MRI of rectal cancer—relevant anatomy and staging key points

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Abstract
Rectal cancer has the eighth highest cancer incidence worldwide, and it is increasing in young individuals. However, in countries with a high human development index, mortality is decreasing, which may reflect better patient management, imaging being key. We rely on imaging to establish the great majority of clinical tumour features for therapeutic decision-making, namely tumour location, depth of invasion, lymph node involvement, circumferential resection margin status and extramural venous invasion. Despite major improvements in technique resulting in better image quality, and notwithstanding the dissemination of guidelines and examples of standardised reports, rectal cancer staging is still challenging on the day-to-day practice, and we believe there are three reasons. First, the normal posterior pelvic compartment anatomy and variants are not common knowledge to radiologists; second, not all rectal cancers fit in review paper models, namely the very early, the very low and the mucinous; and third, the key clinical tumour features may be tricky to analyse. In this review, we discuss the normal anatomy of the rectum and posterior compartment of the pelvis, systematise all rectal cancer staging key points and elaborate on the particularities of early, low and mucinous tumours. We also include our suggested reporting templates and a discussion of its comparison to the reporting templates provided by ESGAR and SAR.

Keywords: Anatomy, Anatomic variants, Rectum, Rectal cancer, Staging, Magnetic resonance

Key points
- Imaging is the pillar upon which therapeutic decisions are made in rectal cancer patients.
- Knowledge of normal anatomy and variants of the posterior pelvic compartment is mandatory for rectal cancer staging.
- We provide a roadmap for rectal cancer staging which includes anatomy and anatomic variants of the posterior pelvis, all key staging features and the particularities of early, low and mucinous tumours.

Background
Rectal cancer is one of the best examples of success of clinical research in the past 40 years. Total mesorectal excision (TME) alone, as opposed to blunt “pelvic rape”, resulted in an increase in the 5-year cancer-specific survival rate from 38 to 68% [1]. The introduction of preoperative chemoradiation therapy in high-risk patients reduced local recurrence rates to 6% as opposed to 13% when given post-operatively [2]. We have slowly moved from specialty-centred decisions to generalised multidisciplinary patient management in which radiology became the pillar for risk stratification. In fact, with a differentiated multimodality treatment based on dedicated preoperative MR imaging, local recurrence has lost relevance compared to early diagnosis, treatment-related morbidity and metastatic disease prevention and control [3]. Despite major improvements in technique resulting in better image quality, and notwithstanding the dissemination of guidelines and examples of staging templates, rectal cancer staging is still challenging. It requires a
thorough convolution of radiologists with normal anatomy and technical pitfalls and a clear and systematised knowledge of the key imaging features of rectal cancer for decision-making. In this review, we have first focused on the normal anatomy of the posterior compartment of the pelvis, including the definitions of high/mid/low rectum, compartment boundaries, rectal blood supply and lymphatic drainage, and then systematised the staging key points, namely T staging and sub-staging, N staging and tumour deposits, M staging, circumferential margin of resection and extramural venous invasion. We have further included a discussion on the particularities of early, low and mucinous rectal cancers and provided our own staging templates. Even though no paper will ever replace validated experience and advice from senior experts, we aim to contribute to an easier and smoother training of interested radiologists.

Main Text

MR imaging of the normal rectum

From where up to where down

The rectum ends distally at the anorectal transition. The anorectal transition may be defined by 2 anatomic landmarks: the first is an abrupt increase in thickness of the inner muscular layer, corresponding to the upper limit of the internal sphincter of the anus (Fig. 1a) [4]. The other is the superior border of the puborectalis—thesling or U-shaped portion of the levator ani muscle complex (or “pelvic diaphragm”)—which is anchored anteriorly to the inferior pubic ramus on each side of the symphysis pubis and posteriorly to the anococcygeal raphe (Fig. 1b) [5, 6].

The definition of the upper limit of the rectum is an intraoperative definition, corresponding to the lower limit of the internal sphincter of the anus (Fig. 1a) [4]. The other is the superior border of the puborectalis—the sling or U-shaped portion of the levator ani muscle complex (or “pelvic diaphragm”)—which is anchored anteriorly to the inferior pubic ramus on each side of the symphysis pubis and posteriorly to the anococcygeal raphe (Fig. 1b) [5, 6].

The rectal wall

Although peristalsis, pulsation, breathing and susceptibility from bowel air may cause image artefacts, in optimal conditions, the layers of the rectal wall should be clearly defined. The mucosa is a thin, dark regular line on T2 (Fig. 3a). It is underlined by the T2-hyperintense fat-rich submucosa which is highly variable in thickness from patient to patient and also according to the degree of distension of the rectum (Fig. 3a). The muscularis propria is dark on T2 (similarly to skeletal muscle) and...
is composed of an inner circular layer and an outer longitudinal layer (Fig. 3a). Once again, its thickness varies according to the degree of distension of the rectum. The longitudinal layer of the muscularis propria is covered by the fat-rich mesorectum, which is highly variable in thickness according to body composition and unevenly distributed (Fig. 3a–d). Anteriorly, it may be very thin or even not visible, particularly in the 2 cm above the ano-rectal transition (Fig. 3c, d) [12].

