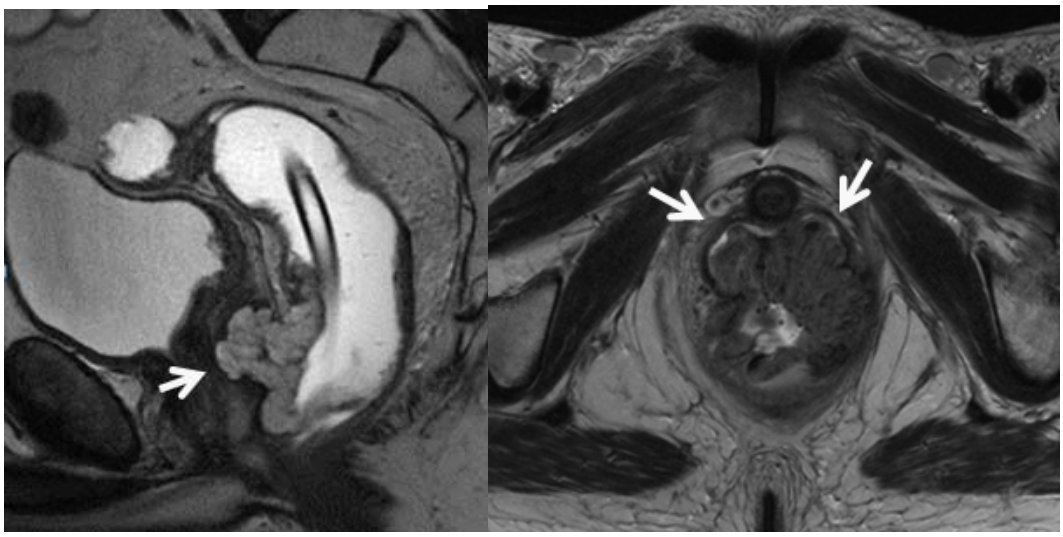


Figure 12: MRI Category T4b – Sagittal and axial T2W images demonstrating T4b disease. In the image on the left, a high T2 signal mucinous tumor is invading the prostate gland (white arrow). In the image on the right, the tumor is invading the vagina and at least abutting the puborectalis (white arrow points to vaginal wall, vagina contains high signal intensity gel).

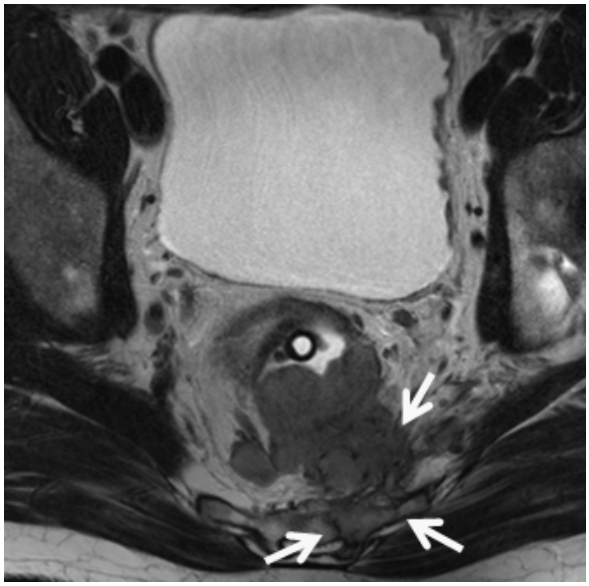


Figure 13: MRI category T4b – Axial T2W image demonstrates T4b disease with bulky tumor invading the sacrum (white arrows).

Assigning MRI T-Categories by MRI has several challenges and nuances:

T1/T2

Differentiation between T1 and T2 tumors confined to the rectal wall can be difficult by MRI and may be supported by EUS,[3] this is typically only required when considering local resection.

T2/T3

Spiculation of the perirectal fat

- **Nodular or broad based tumor extensions into the mesorectal fat should be reported as T3 tumor**
- **Very fine, low signal intensity spicules should be considered fibrosis, not tumor.**
- **Intermediate signal intensity thicker spicules may be considered suspicious for tumor extension.**

A review of the literature by the Cancer Care Ontario group found that in studies including T1-T4 tumors, overstaging and understaging occurred most often between T2 and T3 tumors (i.e., the threshold for treatment decision-making for a need for neoadjuvant treatment)[4-10].

Perirectal invasion most often appears with a broad based, pushing margin, but can be seen as finger like extensions of intermediate signal intensity extending into the mesorectal fat. A technical limitation of MRI is the inability to differentiate between benign spiculations into perirectal fat (related to desmoplastic reaction, peritumoral fibrosis, or inflammation) and spiculations with malignant extension. There is lack of consensus with regards to how to categorize this pattern of spiculation in the absence of nodular or broad based tumor extension into the fat. For example, the MERCURY group, led by Dr. Gina Brown [11], considers this pattern of spiculation into the perirectal fat to represent T2 tumor with benign desmoplastic reaction whereas another leading group from the Netherlands, led by Dr. Regina Beets-Tan [4], considers this pattern to represent a T3 tumor. *Given the lack of consensus, institutions should come to an agreement on how to report this finding to increase consistency (though not accuracy) in reporting.* The Cancer Care Ontario guidelines recommend that spiculation into the perirectal fat should be reported as a "T2/early T3 tumor". For fine, low signal intensity spicules, we suggest considering this fibrosis and not tumor.

T3

- **The area of deepest invasion of a tumor often overlies a central area of ulceration and is rarely at the margin or raised, rolled edges of the tumor (Figure 14).**

The most common appearance of rectal cancer on MRI is an annular or semiannular tumor of intermediate signal intensity projecting into the bowel lumen. As tumor advances and increases in size, the tumor frequently begins to ulcerate centrally. *This ulceration typically overlies the area of deepest invasion through the bowel wall.*

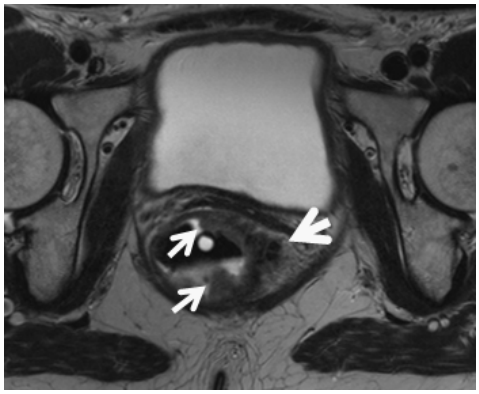


Figure 14. Semiannular rectal cancer with ulceration and invasion into the mesorectal fat.

T4b

- **Definite invasion: loss of intervening fat plane *<u>and</u>* corresponding T2 signal abnormality within the adjacent structure**

- **Possible invasion: loss of intervening fat plane *<u>but no</u>* corresponding T2 signal abnormality within the organ (Figure 15).**
  It is not possible on imaging to determine whether the tumor abuts or is adherent to adjacent structures if there is loss of fat plane but no abnormal T2 signal within the structure to indicate definite invasion. It is best to describe abutment with possible invasion in this instance.

- **No invasion: preservation of the intervening fat plane.**

Definite invasion requires combined resection of involved structure for curative intent surgery, so all invaded or possibly invaded structures must be clearly specified. The synoptic report provides a "checklist" of structures that must be carefully assessed.

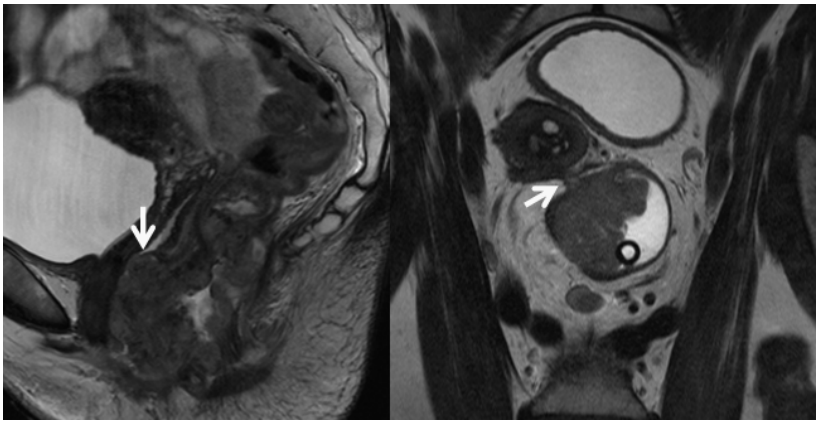


Figure 15. Possible invasion: loss of intervening fat plane but no corresponding T2 signal abnormality within the organ.

In cases where a specific T-category cannot be assigned with certainty, we recommend reporting a range of possible T-categories. Although this is not expected to change the actual accuracy of T-category reporting (which is a limitation of MRI technology), it is anticipated that reporting a range of categories will emphasize that diagnostic uncertainty exists and thereby improve communication between the radiologist and clinical team and assist with treatment decision-making.

