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Accuracy of MRI in Predicting Circumferential Resection Margin and Mesorectal Fascia Involvement for Locally Advanced Rectal Cancer Keeping Operative Findings as a Gold Standard

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ABSTRACT

Background: Locally advanced rectal cancer requires precise preoperative staging in order to allow perioperative planning and the best oncological outcomes. MRI has become the norm in the evaluation of circumferential resection margin and involvement of the mesorectal fascia. Thorough analysis of these parameters assists in the decision regarding neoadjuvant therapy and provides an estimate of the risk for local recurrence. **Objective:** To determine the accuracy of magnetic resonance imaging in determining the circumferential resection margin involvement and mesorectal fascia involvement for patients with locally advanced rectal cancer, while using operative findings as the gold standard. **Study Design:** Cross-sectional validation study. **Duration and Place of Study:** The study was conducted from June to November 2024 at the Department of Diagnostic Radiology, Shaikh Zayed Hospital, Lahore. **Methodology:** A total of 200 patients aged 20–70 years undergoing surgery for rectal carcinoma were enrolled. High-resolution pelvic MRI was performed using a 1.5T scanner, and findings regarding CRM and MRF involvement were recorded. Surgical assessment served as the gold standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated. **Results:** The mean age of patients was 47.23 ± 9.22 years with a mean symptom duration of 6.50 ± 3.08 months. MRI demonstrated a sensitivity of 85.90%, specificity of 90.70%, and diagnostic accuracy of 89.00%. PPV and NPV were 83.60% and 92.10%, respectively. Diagnostic performance was higher in females (96.00% accuracy), younger patients (≤40 years), and those with shorter symptom duration (≤6 months). **Conclusion:** MRI is a highly accurate and reliable modality for preoperative assessment of CRM and mesorectal fascia involvement in locally advanced rectal cancer.

INTRODUCTION

Magnetic Resonance Imaging (MRI) has emerged as the gold standard imaging modality in preoperative staging of locally advanced rectal malignancy, and in particular in assessing circumferential resection margin (CRM) involvement and mesorectal fascia (MRF) involvement.[1] Its superb resolution is able to delineate the spatial relationship of the tumor to surrounding tissues in excellent detail and is most important in preoperative surgical decision-making.[2] A determination of whether the malignancy is within 1 mm of the mesorectal fascia is one of the most powerful preoperative predictors of CRM involvement and is associated directly with risk for local recurrence and long-term oncologic outcomes.[3]

MRI provides valuable information by defining the extent of tumor invasion into the mesorectum and enables T-stage differentiation and more accurate assessment of nodal involvement.[4] Assessment of the MRF with MRI aids in staging tumors as resectable or requiring neoadjuvant chemoradiation therapy.[5] Preoperative therapy is generally advised when the MRF is at risk or involved to achieve tumor downstaging and maximize the chance of achieving a negative CRM.[6] The prognostic performance of MRI for CRM involvement has been validated in numerous prospective studies and cements its essential role in multidisciplinary rectal cancer management.[7]

In addition to surgical planning, MRI assists in risk stratification and tailoring therapy by defining low-risk and high-risk tumors.[8] This allows the clinician to avoid overtreatment in early-stage disease while permitting appropriate intensification of therapy in patients with a high risk.[9] Staging with MRI helps in the determination of the probability of sphincter preservation and in decision-making regarding total mesorectal excision or more limited resections.[10] Moreover, MRI has an essential function in post-neoadjuvant restaging in order to allow

assessment of response to therapy and residual disease, significant in further interventional planning.[11]

Despite its advantages, MRI interpretation requires experience to attain diagnostic competence with specific focus on marginally involved cases.[12] Interobserver variation can potentially influence the assessment of CRM and MRF involvement; hence reporting schemes such as the MERCURY criteria and template-based MRI reporting are recommended.[13]

Sim et al. reported that rectal MRI showed high accuracy when compared with intraoperative findings, with rater 1 achieving 92.7% and rater 2 94.7% accuracy.[14] Jung et al. found an overall accuracy of 90.7% for MRI in predicting tumor location, with site-specific accuracy of 93.5% above, 90.0% on, and 84.6% below the peritoneal reflection (p=0.061).[15] Khan et al. evaluated MRI for preoperative staging and found MRI-based T staging had 87.2% accuracy, with sensitivity of 80.77%, specificity of 93.10%, positive predictive value of 91.30%, and negative predictive value of 84.38%. For mesorectal fascia involvement, accuracy was 88.89%, with sensitivity of 75%, specificity of 92.86%, positive predictive value of 75%, and negative predictive value of 92.86% with a prevalence of 38.46%.[16]

There is a pressing need to evaluate the prognostic relevance of MRI in terms of circumferential resection margin and mesorectal fascia involvement in locally advanced rectal cancer based on their significant effects on surgical planning and prognosis. Preoperative staging accurately can help in selecting appropriate neoadjuvant therapy candidates and improving oncological outcomes. Despite widespread use, geographic variation in techniques in imaging and interobserver variation in interpretation pose the risk of affecting diagnostic accuracy and prompting us to conduct this study in the clinical scenario at our site.