Keep in mind A small enema before MR imaging may minimise susceptibility from bowel air [13]. Spasmolytic agents such as butylscopolamin or glucagon significantly reduce artefacts from peristalsis and may be administered to improve image quality in the absence of contraindications (Fig. 4) [13]. Our rectal cancer staging acquisition parameters at 1.5T are presented in Table 1.

The envelope
The rectum is out of the peritoneal cavity, and its serosa—the mesorectal fascia—is displaced radially to contain a large fatty cushion—the mesorectum. The mesorectal fascia is usually described as a pencil-drawn hypointense line on T2. However, it is a multi-layered envelope that presents with gaps, particularly at its lower antero-lateral aspect, which means that at some points it may not be visible and we must extrapolate its expected position (Fig. 5a) [14]. Also, it is juxtaposed to the parietal fascias, which contain the autonomic nerves [14]. As such, multiple pencil-drawn T2-hypointense lines may be apparent, in which case the innermost should be considered (Fig. 5b). The virtual space between the mesorectal fascia and the parietal fascias is the holy plane of rectal cancer surgery—the plane through which the surgeon must perform sharp dissection to obtain optimal oncologic results with minimal bleeding and autonomic nerve damage-related morbidity.

The parietal fascias have different names according to location. Anteriorly, in between the anterolateral neurovascular bundles and extending cranio-caudally from the pelvic floor to the peritoneal reflection is the trapezoidal-shaped Denonvillier fascia (Fig. 5c, d) [15]; posteriorly, covering the sacrum, is the presacral fascia (Fig. 5d); and extending between the mesorectal fascia and the presacral fascia at the level of S2/S4 is the Waldeyer’s/rectosacral fascia (Fig. 5e). It divides the retrorectal space into superior and inferior compartments [14, 16–18].

Caudally, the mesorectal fascia is in continuity with the intersphicteric plane (Fig. 5f) [18]. Cranially, it is in continuity with the peritoneal reflection, which is lower anteriorly, of intermediate height laterally and higher posteriorly. The most relevant reference while staging rectal cancer is the anterior peritoneal reflection, which we should look for in the plane immediately below any pelvic small bowel loops and the sigmoid take-off. Its appearance on (oblique) axial plane is that of a seagull or V-shaped T2-hypointense line infolding (Fig. 6a). On mid-sagittal plane, this T2-hypointense line extends roughly horizontally from the anterior rectal wall to the roof of the mesorectal fascia, most commonly at the level of the torus uterinus in women or superior bladder in men (Fig. 6b) [19, 20].
Fig. 3 The rectal wall. The mucosa is visible on T2-weighted imaging as a regular thin (≈ 1 mm) hypointense line delimiting the lumen (red arrow in a). The submucosa is hyperintense and of variable thickness (double-headed blue arrow in a). It may not be visible when the rectum is distended. The **muscularis propria** is composed of an inner circular layer (green arrow in a) and an outer longitudinal layer (purple arrow in a) which may be separated by a thin layer of fat, as in the example shown. Lying externally to it is a cushion of mesorectal fat (delimited in red in a) that tapers inferiorly (delimited in red in c) and anteriorly, where it can be thin (between arrows in c) or even invisible (between arrows in d), in which case the mid/low rectum appears juxtaposed to the Dennonvillier fascia.

Fig. 4 Sagittal T2-weighted images before (a) and 5 min after (b) IV administration of a spasmolytic agent (butylscopolamine 20 mg). Notice how the walls of the rectum and small bowel are much better defined due to limited peristalsis.
reflection is located most commonly 1 to 4 cm below S1–S2 and corresponds to the upper limit of the rectum [21, 22]. It is not easily identified.

Keep in mind The anterior peritoneal reflection can easily be identified whenever there is a small amount of free peritoneal fluid because in the supine position it will accumulate at the deepest point of the rectovesical or rectouterine pouch, exactly where the peritoneum “reflects” (Fig. 6c). The height of the anterior peritoneal reflection is variable, and it may not be visible in > 10–25% of cases [19, 20].