Extramural Depth of Invasion (EMD)

- **Extramural depth of invasion (EMD) should be reported for all T3 tumors (Figure 16).**
- **EMD is measured for the definitive tumor border only and does not include spiculations into the perirectal fat.**
- **Invasive border may be from broad based bulging or nodular tumor mass or from EMVI if in continuity with the primary tumor mass.**
- **For T1 and T2 tumors, EMD should be recorded as "0 mm".**

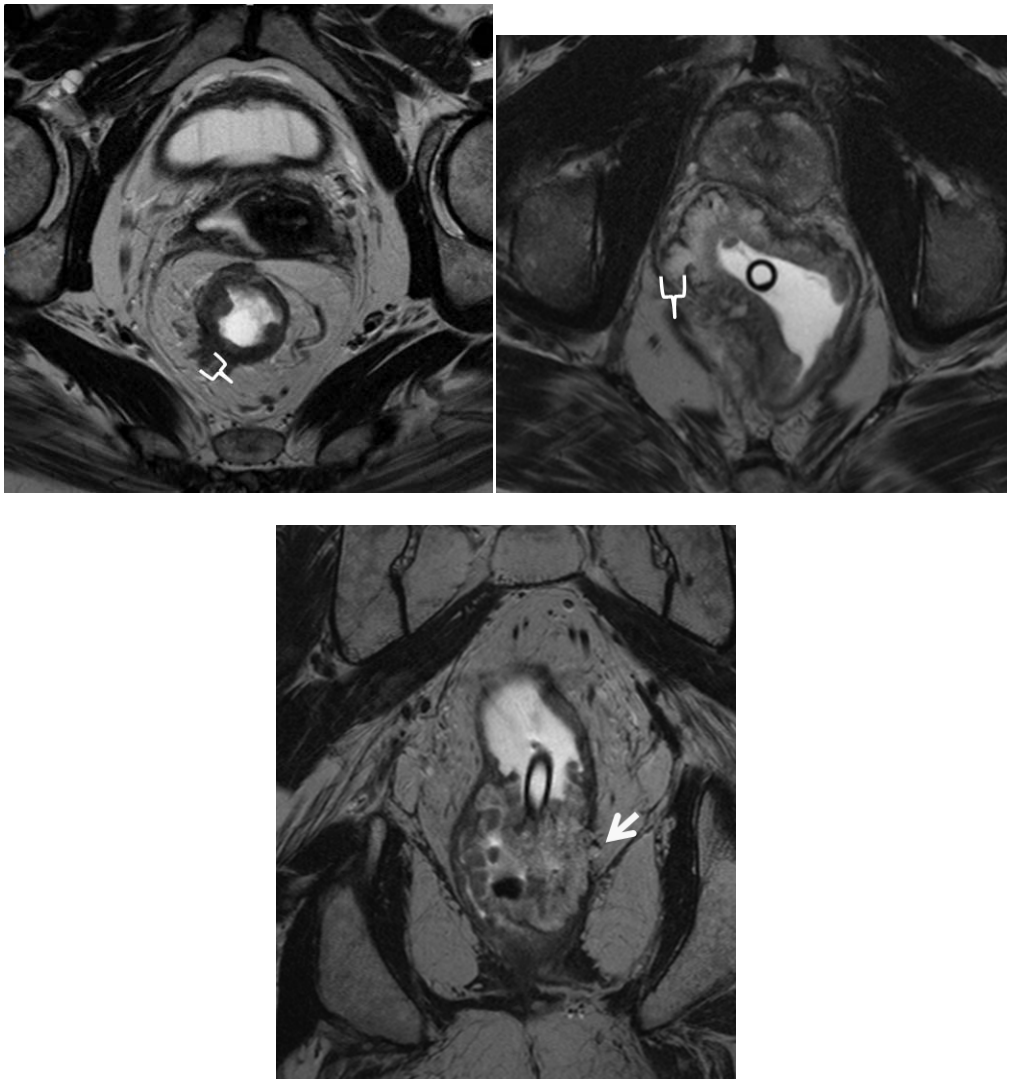


Figure 16. Measuring EMD from outer edge of muscularis propria to outer edge of leading tumor

Extramural depth of invasion (EMD) is defined as the extension of tumor into the perirectal fat beyond the muscularis propria, and applies to all T3 and T4 tumors. Current NCCN guidelines [12] recommend preoperative radiation therapy with or without combined chemotherapy for all T3 rectal cancers without distant metastases, regardless of EMD.

However, several retrospective studies have shown that T3 tumors with EMD < 5 mm have improved rates of local recurrence and survival (similar to T1/T2 tumors [13]) compared to T3 tumors with EMD > 5 mm [14-20].

Based on this rationale, the multicenter MERCURY trial showed that high resolution staging MRI correctly identified the extent of tumor invasion to within 5 mm in 92.5% of patients, with a mean of only 0.5 mm (95% CI: -0.49-0.40 mm) between EMD reported on MRI and the pathologic specimen [21]. Other studies [22] show more variability.

Therefore, EMD is included on the synoptic MRI report. This measurement should be reported for all T3 tumors. As per the MERCURY study group, EMD is measured for the definitive tumor border only and does not include spiculations or haziness in the perirectal fat. For T1 and T2 tumors, the EMD should be reported as "0 mm". Measuring EMD of < 1mm can be challenging because of surrounding desmoplastic reaction, fibrosis, or inflammation and can be sources of measurement error.

Although not considered in the AJCC staging system (7th edition) T3 subcategories are incorporated into various MR reporting templates based on EMD as follows (Figure 17):

T3a: < 1mm
T3b: 1 - <5 mm
T3c: 5-15 mm
T3d: > 15 mm

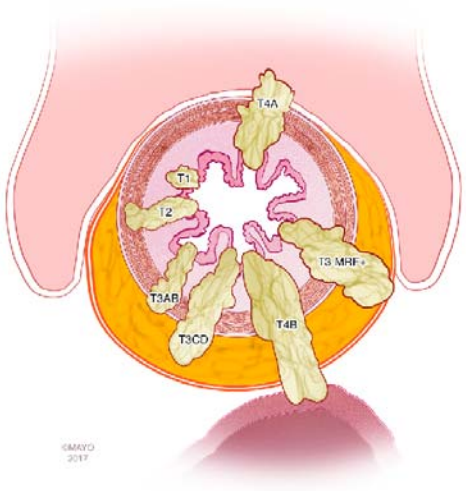


Figure 17. Schematic showing MR T-categories, including T3 substaging

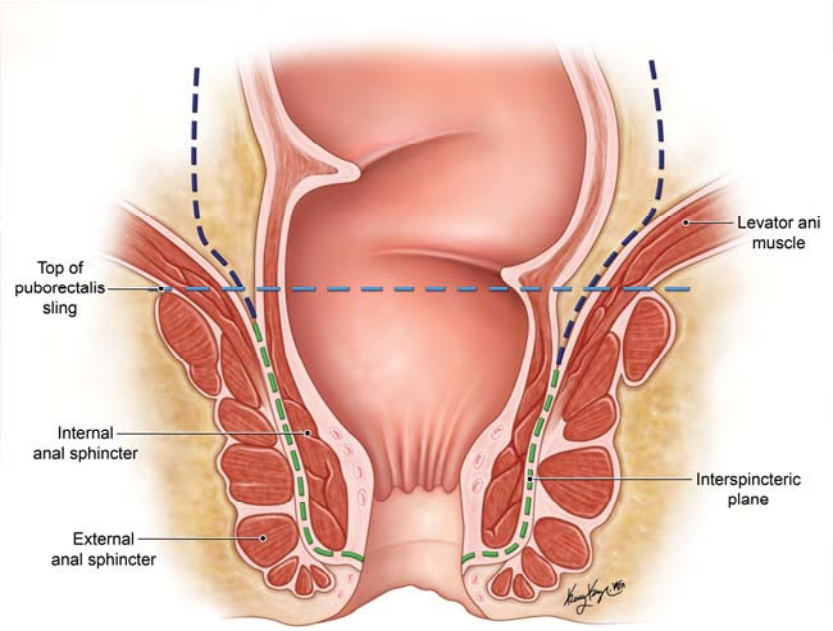
Low Rectal Tumors

Low rectal cancers are defined as tumors that arise within 5 cm of the anal verge and account for 1/3rd of all rectal cancers (6). Tumors in this region warrant special mention due to challenges these tumors pose from treatment perspective. Surgical treatment of low rectal tumors is technically more difficult as the mesorectal fascia tapers downwards in this region. Given this anatomy, there is a higher incidence of threatened CRM and local recurrence in low rectal cancers (6, 7).

Further low rectal cancers may involve the anal sphincter complex, pre-operative knowledge of which is vital as that determines surgical approach. If the anal sphincter is not involved by the tumor, patients are treated with sphincter preserving, low anterior resection (7). If the anal sphincter is involved by the tumor, surgical approach depends upon the radial extent of the tumor. If the intersphincteric plane and mesorectal fascia are not involved by the tumor, it may still be feasible to consider intersphincteric resection with ultra-low coloanal anastomosis (8, 9). However, if the tumor breaches the intersphincteric plane, anal sphincter preservation may no longer be possible as these would require radical extra- levator abdominoperineal resection with permanent colostomy.

When reporting MRI of low rectal cancers, it is important to first identify the relationship of the inferior margin of the rectal tumor to the top border of puborectalis (7, 10). Based on this relationship, low rectal tumors may be broadly classified as: (i) tumors in which the lower extent of the tumor is clearly above the top border of puborectalis and (ii) tumors in which the lower extent of the tumor is at or below the top border of puborectalis[2,4] (See Figure 18).

Figure 18



Low rectal tumors in which the lower margin of the tumor is above the top border of puborectalis may be amenable to sphincter sparing low anterior resection and should be reported similarly to upper and mid rectal tumors on the synoptic MRI report.

