JOURNAL Of Medical Science And Clinical Research
IGM Publication   An Official Publication Of IGM Publication

Role of MRI in Preoperative Assessment of Rectal Cancer

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Abstract
Rectal adenocarcinoma is a common malignancy with high mortality and morbidity .Over the past few years, significant progress has been made in the management of rectal cancer with advances in both surgical technique and adjuvant therapies. Several studies have been published showing the ability of MRI to accurately stage rectal cancer and to identify the relevant anatomy. Many studies have shown good agreement between MRI findings and both surgical and histopathological findings. MRI allows proper preoperative tumor staging by assessment of the tumor itself, nodal spread and depth of tumor invasion which allows the triage of patients to up-front surgical resection or neoadjuvant therapy. Our work included 40 patients presented with rectal carcinoma with age ranging between 25 and 90 years with the aim to evaluate the role of MRI in staging of preoperative cases of rectal cancer. All patients in this study were imaged using 1.5T superconducting magnet MRI machines and the assessment of tumours was carried including its location , distance from sphincter complex, degree of extramural spread, T stage, N stage, relation to peritoneal reflections, and relations to pelvic viscera and the presence of extramural vascular invasion. MRI proved very useful and accurate in assessment of all these factors which enabled accurate patient staging and aided in the choice of therapy.
Keywords: *APR: anterior peritoneal reflection. CRM: circumferential resection margin, MRF: mesorectal fascia, EMVI: extramural vascular invasion. TSE: turbo spin echo. TME: total mesorectal excision.*

Introduction
MRI imaging plays an important role in the multidisciplinary team approach to rectal cancer MRI with rectal cancer protocol modification is now the preferred modality for rectal cancer staging and restaging in most speciality institutions.[1]

MRI allows the accurate detection of prognostic signs such as the distance between the caudal tumour margin and the anorectal junction, the mesorectal fascia infiltration and the presence of extramural vascular invasion.[2] Furthermore, MRI is able to assess for lymph nodes and tumor deposits in the tissues beyond the mesorectal fascia, including the pelvic sidewall, which, if unaddressed, are a source of residual and/ or recurrent disease.[3]

High resolution MRI images can clearly identify different layers of the rectal wall and their relation to surrounding structures or mural lesions. Moving from the lumen outward, the innermost mucosal layer seems as a low–signal-intensity

band, and the submucosal layer seems as a high-signal intensity band. The muscularis propria seems as a low-signal-intensity band that serves as the boundary between the rectum and the perirectal fat.[4]

Tumor staging is crucial for prognosis and treatment planning. Rectal cancer staging is based on the TNM and UICC (International Union Against Cancer) staging systems .There are two independent predictors: the local status of the tumor (T stage) and the presence or absence of metastatic nodes (N stage).[5]

Nodal staging of rectal tumours include N1 (with affected 1 to 3 nodes) and N2 (with affected more than 3 nodes). The regional nodal spread involve: superior, middle, inferior and peri-rectal, pre and lateral sacral, sigmoid and inferior mesenteric as well as internal iliac nodes. The other nodal stations that are considered non-regional and distant metastatic include inguinal, external iliac, common iliac and para-aortic nodes.[6]

Circumferential resection margin is an important factor to consider in evaluating cases of rectal cancer .It is defined simply as the distance from the edge of the tumor to the margin of the resected specimen. And can be replaced by the term mesorectal fascia (MRF) for MRI based staging. The potential CRM is considered involved on MRI if the shortest distance from the outermost part of the tumor to the adjacent MRF is less than 1 mm. The MRF defines the plane of TME surgery at and above the level of the top of the puborectalis sling. Below the puborectalis sling, the TME plane is defined as the space between the muscle coat of the rectum becoming the internal sphincter and the fibers of the puborectalis sling that merge with the external sphincter fibers. At this level, tumor invading the intersphincteric plane or extending to within 1 mm of the levator muscle is considered to potentially involve the CRM.[7]

