Optimal imaging staging of rectal cancer

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1. Clinical significance of imaging

A patient diagnosed with rectal cancer is managed by a multidisciplinary team in which the radiologist nowadays participates as a full sparring partner. His/her imaging findings can influence the treatment decision-making. The local staging work-up consists of endorectal ultrasound and/or magnetic resonance imaging (MRI). The distant staging work-up depends on the local policy but often consists of ultrasound or computed tomography (CT) of the liver and chest X-ray or chest CT. While previously all patients underwent a standardised resection, nowadays there is evidence that imaging can identify the high risk patients with locally advanced rectal cancer whose tumour is threatening or invading the mesorectal fascia and needs preoperative treatment. This article discusses the role of the different imaging modalities for local staging and restaging of rectal cancer and their accuracies for identifying the risk factors for local recurrence and for assessing response to preoperative chemoradiotherapy. The chapter ends with future perspectives in rectal cancer imaging.

2. Staging modalities

2.1. *Endorectal ultrasound (EUS)*

The main strength of endorectal (or endoluminal) ultrasound (EUS) is its excellent spatial resolution, particularly for tissues that are located near the ultrasound probe. For tissues that are at a greater distance from the probe, the performance of EUS is limited. As a result, EUS is accurate mainly for the assessment of tumour ingrowth in the bowel wall and hence for the discrimination between tumours that are limited to the submucosa (T1) versus tumours showing ingrowth in the muscularis externa (T2). For the evaluation of tumour penetration into the perirectal fat (i.e. T3 tumours), EUS reaches results similar to those of MRI and experiences the same interpretation difficulties; these are related to problems in distinguishing desmoplastic stranding in T2 tumours from tumour stranding in T3 tumours (see section on tumour staging). Because of its limited field of view, EUS is less suitable for the assessment of tumour infiltration into the mesorectal fascia (MRF), tumour extension to the high dorsal pelvic wall and evaluation of lymph nodes – in particular those in the high mesorectum along the superior rectal vessels. Furthermore, it is often difficult to position the ultrasound probe and visualise high and/or stenosing tumours, resulting in inconclusive results in >10% of patients [1]. Another drawback of EUS compared to cross-sectional imaging techniques is that it is highly operator-dependent and requires a learning curve before optimal diagnostic performance can be obtained [2]. A potential benefit of EUS compared to CT and MRI is that it allows for tissue biopsies within one single examination, so that histopathological confirmation can immediately be obtained.

2.2. *Computed tomography (CT)*

Multislice CT (MSCT) is often considered the modality of first choice for the distant staging of colorectal cancer (e.g. the detection of metastatic spread to the liver and/or lungs). Although it has been proposed by some authors that simultaneous staging of the rectal tumour using CT as a 'one-stop-shop' imaging tool may be beneficial, there are several drawbacks to the use of CT for assessing the local tumour status. First of all, the soft tissue contrast of CT is limited, making it more difficult to distinguish between tumours limited to the bowel wall and those which have penetrated the wall. For the assessment of an involved mesorectal fascia, MSCT is reported to have moderate to poor accuracy (54–66%). Interestingly, CT can reach fairly good diagnostic performance for assessing the MRF in tumours that are located in the mid–high rectum with reported positive predictive values (PPVs) and negative predictive values (NPVs) of 86% and 94%, respectively. It is particularly in low rectal tumours where the limited soft tissue contrast of CT hampers a reliable differentiation between the tumour and surrounding structures, resulting in a PPV and NPV of only 53% and 73% in assessing an involved MRF [3]. For the evaluation of lymph nodes, CT experiences the same difficulties as MRI and EUS, which are discussed in detail below.