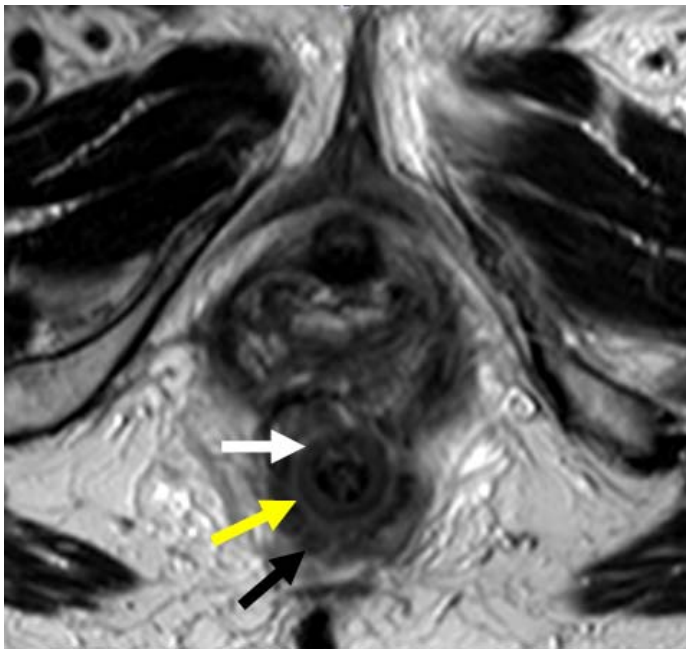
For low rectal cancers in which the lower extent of the tumor is at or below the top border of puborectalis, it is important to specify the degree of radial extent of the tumor as follows:

[] [Invades internal sphincter only]

[] [Invades internal sphincter and extends into intersphincteric plane]

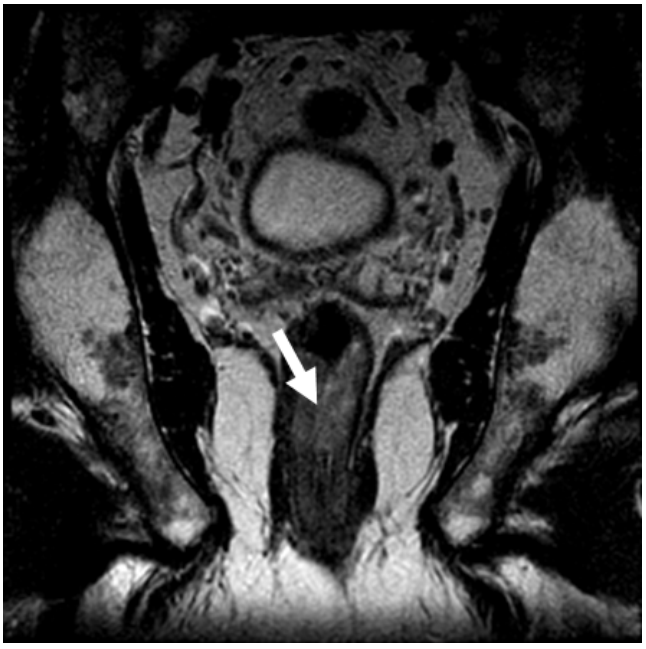
[] [Invades into or through external sphincter]

Figure 19



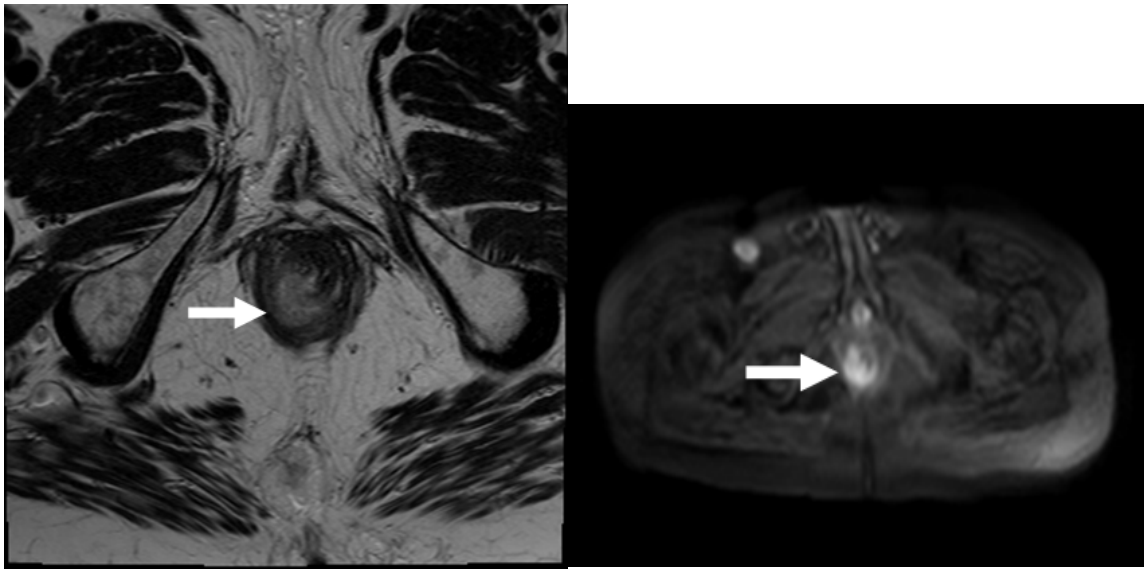
Normal appearances of internal anal sphincter (white arrow), intersphincteric plane (yellow arrow) and external anal sphincter (black arrow)

Figure 20



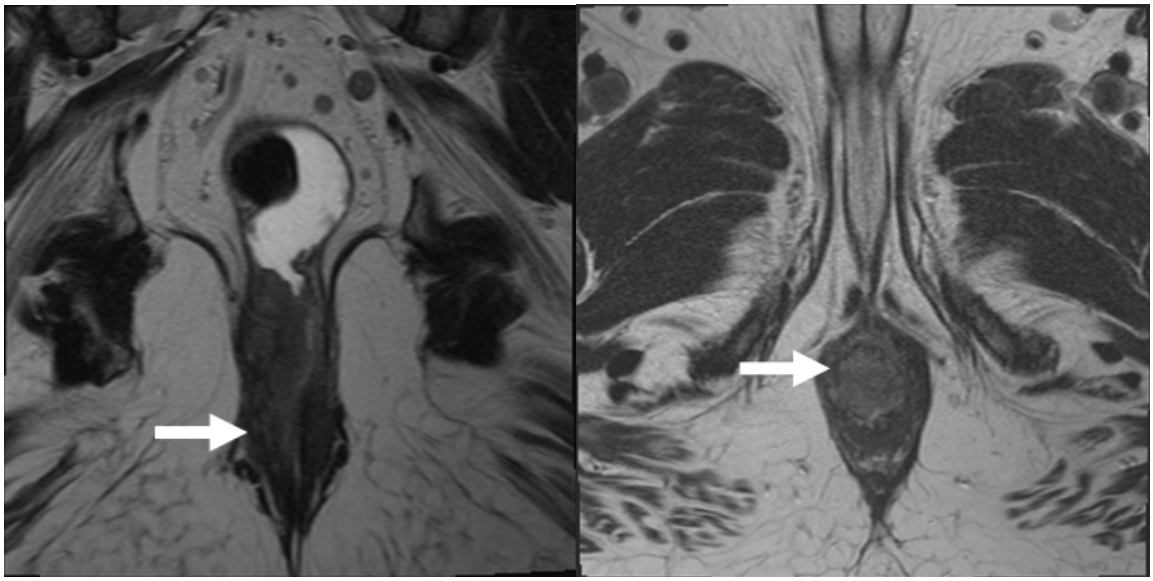
Low rectal tumor with involvement of the internal sphincter but intersphincteric plane is not involved. This would be amenable for intersphincteric dissection.

Figure 21A and 21B



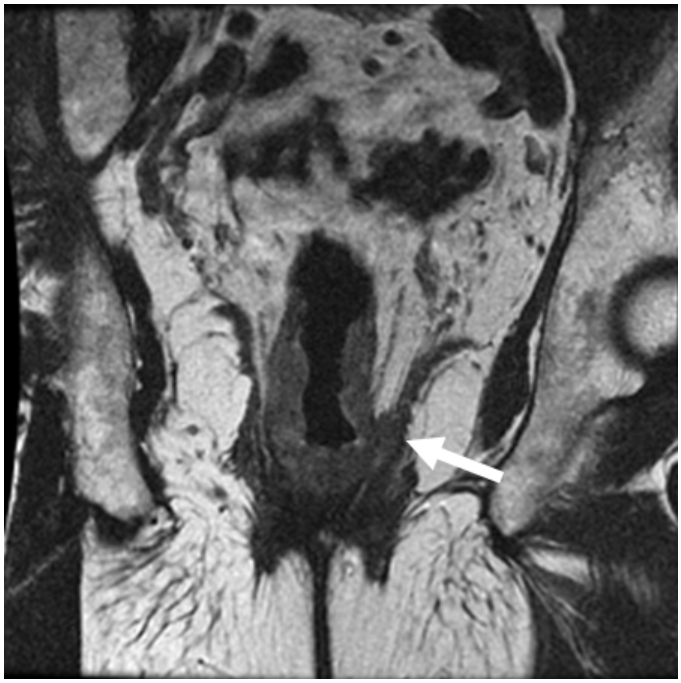
Low rectal tumor invading the internal sphincter, intersphincteric plane and extending to external sphincter. This tumor is not amenable for sphincter sparing surgery.