The blood supply Arterial blood arrives at the rectum through 4 routes. The main route is the superior rectal artery, which is the continuation of the inferior mesenteric artery when it crosses the left common/internal iliac artery (Fig. 7a) [22]. The middle rectal arteries are inconsistent (present in 36–57% of cases) and highly variable. They may be unilateral, double or treble and may arise from the internal iliac or one of its branches [22–24]. They usually reach the mesorectum through either its antero-lateral or postero-lateral aspect, roughly 6 cm above the pelvic floor (Fig. 7b) [22]. The inferior rectal arteries originate from the internal pudendal arteries below the levator ani muscle, cross the ischioanal fossa anteromedially and irrigate the distal rectum, anal canal and internal and external anal sphincters (Fig. 7c) [24]. The middle sacral artery courses inferiorly along the surface of the lumbo-sacral vertebrae, within the presacral space and usually contributes with small vessels to the posterior surface of the rectum (Fig. 7d) [24]. The 4 rectal arterial routes communicate extensively through intramural anastomosis. However, in the posterior and inferior portion of the low rectum, there is a relatively vessel-deficient area which may explain why most anastomotic leaks after low anterior resections (LAR) occur in this location (Fig. 8) [22].

The venous drainage takes place through both an outer muscularis plexus that extends longitudinally from the anterior peritoneal reflexion down to the levator ani, and an inner submucosal plexus which runs through the whole extension of the rectum and continues down to the anus [22]. Both plexus anastomose superiorly give rise to the superior rectal vein, draining the roughly upper 2/3 of the rectum into the portal circulation through the inferior mesenteric vein [22]. Inferiorly, the inner plexus becomes the inferior rectal vein. A middle rectal vein may be found in about 32.6%, usually unilaterally and rarely accompanied by a middle rectal artery. Inferior and middle rectal veins drain roughly the distal 1/3 of the rectum into the systemic circulation through the internal iliac vein [22, 25].

Keep in mind Surgeons may find information on the presence of middle rectal artery(ies) and vein(s), their route and calibre useful to prevent unexpected bleeding, and as such, we should provide that information on staging reports. The fact that the lower 1/3 of the rectum drains into the systemic circulation rather than the portal circulation may at least partially justify the higher rate of lung metastasis in patients with low rectal cancer [26].

The lymphatic drainage The intramural lymphatic network drains to extramural lymphatics that in general follow the course of blood vessels [24]. Along the course of lymphatics within the mesorectum, we find a variable number of lymph nodes (mean 6.8 to 73.7 in surgical TME specimens with varied disease processes, surgical technique and pathology processing) [27–30]. Their size ranges between 2 and 10 mm in normal subjects, and they are more numerous
and larger in the upper and posterior mesorectum (Fig. 9) [27–30]. Normal/reactive lymph nodes on T2-WI MR imaging appear homogeneous in 48 to 88% and with smooth, sharply demarcated borders in 80 to 94% of cases [31, 32].

In approximately 70% of cases, they will show a smooth and regular, uninterrupted chemical shift effect on T2-WI in the phase encoding direction, likely the result from the sharp interface between the water-rich subcapsular sinus

**Fig. 5** The mesorectal fascia may present with gaps, particularly anterolaterally (arrows in a). It is a multilayered envelope and as such multiple hypointense lines may be apparent (arrows in b). Anteriorly, in between the neurovascular bundles, extending from the peritoneal reflection down to the pelvic floor, the mesorectal fascia is juxtaposed to the Denonvillier fascia (between red arrows in c and d). Posteriorly, it is juxtaposed to the presacral fascia (blue arrows in d). Sometimes, the presacral compartment is divided by the Waldeyers fascia (arrow in e) into superior and inferior compartments. Inferiorly, the mesorectal fascia tappers and is “lost” within the intersphincteric plane (arrows in f).
Fig. 6 The peritoneal reflection, when visible, may present with a seagull or V-shaped appearance on the (oblique) axial plane (arrow in a). The sagittal plane is depicted as a hypointense line extending from the rectal wall to the roof of the mesorectal fascia (arrow in b). It is more easily identified whenever there is a small amount of peritoneal effusion, which will accumulate immediately above it (arrow in c).

Fig. 7 The rectum’s arterial supply has 3 to 4 routes. The main route is the superior rectal artery (arrow in a). The middle rectal arteries are inconsistent but may be present in up to 57% of cases. In b, a large calibre right middle rectal artery (arrow) arising from the internal iliac artery pierces the mesorectal fascia at its anterolateral aspect. The inferior rectal arteries originate from the internal pudendal arteries, are usually small in caliber and cross the ischioanal fossae towards the anal canal (arrows in c). The middle sacral artery courses down along the lumbosacral vertebrae, within the presacral space (arrow in d).
and the mesorectal fat (Fig. 10) [32]. Lymph nodes located within the mesorectum, along the inferior and superior rectal vessels, along the inferior mesenteric vessels and along the internal iliac vessels and their branches are considered regional.

Keep in mind Although considered regional by the AJCC, internal iliac lymph nodes, commonly referred to as “lateral pelvic lymph nodes”, are outside of the “circumferential margin of resection” in rectal cancer surgery and as such pose different management challenges (see below).