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1359-6349/$ - see front matter
http://dx.doi.org/10.1016/j.ejcsup.2013.07.031

2.3. *Positron emission tomography (PET)*

PET allows for the detection of metabolically active tissues (e.g. malignant tumours) using tumour-tracing radiopharmaceuticals, of which in oncology the glucose analogue ^{18}F-fluorodeoxyglucose (^{18}F-FDG) is the most widely adopted. FDG-PET can be performed in combination with computed tomography (CT). This hybrid PET–CT allows for a simultaneous assessment of tumour morphology together with the functional information from PET. The role of PET(–CT) for the primary staging of colorectal cancer is limited. Because PET is known to miss small metastatic lesions in the liver – due to its limited spatial resolution – it is not recommended as the staging modality of first choice. However, in patients with known liver metastases scheduled for liver surgery, PET(–CT) is very accurate in excluding the presence of extrahepatic lesions such as lymph-node and bone metastases. In this context, the use of PET can significantly decrease the number of futile laparotomies [4]. A second clinical application of PET(–CT) is the detection of recurrent tumours in patients with a suspected recurrence after primary surgical treatment for colorectal cancer. In this setting PET has advantages over CT, MRI and EUS in differentiating between recurrent tumour and postoperative scar tissue. Recently there is a growing interest in the use of PET(–CT) as a tool to predict treatment response in patients with locally advanced rectal cancer treated with chemoradiotherapy. Assessment of the decrease in the standardised uptake value (SUV) during chemoradiation has been reported by several authors to be a strong indicator for therapeutic efficacy [5]. Although at present these findings will not yet impact the treatment plan, in the future early response prediction using functional imaging methods such as PET may be of great clinical value as this may allow for early treatment adaptations to enhance the chance of a good therapeutic response.

2.4. *Magnetic resonance imaging (MRI)*

MRI using modern phased-array external coils offers the advantages of an excellent soft tissue contrast, high spatial resolution and a large field of view. This makes MRI an invaluable technique for detailed morphological information on both the tumour and its extension into the surrounding mesorectal compartment and neighbouring organs. MRI is the recommended imaging method for staging and restaging of rectal cancer in most European countries. The following sections will elaborate on aspects of MRI relevant for rectal cancer imaging, including the optimal MR protocol.

3. MRI protocol for the staging of rectal cancer

3.1. *Patient preparation*

MRI using phased array external coils has become the standard technique for state-of-the-art imaging of rectal cancer. MRI using an endorectal coil, although similar in performance to EUS for the assessment of superficial (T1 and T2) tumours, has not gained worldwide acceptance. First, endorectal MRI is more cumbersome in application and less patient-friendly than EUS and does not allow for simultaneous tumour biopsies, which is an added advantage of EUS. Furthermore, coil positioning for endorectal MRI can be very difficult, particularly in high and/or stenosing tumours. For phased array MRI routine use of spasmolytics or bowel preparation is not required. Nevertheless, occasional use of spasmolytics may be helpful when severe bowel movement artefacts are already visible on the (sagittal) planning scan, particularly in patients presenting with tumours situated high in the rectum and thus nearer to adjacent small bowel loops. Use of endorectal contrast or filling (for example using ultrasonography gel) is not recommended as part of standard clinical routine. The main argument for applying endorectal filling is to allow a more confident assessment of the exact tumour location within the lumen, particularly in smaller-sized tumours [6]. However, given the fact that information on the tumour location is given during endoscopy, the use of intraluminal filling does not outweigh its potential disadvantages. Apart from the patient burden, the introduction of endorectal contrast causes stretching of the rectal wall which in turn compresses the mesorectal compartment. Hence, rectal distension may hamper the assessment of lymph nodes in the mesorectal compartment and can also result in overestimation of tumour invasion of the mesorectal fascia [7], which are in fact two of the principal important factors that need to be evaluated with MRI (see also section below on assessing risk factors for local recurrence).

3.2. *Imaging sequences*

A standard rectal MR protocol should consists of multiplanar T2-weighted Fast Spin Echo (T2W FSE) sequences, since these offer an optimal soft tissue contrast between the tumour, the mesorectal fat and the mesorectal fascia surrounding the mesorectal compartment. The optimal slice thickness of the T2W sequences ranges between 1 and 3 mm and should not exceed 5 mm. A sagittal T2W sequence should be first obtained in order to localise the tumour and allow for proper angulation of the axial and coronal planes. It is of the utmost importance that the axial and coronal planes are angled exactly perpendicular and parallel to the longitudinal tumour axis (as identified on the sagittal scan) so that the relationship of the tumour with the surrounding organs and structures can reliably be assessed. In very low rectal tumours the coronal sequences should be angled parallel to the anal canal to establish the relation of the tumour to the pelvic floor and anal sphincter musculature. There is no solid evidence yet for the routine use of additional sequences other than T2W sequences in three planes. Fat-suppression sequences are not recommended since they do not allow a proper appreciation of the mesorectal fascia. A (non-enhanced) T1-weighted sequence may be useful for the evaluation of coincidental findings in other pelvic organs, but is not required for the staging of rectal cancer. There is no solid indication for the administration of intravenous contrast agents. Gadolinium contrast was shown not to be beneficial for T-stage and CRM evaluation [8]. Although experimental studies have investigated the use of dynamic contrast-enhanced MRI and lymph-node-specific contrasts, at the time of writing these techniques are not yet recommended for daily clinical