Figure 22A and 22B



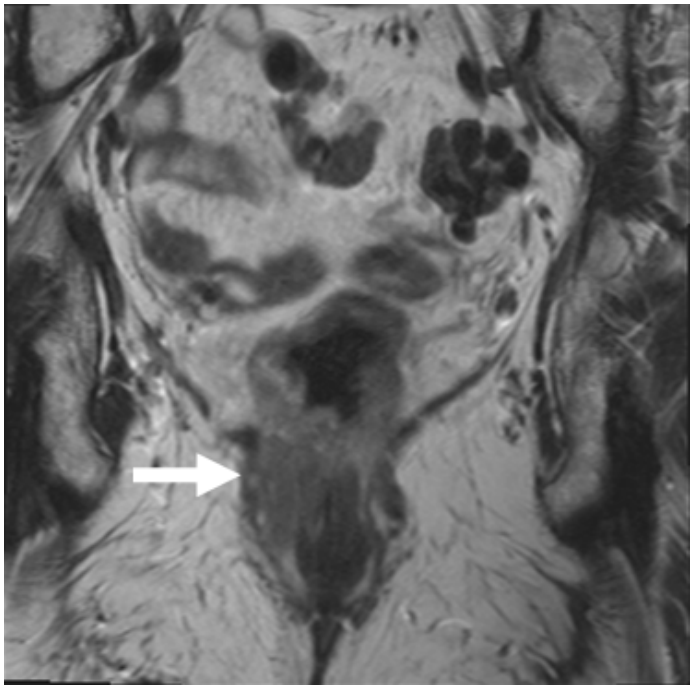
Coronal and axial high resolution T2 weighted images in another patient show low rectal tumor invading the external anal sphincter

Figure 23



Low rectal tumor extending beyond the intersphincteric plane and invading levator ani in another patient. This would require extra levator abdominoperineal resection with colostomy.

Figure 24



Coronal T2 weighted images shows low rectal tumor invading the internal sphincter, intersphincteric plane and external anal sphincter.

(3) Extramural Venous Invasion

Extramural vascular invasion (EMVI) refers to the extension of rectal tumor beyond the muscularis propria into the adjacent vessels in mesorectum (11, 12), and may be seen in up to 1/3rd of the rectal tumors. Although this is primarily a pathological feature, MR has been shown to be reliable for identifying EMVI, with 88% specificity and 62% sensitivity (13).

Numerous studies have demonstrated that EMVI in rectal cancer is associated with poor prognosis, including higher risk of CRM involvement and local recurrence as well as higher incidence of nodal and distant metastatic spread (13-16). A recent meta-analysis confirmed that MRI-detected extramural vascular invasion in rectal cancer is an independent negative prognostic factor and may be associated with five-fold increased risk of synchronous metastases, and four-fold increased risk of developing metastases in follow-up after surgery (11).

On MR, EMVI may be identified as extension of low tumor signal intensity extending into the adjacent mesorectal vein. The recent MERCURY trial reported fair to moderate interobserver agreement ((k=0.41, 95% CI 0.31-0.49) among 18 radiologists for detecting EMVI on rectal MR scans (17).

An MRI based classification of EMVI proposed by Brown is illustrated below (13). This classification of EMVI Negative and EMVI Positive will be used for the synoptic MRI report. When EMVI is present, the distance and clock face position of the EMVI in relation to the MRF should be reported.

Figure 25 – EMVI Negative

- Pattern of tumor extension through muscularis propria is not nodular *or* no tumor extension in the vicinity of any vascular structure.
- If stranding is demonstrated near extramural vessels, these vessels are of normal caliber with no definite tumor signal within.

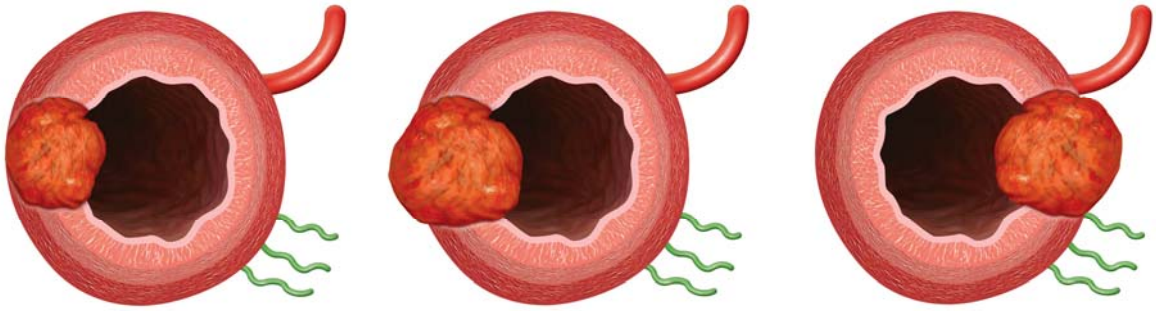


Figure 26 – EMVI Positive

- Intermediate signal intensity within vessels in the vicinity of the tumor *or* obvious irregular vessel contour.

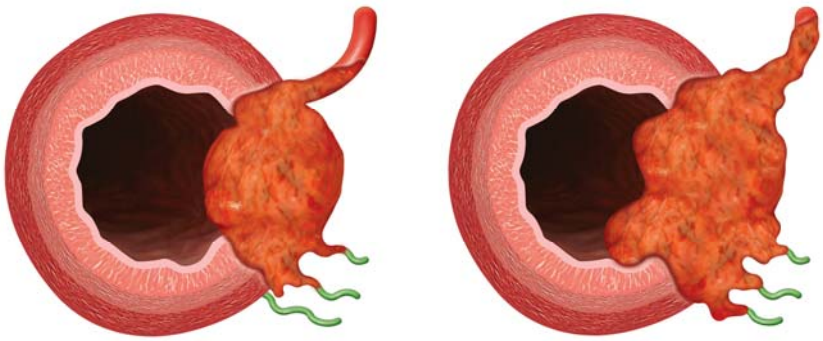
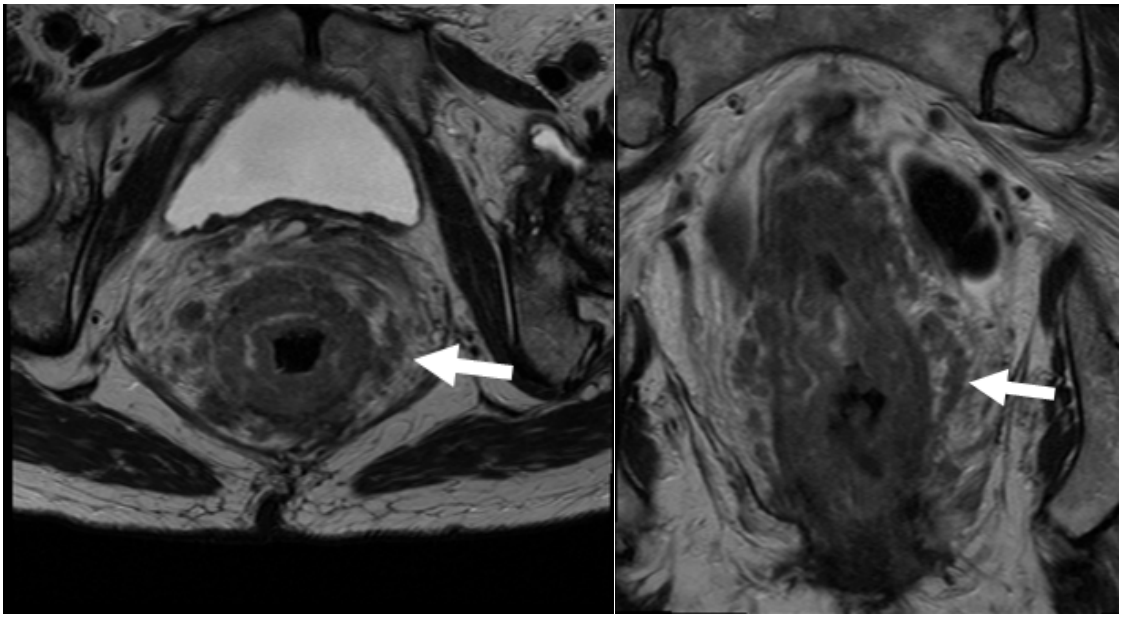


Figure 27



Axial and coronal T2 weighted images show locally advanced rectal cancer extending beyond muscularis propria and into the mesorectal vessel (white arrow). Note the tumor signal intensity replacing the normal flow void within the mesorectal vein.

(4) Circumferential Resection Margin

Background:

In order to accurately stage rectal cancer, the reader must have an understanding of the peritoneal and extraperitoneal planes. The rectum is partially covered anteriorly and posteriorly by a peritoneal lining. The transition points between peritonealized and non-peritonealized aspects of the rectum are called “peritoneal reflections”.

The locations of the peritoneal attachments/reflection are variable between genders and individual patients. Anteriorly, the peritoneal reflection is typically located deeper in the pelvis (caudal) than it is posteriorly. In women, the anterior peritoneal reflection is often found along the posterior aspect of the lower uterine segment. In men, it is typically found at the level of the prostate base/seminal vesicles (although these landmarks are variable between patients).

Posteriorly, the peritoneal reflection is located more superiorly than it is anteriorly. The peritoneum typically attaches along the posterior rectal wall in a V-shaped configuration (See Figure 3 below).

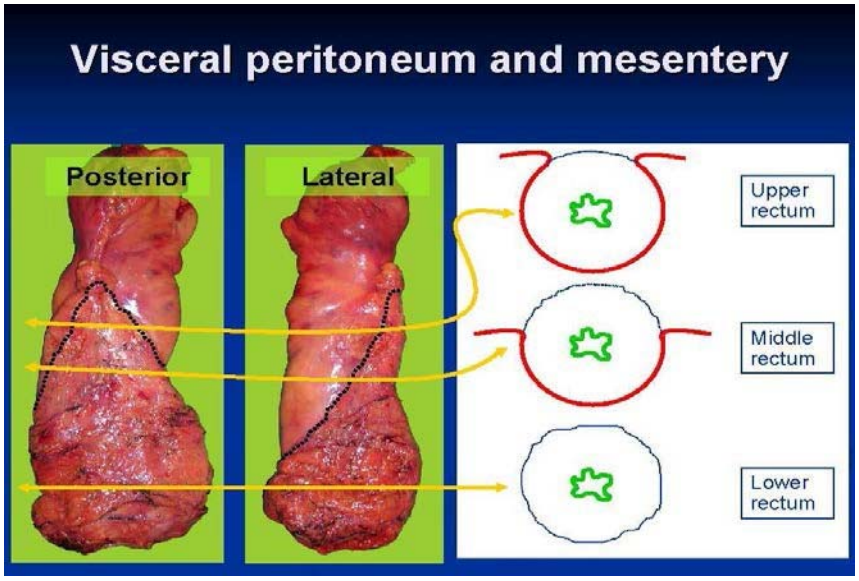


Figure 9: Location of peritoneal reflection – Varies based on the location of the tumor (upper/mid/lower rectum), and whether the lesion is anterior, posterior, or lateral in position.