MRI has shown very high sensitivity and specificity in defining distance of tumours from the CRM (in another term distance from the MRF). In the MERCURY Study, which included a total of 349 patients who underwent pre-operative MRI assessment followed by TME surgery, a specificity of defining distance of tumour from CRM on MRI was 92%.[8]

Despite variation in the use of preoperative treatment, wide agreement exists that all patients with potential margin involvement on MRI should be offered chemo-radiotherapy because this treatment has led to a decrease in margin positivity rates.[9]

Materials and Methods

This study was conducted on 40 adult patients diagnosed with rectal cancer, referred to private Radiology centres for MRI staging. All patients proved to have cancer rectum located within 15 cm from the external anal verge according to their colonoscopy findings and the histopathological results.

All MRI studies were acquired on an Avanto 1.5T closed magnet MRI machine (Siemens, Erlangen, Germany). Phased array surface coil was applied to the pelvis. Rectal filling with 100cc of ultrasound gel was used in only 15 cases. MRI sequences included:

1. Initial sagittal and coronal scout scans
2. Midline sagittal T2-weighted TSE
3. High resolution axial T2-weighted TSE, perpendicular to the long axis of the tumour
4. Coronal T2-weighted TSE, parallel to the long axis of the tumour or the anal canal according to tumour location

The sequences were used with the following parameters (TE90–110ms, TR 4000– 5000 ms, matrix 265x265, field of view (FOV) 18-24 cm, slice thickness 3 mm with 1 mm gap distance, number of signal averages:4)

5. DWI was performed in the axial plane by using a single-shot echo- planar sequence with the sensitivity encoding technique. The b values corresponding to the diffusion-sensitizing gradient were 0, 500, and 1000 sec/mm^2. All images were acquired with a section thickness of 5 mm

and processed to generate trace apparent diffusion coefficient (ADC) maps on which ADC values were measured in n x10^{-3} mm^2/s.

6. Axial T1 weighted sequence was done in a limited number of cases.
7. No contrast intravenous contrast was given.

TNM classification was applied according to described criteria in AJCC 8th edition. The circumferential resection margin was evaluated and considered positive when tumor margin, suspicious lymph node, suspected EMVI or tumour deposit is found within 1 mm of the fascia of the mesorectum. For staging of the lymph nodes (N staging), the regional lymph nodes were evaluated based on their number and their size. Lymph nodes with more than 5mm short axis diameter were considered metastatic, while nodes < 5 mm were considered to be uninvolved. Also margin irregularity, speculation, and eccentric necrosis were considered as signs of nodal involvement

Results

This study was conducted on 40 Egyptian patients referred to a radiology private centre with diagnosis of rectal cancer by endoscopy and histopathology, and no history of surgical intervention. Age of examined patients ranged from 25 to 90 years with mean age 54 years. The study included 20 males and 20 females with male to female ration of 1:1. The most common **clinical presentation** in our patients was bleeding per rectum, which was found in 35 out of 40 patients. Around 37% of patients complained from altered bowel habits, 50% complained of pelvic pain and 25 % showed generalized symptoms of cachexia. None of our patients presented by intestinal obstruction or distant organs metastatic lesions **(Table 1)**. **Length of rectal cancer** in our cases ranged from 3cm to maximum of 20cm (in one case where the cancer involved the whole length of the rectum together with the recto-sigmoid junction). Mean tumour length was 6cm. **The**