METHODOLOGY

This cross-sectional study was carried out from June to November 2024 in the Department of Diagnostic Radiology at Sheikh Zayed Hospital, Lahore. A total of 200 patients undergoing surgery for rectal carcinoma were included. The sample size was determined based on an anticipated sensitivity of 80.7% with a 9% margin of error, specificity of 93% with a 4.5% margin of error, and a prevalence of 38.46%.[16]

The study population included both male and female patients aged between 20 and 70 years scheduled for elective rectal cancer surgery. Patients with prior surgical intervention for rectal malignancy, history of chemotherapy or radiotherapy, or the presence of metallic implants and contraindicated to MRI were excluded. After institutional ethical approval, written informed consent was obtained from all participants. Baseline information including age, gender, and relevant clinical history—such as rectal bleeding, altered bowel habits, and abdominal discomfort—was collected. Duration of symptoms was documented in weeks based on patient report.

High-resolution pelvic MRI scans were performed on all patients using a 1.5 Tesla HDX GE scanner. Imaging was conducted by a consultant radiologist with at least five years of experience. Tumour staging was assessed based on MRI signal intensity patterns: when the signal was limited to the submucosa, it was considered early-stage; invasion into the muscle layer or perirectal fat indicated more advanced disease; extension into adjacent organs was categorized as the most severe form. Tumour contact with the mesorectal fascia or proximity of less than 1 mm to the circumferential margin was considered evidence of involvement.

Following imaging, all patients underwent surgery by a consistent surgical team adhering to standardized protocols. Intraoperative assessment involved direct visualization and palpation to evaluate tumour extension. Involvement of the circumferential resection margin was recorded when tumour was seen or felt at or within 1 mm of the radial margin. Mesorectal fascia was considered involved if tumour penetration extended beyond the mesorectal envelope into adjacent tissues. MRI findings were compared with these surgical assessments to determine imaging accuracy.

Based on concordance between MRI and operative findings, cases were labelled accordingly. A case was classified as true positive when MRI indicated advanced disease (T3 or T4) with confirmed involvement of the circumferential margin or mesorectal fascia during surgery. A true negative was recorded when MRI suggested early disease (T1 or T2) and no intraoperative involvement of these structures was found. False positives were defined where MRI predicted invasion not confirmed during surgery, and false negatives when imaging failed to detect tumour spread that was later observed intraoperatively.

Data entry and statistical analysis were performed using SPSS version 27. Continuous variables like age and symptom duration were presented as mean ± standard deviation. Categorical variables such as gender, MRI T staging, operative findings, and diagnostic classifications were expressed as frequencies and percentages. Diagnostic performance indicators including sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were calculated. Stratification was done by age, duration of symptoms and gender, and post-stratification chi-square tests were applied to assess associations using 2X2 tables. A p-value of ≤0.05 was considered statistically significant.

RESULTS

The patient demographics revealed a mean age of 47.23±9.22 years with a mean symptom duration of 6.50±3.08 months, comprising 125 males (62.5%) and 75 females (37.5%), with T-staging distribution showing T1 in 87 patients (43.5%), T2 in 40 patients (20.0%), T3 in 46 patients (23.0%), and T4 in 27 patients (13.5%) as shown in Table-I.

Table I

Patient Demographics

Demographics		Mean ± SD
Age (years)		47.23±9.22
Duration (months)		6.50±3.08
Gender	Male n (%)	125 (62.5%)
	Female n (%)	75 (37.5%)
T Staging at MRI	T1 n (%)	87 (43.5%)
	T2 n (%)	40 (20.0%)
	T3 n (%)	46 (23.0%)
	T4 n (%)	27 (13.5%)

The overall diagnostic findings demonstrated that MRI identified 73 positive cases (36.5%) and 127 negative cases (63.5%), while surgical findings revealed 71 positive cases (35.5%) and 129 negative cases (64.5%) as shown in Table-II.

Table II

Overall results of MRI and Surgical Findings in diagnosis

Findings	MRI	Surgical Findings
Positive	73 (36.5%)	71 (35.5%)
Negative	127 (63.5%)	129 (64.5%)
Total	200 (100%)	200 (100%)

The comparative analysis between MRI and surgical findings showed 61 true positives, 12 false positives, 10 false negatives, and 117 true negatives, with a chi-square value of 115.97 and p-value of 0.000, indicating statistically significant correlation as shown in Table-III.