With permission from Dr. Mahmoud Khalifa, Joint Chief, Anatomic Pathology, Sunnybrook Health Sciences Centre and University Health Network.

BLUE Line = CRM (non-peritonealized rectum)
RED Line = Peritonealized Rectum (not CRM)

Definitions:

(a) **Circumferential Radial Margin (CRM)**

a. The CRM is a pathologic term that is specific to the surgically dissected surface of the specimen. It does not refer to the imaging boundaries visible on MRI. The CRM is marginated by the anterior peritoneal reflection, and it refers specifically to the **non-peritonealized**, or caudal aspect of the rectum (Figure 9).

The configuration of the CRM depends on the location of the rectal tumor:

- Low rectal tumors have a circumferential CRM (completely caudal to peritoneal reflection)
- Mid rectal tumors have a CRM that is present posteriorly and laterally, but absent anteriorly (as the anterior surface is peritonealized).
- High rectal tumors have a small, focal CRM.

Based on the above, the CRM is not applicable to tumors located above the anterior peritoneal reflection, where the rectum is peritonealized.

(b) **Mesorectal fascia:** The CRM is determined pathologically by the extent of the surgical resection, and therefore cannot be predicted on MRI. The term "mesorectal fascia" (MRF) is considered the imaging equivalent of the CRM, and by convention, is used for MR based staging and synoptic reporting.

Similar to the pathological CRM, the MRF is only circumferential for rectal tumors **below** the anterior peritoneal reflection. *The term does not apply to upper, anterior, and anterolateral tumors above the peritoneal reflection where the rectum is peritonealized.*

- **The CRM is a pathologic term that refers to the surgically dissected surface of the specimen, and corresponds to the non-peritonealized aspect of the rectum. It is not applicable to MR images.**
- **The MRF is the imaging equivalent of the CRM.**
- **The MRF is only circumferential for rectal tumors below the anterior peritoneal reflection.**
- **The MRF does not apply to the anterior, peritonealized surface of the rectum above the anterior peritoneal reflection.**

While Beets-Tan has reported that a minimum distance of 5 mm to the MRF results in a 2 mm CRM, more recently Brown has prospectively demonstrated that a minimum CRM of 1 mm on MRI results in a negative CRM in patients who have had surgery alone or pre-op chemoradiation followed by surgery.[15,24,25]

This is clinically relevant since a negative CRM (defined as $\geq$ 1 mm) is associated with a significantly lower risk of local recurrence than a positive CRM (defined as < 1 mm).[26]

For the synoptic report, the minimum distance to the MRF refers to the shortest distance of the most penetrating margin of primary tumor to the MRF.

A positive CRM is defined as the nodular or pushing border of the tumor, within 1 mm of the MRF. (This does not include spiculations or haziness in the perirectal fat.)

Potentially suspicious lymph nodes, tumor deposits, and EMVI are not used as criteria for a positive CRM, but may be described for purposes of surgical planning.

The minimum distance to the MRF should be reported only for ≥T3 stage tumors, where the MRF can be adequately seen or reasonably estimated (i.e. at the level of the prostate and seminal vesicles).

In addition to the distance to the MRF, the *location, image and series number* of the penetrating component of disease should be reported. Location may be provided by laterality (left or right perirectal space), clockface convention, and location relative to the tumor (e.g. above/below primary lesion).

The distance to the MRF should be reported as “not applicable” for any tumor above the peritoneal reflection that involves the peritonealized portion of the rectum (i.e., upper, anterior and anterolateral tumors). This includes T4 tumors involving the peritonealized portion of the rectum (i.e., T4a tumors). For T4 tumor involving adjacent structures (i.e., T4b), the distance to the MRF should be reported as “0”.

- **The minimum distance to the MRF should be reported for all T3 or higher stage tumors where the MRF can be adequately seen or can be reasonably estimated.**

- **The minimum distance to the MRF refers to the shortest distance between the most penetrating components of the primary tumor to the MRF. The definitive tumor border is the nodular or pushing border of the tumor, and does not include spiculations or haziness of the perirectal fat.**

- **Potentially suspicious lymph nodes, tumor deposits, and EMVI are not used as criteria of a positive CRM, but may be described for purposes of surgical planning.**

- **If it is not possible to reasonably estimate the MRF, the minimum distance to the MRF should be reported as "unable to assess**".

- **The distance to the MRF should be reported as "not applicable" for tumors above the peritoneal reflection involving the peritonealized portion of the rectum (including T4a tumors).**

- **For T4 tumors invading adjacent structures, the distance to the MRF should be reported as "0".**

D. Lymph Nodes

(1) Mesorectal Lymph Nodes and Tumor Deposits

- **In the TNM system, disease involving only the regional lymph nodes, including the mesorectal and obturator/internal iliac lymph nodes, accounts for N stage; involvement of other nodes is regarded as metastatic disease (M1)[1].**

A Cancer Care Ontario literature review showed that MRI has relatively poor accuracy for assessing nodal status (sensitivity 77.0 [95% CI 59-81] and specificity 71 [95% CI 69-84]).

- **Any mesorectal lymph node or tumor deposit with an irregular border, mixed signal intensity and/or size ≥ 9 mm in the short axis should be reported as "suspicious".**

(a) Lymph Node Size

Metastatic LNs distribute across wide range of nodal sizes so small met LNs are under staged while large sized reactive LNs are over staged. Although a size cut-off of 5 mm has been used by clinicians to assess nodal status, there is no evidence in the literature to support this size cut-off. In fact, in one study, 15% of lymph nodes ≤ 5 mm were involved with metastatic disease,[2] suggesting that there is no size limit below which nodal metastasis can be ruled out. In this same study, using a 5 mm cut off gave a sensitivity and specificity of 81% and 68% for metastasis, respectively.[2] No matter what cut-off is used, the overall predictive value of lymph node size is poor due to the substantial overlap between benign and malignant lymph nodes.

Large lymph nodes, on the other hand, are highly specific for nodal metastasis.[2-5] Both Kim and Brown have reported a 100% specificity to detect lymph node metastasis using the following size criteria: 8 mm in the short axis and 1 cm "maximal" diameter, respectively, and more recently Ogawa has reported 96.4% sensitivity using 10 mm short axis (Table x). Given that lymph node staging may not be as strong a prognostic factor as during the preTME era and given the potential morbidity associated with radiation therapy, we believe it is better to be more specific than sensitive.

Therefore, for the purpose of the synoptic MRI report, a size criterion of equal to or greater than 9 mm in the short axis has been selected.

All of the mesorectal lymph nodes will be resected during a standard TME surgery. Diffusion weighted and post contrast imaging can be helpful in detecting lymph nodes but are not suitable for characterization.

Table 2

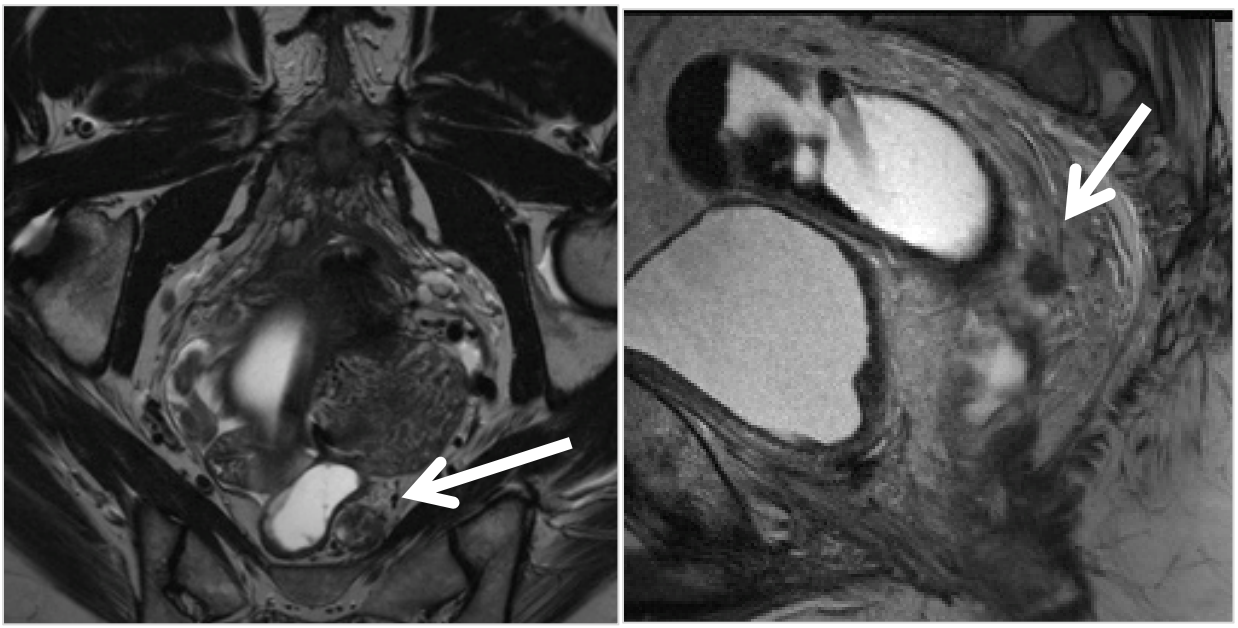
Author	N	Criteria	Sensitivity %	Specificity %
Ogawa, 2016	449 patients	10 mm short axis	19.5	96.4
Matsuoka, 2004	51 patients	6 mm long axis	77.8	78.3
Kim (Beets-Tan), 2004	75 patients	8 mm short axis	45.0	100.0
Brown, 2003	284 lymph nodes	1 cm “max diameter”	3	100.0

- **Irregular borders and mixed signal intensity or both are better predictors of lymph node metastasis than size.**
- **Metastatic lymph nodes from mucinous tumor may be high signal intensity, similar to the intensity of the primary tumor, and can be inconspicuous in the high signal intensity perirectal fat.**

(b) Lymph node border and signal characteristics

Lymph node border and signal properties appear to be more specific predictors of lymph node metastasis than size criteria. Notably, irregular borders and mixed signal intensity on T2-weighted imaging are individually highly specific and, in combination, are sensitive and specific to predict lymph node metastasis (sensitivity 85%, specificity 98%) (Figure 29).[2-4]

Figure 29. Heterogeneous and irregular perirectal lymph nodes, likely metastatic.