lesions were classified according to their location in the upper third of the rectum ''>10 cm from the anal verge''; in the middle third of the rectum ''5-10 cm from the anal verge "and in the lower third of the rectum ''<5 cm from the anal verge''. We found, in our patients, the highest incidence of rectal neoplasm occurred in the lower third (50%) followed by the middle third (35%), then upper third (12.5%). Involvement of the whole rectum occurred in one case. **(Table2). Signal intensity** of rectal cancers in our cases on T2 weighted images was intermediate in most of the cases (75%). Few cases showed hyper intensity or heterogeneous signal while one case showed hypointense signal. **Restricted diffusion** was found in 31 cases (77.5% of our study). **According to tumour morphological pattern:** Annular mural wall thickening was the most common morphological pattern in our cases (60%) followed by polypoidal thickening (35%) and lastly presentation by fungating mass which was present in only two cases. Regarding **T staging of the tumour (Table 3):** No lesion was staged as T1 by MRI i.e., no lesion was seen limited to the submucosa of the rectal wall. In 8 cases, the lesion was staged as T2, and the study showed invasion of the muscularis propria with no penetration of perirectal fat planes. Most of the cases in our serious (25 cases, 62.5%) were diagnosed as T3, where there was invasion of all rectal layers with perirectal fat infiltration yet without pelvic organ involvement. Seven cases were staged as T4 tumours. One case showed only peritoneal infiltration (T4a). The other 6 cases showed infiltration of nearby pelvic organs or advanced anal sphincters infiltration. **Nodal affection (Table 4)** was determined in the study according to combining size and shape criteria. Nodes were considered suspicious if it has one or more of the following features (size more than 5mm in short axis, globular shape, heterogonous or hyperintense signal intensity, irregular borders and restricted diffusion). Seven cases in our series showed no suspicious nodes (N0), 14 cases showed 1-3 suspicious nodes (N1) and 19 cases

showed more than 3 suspicious nodes (N2). Suspicious non regional nodes were found in only five patients (15%). **Invasion of the anterior peritoneal reflection was noted** in only three cases in our study (5 %) One of these cases showed only peritoneal infiltration, one case showed invasion of posterior vaginal wall and the third one showed invasion of the uterine fundus. Regarding **CRM involvement,** 26 patients in our study (65%) showed positive CRM. **EMVI**: Extramural vascular invasion (EMVI) was determined in cases showing discrete serpiginous or tubular projections of intermediate signal intensity into perirectal fat, following the course of a visible perirectal vessel. 16 cases (40%) were found to have this finding. **Table 5** shows the correlation between incidence of extra mural vascular invasion and T stage of the tumour. **Specific Staging of low rectal tumours (Sphincteric involvement** (which included 20 cases, 50% of the study) is shown in **Table 6** : Stage 1 the tumour is limited to rectal wall with intact muscle coat. Stage 2: The tumour replaces muscle coat (internal sphincter) but with still clear intersphincteric plane**.** Stage 3 the tumour invades intersphincteric plane or within 1 mm of levator muscle**.** Stage 4: the tumour invades external anal sphincter or within less than 1mm or beyond levator muscle with or without invasion of other pelvic organs**.**

Involvement of pelvic organs: Six cases in our study showed invasion of related pelvic organs, rendering patient stage T4b, including the following: A 50 year old male with invasion of prostate, the seminal vesicle and the pelvic wall on one side. Three cases showed invasion of the lower vagina. One case, a 55 year old female patient with high rectal tumour reaching distal sigmoid, had a fungating tumour perforating peritoneal reflection and invading uterine fundus. A 31 year old female patient with low rectal tumour showed invasion of puborectalis muscle.

Table 1: Distribution of patients according to clinical presentation

Clinical presentation	Number of patients	% of total
General cachexia and weight loss	10	25%
Bleeding per-rectum	35	87%
Altered bowel habits	15	37.5%
Abdominal pain	20	50%

Table 2: distribution of patients according to tumour location

Tumour location	Frequency	Percent
upper	5	12.5
middle	14	35
lower	20	50
whole	1	2.5
Total	**40**	**100**

Table 3: Distribution of patients according to T stage

T stage	Frequency	Percent
T2	**8**	**20.0**
T 3	**25**	**62.5**
T3a<5mm	4	10.0
T3b5-10mm	10	25.0
T3c>10mm	11	27.5
T4	**7**	**17.5**
T4a	1	5.0
T4b	6	12.5
Total	**40**	**100.0**

Table 4: Distribution of cases according to Nodal stage

Nodal stage	Frequency	Percent
N0	7	17.5
N1	14	35
N2	19	47.5
Total	40	100.0

Table 5: Correlation between incidence of extra mural vascular invasion and T stage of the tumour