practice [9–11]. Similarly, diffusion weighted imaging (DWI) sequences have so far been obtained mainly in research protocol settings, although there is growing evidence that the addition of DWI may be valuable, especially in the restaging setting after chemoradiation to re-evaluate the primary tumour (see also section on diffusion-weighted MRI below).

4. Assessing the risk factors for local recurrence using MRI

There are four main risk factors for developing a local recurrence, which are used to determine treatment planning: (1) the tumour height (low, middle or upper third of the rectum), (2) the local extent of the tumour (T-stage), (3) involvement of the mesorectal fascia and (4) nodal involvement (N-stage).

4.1. *Tumour height*

Tumour height is an important parameter as low rectal tumours (e.g. within the first 5 cm above the anal verge) are known to have a worse prognosis than tumours situated higher in the rectum. As a result of the distal tapering of the mesorectum and consequent decrease of the thickness of the fat plane surrounding the rectum, low tumours have a relatively close relationship with the mesorectal fascia, the pelvic floor muscles and the anterior pelvic organs (prostate/seminal vesicles in men and vagina/uterus in women) and have a higher risk of invasion.

Although the tumour height can be accurately measured on MRI (often using the anorectal junction as a reference point) the surgeon is generally already aware of the tumour location from his endoscopic assessment, so often this is not one of the strong arguments to perform imaging. In the United States, the location of the tumour in relation to the peritoneal reflection is often used as an additional landmark to determine whether a patient requires neoadjuvant treatment (if the tumour is below the peritoneal reflection) or not (if the tumour is above the peritoneal reflection). The level of the tumour in relation to the peritoneal reflection can be accurately assessed using MRI [12].

4.2. *Tumour (T-)stage*

The overall reported accuracy for T-stage prediction with phased array MRI varies between 67% and 83% [13]. The main strength of MRI is the evaluation of large T3 tumours that penetrate the muscular rectal wall and T4 tumours invading adjacent organs, for which MRI has been reported to achieve sensitivities and specificities of 74% and 76% (in T3 tumours) and 82% and 96% (in T4 tumours), respectively [14]. MRI, however, is known to have difficulties in differentiating between superficial T1 and T2 tumours. As opposed to EUS, with MRI it is not possible to separately appreciate all three layers of the rectal wall. The submucosal layer of the rectal wall is not visualised on phased-array MRI (except when there is oedema). Hence, differentiation between a T1 tumour limited to the submucosa and a T2 tumour penetrating the muscularis propria is not feasible. Consequently, EUS remains the cornerstone technique for the selection of superficial T1 tumours that can be considered for local excision. Another limitation of MRI (as well as EUS) is the differentiation between T2 and borderline T3 tumours. Desmoplastic strands into the mesorectal fat in a T2 tumour without actual tumour infiltration cannot be discriminated from desmoplastic reactions containing tumour nests indicating a T3 tumour. In practice, this results in the over-staging of a considerable number (up to 40%) of T2 tumours because radiologists tend to err 'on the safe side' rather than risk under-staging [15,16]. Only when the bowel wall on T2-weighted MR images is visualised as a completely intact hypointense line around the tumour does this indicate an intact muscular bowel layer, which can be used as a reliable predictor for the tumour being limited to the bowel wall (T1–2) with a PPV of 86–91% [17].