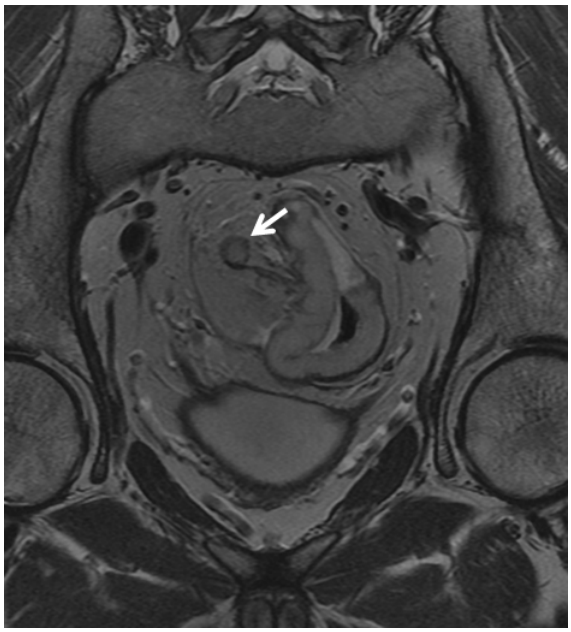


Figure 30: Oblique axial T2W image through a mucinous tumor demonstrates high signal intensity within a metastatic mesorectal lymph node (white arrow), similar in intensity to the primary tumor. Sometimes because of the relative isointensity with the mesorectal fat, these can be overlooked.

(c) Distribution

- **Most involved mesorectal lymph nodes are most often at the same level or proximal to the level of the tumor.**
- **Any lymph nodes closely approximating the mesorectal fascia (within 1 mm) should be described to alert the surgeon to its presence near the resection margin**

Most involved mesorectal lymph nodes are found at or proximal to the level of the tumor.[6,7] Although mesorectal lymph nodes below the level of the tumor are uncommon, they may affect the extent of both the radiation field and surgery. For this reason, the location of suspicious mesorectal lymph nodes below the level of the tumor may be described in free text.

The primary role of staging MRI is to differentiate between node negative (N0) and node positive (N+)

disease as patients with N+ disease will be selected for preoperative neoadjuvant treatment regardless of T-category. The number of involved lymph nodes (N1/N2) will typically be made at pathology, but the synoptic report provides an option of reporting the total number of lymph nodes and of suspicious lymph nodes.

The IMA nodes are important for treatment planning (especially in higher risk patients with positive mesorectal nodes or positive EMVI) and are inconsistently covered by the imaging field on rectal cancer staging MRI. If the IMA node station is included in the field of view, it should be assessed for suspicious nodes. If it is not included, that should be indicated and the superior most suspicious lymph node or deposit should be described. The regional lymph nodes along the IMA should also be assessed at CT staging.

(2) Extra-mesorectal lymph nodes

- **Non total mesorectal excision (TME) extra-mesorectal lymph nodes (including external and common iliac and inguinal lymph nodes) are considered metastatic (M1) disease.**
- **For locoregional extra-mesorectal non-TME lymph nodes (i.e., internal iliac or obturator) we recommend using the same criteria as for mesorectal lymph nodes**
- **For M1 lymph nodes, we recommend using a 1 cm short axis cut off (as commonly used in the rest of the body), or smaller if lymph nodes have obvious signal heterogeneity and/or irregular borders.**

Among published series where pelvic side wall dissection was studied, extramesorectal lymph node metastasis has been reported in up to 17% of patients and is most commonly found in association with locally advanced, low rectal cancers. There is no evidence that routine treatment of these nodes (with surgery and/or radiation) improves clinical outcomes.[8-10] Overall, the optimal imaging criteria for identifying extramesorectal lymph nodes have been less well studied than for mesorectal nodes (table 3).[5,11,12]

Table 3

Author	N	Criteria	Sens %	Spec %
Arii, 2006	53 patients	7 mm in diameter	56	97%
Matsuoka, 2007	51 patients	5 mm short axis	67	83%
Ogawa, 2016	268 patients	5 mm short axis 10 mm short axis	68.5 27.5	79.7 99.1

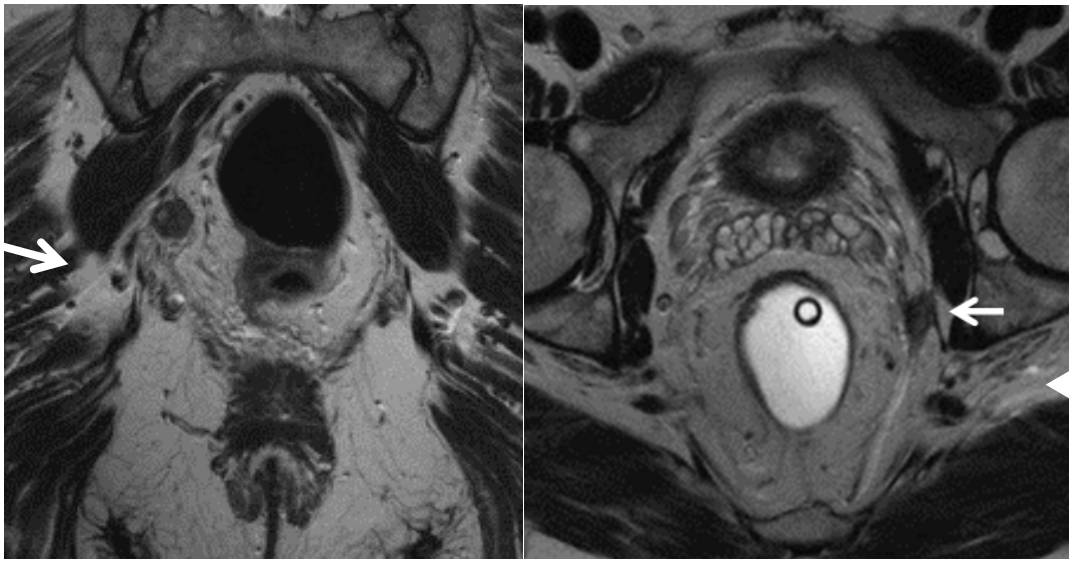


Figure 31: Locoregional extra-mesorectal lymph nodes

T2W coronal (left) and axial (right) images demonstrate metastatic internal iliac lymph nodes (white arrows). These should be documented in the synoptic report as their presence may alter the radiation field and/or surgical plan.

E. Other: This is an area to free-text any additional relevant findings, including bone metastases.

REFERENCES

1. NCCN guideline version 2 2016

2. Kapiteijn E, Marijnen CA, Nagtegaal ID, et al. Preoperative radiotherapy combined with total mesorectal excision for resectable rectal cancer. N Engl J Med. Aug 30 2001;345(9):638-646.

3. Sebag-Montefiore D, Stephens RJ, Steele R, et al. Preoperative radiotherapy versus selective postoperative chemoradiotherapy in patients with rectal cancer (MRC CR07 and NCIC-CTG C016): a multicentre, randomised trial. Lancet. Mar 7 2009;373(9666):811-820.

4. Sauer R, Becker H, Hohenberger W, et al. Preoperative versus postoperative chemoradiotherapy for rectal cancer. N Engl J Med. Oct 21 2004;351(17):1731-1740.

5. Bujko K, Nowacki MP, Nasierowska-Guttmejer A, Michalski W, Bebenek M, Kryj M. Long-term results of a randomized trial comparing preoperative short-course radiotherapy with preoperative conventionally fractionated chemoradiation for rectal cancer. Br J Surg. Oct 2006;93(10):1215-1223.

6. Improved survival with preoperative radiotherapy in resectable rectal cancer. Swedish Rectal Cancer Trial. N Engl J Med. Apr 3 1997;336(14):980-987.

7. Ngan SY, Burmeister B, Fisher RJ et al. Randomized trial of short course radiotherapy versus long couse chemoraditation comparing rates of local reccurence in patients with T3 rectal cancer: Trans Tasman Radiation Oncology Group Trial 01.04 J Clin Oncol 2012;31:3827-383

8. Fernandez-Martos C, Pericay C, Aparicio J, et al. Phase II, randomized study of concomitant chemoradiotherapy followed by surgery and adjuvant capecitabine plus oxaliplatin (CAPOX) compared with induction CAPOX followed by concomitant chemoradiotherapy and surgery in magnetic resonance imaging-defined, locally advanced rectal cancer: Grupo cancer de recto 3 study. J Clin Oncol 2010;28:859–865.

