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Original Research Article

MRI Staging of Carcinoma Rectum with Peroperative and Pathological Correlation

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Abstract:

Background: Carcinoma rectum is one of the leading causes of cancer-related mortality worldwide. Accurate preoperative staging is essential for determining optimal treatment strategies, particularly regarding the use of neoadjuvant chemoradiotherapy and the selection of appropriate surgical techniques. Magnetic resonance imaging (MRI) has emerged as the preferred modality for locoregional staging of rectal carcinoma, offering superior soft-tissue resolution and multiplanar capability. This study is aimed to evaluate the diagnostic accuracy of 1.5-Tesla MRI in preoperative T-staging and nodal assessment of rectal carcinoma and to correlate these findings with peroperative and histopathological data.

Methods: A hospital-based observational study was conducted at a tertiary care teaching hospital. Fifty patients with histologically confirmed carcinoma rectum were enrolled. MRI was performed using a 1.5-Tesla unit employing T1-weighted, T2-weighted (axial, sagittal, and coronal), diffusion-weighted imaging (DWI), and dynamic contrast-enhanced (DCE) sequences. TNM staging based on MRI findings was correlated with intraoperative findings and postoperative histopathological examination (HPE) in 26 surgically managed patients.

Results: The study population comprised 37 males (74%) and 13 females (26%), predominantly aged above 50 years. Adenocarcinoma was the most common histological type (94%). Mid-rectal location was most frequent (64%). MRI identified mesorectal fascia (MRF) invasion in 6 patients (12%) and extramural vascular invasion (EMVI) in 11 patients (22%). Lymph node involvement was detected in 27 patients (54%), predominantly in the mesorectal compartment. MRI staging demonstrated a sensitivity of 89%, specificity of 71%, and overall accuracy of 86.42% for T2 stage when compared to HPE. Among 31 post-chemoradiotherapy patients, tumour regression grade (TRG) assessment showed Grade 3 response in 55% of cases.

Conclusion: MRI is a highly accurate and reliable modality for preoperative staging of carcinoma rectum. It provides critical information on T-stage, circumferential resection margin, extramural vascular invasion, and nodal status with sensitivity and specificity comparable to the gold standard histopathological assessment. DWI sequences are particularly valuable in treatment response evaluation and surveillance for recurrence. MRI should be adopted as the standard first-line imaging investigation in rectal cancer management.

Keywords: Rectal carcinoma; MRI staging; TNM classification; circumferential resection margin; extramural vascular invasion; diffusion-weighted imaging; tumour regression grade; total mesorectal excision; chemoradiotherapy; histopathological correlation.

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Introduction

Colorectal cancer (CRC) is a significant global health burden, ranking as the third most common malignancy and the fourth leading cause of cancer-related deaths worldwide [1]. Rectal carcinoma, in particular, poses unique clinical challenges owing to its anatomical location within the pelvis, its propensity for local recurrence, and its complex management algorithms [2]. The annual incidence rates for rectal carcinoma in Indian men and women are 4.1 and 3.9 per 100,000, respectively, with mortality rates mirroring those observed in developed nations [3]. Although rectal carcinoma historically affects individuals over 50 years of age, there has been a concerning rise in incidence among younger age groups, with the death rate increasing by approximately 1% per year in this

demographic. The prognosis of rectal cancer is heavily influenced by the stage at presentation and the adequacy of surgical resection. Total mesorectal excision (TME) has emerged as the surgical standard, demonstrating a reduction in mortality from 16% to 9% and a local recurrence rate of less than 10% when performed as an isolated treatment [4]. Achieving a negative circumferential resection margin (CRM) is paramount; a positive CRM is strongly associated with local recurrence, distant metastasis, and diminished overall survival [5]. For locally advanced rectal cancers (LARC), preoperative chemoradiotherapy (CRT) is widely recommended to downstage the tumour and optimize resectability prior to surgery.

Accurate preoperative staging is the cornerstone upon which individualized treatment decisions are made. Several imaging modalities—including endorectal ultrasound (EUS), computed tomography (CT), positron emission tomography (PET-CT), and magnetic resonance imaging (MRI)—have been evaluated for this purpose. Among these, MRI has been established as the gold standard for locoregional staging, owing to its superior soft-tissue contrast resolution, multiplanar capability, and ability to assess mesorectal fascia (MRF) involvement, extramural vascular invasion (EMVI), and nodal status without ionizing radiation [6]. The MERCURY (Magnetic Resonance Imaging in Rectal Cancer European Equivalence) study validated the use of high-resolution pelvic MRI, demonstrating diagnostic accuracy of 90–100% for predicting CRM status [7,8].