Staging rectal cancer

The primary—T stage

We find reading the endoscopy report carefully to aid in the interpretation of the images—we should check whether the gastroenterologist found a suspicious focus in a benign polyp or a clearly malignant infiltration of the rectal wall and pay special attention to the lesions’ shape description, estimated location, size and circumference of involvement. Also, we believe DWI may help locate small primary tumours, given on high b value images they will present most commonly with high signal intensity, but high-resolution T2-weighted imaging (T2-WI) perpendicular to the long axis of the tumour is the pillar of T staging given it provides the highest rectal wall layer detail. The maximum depth of tumour invasion will determine the MR imaging T stage (mrT) (Figs. 11 and 12).

Although NCCN guidelines consider any tumour ≥ mrT3 eligible for neoadjuvant therapy, in many European countries, mrT3 sub-classification according to the depth of invasion beyond muscularis propria is incorporated in the decision-making framework (Fig. 11) [33, 34]. Neoadjuvant therapy is, according to European (ESMO) guidelines, reserved for tumours > mrT3b which pose a higher risk of local recurrence (23.6% vs 10.4%) [34]. Reported MR imaging accuracy for the assessment of T stage is variable, ranging from 66 to 94% using pathology as a reference standard [35, 36]. The main difficulty is the differentiation between T2 and T3, and discriminating between the two is particularly relevant on low tumours given the much thinner cushion of mesorectal fat and consequent proximity to sphincter complex and middle pelvic compartment structures [35, 36]. T2 tumours may present with desmoplastic reaction leading to overstaging as T3. Desmoplasia tends to present as thin spiculae of T2-hypointensity surrounding invaded muscularis propria,
whereas T3 tumours usually present with a broad-based or nodular T2-intermediate-signal front at mesorectal fat [37].

Keep in mind The maximum depth of invasion tends to occur at the tumour’s centre, and in large tumours, orientation of the slices perpendicular to it may be the most useful. On the other hand, it is common for the tumour’s periphery to overhang the rectal wall into the lumen (Fig. 12c, d, f).

**The circumferential margin of resection**
The circumferential margin of resection (CRM) is the plane where surgeons must dissect in order to perform a standardised total mesorectal excision (TME). It corresponds to the full circumference of the mesorectal fascia and, in tumours extending down into the anal canal, to the intersphincteric plane, with which the mesorectal fascia is in continuity inferiorly. The minimum distance between the tumour and the circumferential margin of resection on high-resolution T2-WI acquired perpendicular to its long axis should be recorded, as well as its location and extent. CRM is considered involved if the tumour lies < 1 mm from it (Fig. 13a) [38]. Although MR imaging was considered very accurate and reliable at predicting a clear margin in 2 seminal studies by Brown et al. and Beets-Tan et al., in a large meta-analysis, the sensitivity and specificity for margin involvement using a 1-mm cutoff were of only 76% and 88% respectively [39–41]. Margin involvement at MR imaging is associated with higher local recurrence rates (20% vs 7.1%), worse overall survival (42.2% vs 62.2%) and disease-free survival (47.3% vs 67.2%) [39, 42]. It is considered an indication for neoadjuvant therapy by both NCCN and ESMO guidelines [33, 34].

**The extramural venous invasion**
Extramural venous invasion (EMVI) on the histopathology of rectal cancer surgery specimens is an independent predictor of local recurrence, distant recurrence and worse overall survival [43]. MR imaging may detect EMVI with low sensitivity (62%) but high specificity (88%), using pathology as the gold standard [43]. It is depicted as intermediate signal intensity within vessels, with or without associated expansion and contour irregularity. It is generally in continuity with the primary tumour, but discontinuous mrEMVI may also be observed. The likelihood of mrEMVI may be graded based on an ordinal scale by Smith et al., grades 3 and 4,
Fig. 12 Examples of differently T-staged tumours. a, b Arrows point to an early polypoid tumour occupying the full depth of the submucosa centrally and therefore staged clinically as mrT1sm3/early T2. Total mesorectal excision was performed, and at pathology, it corresponded to a T1sm3. c, d This ulcerated tumour extends in depth through the full thickness of the muscularis propria and was therefore staged as an MR advanced T2 (red arrows), which was confirmed at pathology. Notice how the periphery of the tumour overhangs the rectal wall both in the axial and coronal planes (blue arrows). e, f This mid-high, sub-circumferential rectal cancer extends 4 mm into the mesorectal fat at its most central area (red arrows) and was therefore staged as T3b. Notice the overhanging edges on the sagittal plane (blue arrows in f). g, h An anterior mid-high rectal cancer crosses the Denonvillier fascia and the peritoneal reflection to invade the seminal vesicles in this male patient, corresponding to an mrT4b. The patient underwent chemoradiation and is currently under palliative treatment due to distant metastatic disease.
characterised by the presence of intermediate signal intensity within vessels (Fig. 14), being associated with a lower relapse-free survival (35% vs 74%) [43, 44] and a higher risk of synchronous (OR 5.68; 95 CI 3.75–8.61) and metachronous (OR 3.91; 95 CI 2.61–5.86) metastasis [45]. Its presence is considered an indication for neoadjuvant therapy according to ESMO guidelines [34]. It is not part of the NCCN guidelines [33].