4.3. *The mesorectal fascia (MRF)*

Preoperative knowledge of tumour involvement of the MRF is critical in order to determine whether it will be possible to obtain a complete resection of the tumour. Assessment of the MRF is only relevant in the case of a T3 or T4 tumour. When it is established that the tumour is surrounded by an intact bowel wall (indicating a T1–2 tumour) the MRF will never be involved [13]. In the case of a $\geqslant$T3 tumour, the relation between the tumour and the MRF should be evaluated (i.e. the circumferential resection margin at TME). When the tumour invades the MRF or extends within a margin of <1 mm, the MRF is involved. It is well known that MRI is very accurate in evaluating tumoural involvement of the MRF. In a large patient cohort the MERCURY study group found an overall accuracy of >90% for MRI in predicting tumour involvement of the MRF [18]. In a meta-analysis of seven individual reports (including the MERCURY cohort) sensitivities and specificities for MRI ranged between 60% and 88% and between 73% and 100% respectively [19].

4.4. *Lymph nodes and extramural venous invasion (EMVI)*

In addition to MRF involvement, lymph-node status comprises one of the main factors that determine the necessity for the addition of neoadjuvant radiotherapy and/or chemotherapy. Unfortunately, so far MRI, EUS and CT have not proved to be sufficiently accurate to determine the nodal status. The main problem is that imaging relies on nodal size (i.e. short axis diameter) as the main criterion to discriminate between benign and metastatic nodes. In rectal cancer in particular it is known that size is not a reliable predictor because metastases frequently occur in small (<5 mm) nodes [20]. As a result there is no reliable size threshold, and cut-off sizes have been reported ranging from 'any visible node' to >1 cm. In practice, the chosen size threshold depends mainly on the desired balance between sensitivity and specificity, more often favouring the former. Two meta-analyses that analysed the pooled data from nodal imaging studies using size criteria on EUS, CT or MRI showed similarly poor sensitivities and specificities in the range of 55–78% [14,19]. Some authors have shown that the use of morphological criteria in addition to size can improve the diagnostic performance of imaging in assessing the lymph nodes with reported sensitivities of 36–85% and specificities of 95–100% [21,22]. Nodes with a sharply delineated border and homogeneous signal

intensity tend to be benign. In contrast, nodes with an irregular border and heterogeneous signal pattern are more likely to be involved. These criteria have not, however, been widely implemented into clinical practice, probably partly because these features are quite difficult to evaluate in very small nodes (⩽2–3 mm). Apart from nodes within the lower and mid mesorectal compartment, a report on rectal cancer should also mention any suspicious nodes that are located high in the mesorectum, along the superior rectal vessels, as well as outside the mesorectum below the internal iliac bifurcation at the root of the medial rectal vessels (the lateral nodes), as involvement of these nodes harbours a higher risk for distant and local recurrence and will need to be included in the radiation field and/or removed with surgery.

Extramural venous (or vascular) invasion (EMVI) is the presence of tumour invasion in the veins in the vicinity of the tumour. EMVI, as established at histology, is known to be associated with an increased risk of local and distant recurrence and an impaired overall survival [23]. As such, EMVI is considered an important prognostic marker at histopathology. It has been shown that the presence of EMVI can be assessed on MRI based on the presence of tumoural signal intensity within vessels surrounding the rectum, or the presence of a nodular expansion or irregular vessel contour as criteria [24]. It has furthermore been suggested that the presence of EMVI may be related to the presence of nodular disease, since lymphatic vessels run parallel to blood vessels and may therefore be simultaneously invaded by the tumour. In one report, a high EMVI score had been shown to predict the presence of N2 disease with low to moderate sensitivity (56%) and relatively high specificity (81%) [25]. The exact correlation between EMVI and the presence of nodal metastases, however, is not well established.

5. Restaging after neoadjuvant treatment

Traditionally, restaging with MRI after neoadjuvant treatment had only a limited role, since the surgeon would proceed with the original surgical treatment plan as determined on the basis of the primary staging MRI, regardless of the response after chemoradiotherapy. Nowadays the role of restaging with imaging is emerging as surgeons recognise its value for planning the surgical approach. For example, if a tumour is shown to have downsized and retracted from initially invaded organs and/or the MRF, a standard total mesorectal excision (TME) instead of a more extended pelvic resection can be considered. Retraction from the anal canal may allow for sphincter-preserving surgery. Although still controversial, alternative treatments such as a local, transanal excision or deferral from surgery (a so called 'wait-and-see policy) in the selected group of very good or complete responding patients have been reported by several groups with very promising results [26,27]. This paradigm shift in treatment puts the relevance of a restaging with imaging into a whole new perspective. Although the importance of a restaging MRI is acknowledged, there is no clear consensus on what should be the time interval between the completion of the neoadjuvant treatment and the response evaluation with imaging. It is believed that a longer interval (i.e. at least 6 weeks) provides better insight into the final treatment response.