Despite advances in imaging technology, challenges persist in the differentiation of T2 from early T3 tumours, in the characterisation of sub-centimetre lymph nodes, and in the post-treatment restaging of patients who have received neoadjuvant therapy. Diffusion-weighted imaging (DWI) and dynamic contrast-enhanced (DCE) MRI sequences have been introduced to augment conventional T2-weighted imaging and address some of these limitations, particularly in the assessment of treatment response and detection of recurrence [9].

The current study was undertaken to prospectively evaluate the diagnostic performance of 1.5-Tesla MRI in the preoperative staging of rectal carcinoma, to assess relevant prognostic parameters including EMVI and CRM, and to correlate the MRI-based staging with intraoperative observations and postoperative histopathological findings at a tertiary care centre in Southern India.

The specific objectives of this study were: (1) to evaluate the usefulness of MRI in preoperative T-staging of primary rectal tumours; (2) to assess extramural vascular invasion (EMVI) and nodal status as important prognostic factors; (3) to characterise the size and morphological features of metastatic lymph nodes on MRI; (4) to correlate MRI findings with peroperative and pathological findings; (5) to assess the efficacy of diffusion-weighted imaging (DWI) in detecting tumour response and recurrence; and (6) to determine whether contrast-enhanced MRI adds diagnostic value to non-contrast sequences.

Materials and Methods

This was a hospital-based, prospective observational study conducted at the Department of Radiodiagnosis at a tertiary care teaching hospital in South India in collaboration with the Departments of Surgery and Oncology. The study was carried out over a period of two and a half years. Ethics committee approval was obtained prior to enrolment, and written informed consent was obtained from all participants. The study adhered to the principles of the Declaration of Helsinki.

A total of 50 patients with histologically confirmed carcinoma rectum were enrolled. The study included two cohorts: newly diagnosed patients presenting for primary staging and previously treated patients on follow-up surveillance post-chemoradiotherapy or surgery. Inclusion criteria encompassed all newly diagnosed cases of rectal carcinoma and previously treated patients undergoing follow-up evaluation. Exclusion criteria included contraindications to MRI such as cardiac pacemakers, metallic implants, intracranial clips, and claustrophobia, as well as patients medically unfit for contrast administration.

All patients were scanned on a 1.5-Tesla MRI unit using a pelvic phased-array surface coil, without prior bowel preparation or endorectal coil insertion, in accordance with standard MERCURY protocol recommendations [7,8]. The imaging protocol incorporated multiple sequences: T1-weighted (T1W) axial, T2-weighted (T2W) in axial, sagittal, and coronal planes, short tau inversion recovery (STIR), T1 fat-saturation (FS), diffusion-weighted imaging (DWI), T1 fat-saturation post-contrast, and dynamic contrast-enhanced (DCE) MRI. Gadolinium-DTPA was administered intravenously at a dose of 0.1 mmol/kg at a rate of 1 ml/second for contrast studies.

Rectal tumours were classified as low (less than 5 cm from the anal verge), mid (5–10 cm), or high (greater than 10 cm) based on the caudal extent of the tumour on sagittal imaging. The complete MRI technical parameters are summarised in Table 1.

Images were interpreted by experienced radiologists blinded to clinical data. TNM staging was performed according to the American Joint

Committee on Cancer (AJCC) eighth edition classification system [10]. T-staging was assessed primarily on high-resolution axial T2W images obtained perpendicular to the tumour axis. The tumour was assessed for depth of invasion through the rectal wall layers, breach of the mesorectal fascia, peritoneal reflection involvement, and infiltration of adjacent organs. CRM was defined as positive when the tumour-MRF distance was less than 1 mm and threatened when between 1–2 mm; a distance greater than 2 mm was classified as negative [11]. EMVI was identified as intermediate T2 signal within mesorectal vessels with focal enlargement and irregular wall contour. Lymph node assessment incorporated size, morphological irregularity, and internal signal characteristics on T2W and DWI sequences. In post-treatment patients, tumour regression grade (TRG) was assigned per the modified Mandard criteria (TRG 1–5) [12].