Lymph node involvement and tumour deposits
In rectal cancer patients, nearly 48% of positive lymph nodes are ≤5 mm. As such, size criteria to identify nodal involvement and tumour deposits have been developed. In the context of extramural venous invasion (mrEMVI), it is important to evaluate the circumferential margin of resection for involvement. The presence of mrEMVI is associated with a lower relapse-free survival and a higher risk of synchronous and metachronous metastasis. It is recommended to consider neoadjuvant therapy if mrEMVI is present, according to the ESMO guidelines. The NCCN guidelines do not include this recommendation.

**Fig. 13** Circumferential margin of resection involvement. **a** A T3d tumour invades the mesorectal fascia on the left side (arrow). **b** A 1–2 mm fat plane between this mrT3b low rectal cancer and the sphincter complex (arrow) is observed and as such the circumferential margin of resection may be considered free.

**Fig. 14** MR extramural venous invasion (mrEMVI) is characterised by the presence of intermediate signal intensity tumour signal within vessels, which may be expanded (arrows in **a** to **d**) with (arrow in **a**) or without contour irregularity.
involvement are not reliable [27–30, 46]. Although normal lymph nodes are more numerous and larger in the upper and posterior mesorectum (Fig. 9), the incidence of nodal metastases is the same in anterior, lateral and posterior locations [27–30]. Regional positive lymph nodes in a more cranial location are associated with a higher risk of distant metastases [46]. Advanced T stage is associated with a higher number of positive lymph nodes, particularly small in size [46]. Most involved lymph nodes occur within the 1 cm proximal and the 1 cm distal to the tumour [47], and further spread occurs cranially in more than 90% of cases [48–50]. In the case of rectal cancers at the level of or below the peritoneal reflection, particularly ≥ T3, further spread may also occur to the lateral pelvic compartments [30, 51]. In fact, the lower the tumour, the more likely lateral spread is, going from 11.4% between 4 and 6 cm from the anal verge to 33.3% below 4 cm (Fig. 15) [51].

For nodes in the lateral pelvis, mostly size criteria have been tested, with variable cutoffs and variable outcomes [52–56]. According to research by the Lateral Node Study Consortium, in the particular case of cT3/4 low tumours, lateral lymph nodes with a short axis of at least 7 mm on staging MR have a significantly higher risk of lateral recurrence and lateral lymph node dissection in such cases may reduce lateral recurrences significantly [57]. For nodes > 3 mm in the mesorectum, contour irregularity, signal heterogeneity and interruption or absence of chemical shift artefact on T2-WI are the most

Fig. 15  a This patient presents with a polypoid tumour (blue arrow in a) located 7 cm above the anal verge. Tumour is underlined by a clear, uninterrupted, hyperintense submucosal fat plane and may as such be staged as mrT1 sm1/2. The patient also presented with a hypointense round lymph node in the mesorectum (red arrow), at tumour plane, 10 o’clock, with a slightly irregular contour anterolaterally. A very bulky, irregularly contoured, heterogeneous lymphadenopathy was found in the obturator space of the right lateral pelvic sidewall. The patient was selected for chemoradiation therapy.

Fig. 16 This patient with a large T3 MRF+ rectal cancer (yellow arrow in a) presents with a hypointense, highly irregular, intermediate-to-low signal intensity nodule in the mesorectum (red arrows in a and b) that does not interrupt the course of a vein but is irregular enough for us to admit the possibility of an extranodal deposit (mrENTD). The patient also presented with a round, hypointense slightly heterogeneous and slightly irregularly contoured lesion which we believe to be a lymphadenopathy (blue arrow in b).
reliable criteria for tumour infiltration [31, 32, 39]. No reliable criteria exist for nodes smaller than that [31, 39]. N staging based on MR imaging may be reported symmetrically to the TNM staging system.

Tumour deposits are defined according to AJCC 2018 as discrete tumour nodules in the rectal cancer pathology specimen within the lymphatic drainage area of the primary tumour without identifiable lymphatic, vascular or neural tissue, irrespective of their morphology [58]. If a vessel wall/remnant is identified, the lesion should be classified as lymphovascular invasion, further subclassified as either lymphatic or venous. If neural structures are identified, the lesion should be classified as perineural invasion. Tumour deposits are found in 3.3% of rectal cancer specimens without lymph node involvement, in which case N1c should be recorded (TNM classification), but when lymph nodes are positive, tumour deposits are not to be added to the total positive lymph node count. Lord et al. are currently studying the differentiation of extranodal tumour deposits (mrENTDs) from involved lymph nodes on MR imaging—the subject of an ongoing clinical trial named COMET [59]. Their imaging definition is quite different from the pathologic definition described above [59]. mr-ENTDs are described as comet-shaped nodules of tumour which appear to directly interrupt the course of a vein (Fig. 16) [59].