Table III

Comparison of MRI versus Surgical Findings in diagnosis

MRI	Surgical Findings		Total
	Positive	Negative	
Positive	61 (TP)	12 (FP)	73
Negative	10 (FN)	117 (TN)	127
Total	71	129	200

Chi square = 115.97
P value = 0.000
Key:
TP = True positive
FP = False positive
FN = False negative
TN = True negative

The diagnostic performance parameters demonstrated excellent accuracy with sensitivity of 85.90%, specificity of 90.70%, diagnostic accuracy of 89.00%, positive predictive value of 83.60%, and negative predictive value of 92.10% as shown in Table-IV.

Table IV

Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of MRI in diagnosis

Diagnostic Parameter	Result
Sensitivity	85.90%
Specificity	90.70%
Diagnostic Accuracy	89.00%
PPV	83.60%
NPV	92.10%

Stratified analysis revealed that patients aged ≤40 years showed superior performance with 85.00% sensitivity, 100.00% specificity, 94.10% diagnostic accuracy, 100.00% PPV, and 91.20% NPV, while those >40 years demonstrated 86.50% sensitivity, 83.60% specificity, 84.80% diagnostic accuracy, 78.90% PPV, and 89.70% NPV; gender-based analysis showed males had 86.50% sensitivity, 83.60% specificity, 84.80% diagnostic accuracy, 78.90% PPV, and 89.70% NPV, whereas females exhibited 84.20% sensitivity, 100.00% specificity, 96.00% diagnostic accuracy, 100.00% PPV, and 94.90% NPV; duration-based stratification indicated that patients with symptoms ≤6 months had 86.40% sensitivity, 100.00% specificity, 95.10% diagnostic accuracy, 100.00% PPV, and 92.90% NPV, while those with symptoms >6 months showed 85.20% sensitivity, 76.00% specificity, 79.20% diagnostic accuracy, 65.70% PPV, and 90.50% NPV as shown in Table-V.

Table V

Stratified analysis of Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of MRI in diagnosis with age, gender and duration of symptoms

Variables	Groups	Diagnostic Parameter	Result
Age (years)	≤40	Sen	85.00%
		Spec	100.00%
		DA	94.10%
		PPV	100.00%
		NPV	91.20%
	>40	Sen	86.50%
		Spec	83.60%
		DA	84.80%
		PPV	78.90%
		NPV	89.70%
Gender	Male	Sen	86.50%
		Spec	83.60%
		DA	84.80%
		PPV	78.90%
		NPV	89.70%
	Female	Sen	84.20%
		Spec	100.00%
		DA	96.00%
		PPV	100.00%
		NPV	94.90%
Duration of Symptoms (months)	≤6	Sen	86.40%
		Spec	100.00%
		DA	95.10%
		PPV	100.00%
		NPV	92.90%
	>6	Sen	85.20%
		Spec	76.00%
		DA	79.20%
		PPV	65.70%
		NPV	90.50%

DISCUSSION

This study demonstrated that MRI exhibits high diagnostic accuracy (89.00%) in predicting circumferential resection margin and mesorectal fascia involvement in locally advanced rectal cancer, with sensitivity of 85.90% and specificity of 90.70%. The excellent diagnostic performance can be attributed to MRI's superior soft tissue contrast resolution and multiplanar imaging capabilities, which enable precise visualization of the mesorectal fascia and its relationship to the tumor, allowing accurate assessment of potential circumferential resection margin involvement. The high specificity of 90.70% reflects MRI's ability to accurately identify cases without mesorectal fascia involvement, primarily due to its capacity to clearly delineate tissue planes and distinguish between tumor extension and surrounding inflammatory changes. The sensitivity of 85.90% indicates MRI's effectiveness in detecting true cases of circumferential resection margin involvement, though the 14.10% false negative rate may be explained by limitations in detecting microscopic tumor deposits or small areas of fascia involvement that fall below the spatial resolution threshold of current MRI technology. The positive predictive value of 83.60% suggests that when MRI indicates circumferential resection margin involvement, there is a high probability of actual involvement, while the negative predictive value of 92.10% demonstrates MRI's reliability in ruling out involvement when negative findings are present. The stratified analysis revealed superior diagnostic performance in younger patients (≤40 years) and those with shorter symptom duration (≤6

months), which may be related to reduced inflammatory changes and tissue fibrosis that can obscure tumor margins in older patients and those with prolonged symptoms, thereby enhancing image quality and diagnostic precision in these subgroups.

Our study results demonstrated excellent diagnostic performance of MRI in predicting circumferential resection margin (CRM) and mesorectal fascia involvement in locally advanced rectal cancer, with sensitivity of 85.90%, specificity of 90.70%, diagnostic accuracy of 89.00%, positive predictive value of 83.60%, and negative predictive value of 92.10%. These findings agree closely with some previous work but also show some important discrepancies which need to be addressed in full.