5.1. *Residual tumour versus fibrosis*

Basically, a report of a restaging MRI should include an assessment of the same items as during primary staging (i.e. T-stage, MRF and N-stage). However, an important additional challenge in the restaging setting is the interpretation of post-treatment fibrosis. As a result of the chemoradiotherapy the tumour and nodes shrink and become fibrotic. On post-treatment T2W MRI this fibrosis is visualised as a hypointense bowel thickening at the previous site of the primary tumour or in the nodes. It is extremely difficult to differentiate between mere fibrosis and fibrotic tissues still containing (small) islets of residual tumour. Because radiologists will tend to over-stage rather than under-stage, relatively high over-staging rates (up to 50%) as compared with primary staging have been reported. Overall accuracies for determining the T-stage after chemoradiotherapy (the yT-stage) range between 43% and 60% [28,29]. More favourable results have been suggested for the selection of patients with a 'good' tumour response (i.e. tumour down-staging to yT0–2). It has been shown that post-CRT MRI can accurately predict tumours that are confined to the bowel wall (ypT0–2) with PPVs of 86–91% and NPVs of 70–75% [17]. However, for the specific selection of patients with a complete tumour response (yT0) results – in particular PPV – are much poorer, and up to 80% of patients with a complete response are over-staged as having residual tumour [15,30]. This suggests that, using standard MRI, it will be very difficult to select patients for a 'wait-and-see' policy.

5.2. *Tumour regression from the MRF*

Similar to restaging of the tumour, the reassessment of the MRF is hampered mainly by difficulties in interpreting post-treatment fibrosis. In the case of residual fibrotic involvement of the mesorectal fascia, it is difficult to determine whether there is still actual tumour involvement and a substantial number of patients will be over-staged. However, there are some patterns that can help radiologists in confidently assessing tumour clearance from a previously involved MRF. If a fatpad of >2 mm reappears between the tumour and MRF, we can be confident that the MRF will be free of tumour. If there is only some residual (fibrotic) stranding into the MRF, the MRF will also be likely to be free of tumour [31]. NPVs in the range of 91–100% have been reported for reassessment of MRF involvement after CRT indicating that the patients with a free MRF can be reliably selected. PPVs, however, are much lower (ranging between 44 and 68%), reflecting the over-staging problems described above [18,28,31]. Park et al. suggested that the evaluation of tumour clearance from the MRF after CRT may be improved by the addition of diffusion-weighted imaging, although these results have not (yet) been confirmed by other studies [32].

5.3. *Lymph nodes and EMVI after chemoradiation*

As a result of chemoradiation treatment the majority of the lymph nodes will decrease in size or even completely disappear. Hence, the median number and size of lymph nodes after CRT is significantly lower than at primary staging. The main aim of re-evaluating the nodal stage after CRT is to

establish whether there are remaining metastatic nodes left inside but also outside the mesorectum, or if all initially suspicious nodes have become sterilised. In the latter case, a patient with a concomitantly good response of his primary tumour may be a candidate for organ-saving treatments (local excision or wait-and-see), yet at the time of writing this is still within the scope of clinical trials and not clinical routine. A careful comparison of nodes before and after chemoradiation is of crucial importance when interpreting nodes on post-CRT MRI. Also, a re-evaluation of any initially suspicious extramesorectal nodes should be performed in order to determine whether a lateral lymph-node dissection will be required. The diagnostic performance of post-chemoradiation MRI for restaging of the nodes is reported to be equal or slightly better than with primary staging MRI, with accuracies varying from 64% to 88% [28,33,34]. The criteria used for the restaging of nodes are similar to those used for primary nodal staging (size and, to a lesser extent, the nodal border and signal intensity), but it has been suggested by some authors that size criteria work better in the restaging setting. A possible explanation for this is that many irradiated nodes disappear, and of the remaining small nodes over 80% are sterilised [35]. Hence, nodes that remain large in size after CRT are more likely to be malignant.