Although T stage now prevails, lymph node positivity on MR imaging is still considered an indication for neoadjuvant therapy according to NCCN guidelines, whereas ESMO guidelines admit surgery upfront for N positive patients without involvement of the circumferential margin of resection or mrEMVI, preferably ≤ T3a-b [33, 34].

Keep in mind In the authors’ perspective, the differentiation between positive lymph nodes with extracapsular extension, ENTDs and discontinuous EMVI on MR imaging may be difficult. Evidence suggests all of these entities entail a worse outcome compared to confined lymph node involvement. As such, pointing extranodal...

Fig. 17. A patient with an mrT3d MRF+ high rectal cancer also presents with a very irregular hypointense lesion in the high mesorectum (red arrow in a) that appears to both interrupt the course of a vein suggesting mrENTD (blue arrow in a) and to grow within it suggesting discontinuous mrEMVI (blue arrow in b). It is also in continuity with a round, irregular and heterogeneous structure appearing to be a positive lymph node with extracapsular extension (yellow arrows in b and c). The patient presented with synchronous metastatic liver disease, visible on b900 DWI (green arrows in d).
tumour on staging reports may be more important than matching its exact pathologic diagnosis (Fig. 17) [60].

**The specific scenarios**

**The very early rectal cancers**

Very early rectal cancers, defined as low grade (G1/G2) cT1 cN0 cEMV1- tumours [33], can be subclassified based on the depth of invasion of the submucosa, tumours with < 1 mm of submucosal invasion having a practically null risk of lymph node metastasis [61]. This means transanal endoscopic microsurgery (TEM) can provide similar outcomes to TME in these patients, with much reduced morbidity and mortality [34]. The risk of lymph node metastases in cT1 tumours extending beyond 1 mm is relatively low (≈ 10%), particularly if G1/G2, V0, L0 [34, 62] and TEM may still be a reasonable upfront approach.

MR imaging may have a role in the selection of these patients: Balyasnikova et al. could differentiate patients with either no evidence of submucosal invasion or a visibly spared ≥ 1 mm submucosa (mrT1 sm1/2)—considered eligible for TEM, from patients with no visibly spared submucosa or partially preserved muscularis (mrT1 sm3/earlyT2), with an accuracy of 89% and a good interobserver agreement (k = 0.74) [62]. Results of a larger UK multi-institutional trial (SPECC) are now awaited. MR imaging may also help assess lymph node involvement upfront and monitor recurrence after TEM. Fig. 18 depicts examples of both mrT1sm1/2 and mrT1sm3/earlyT2.

**The low rectal cancers**

A tumour with its lower edge less than 6 cm above the anal verge is considered a low rectal cancer [63](Fig. 19). Its prognosis is worse, with higher rates of local recurrence and poorer survival [63]. These figures may result from the inferior mesorectal tapering and closer proximity of tumours to the pelvic floor and middle pelvic compartment structures, requiring more mutilating surgical procedures and being associated with higher rates of margin positivity [64]. A specific MR imaging staging system was developed by Shihab et al. to address the particularities of low rectal cancer and aid in surgery planning [63, 65, 66]. According to it, tumours confined to the bowel wall not extending through its full thickness are considered mrLR1, tumours replacing the muscle coat but not reaching the intersphincteric plane are considered mrLR2, tumours invading the intersphincteric plane or lying within 1 mm to the levator muscle are considered mrLR3 and tumours invading the external anal sphincter and being within 1 mm

**Fig. 18** Two different patients with two different early rectal cancers are depicted in a and b. In a, a thin submucosal fat plane is observed between the intermediate signal intensity tumour and the tented muscularis propria. Tumour may therefore be staged as mrT1sm1/2. Pathology of the total mesorectal excision specimen revealed a pT1sm1; in b, the tumour abuts the inner circular layer of the muscularis propria and may therefore be staged as mrT1sm3/earlyT2. Pathology of the total mesorectal excision specimen revealed a pT1sm3.