Descriptive statistics were used to summarise demographic and imaging data. The diagnostic performance of MRI was evaluated by computing sensitivity, specificity, and overall accuracy for each T-stage using histopathological examination (HPE) of surgical specimens (n=26) as the reference standard. Correlation between EMVI, lymph node morphology, diffusion restriction, and nodal metastasis patterns was analysed using contingency tables. Data were analysed using standard statistical software.

Results

Fifty patients with carcinoma rectum were recruited over the study period. The majority (70%) were above 50 years of age, with the largest cohort (36%) being older than 60 years. The male-to-female ratio was 2.8:1, with 37 male (74%) and 13 female (26%) patients. Only 3 patients (6%) were below 40 years of age.

The most common presenting symptom was bleeding per rectum, reported in 29 patients (58%), followed by constipation (20%), altered bowel habits (14%), and lower abdominal pain (8%). Among the 50 patients, 31 (62%) were previously diagnosed cases who had received chemoradiotherapy, while 19 (38%) were newly diagnosed. The age and sex distribution of patients is presented in Table 2.

Table 1: MRI Technical Parameters Used in the Study Protocol

Sequence	Imaging Plane	TR/TE (ms)	Flip Angle (°)	FOV	Slice Thickness	Matrix
T1W (non-contrast)	Axial	500/20	90	350×350 mm	6 mm	256×512
T2W (non-contrast)	Axial / Sagittal / Coronal	4500–7500 / 135	180	20 cm (high-res)	3 mm	318×512
FS T1W (post-contrast)	Axial / Sagittal / Coronal	500/11	90	300×300 mm	6 mm	512×512
DWI	Axial	—	—	350×350 mm	5 mm	128×128
DCE-MRI	Axial (dynamic)	—	—	300×300 mm	5 mm	256×256

Table 2: Age and Sex Distribution of Study Patients (N=50)

Age Group (Years)	Male (n)	Female (n)	Total (n)	Percentage (%)
< 40	3	0	3	6%
41–50	10	2	12	24%
51–60	12	5	17	34%
> 60	12	6	18	36%
Total	37	13	50	100%

The majority of tumours (64%) were located in the mid-rectum, followed by the high rectum (28%) and low rectum (8%). Adenocarcinoma was the predominant histological type, accounting for 47 patients (94%), followed by adenosquamous carcinoma in 2 patients (4%) and mixed neuroendocrine tumour in 1 patient (2%).

On T2-weighted imaging, tumour signal intensity was characterised as hyperintense in 52% of cases, intermediate in 34%, hypointense in 4%, and non-visible (post-treatment complete response) in 10%. DWI and contrast-enhanced sequences each contributed to tumour detection in 43 patients (86%), while T2W imaging alone demonstrated the growth in 45 patients (90%), indicating that contrast administration did not substantially improve primary tumour detection beyond conventional sequences. Mesorectal fascia (MRF) invasion was identified in 6 patients (12%), indicating a threatened or positive CRM in these cases. Extramural vascular invasion (EMVI) was detected in 11 patients (22%), manifesting as intermediate T2 signal intensity within mesorectal vessels with focal enlargement and wall irregularity. Lymph node involvement was identified in 27 patients (54%), with the mesorectal compartment being the most commonly affected (54%), followed by iliac nodes (30%), para-aortic nodes (12%), and obturator nodes (8%).

All nodal involvement cases were categorised as N1 stage. The mean size of the smallest positive node was 7.07 ± 2.09 mm. Only 2 patients (4%) exhibited distant metastasis to solid organs (bone and liver). The key imaging findings are summarised in Table 3.

Table 3: Key MRI Findings: Tumour Location, Vascular Invasion, and Nodal Status (N=50)

Parameter	Subgroup	Number of Patients	Percentage (%)
Tumour Location	High rectum (>10 cm)	14	28%
	Mid rectum (5–10 cm)	32	64%
	Low rectum (<5 cm)	4	8%
MRF Invasion	Present	6	12%
	Absent	44	88%
EMVI	Present	11	22%
	Absent	39	78%
Lymph Node Status	Involved	27	54%
	Not Involved	23	46%
Distant Metastasis	Present	2	4%
	Absent	48	96%

Analysis of the relationship between EMVI, lymph node morphological features, DWI characteristics, and nodal metastasis revealed several significant associations. Among the 11 patients with EMVI, all 11 (100%) demonstrated regional nodal involvement, and 9 (82%) showed distant nodal metastasis.