There is no evidence (yet) to support the benefit of the re-evaluation of EMVI after CRT. In currently available literature EMVI has been assessed mainly in patients undergoing immediate surgery (without preoperative treatment). In the reports where patients undergoing neoadjuvant treatment were included, no subset analyses were performed to specifically investigate the value of assessing EMVI after preoperative CRT.

6. Future perspectives

The time has passed when imaging was used to only provide information on tumour morphology. Functional imaging techniques give more comprehensive information on tumour morphology and underlying tissue characteristics. Some of these imaging biomarkers have already been implemented into clinical protocols, others are still under investigation. Multiparametric imaging in rectal cancer patients will significantly improve the radiologist's performance, in particular for treatment response evaluation. Apart from that, technical developments in MR scanner hardware allow for innovative moving table techniques which generate whole-body MR images complementary to whole-body PET. The clinical introduction of hybrid PET–MR scanners combining both morphological and functional whole-body imaging within one single examination is the beginning of a new era.

6.1. *Diffusion-weighted MRI (DWI)*

One of the most promising functional MR techniques for oncological imaging is diffusion-weighted MRI (DWI). Although originally used for the assessment of brain ischaemia, body applications of DWI are now also increasingly beginning to set the pace. DWI uses differences in the movement ('diffusion') of water protons between tissues with a different cellular density to differentiate between tumoural and non-tumoural tissues. Moreover, DWI can provide quantifiable data reflecting a tissue's cellular structure, referred to as the apparent diffusion coefficient (ADC). Both the visual assessment of diffusion images, as well as the quantitative measurement of ADC, have shown great potential for rectal cancer imaging, in particular for the evaluation of the therapeutic response of rectal tumours after chemoradiotherapy. It has been shown by several authors that, compared with standard MRI, DWI offers significantly better diagnostic performance for the selection of patients with a good or complete response of their primary tumour after CRT, with reported AUCs up to 0.88 [30,36,37]. Although at present DWI is being investigated mainly in research settings and its true clinical potential has yet to be proven, DWI sequences are already frequently implemented into clinical protocols.

6.2. *Dynamic and lymph node contrast-enhanced MRI*

Measurements of tumour microvascular perfusion are known to be valuable for cancer detection and treatment monitoring. Dynamic contrast-enhanced (DCE) or 'perfusion' MRI techniques could be a promising adjunct to morphological MRI in early response prediction. A pre-treatment measured K^{trans} perfusion parameter has been shown in early studies to be valuable in distinguishing between patients with good or poor responses. Another potentially interesting topic in the field of lymph node imaging is the use of 'lymph-node-specific' MR contrast agents. Very promising results have been shown for the use of ultrasmall particles of iron oxide (USPIO), but this contrast has so far not been approved by the Food and Drug Administration for clinical use. Other MR contrasts such as gadofosveset-trisodium are currently being investigated. Although initial results seem very encouraging, these will need to be confirmed in large multicentre studies to warrant implementation into clinics.

7. Conclusions and recommendations

Since the treatment for rectal cancer has emerged from a 'one-size-fits-all' strategy towards a personalised treatment plan based on a patient's individual tumour risk profile, the role of the radiologist within the multidisciplinary team has changed. The radiologist now plays a full consulting role, and his imaging findings can influence treatment management. The current role of CTs (and PET–CTs) is mainly for the assessment of distant tumour spread. For local tumour staging MRI and EUS are the main players. EUS remains the best technique for the evaluation of low-risk, superficial tumours (T1–2) that may primarily be treated with (local) excision. For the evaluation of larger tumours, in particular for the assessment of large tumours that have a risk for invasion of the mesorectal fascia and neighbouring pelvic organs, MRI is the technique of first choice. Although lymph-node status is an important determinant for treatment, none of the currently available imaging modalities (CT, MRI or EUS) is sufficiently accurate to reliably assess the nodes.