**Fig. 19** A low rectal cancer is depicted with its lower edge 48 mm above the anal verge. Measurement is made from the central axis of the anus to the central axis of the rectum at the plane of the lower edge of the tumour.
and beyond the levator muscle, with or without invading adjacent structures, are considered mrLR4 (Fig. 20) [66]. mrLR1 tumours confined to the low rectum may be approached by LAR, in which the mesorectum is removed en bloc down to the pelvic floor. mrLR1 tumours extending into the anal canal may be approached with a LAR + intersphincteric dissection [4]. Low colorectal anastomosis or coloanal anastomosis may be performed upon favourable sphincter competence in these procedures, to avoid a permanent stoma, but the rate of
anastomotic leak and pelvic sepsis is increased and may significantly reduce patient quality of life. MrLR2 may be approached with standard abdominoperineal excision (SAPE), also known as an intersphincteric APE, in which the distal colon, rectum and anal sphincter are removed en bloc [4, 67]. When surgical treatment is considered for MrLR3-4, an extralevator abdominoperineal excision (ELAPE) is oncologically safer (less chance of R1 resection), in which dissection along the mesorectal fascia ends caudally at the levator origin and is met by a perineal dissection along the outer surface of the levators [4, 68]. ELAPE is associated with lower perforation and margin involvement rates, and consequent lower local recurrence rates than SAPE, albeit at the cost of higher perineal

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**Fig. 21** In **a** to **c**, we observe a low/mid rectal cancer with a predominance of high signal intensity in accordance with a mucinous histologic subtype. It presents with bilateral (arrows in **a**) and anterior (arrow in **b**) transgression of the mesorectal fascia, extending into the pelvic sidewall and middle pelvic compartment, respectively. It may not be easy to define its exact boundaries due to the approximation of signal intensity to that of fat (arrow in **c**). **b0 DWI** images are fat-suppressed T2-WI and may aid in the distinction (arrow in **d**). **T1WI** may work even better, namely to define or exclude a fat plane between tumour and circumferential margin of resection. In **e**, a low mucinous rectal cancer appears to invade the levator muscle on T2-WI but in the corresponding **T1WI** (**f**), we see a thin fat plane between the two.
morbidity [68]. For tumours located both above and below the puborectalis sling or located anteriorly, at the level of the prostate, pelvic exenteration may be more appropriate [69]. In the particular case of very low rectal tumours (< 4 cm from the anal verge), mRT > 2 may by itself be an indication for neoadjuvant therapy according to European guidelines, whereas for higher locations, it may be reserved for mR > T3b if good quality TME can be assured [33]. Examples of mR1-4 are given in Fig. 20.

Keep in mind In low rectal tumours, additional oblique axial and coronal T2-WI planes perpendicular and parallel to the long axis of the anal canal, respectively, should be acquired when needed. The anal verge may be identified on sagittal T2-WI as the lower limit of the perianal hypointense skin change (Fig. 19).

**The mucinous rectal cancers**

Mucinous adenocarcinomas comprise 10–20% of all rectal cancers, tend to affect younger patients and are

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**Pelvic MRI for mid/high rectal cancer staging**

**Clinical information**

**Technique**

High resolution T2-WI in sagittal, oblique axial and oblique coronal planes, and oblique axial DWI were acquired after a small enema (...) and spasmytotopic agent administration (...).

**Results**

The tumour is infiltrative polyoid and not partially mucinous.

Its caudal edge is located ....mm above the anal verge and ....mm above the ano-rectal transition.

It is ....mm in length and its cranial edge is located at the level of the anterior peritoneal reflection. ....mm below is confined to the mucosa. invades part of the submucosa. invades the whole submucosa. invades part of the muscularis propria. invades the whole muscularis propria.

It extends from .... to .... o’clock and extends ....mm beyond the muscularis propria.

Its deepest edge is located at .... o’clock, reaching the CRM, extending beyond the CRM to invade a non-nodular pattern, without adjacent vessels. minimal signal intensity changes not adjacent vessels. signal intensity changes adjacent to normal-calibre vessel(s). intermediate signal within vessel(s) with slight expansion. vessel(s) with irregular contour and clear tumoural signal.

The peritumoral area shows minimal signal intensity changes adjacent to normal-calibre vessel(s). intermediate signal within vessel(s) with slight expansion. vessel(s) with irregular contour and clear tumoural signal.

There are .... suspicious mesorectal lymph nodes, none of which reaching the CRM, none of which invading the CRM at ...., none of which invading the CRM at ...., none of which invading the CRM at .... of which being superior hemorrhoidal/ mesenteric and none less than 5 cm below the tumour. .... less than 5 cm below the tumour.

In the pelvic sidewalls (PSW), we find no suspicious lymph nodes. .... suspicious lymph nodes at ....

There are no tumour deposits.

There is one tumour deposit at ....

There are no tumour deposits at ....

We find no relevant additional pelvic findings.