In contrast, among the 39 patients without EMVI, only 16 (41%) had regional nodal involvement and 6 (15%) had distant nodal metastasis. Lymph node morphology also demonstrated a strong relationship with metastatic involvement; of the 27 node-positive patients, 15 (56%) had irregular nodal margins, all of whom showed regional involvement and 9 had distant nodal spread, compared to only 6 of 12 (50%) with regular margins demonstrating distant nodal metastasis.

Diffusion restriction on DWI was the most sensitive marker: 24 of 27 node-positive patients (89%) showed diffuse restriction, with 14 demonstrating distant nodal involvement, versus only 1 of 3 non-restrictive nodes with distant spread. These findings are detailed in Table 4.

Table 4: Correlation of EMVI, Lymph Node Morphology, and DWI Restriction with Nodal Metastasis

Feature	Subgroup (n)	Regional Nodal Mets	Distant Nodal Mets
EMVI	Present (n=11)	11 (100%)	9 (82%)
	Absent (n=39)	16 (41%)	6 (15%)
Node Morphology	Irregular (n=15)	15 (100%)	9 (60%)
	Regular (n=12)	12 (100%)	6 (50%)
DWI Restriction	Present (n=24)	24 (100%)	14 (58%)
	Absent (n=3)	3 (100%)	1 (33%)

Surgical intervention was performed in 26 patients, all of whom underwent postoperative HPE staging. MRI staging in these patients revealed T2 in 19 cases, T3A in 6, and T3B in 1 case, which exactly matched the HPE staging distribution — demonstrating near-perfect agreement at the group level.

At the individual case level, MRI T-staging showed a sensitivity of 89%, specificity of 71%, and overall accuracy of 86.42% for T2 tumours. For T3A tumours, sensitivity was 66.67% with a specificity of 89.47% and accuracy of 84.10%. T3B tumours yielded 100% sensitivity, specificity, and accuracy, albeit in a small subgroup (n=1). The cross-tabulation of HPE staging versus MRI staging and the diagnostic performance parameters are presented in Table 5.

These results are consistent with published benchmarks for high-resolution pelvic MRI staging, confirming its role as an accurate non-invasive preoperative staging tool [13,14].

Table 5: Diagnostic Performance of MRI T-Staging Compared with Histopathological Examination (HPE) as Reference Standard (N=26)

T Stage	HPE Cases (n)	MRI Correct (n)	Sensitivity (%)	Specificity (%)	Accuracy (%)
T2	19	17	89.0%	71.0%	86.42%
T3A	6	4	66.67%	89.47%	84.10%
T3B	1	1	100%	100%	100%

Among the 31 previously treated patients who had undergone chemoradiotherapy, tumour regression grading was performed using DWI and DCE-MRI. The majority (55%) demonstrated Grade 3 regression (more than 50% fibrosis with residual viable tumour), followed by Grade 4 (22%), Grade 1 complete response (13%), and Grade 2 (10%). Treatment-related complications were observed in 8 patients in total (16%), of whom 2 were newly diagnosed patients and 6 were post-chemoradiotherapy cases, reflecting the inherent morbidity of multimodal rectal cancer treatment.

Discussion

This prospective hospital-based study evaluated the role of 1.5-Tesla MRI in preoperative staging of 50 patients with carcinoma rectum and correlated the findings with peroperative and histopathological data. Our findings demonstrate that MRI provides highly accurate staging information across multiple dimensions of tumour assessment and is well-suited for guiding individualised treatment planning.

The epidemiological profile of our study cohort aligns with globally reported trends. Most patients (70%) were above 50 years of age, consistent with the recognized association between advancing age and colorectal cancer risk [2,3]. The male predominance (male-to-female ratio 2.8:1) observed in our study is in agreement with population-based incidence data from both developed and developing nations [1]. The predominance of mid-rectal adenocarcinoma (64%) is expected, as this anatomical zone represents the most frequent site of rectal malignancy and poses particular challenges regarding sphincter preservation and CRM adequacy [5]. The small proportion of low rectal tumours (8%) in our cohort likely reflects referral patterns and prior treatment in a subset of patients.

The detection of rectal tumours using different MRI sequences in our study revealed that T2W imaging identified the growth in 90% of patients, while both DWI and contrast-enhanced imaging contributed in 86%.