T stage	EMVI		
	p	n	Total
T2	0	8	8
T3a<5mm	1	3	4
T3b5-10mm	4	6	10
T3c>10mm	6	5	11
T4a	1	0	1
T4b	4	2	6
Total	**16**	**24**	**40**

Table 6 : frequency of low rectal tumors according to sphincteric invasion

Sphincteric involvement staging	Frequency	Percent
stage1	1	5%
stage2	6	30%
stage 3	2	10%
stage 4	5	25%
N/A	6	30%
Total	**20**	**100.0**

Cases

Case 1: 40 years old male with lower third rectal cancer extending to involve the anal canal

Figure 1: A: coronal T2WI showing polypoial tumour with intermediate signal intensity involving lower rectum and the anal canal with involvment of both internal and external sphincters (dashed arrow) and levator muscle (solid arrow) on the left side.curved arrow: normal right levaor muscle). **B:** axial image in the lower rectum showing the tumour involving four quadrants of the rectal wall with linear extension into mesorectal fat

Case 2: A 48 year old male patient with middle rectal cancer, having small extra mural extension (6mm) with multiple locoregional suspicious nodes (>6), some of them abutting MRF. Preliminary imaging staging was T3bN2b

Figure 2: A: sagittal T2WI showing longitudinal extent of the tumour. Distance of lower edge was located 7 cm from anal verge and about 1.5 cm from puborectalis. B:axial T2W image showing circumferential involvement of the rectal wall by tumour focal area of extra mural extension is noted at 3 o'clock axis (thick white arrow). A suspicious mesorectal node is seen (thin white arrow) abutting the MRF

Case 3: A 50 year old male patient presented lower rectal mass lesion limited to rectal wall with no mesorectal extension .Extension into proximal internal sphincter was noted with clear intersphincteric plane. 3 suspicious mesorectal

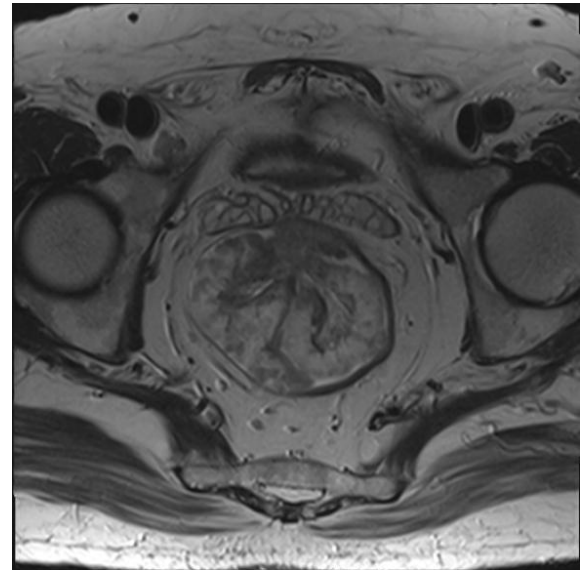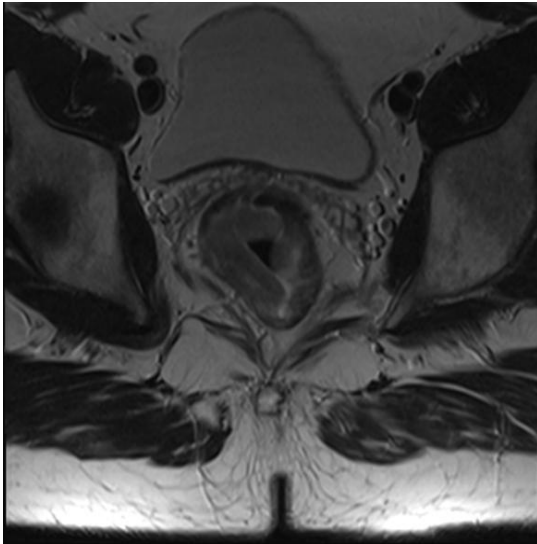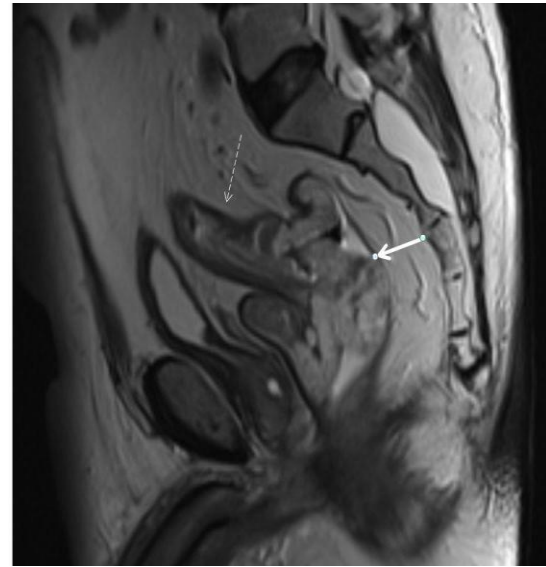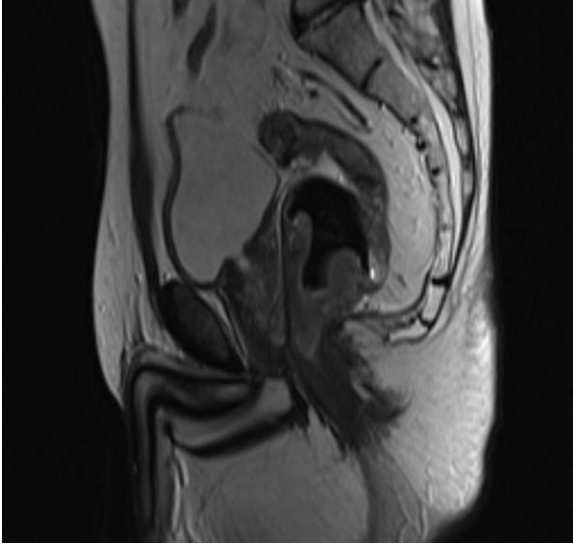nodes were seen. Preliminary imaging based staging was c T2N1.