9. Cercek A, Goodman KA, Hajj C, et al. Neoadjuvant chemotherapy first, followed by chemoradiation and then surgery, in the management of locally advanced rectal cancer. J Natl Compr Canc Netw 2014;12:513–519.

10. Perez K, Safran H, Sikov W, et al.Complete neoadjuvant treatment for rectal cancer: the Brown University Oncology Group CONTRE study. Am J Clin Oncol,2014.

11. Habr-Gama A, Perez RO, Nadalin W, et alOperative versus nonoperative treatment for stage 0 distal rectal cancer following chemoradiation therapy: long-term results. Ann Surg 2004;240:711–717; discussion 717–718.

12. Maas M, Beets-Tan RG, Lambregts DM, et al. Wait-and-see policy for clinical complete responders after chemoradiation for rectal cancer. J Clin Oncol 2011;29:4633–4640.

13. Bipat S, Glas AS, Slors FJ, Zwinderman AH, Bossuyt PM, Stoker J. Rectal cancer: local staging and assessment of lymph node involvement with endoluminal US, CT, and MR imaging--a meta-analysis. Radiology. 2004;232(3):773-83.

14. Beets-Tan RG, Lambregts DM, Maas M, Bipat S, Barbaro B, Caseiro-Alves F, et al. Magnetic resonance imaging for the clinical management of rectal cancer patients: recommendations from the 2012 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. Eur Radiol. 2013;23(9):2522-31.

15. Gollub MJ, Lakhman Y, McGinty K, Weiser MR, Sohn M, Zheng J, et al. Does gadolinium-based contrast material improve diagnostic accuracy of local invasion in rectal cancer MRI? A multireader study. AJR Am J Roentgenol. 2015;204(2):W160-7.

16. Vliegen RF, Beets GL, von Meyenfeldt MF, Kessels AG, Lemaire EE, van Engelshoven JM, et al. Rectal cancer: MR imaging in local staging--is gadolinium-based contrast material helpful? Radiology. 2005;234(1):179-88.

17. Taylor FG, Swift RI, Blomqvist L, Brown G. A systematic approach to the interpretation of preoperative staging MRI for rectal cancer. AJR Am J Roentgenol. 2008;191(6):1827-35.

18. Nagtegaal ID, van de Velde CJ, Marijnen CA, van Krieken JH, Quirke P, Dutch Colorectal Cancer G, et al. Low rectal cancer: a call for a change of approach in abdominoperineal resection. J Clin Oncol. 2005;23(36):9257-64.

19. 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(4):632-9.

20. Akagi Y, Kinugasa T, Shirouzu K. Intersphincteric resection for very low rectal cancer: a systematic review. Surg Today. 2013;43(8):838-47.

21. Martin ST, Heneghan HM, Winter DC. Systematic review of outcomes after intersphincteric resection for low rectal cancer. Br J Surg. 2012;99(5):603-12.

22. Battersby NJ, How P, Moran B, Stelzner S, West NP, Branagan G, et al. 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(4):751-60.

23. Siddiqui MRS, Simillis C, Hunter C, Chand M, Bhoday J, Garant A, 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):1513-9.

24. Gibson KM, Chan C, Chapuis PH, Dent OF, Bokey L. Mural and extramural venous invasion and prognosis in colorectal cancer. Dis Colon Rectum. 2014;57(8):916-26.

25. 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(2):229-36.

26. Kim YC, Kim JK, Kim MJ, Lee JH, Kim YB, Shin SJ. Feasibility of mesorectal vascular invasion in predicting early distant metastasis in patients with stage T3 rectal cancer based on rectal MRI. Eur Radiol. 2016;26(2):297-305.

27. Sohn B, Lim JS, Kim H, Myoung S, Choi J, Kim NK, et al. MRI-detected extramural vascular invasion is an independent prognostic factor for synchronous metastasis in patients with rectal cancer. Eur Radiol. 2015;25(5):1347-55.

28. Chand M, Evans J, Swift RI, Tekkis PP, West NP, Stamp G, et al. The prognostic significance of postchemoradiotherapy high-resolution MRI and histopathology detected extramural venous invasion in rectal cancer. Ann Surg. 2015;261(3):473-9.

29. Taylor FG, Quirke P, Heald RJ, Moran B, Blomqvist L, Swift I, et al. 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(4):711-9.

30. Wong RK, Berry S, Spithoff K, et al. Preoperative or postoperative therapy for stage II or III rectal cancer: an updated practice guideline. Clin Oncol (R Coll Radiol). May 2010;22(4):265-271.

31. Kapiteijn E, Marijnen CA, Nagtegaal ID, et al. Preoperative radiotherapy combined with total mesorectal excision for resectable rectal cancer. N Engl J Med. Aug 30 2001;345(9):638-646.

32. Sebag-Montefiore D, Stephens RJ, Steele R, et al. Preoperative radiotherapy versus selective postoperative chemoradiotherapy in patients with rectal cancer (MRC CR07 and NCIC-CTG C016): a multicentre, randomised trial. Lancet. Mar 7 2009;373(9666):811-820.

33. Sauer R, Becker H, Hohenberger W, et al. Preoperative versus postoperative chemoradiotherapy for rectal cancer. N Engl J Med. Oct 21 2004;351(17):1731-1740.

34. Bujko K, Nowacki MP, Nasierowska-Guttmejer A, Michalski W, Bebenek M, Kryj M. Long-term results of a randomized trial comparing preoperative short-course radiotherapy with preoperative conventionally fractionated chemoradiation for rectal cancer. Br J Surg. Oct 2006;93(10):1215-1223.

35. Improved survival with preoperative radiotherapy in resectable rectal cancer. Swedish Rectal Cancer Trial. N Engl J Med. Apr 3 1997;336(14):980-987.

36. Cancer Care Ontario (2012b). User's Guide for the Synoptic MRI Report for Rectal Cancer Retireved from https://www.cancercare.on.ca/common/pages/UserFile.aspx?fileId=133269

37. 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. Jan 20 2012.

38. Extramural depth of tumor invasion at thin-section MR in patients with rectal cancer: results of the MERCURY study. Radiology. Apr 2007;243(1):132-139.

39. Bipat S, Glas AS, Slors FJ, Zwinderman AH, Bossuyt PM, Stoker J. Rectal cancer: local staging and assessment of lymph node involvement with endoluminal US, CT, and MR imaging--a meta-analysis. Radiology. Sep 2004;232(3):773-783.

40. 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. Oct 2004;52(1):78-83.

41. Vliegen RF, Beets GL, von Meyenfeldt MF, et al. Rectal cancer: MR imaging in local staging--is gadolinium- based contrast material helpful? Radiology. Jan 2005;234(1):179-188.

42. Merkel S, Mansmann U, Siassi M, Papadopoulos T, Hohenberger W, Hermanek P. The prognostic inhomogeneity in pT3 rectal carcinomas. Int J Colorectal Dis. Sep 2001;16(5):298-304.

43. Willett CG, Badizadegan K, Ancukiewicz M, Shellito PC. Prognostic factors in stage T3N0 rectal cancer: do all patients require postoperative pelvic irradiation and chemotherapy? Dis Colon Rectum. Feb 1999;42(2):167-173.

44. 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. Feb 17 2001;357(9255):497-504.

45. Maier AG, Kersting-Sommerhoff B, Reeders JW, et al. Staging of rectal cancer by double-contrast MR imaging using the rectally administered superparamagnetic iron oxide contrast agent ferristene and IV gadodiamide injection: results of a multicenter phase II trial. J Magn Reson Imaging. Nov 2000;12(5):651-660.

46. Matsuoka H, Masaki T, Sugiyama M, et al. Gadolinium enhanced endorectal coil and air enema magnetic resonance imaging as a useful tool in the preoperative examination of patients with rectal carcinoma. Hepatogastroenterology. Jan-Feb 2004;51(55):131-135.

47. Videhult P, Smedh K, Lundin P, Kraaz W. Magnetic resonance imaging for preoperative staging of rectal cancer in clinical practice: high accuracy in predicting circumferential margin with clinical benefit. Colorectal Dis. Jun 2007;9(5):412-419.

48. Branagan G, Chave H, Fuller C, McGee S, Finnis D. Can magnetic resonance imaging predict circumferential margins and TNM stage in rectal cancer? Dis Colon Rectum. Aug 2004;47(8):1317-1322.

49. Arii K, Takifuji K, Yokoyama S, et al. Preoperative evaluation of pelvic lateral lymph node of patients with lower rectal cancer: comparison study of MR imaging and CT in 53 patients. Langenbecks Arch Surg. Sep 2006;391(5):449-454.

50. Poon FW, McDonald A, Anderson JH, et al. Accuracy of thin section magnetic resonance using phased-array pelvic coil in predicting the T-staging of rectal cancer. Eur J Radiol. Feb 2005;53(2):256-262.

51. Brown G, Richards CJ, Newcombe RG, et al. Rectal carcinoma: thin-section MR imaging for staging in 28 patients. Radiology. Apr 1999;211(1):215-222.

52. Battersby NJ, How P, Moran B, et al. 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. Annals of Surgery.Mar 2015;0(0): 1-10.

53. Taylor FG, Quirke P, Heald RJ, et al. 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. Apr 2011;253(4):711-719.

54. 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. Oct 1 2011;29(28):3753- 3760.

55. Quirke P, Durdey 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. Nov 1 1986;2(8514):996-999.

56. Salerno G, Daniels IR, Moran BJ, Wotherspoon A, Brown G. Clarifying margins in the multidisciplinary management of rectal cancer: the MERCURY experience. Clin Radiol. Nov 2006;61(11):916-923.

57. 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. Feb 2008;95(2):229-236.