Importantly, contrast administration did not substantially improve primary tumour detection beyond T2W imaging alone. This finding is consistent with recommendations from the European Society of Gastrointestinal and Abdominal Radiology (ESGAR) that high-resolution T2-weighted imaging without fat suppression serves as the primary sequence for rectal cancer staging [8,9]. Contrast sequences, however, retain value in the post-treatment context for differentiating viable tumour from fibrosis and oedema.

MRF invasion was identified in 12% of cases in our study, indicative of a threatened or positive CRM. CRM positivity is one of the most significant prognostic determinants in rectal cancer; studies have demonstrated that a positive CRM is associated with an approximately three-fold increase in local recurrence risk [11]. EMVI was detected in 22% of patients in our cohort. Consistent with established literature, our data confirmed that EMVI was strongly correlated with both regional and distant nodal spread — all 11 EMVI-positive patients had regional nodal involvement, and 82% had distant nodal metastasis, compared to only 15% of EMVI-negative patients [15]. MRI detection of EMVI using the T2W criterion of intermediate signal within mesorectal vessels has been shown to have moderate sensitivity and high specificity, serving as an independent predictor of haematogenous metastasis [16].

Lymph node staging remains the most challenging aspect of rectal MRI interpretation. In our study, nodal involvement was identified in 54% of patients, primarily in the mesorectal compartment. A key finding was the mean size of the smallest positive node (7.07 ± 2.09 mm), underscoring the well-documented limitation that size alone is an insufficient criterion for nodal characterisation, as 30–50% of metastatic deposits occur in nodes smaller than 5 mm [17,18]. Our analysis demonstrated that irregular nodal morphology and diffuse diffusion restriction on DWI were significantly associated with distant nodal spread. Diffuse DWI restriction was the most sensitive marker, present in 89% of node-positive cases, consistent with reports demonstrating DWI superiority over morphological criteria for detecting sub-centimetre metastatic nodes [19].

The central finding of this study was the high diagnostic accuracy of MRI T-staging when validated against HPE. Sensitivity of 89% and overall accuracy of 86.42% for T2 stage, and accuracy of 84.10% for T3A, are consistent with the published literature. In a seminal meta-analysis by Al-Sukhni et al., MRI demonstrated 87% sensitivity for tumour T-staging and 77% sensitivity for nodal involvement assessment [20]. Similarly, Chatterjee et al. reported MRI sensitivities of 80–90% for T-stage determination, mirroring our results. The occasional overstaging of T3A tumours (sensitivity 66.67%) reflects the well-known challenge of distinguishing desmoplastic reaction and pericolonic inflammation from true tumour infiltration — a limitation inherent to T2W imaging that is recognised across multiple studies [13,14].

Post-treatment restaging in our cohort of 31 chemoradiotherapy-treated patients revealed a Grade 3 regression (partial response with residual

tumour in >50% fibrosis) in the majority (55%), with complete radiological response (Grade 1) achieved in 13%. DWI played a pivotal role in identifying residual tumour signal from treatment-related fibrosis, as intermediate signal on T2W imaging is non-specific in the post-treatment setting [12].

These findings corroborate studies reporting that multiparametric MRI, incorporating DWI and DCE sequences, offers superior post-CRT restaging accuracy compared to conventional T2W imaging alone [9]. The ability to identify complete responders preoperatively is increasingly important given the emerging interest in organ-preservation strategies in rectal cancer management.

Conclusion

This study affirms that MRI is the most comprehensive and accurate non-invasive modality for the preoperative assessment of carcinoma rectum. It reliably characterises T-stage, CRM status, EMVI, lymph node morphology and distribution, and treatment response with diagnostic accuracy comparable to the gold standard histopathological examination.

MRI T-staging in this cohort demonstrated sensitivities of 66.67–100% and overall accuracy of 84–100% across staging categories, directly influencing surgical planning and multidisciplinary treatment decisions.

DWI sequences were particularly valuable in the post-treatment surveillance setting, enabling identification of residual or recurrent tumour from fibrosis. Contrast-enhanced sequences did not add significant diagnostic benefit for primary tumour detection but remain relevant in the assessment of treatment response and nodal characterisation.

Given its high accuracy, reproducibility, and safety profile, MRI should be universally adopted as the first-line staging investigation in all patients with rectal carcinoma, interpreted within the framework of a dedicated multidisciplinary team. Future work should focus on standardising post-CRT restaging protocols and establishing validated DWI criteria for nodal characterisation in the Indian population.

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