Figure 3: A: sagittal T2W image showing tumour location in the lower rectum with short extension into proximal internal sphincter. B: axial T2WI showing tumour having homogenous intermediate signal intensity involving two quadrants of rectal wall .No extra mesorectal extension.

Case 4 : A 77 year old male patient presented by middle third rectal cancer of mucinous origin having hyperintense signal with no restricted diffusion . no extra mural extension was noted and no EMVI. Multiple suspicious mesorectal nodes were seen) >4) some of them abutting the MRF "involved CRM". The tumour was associated with recto-rectal intussusception .preliminary imaging based staging was T2N2
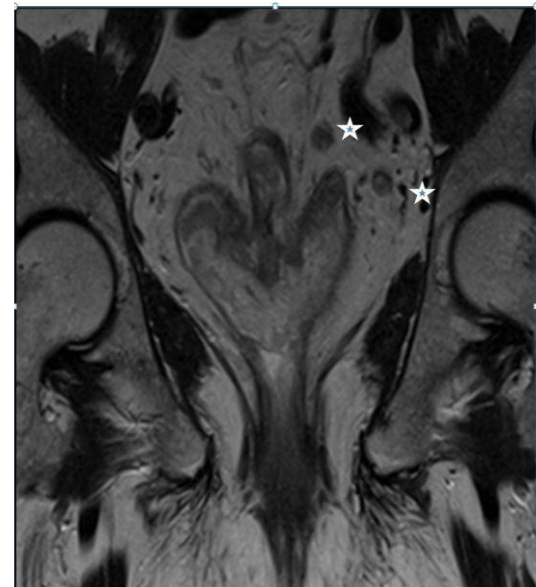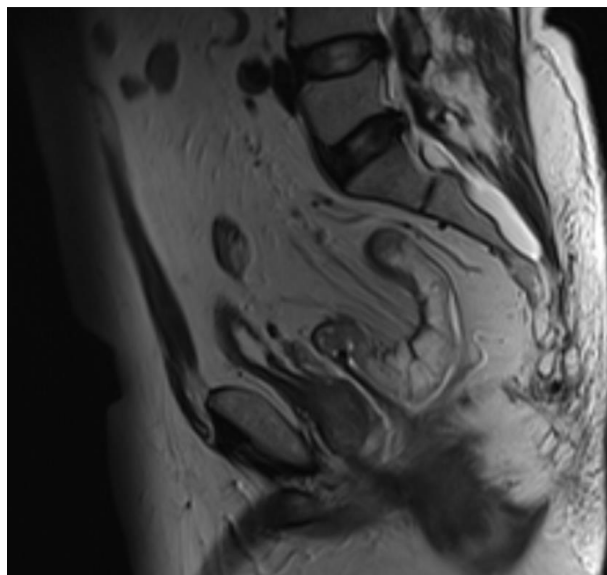
Figure 4:A and B: sagittal T2W images at and off the midline showing the longiudinal exent of the tumour. the solid arrow points to the middle rectum invlolved by the cancer" the intussuscipiens" and the dashed arrow points to the uninvolved prolapsing upper rectum " the intussusceptum". **C:** axial T2WI though the mid rectum show circumferential involvement by the tumour still with preserved outer hypointnes muscularis propria with no extramural extension "T2"