The role of imaging for restaging after neoadjuvant chemoradiotherapy is rapidly advancing. While previously the

surgical treatment plan was established on the basis of the findings of primary staging, this plan may now be altered on the basis of the response of the tumour to CRT and the new findings at restaging imaging. The main difficulty after chemoradiotherapy is the differentiation on imaging between small residual disease and post-radiation fibrosis. Together with the dilemma of accurate nodal staging, these two challenges need to be addressed in the coming years. New hybrid and versatile MRI techniques, however, are on the horizon that may be able to offer a solution.

Conflict of interest statement

None declared.

REFERENCES

[1] Ptok H, Marusch F, Meyer F, et al. Feasibility and accuracy of TRUS in the pre-treatment staging for rectal carcinoma in general practice. Eur J Surg Oncol 2006;32:420–5.
[2] Carmody BJ, Otchy DP. Learning curve of transrectal ultrasound. Dis Colon Rectum 2000;43:193–7.
[3] Wolberink SV, Beets-Tan RG, de Haas-Kock DF, et al. Multislice CT as a primary screening tool for the prediction of an involved mesorectal fascia and distant metastases in primary rectal cancer: a multicenter study. Dis Colon Rectum 2009;52:928–34.
[4] Wiering B, Adang EM, van der Sijp JR, et al. Added value of positron emission tomography imaging in the surgical treatment of colorectal liver metastases. Nucl Med Commun 2010;31:938–44.
[5] de Geus-Oei LF, Vriens D, van Laarhoven HW, van der Graaf WT, Oyen WJ. Monitoring and predicting response to therapy with 18F-FDG PET in colorectal cancer: a systematic review. J Nucl Med 2009;50(Suppl. 1):43S–54S.
[6] Wallengren NO, Holtas S, Andren-Sandberg A, et al. Rectal carcinoma: double-contrast MR imaging for preoperative staging. Radiology 2000;215:108–14.
[7] Slater A, Halligan S, Taylor SA, Marshall M. Distance between the rectal wall and mesorectal fascia measured by MRI: Effect of rectal distension and implications for preoperative prediction of a tumour-free circumferential resection margin. Clin Radiol 2006;61:65–70.
[8] Vliegen RF, Beets GL, von Meyenfeldt MF, et al. Rectal cancer: MR imaging in local staging–is gadolinium-based contrast material helpful? Radiology 2005;234:179–88.
[9] Lambregts DM, Beets GL, Maas M, et al. Accuracy of gadofosveset-enhanced MRI for nodal staging and restaging in rectal cancer. Ann Surg 2011;253:539–45.
[10] Will O, Purkayastha S, Chan C, et al. Diagnostic precision of nanoparticle-enhanced MRI for lymph-node metastases: a meta-analysis. Lancet Oncol 2006;7:52–60.
[11] Gollub MJ, Gultekin DH, Akin O, et al. Dynamic contrast enhanced-MRI for the detection of pathological complete response to neoadjuvant chemotherapy for locally advanced rectal cancer. Eur Radiol 2012;22:821–31.
[12] Gollub MJ, Maas M, Weiser M, et al. Recognition of the anterior peritoneal reflection at rectal MRI. AJR Am J Roentgenol 2013;200:97–101.
[13] Beets-Tan RG, Beets GL, Vliegen RF, et al. Accuracy of magnetic resonance imaging in prediction of tumour-free resection margin in rectal cancer surgery. Lancet 2001;357:497–504.
[14] Bipat S, Glas AS, Slors FJ, et al. Rectal cancer: local staging and assessment of lymph node involvement with endoluminal US, CT, and MR imaging – a meta-analysis. Radiology 2004;232:773–83.
[15] Suppiah A, Hunter IA, Cowley J, et al. Magnetic resonance imaging accuracy in assessing tumour down-staging following chemoradiation in rectal cancer. Colorectal Dis 2009;11:249–53.
[16] Kauer WK, Prantl L, Dittler HJ, Siewert JR. The value of endosonographic rectal carcinoma staging in routine diagnostics: a 10-year analysis. Surg Endosc 2004;18:1075–8.
[17] Dresen RC, Beets GL, Rutten HJ, et al. Locally advanced rectal cancer: MR imaging for restaging after neoadjuvant radiation therapy with concomitant chemotherapy. Part I. Are we able to predict tumor confined to the rectal wall? Radiology 2009;252:71–80.
[18] MERCURY Study Group. Diagnostic accuracy of preoperative magnetic resonance imaging in predicting curative resection of rectal cancer: prospective observational study. BMJ 2006;333:779.
[19] Lahaye MJ, Engelen SM, Nelemans PJ, et al. Imaging for predicting the risk factors – the circumferential resection margin and nodal disease – of local recurrence in rectal cancer: a meta-analysis. Semin Ultrasound CT MR 2005;26:259–68.
[20] Wang C, Zhou Z, Wang Z, et al. Patterns of neoplastic foci and lymph node micrometastasis within the mesorectum. Langenbecks Arch Surg 2005;390:312–8.
[21] Kim JH, Beets GL, Kim JH, 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;52:78–83.
[22] 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;227:371–7.
[23] Talbot IC, Ritchie S, Leighton M, et al. Invasion of veins by carcinoma of rectum: method of detection, histological features and significance. Histopathology 1981;5:141–63.
[24] Smith NJ, Shihab O, Arnaout A, Swift RI, Brown G. MRI for detection of extramural vascular invasion in rectal cancer. AJR Am J Roentgenol 2008;191:1517–22.
[25] Koh DM, Smith NJ, Swift RI, Brown G. The relationship between MR demonstration of extramural venous invasion and nodal disease in rectal cancer. Clin Med Oncol 2008;2:267–73.
[26] 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;29:4633–40.
[27] Lezoche G, Baldarelli M, Guerrieri M, et al. A prospective randomized study with a 5-year minimum follow-up evaluation of transanal endoscopic microsurgery versus laparoscopic total mesorectal excision after neoadjuvant therapy. Surg Endosc 2008;22:352–8.
[28] Kulkarni T, Gollins S, Maw A, et al. Magnetic resonance imaging in rectal cancer downstaged using neoadjuvant chemoradiation: accuracy of prediction of tumour stage and circumferential resection margin status. Colorectal Dis 2008;10:479–89.
[29] Allen SD, Padhani AR, Dzik-Jurasz AS, Glynne-Jones R. Rectal carcinoma: MRI with histologic correlation before and after chemoradiation therapy. AJR Am J Roentgenol 2007;188:442–51.
[30] Kim SH, Lee JM, Hong SH, et al. Locally advanced rectal cancer: added value of diffusion-weighted MR imaging in the evaluation of tumor response to neoadjuvant chemo- and radiation therapy. Radiology 2009;253:116–25.