There are the following additional relevant pelvic findings: .... (to include anatomic variants such as middle rectal veins/arteries and their entrance in the mesorectum)

**Conclusion**

Tumour located ....mm above the ano-rectal transition, mRT .... mRMVI .... mRN .... (PSW ....) CRM .... (include relevant considerations such as tumour implants in addition to N+, discontinuous mRMVI outside the pelvis, high suspicious lymph nodes, metastases, etc)
defined histologically by the presence of extracellular mucin in more than 50% of the tumour stroma [69]. There is an association with a history of inflammatory bowel disease and pelvic radiotherapy [69]. This histologic subtype may be associated with a higher T stage upon diagnosis, a greater risk of metachronous metastases and a worse response to chemoradiation, but results regarding the impact on overall survival are conflicting [70, 71]. Although the definition is histologic, it may be that mucinous tumours are more efficiently detected on T2-WI MR imaging than on endoscopic biopsy, imaging definition being more than 50% high signal intensity areas within the tumour—areas with a signal intensity similar to or brighter than that of the mesorectal fat [69, 71]. MR imaging-detected mucinous tumours carry a similarly worse prognosis relative to histology, with
poorer responses to chemoradiation and worse disease-free survival [69] (Fig. 21).

Keep in mind Whenever in doubt, DWI b0 may be useful for the distinction between fat signal, which will be suppressed, and mucin, which will remain bright. Also, we find high-resolution T1-WI may help define the boundary between mucin and fat (Fig. 21).

Rectal cancer staging templates Figures 22 and 23 depict our suggested templates for the staging of mid/high and low rectal cancers respectively. In this section, we discuss the small deviations from SAR and ESGAR consensus guidelines and their reasoning.

Our patients routinely perform a small enema shortly before MR imaging to empty the rectum, which significantly reduces susceptibility artefacts due to air content, improvement being particularly relevant for DWI [72]. Intravenous butilscopolamine is also administered routinely at our centre in the absence of contraindications, between scout and (oblique axial) T2-WI acquisitions, to minimise artefacts due to peristalsis. Neither the use of small enema nor the use of spasmolytic agents has reached consensus by SAR or ESGAR expert panels and is therefore considered optional according to their respective guidelines [13, 73].

Our acquisition protocol is exhibited in Table 1. We routinely perform DWI in staging examinations to help locate small lesions and to serve as a baseline for response assessment. Although DWI is a recommended sequence according to SAR consensus guidelines, it is considered optional upon staging according to ESGAR consensus guidelines [73, 74]. We do not administer intravenous contrast for rectal cancer staging, which is optional according to both guidelines. The exception is a suspicion of pelvic sepsis or fistulization, in which case we find contrast very helpful to delineate abscesses and fistulous tracts respectively. We include an unenhanced T1 sequence, as recommended by SAR [13, 73], which provides an overview of the whole pelvis and may help characterize incidental bone or genito-urinary lesions. It may also help delimit mucinous tumours, as discussed in the “The mucinous rectal cancers” section.

With respect to staging key points, all of our patients are staged with MR imaging unless an absolute contraindication is known, even early tumours, and as such, we have decided to include early tumour sub-staging in our templates as by Balyasnikova et al. [62], which is not part of either SAR or ESGAR consensus guidelines [13, 73]. Also, we have kept the mrLR classification for low rectal tumours [66] given it is well known by our multidisciplinary team. Even though the specific mrLR term is not utilised in the templates by SAR or ESGAR, the depth of invasion subclass options for low tumours is presented similarly in both [13, 73]. We have used the 5-point scale by Smith et al. [43] for mrEMVI assessment since the very beginning of our practice, and we find it helpful for less experienced radiologists. As such, we kept it, whereas SAR and ESGAR have adopted a simpler 3-point and 2-point scale for that purpose, respectively [13, 73]. Finally, our templates leave node involvement interpretation open, whereas both SAR and ESGAR reporting templates adopt strict mixed size-morphology criteria [13, 73]. The reason for this deviation is our own node-by-node analysis experience based on such criteria, which we found suboptimal [74]. We rely on morphologic criteria irrespective of size, namely shape, contour, heterogeneity and chemical shift effect, as explained in the “Lymph node involvement and tumour deposits” section.

Conclusions Pelvic MR imaging is the pillar of clinical rectal cancer staging and the basis for optimal multidisciplinary patient management decision-making. A thorough and systematic knowledge of the relevant normal anatomy and variants, of the key staging imaging features and of the particularities of early, low and mucinous tumours is mandatory for rectal cancer staging MR image interpretation.

Abbreviations

AJCC: American Joint Committee on Cancer; CRM: Circumferential margin of resection; DWI: Diffusion-weighted imaging; EMVI: Extramural venous invasion; ENTD: Extranodal tumour deposit; ESMO: European Society of Medical Oncology; MR: Magnetic resonance; NCCN: National comprehensive cancer network; OR: Odds ratio; T2-WI: T2-weighted imaging; TEM: Transanal endoscopic microsurgery; TME: Total mesorectal excision; TNM: Tumour node metastases staging system

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