D: coronal T2W image depicting tumour locatoin. the two white stars pointing to two involved globuar mesorectal nodes

Discussion

MRI combining large fields of view and high spatial resolution, represents the top advanced modality for staging of rectal cancer being able to provide information about the tumor invasion depth, relationship of the tumour itself and deposits to the MRF, affection of CRM, extramural vascular invasion and lymph node grading. Accordingly, it enables physicians to take effective decisions in patient management.[10]

Rectal lumen distension in MRI staging of rectal cancer is still a controversial issue. Several authors advocate against its use, hypothesizing that it may alter the distance between the tumour and the mesorectal fascia and potentially compromise the CRM evaluation Others advocate.

rectal distension to improve depiction of the primary tumour.[11,12]

High-resolution T2-weighted imaging is the key sequence in the MRI evaluation of primary rectal cancer. This sequence generally consists of thin section (3-mm) axial images obtained orthogonal to the tumor plane. It allows differentiation between rectal tumors confined within the rectal wall (stage T2 tumors) and those that extend beyond the muscularis propria (stage T3 tumors) and also can assess the depth of invasion outside the muscularis propria.[13]

Axial T1-weighted FSE sequence was done in a limited number of cases in our study and it showed substantially inferior tumour characterization compared to the T2-weighted images. This was also noted in multiple previous studies.[13]

Coronal and sagittal images were found in our study to be very useful for showing the relations between the tumor margins and the levator ani muscle, anal sphincter, APR and the related pelvic organs. The importance of the multiplanar imaging of rectal cancer was also discussed by Moreno et al and Hunter et al.[3], [9]

Gadolinium contrast media was not used in our study. In rectal cancer MRI, there are sufficient current data indicating that its use does not increase diagnostic yield for tumor or nodal staging while at same time it adds cost, time for additional sequences, and occasional morbidity.[14]

In our study, most of the cases (75%) showed intermediate T2 signal and about 77% showed diffusion restriction on the diffusion weighted images (DWI). This was matching with Chun et al and Bauer et al. Most of viable rectal tumors initially exhibit intermediate T2 signal between the signal intensity of the muscularis propria and mucosa and show restricted diffusion.[15]

Regarding the tumour T staging; our cases included T2, 3 and 4 stages and the T3c stage was the most predominant, seen in 27.5% of our patients. We used the sub-classification of T3 tumours mentioned by Jhaveri et al[5] (where T3a <5 mm, T3b 5-10mm and T3c >10mm). This is

slightly different from that described by Nougret et al (16) (where T3a <1 mm, T3b 1-5 mm, T3c 5-15 mm, T3d >15 mm).