[31] Vliegen RF, Beets GL, Lammering G, et al. Mesorectal fascia invasion after neoadjuvant chemotherapy and radiation therapy for locally advanced rectal cancer: accuracy of MR imaging for prediction. Radiology 2008;246:454–62.
[32] Park MJ, Kim SH, Lee SJ, Jang KM, Rhim H. Locally advanced rectal cancer: added value of diffusion-weighted MR imaging for predicting tumor clearance of the mesorectal fascia after neoadjuvant chemotherapy and radiation therapy. Radiology 2011;260:771–80.
[33] Kuo LJ, Chern MC, Tsou MH, et al. Interpretation of magnetic resonance imaging for locally advanced rectal carcinoma after preoperative chemoradiation therapy. Dis Colon Rectum 2005;48:23–8.
[34] Chen CC, Lee RC, Lin JK, Wang LW, Yang SH. How accurate is magnetic resonance imaging in restaging rectal cancer in patients receiving preoperative combined chemoradiotherapy? Dis Colon Rectum 2005;48:722–8.
[35] Koh DM, Chau I, Tait D, et al. Evaluating mesorectal lymph nodes in rectal cancer before and after neoadjuvant chemoradiation using thin-section T2-weighted magnetic resonance imaging. Int J Radiat Oncol Biol Phys 2008;71:456–61.
[36] Lambregts DM, Vandecaveye V, Barbaro B, et al. Diffusion-weighted MRI for selection of complete responders after chemoradiation for locally advanced rectal cancer: a multicenter study. Ann Surg Oncol 2011;18:2224–31.
[37] Sun YS, Zhang XP, Tang L, et al. Locally advanced rectal carcinoma treated with preoperative chemotherapy and radiation therapy: preliminary analysis of diffusion-weighted MR imaging for early detection of tumor histopathologic downstaging. Radiology 2010;254:170–8.