58. Brown G, Richards CJ, Bourne MW, et al. Morphologic predictors of lymph node status in rectal cancer with use of high-spatial-resolution MR imaging with histopathologic comparison. Radiology. May 2003;227(2):371-377.

59. Matsuoka H, Nakamura A, Sugiyama M, Hachiya J, Atomi Y, Masaki T. MRI diagnosis of mesorectal lymph node metastasis in patients with rectal carcinoma. what is the optimal criterion? Anticancer Res. Nov-Dec 2004;24(6):4097-4101.

60. Engelen SM, Beets-Tan RG, Lahaye MJ, Kessels AG, Beets GL. Location of involved mesorectal and extramesorectal lymph nodes in patients with primary rectal cancer: preoperative assessment with MR imaging. Eur J Surg Oncol. Jul 2008;34(7):776-781.

61. Koh DM, Chau I, Tait D, Wotherspoon A, Cunningham D, Brown G. Evaluating mesorectal lymph nodes in rectal cancer before and after neoadjuvant chemoradiation using thin-section T2-weighted

62. Steup WH, Moriya Y, van de Velde CJ. Patterns of lymphatic spread in rectal cancer. A topographical analysis on lymph node metastases. Eur J Cancer. May 2002;38(7):911-918.

63. Sugihara K, Kobayashi H, Kato T, et al. Indication and benefit of pelvic sidewall dissection for rectal cancer. Dis Colon Rectum. Nov 2006;49(11):1663-1672.

64. Tan KY, Yamamoto S, Fujita S, Akasu T, Moriya Y. Improving prediction of lateral node spread in low rectal cancers--multivariate analysis of clinicopathological factors in 1,046 cases. Langenbecks Arch Surg. Jun 2010;395(5):545-549.

65. Matsuoka H, Nakamura A, Masaki T, et al. Optimal diagnostic criteria for lateral pelvic lymph node metastasis in rectal carcinoma. Anticancer Res. Sep-Oct 2007;27(5B):3529-3533.

66. Kennedy E, Vella E, MacDonald DB, Wong S, McLeod R, et al. Optimization of preoperative assessment in patients diagnosed with rectal cancer. Toronto (ON): Cancer Care Ontario; 2014 January

67. Taylor FG, Swift RI, Blomqvist L, Brown G. A systematic approach to the interpretation of preoperative staging MRI for rectal cancer. AJR Am J Roentgenol. 2008;191(6):1827-1835.

68. Edge SB BD, Compton CC, Fritz AG, Green GL, Trotti A, (editors). AJCC cancer staing manual, 7th edition. France: Springer; 2010.

69. Bipat S, Glas AS, Slors FJM, Zwinderman AH, Bossuyt PMM, Stoker J. Rectal cancer: Local staging and assessment of lymph node involvement with endoluminal US, CT, and MR imaging - A meta-analysis. Radiology. 2004;232(3):773-783.

70. Beets-Tan RGH, Beets GL, Vliegen RFA, et al. Accuracy of magnetic resonance imaging in prediction of tumour-free resection margin in rectal cancer surgery. Lancet. 2001;357(9255):497-504.

71. Maier AG, Kersting-Sommerhoff B, Reeders JWAJ, et al. Staging of rectal cancer by double-contrast MR imaging using the rectally administered superparamagnetic iron oxide contrast agent ferristene and IV gadodiamide injection: Results of a multicenter phase II trial. J Magn Reson Imaging. 2000;12(5):651-660.

72. Matsuoka H, Masaki T, Sugiyama M, et al. Gadolinium enhanced endorectal coil and air enema magnetic resonance imaging as a useful tool in the preoperative examination of patients with rectal carcinoma. Hepato-Gastroenterol. 2004;51(55):131-135.

73. Videhult P, Smedh K, Lundin P, Kraaz W. Magnetic resonance imaging for preoperative staging of rectal cancer in clinical practice: high accuracy in predicting circumferential margin with clinical benefit. Colorectal Dis. 2007;9(5):412-419.

74. Branagan G, Chave H, Fuller C, McGee S, Finnis D. Can magnetic resonance imaging predict circumferential margins and TNM stage in rectal cancer? Dis Colon Rectum. 2004;47(8):1317-1322.

75. Arii K, Takifuji K, Yokoyama S, et al. Preoperative evaluation of pelvic lateral lymph node of patients with lower rectal cancer: comparison study of MR imaging and CT in 53 patients. Langenbeck Arch Surg. 2006;391(5):449-454.

76. Poon FW, McDonald A, Anderson JH, et al. Accuracy of thin section magnetic resonance using phased-array pelvic coil in predicting the T-staging of rectal cancer. Eur J Radiol. 2005;53(2):256-262.

77. Brown G, Richards CJ, Newcombe RG, et al. Rectal carcinoma: Thin-section MR imaging for staging in 28 patients. Radiology. 1999;211(1):215-222.

78. Network. NCC. NCCN clinical practice guidelines in oncology: Rectal Cancer, Version 3.2017. [Internet] [cited June 21, 2017]. Podcast. Available from: https://www.nccn.org/professionals/physician_gls/PDF/rectal.pdf.

79. Taylor FG, Quirke P, Heald RJ, et al. 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(4):711-719.

80. 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(5):298-304.

81. Willett CG, Badizadegan K, Ancukiewicz M, Shellito PC. Prognostic factors in stage T3N0 rectal cancer: do all patients require postoperative pelvic irradiation and chemotherapy? Dis Colon Rectum. 1999;42(2):167-173.

82. Harewood GC, Kumar KS, Clain JE, Levy MJ, Nelson H. Clinical implications of quantification of mesorectal tumor invasion by endoscopic ultrasound: All T3 rectal cancers are not equal. J Gastroenterol Hepatol. 2004;19(7):750-755.

83. Akagi Y, Shirouzu K, Fujita S, et al. Predicting oncologic outcomes by stratifying mesorectal extension in patients with pT3 rectal cancer: a Japanese multi-institutional study. Int J Cancer. 2012;131(5):1220-1227.

84. 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.

85. Shirouzu K, Akagi Y, Fujita S, et al. Clinical significance of the mesorectal extension of rectal cancer: a Japanese multi-institutional study. Ann Surg. 2011;253(4):704-710.

86. Shin R, Jeong SY, Yoo HY, et al. Depth of mesorectal extension has prognostic significance in patients with T3 rectal cancer. Dis Colon Rectum. 2012;55(12):1220-1228.

87. Fowler JM, Beagley CE, Blomqvist L, et al. Extramural depth of tumor invasion at thin-section MR in patients with rectal cancer: Results of the MERCURY Study. Radiology. 2007;243(1):132-139.

88. Pedersen BG, Moran B, Brown G, Blomqvist L, Fenger-Gron M, Laurberg S. Reproducibility of Depth of Extramural Tumor Spread and Distance to Circumferential Resection Margin at Rectal MRI: Enhancement of Clinical Guidelines for Neoadjuvant Therapy. Am J Roentgenol. 2011;197(6):1360-1366.

89. Brown G, Richards CJ, Bourne MW, et al. Morphologic predictors of lymph node status in rectal cancer with use of high-spatial-resolution MR imaging with histopathologic comparison. Radiology. 2003;227(2):371-377.

90. Kim JH, Beets GL, Kim MJ, Kessels AGH, Beets-Tan RGH. High-resolution MR imaging for nodal staging in rectal cancer: are there any criteria in addition to the size? Eur J Radiol. 2004;52(1):78-83.

91. Matsuoka H, Nakamura A, Sugiyama M, Hachiya J, Atomi Y, Masaki T. MRI diagnosis of mesorectal lymph node metastasis in patients with rectal carcinoma. What is the optimal criterion? Anticancer Res. 2004;24(6):4097-4101.

92. Ogawa S, Hida J, Ike H, et al. Selection of Lymph Node-Positive Cases Based on Perirectal and Lateral Pelvic Lymph Nodes Using Magnetic Resonance Imaging: Study of the Japanese Society for Cancer of the Colon and Rectum. Ann Surg Oncol. 2016;23(4):1187-1194.

93. Engelen SME, Beets-Tan RGH, Lahaye MJ, Kessels AGH, Beets GL. Location of involved mesorectal and extramesorectal lymph nodes in patients with primary rectal cancer: Preoperative assessment with MR imaging. Ejso-Eur J Surg Onc. 2008;34(7):776-781.

94. Koh DM, Chau I, Tait D, Wotherspoon A, Cunningham D, Brown G. Evaluating mesorectal lymph nodes in rectal cancer before and after neoadjuvant chemoradiation using thin-section T2-weighted magnetic resonance imaging. Int J Radiat Oncol. 2008;71(2):456-461.

95. Steup WH, Moriya Y, van de Velde CJH. Patterns of lymphatic spread in rectal cancer. A topographical analysis on lymph node metastases. Eur J Cancer. 2002;38(7):911-918.

96. Sugihara K, Kobayashi H, Kato T, et al. Indication and benefit of pelvic sidewall dissection for rectal cancer. Diseases of the Colon & Rectum. 2006;49(11):1663-1672.

97. Tan KY, Yamamoto S, Fujita S, Akasu T, Moriya Y. Improving prediction of lateral node spread in low rectal cancers-multivariate analysis of clinicopathological factors in 1,046 cases. Langenbeck Arch Surg. 2010;395(5):545-549.

98. Arii K, Takifuji K, Yokoyama S, et al. Preoperative evaluation of pelvic lateral lymph node of patients with lower rectal cancer: comparison study of MR imaging and CT in 53 patients. Langenbeck Arch Surg. 2006;391(5):449-454.

99. Matsuoka H, Nakamura A, Masaki T, et al. Optimal diagnostic criteria for lateral pelvic lymph node metastasis in rectal carcinoma. Anticancer Res. 2007;27(5b):3529-3533.