In our study, nodal affection was determined according to combining size and shape criteria. Nodes were considered suspicious if it has one or more of the following features (size more than 5mm in short axis, globular shape, heterogonous or hyperintense signal intensity, irregular borders and restricted diffusion). The evaluation of these features combined with the size improves diagnostic accuracy.[1] Also it requires high resolution images that cover all nodes of importance, including superior rectal and pelvic sidewall adenopathy.

Extramural vascular invasion (EMVI) is an important independent risk factor for local and distant recurrence .It was seen in 16 cases in our study (40%) ,mostly associated with T3c tumors (6 cases). It was identified by discrete serpiginous or tubular projections of intermediate signal intensity into perirectal fat, following the course of a visible perirectal vessel. Nodularity of the affected vein was seen in more severe cases denoting invasion beyond the wall of the affected veins resulting in the so-called "tumor deposits" within the mesorectal fat.

Distance of the rectal wall tumor, EMVI or enlarged mesorectal nodes from the mesorectal fascia is important independent factor for operative decision because it is considered as the surgical CRM for the total mesorectal excision (TME). The CRM was said to be involved or positive if tumoral tissue (either from the rectal wall its self or EMVI or enlarged mesorectal nodes) seen within 1 mm from the mesorectal fat. Positive CRM was described in 65% of our cases.

The anterior peritoneal reflection (APR) is an important entity to be commented upon while assessing a case of rectal cancer as its affection denotes T4a rectal tumours. It is identified as thin linear hypointensity extending from the upper posterior border of the urinary bladder dome to the junction of the upper two third and lower third of the rectum. In females, it had a variable attachment; may be as low as 5 cm from the anal verge[17] In our study, APR was said to be affected if thick linear hypo-intensity was seen at its anatomical site and this was found in only 3 cases (7.5 %), one of them showed also invasion of posterior vagina wall and one invasion of the uterine fundus.

Invasion of the surrounding viscera is a very important entity to be assessed in MRI staging of rectal cancer because it renders tumour T4b stage and may require additional interference of the gynaecology or the surgical urology staff during the rectal cancer procedure. Pre-operative MRI evaluation of tumor invasion of the surrounding pelvic visceral structures showed 53-100% positive and 93-100% negative predictive values in previous studies.[18] Hence pre-operative MRI evaluation is considered accurate imaging tool for prediction of absence of invasion of the surrounding pelvic visceral structures.

Conclusions

MRI is the modality of choice for staging rectal cancer as it facilitates the accurate assessment of mesorectal fascia and the sphincter complex for surgical planning. Advances in the method and technique of rectal MRI have resulted in improved image acquisition and subsequently increased diagnostic yield. Standardized imaging criteria using thin-section MRI, 3-mm slices, small field of view and multi-planar acquisitions allow more accurate interpretation. Accurate measurement of the depth of extramural tumor spread enables accurate preoperative prediction of tumour prognosis. In addition to size, new criteria such as a spiculated or indistinct border and a mottled heterogeneous appearance could be useful to predict regional lymph node involvement in patients with rectal cancer. The MRI extramural vascular invasion features provide additional important prognostic information, which is important when selective neoadjuvant therapy is being considered. Preoperative MR imaging is accurate for the prediction of absence of tumor invasion into pelvic structures. The

circumferential resection margin status detected at MRI is vital for individual risk stratification as a predictive factor for treatment response and survival before surgery.

MRI imaging for rectal cancer should start by initial localization images in the coronal and sagittal planes followed by small field of view high resolution T2 weighted images in axial, sagittal and coronal planes with angulations depending on tumour location and morphology. Large field of view axial T2 weighted images should be included in the study to ensure all pelvic lymph node groups are examined. Coronal images should be included in the examination of low rectal tumours to assess relations to sphincters, parallel to the tumour itself or the anal canal according to tumour location. Intra-venous contrast injection is not recommended for staging of rectal cancer in MRI and better be abandoned CRM status should be reported in every case whenever feasible. Extra mural depth of invasion should be reported for all T3 and T4 cases. Extra mural vascular invasion, APR involvement and involvement of adjacent organs should be carefully looked for in every report. A structured synoptic MRI report is better used than the descriptive free text form because it ensures that all necessary characteristics are included and are addressed objectively.

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