This study's 89.00% overall diagnostic accuracy has satisfactory agreement with Saeed et al. [17] in their reporting 89.6% diagnostic accuracy for MRI in diagnosing mesorectal fascia involvement in carcinoma rectum patients. This very good agreement in overall accuracy terms means MRI has had consistently very good performance in the heterogeneous population and clinical settings when diagnosing mesorectal fascia involvement that remains a significant factor in diagnosing CRM. Furthermore, our 85.90% sensitivity has close agreement with Saeed et al.[17] in their reporting 89% sensitivity, and our 90.70% specificity has close agreement with 90.4% specificity reported by Saeed et al. [17] These similar results in different studies are yet another testimony in support of MRI's reliability as a tool for this specific diagnosis.

However, when contrasted with Naz et al.[18] where they demonstrated lower diagnostic efficacy of 81.76% for MRI in the diagnosis of rectal carcinoma, findings in this study denote improved performance. This difference may be attributed to our study's specific focus on locally advanced rectal cancer and CRM/mesorectal fascia involvement, whereas Naz et al. [18] evaluated general rectal carcinoma detection. The more targeted approach in our study, combined with potential advances in MRI technology and interpretation techniques, may explain the improved diagnostic accuracy. Additionally, our specificity of 90.70% significantly exceeds the 79.5% specificity reported by Naz et al. [18] suggesting that our methodology or population characteristics may have contributed to better discrimination between positive and negative cases.

Our study's patient population showed T-staging distribution with T1 in 43.5%, T2 in 20.0%, T3 in 23.0%, and T4 in 13.5% of cases. When examining T-staging accuracy in the literature, Opara et al. [19] reported MRI accuracy of 85% for T staging, while our overall diagnostic accuracy of 89.00% for CRM and mesorectal fascia involvement suggests comparable or potentially superior performance. The slight difference may be attributed to the specific anatomical structures being evaluated, as CRM and mesorectal fascia assessment requires detailed evaluation of the relationship between tumor and surrounding structures rather than just tumor depth assessment.

Memon et al. [20] reported MRI sensitivity of 91% and specificity of 52% for preoperative tumor staging of colorectal carcinoma, showing higher sensitivity but significantly lower specificity compared to our findings. The markedly different specificity (52% vs. 90.70%) suggests that our study's focus on locally advanced rectal cancer with specific attention to CRM and mesorectal fascia involvement may have resulted in better discrimination of true negative cases. This difference could also reflect variations in imaging protocols, reader experience, or patient selection criteria between the studies.

The study by Sönmez et al. [21] using 1.0 Tesla MRI with phased-array coils reported variable accuracy depending on imaging technique, with thin-section MRI achieving 67% accuracy for CRM prediction compared to 50% with standard techniques. While their overall accuracy was lower than our 89.00%, their finding that technical refinements improve diagnostic performance supports the importance of optimal imaging protocols. Our superior results may reflect the use of more advanced MRI technology, higher field strength, or refined imaging sequences that have evolved since their study.

Sunitha et al. [22] reported perfect agreement with histopathology for CRM (κ=1.00) and EMVI (κ=1.00), with 100% diagnostic accuracy, which exceeds our findings. This discrepancy may be due to differences in study design, sample size, or specific patient populations. Their perfect correlation suggests either exceptional technical performance or a highly selected patient population, whereas our results may reflect more real-world clinical conditions with a broader patient spectrum.

The meta-analysis by Zhuang et al. [23] reported pooled sensitivity of 0.73 and specificity of 0.74 for MRI in lymph node staging of rectal cancer, which are considerably lower than our specificity of 90.70%. However, direct comparison is limited as our study focused on CRM and mesorectal fascia involvement rather than lymph node staging specifically. The superior specificity in our study may reflect the different anatomical targets being evaluated, as CRM and mesorectal fascia assessment may be more amenable to MRI evaluation than small lymph node metastases.

De La Pinta et al. [24] reported low accuracy (37.6%) for MRI restaging after neoadjuvant chemoradiotherapy, highlighting the challenges of post-treatment assessment. Our study's excellent performance likely reflects evaluation of treatment-naïve patients, as post-treatment changes including fibrosis, inflammation, and tissue necrosis can significantly complicate MRI interpretation. This comparison underscores the importance of timing MRI evaluation appropriately in the treatment sequence.

Our stratified analysis revealed several important findings that provide additional context for MRI performance. Patients age ≤40 years had better performance with 100.00% specificity and 94.10% diagnostic accuracy when compared with >40 years old (83.60% specificity and 84.80% diagnostic accuracy). Age difference can reflect increased tissue contrast in the patient's youth or differences in tumor biology affecting MRI features. Similarly, our gender analysis demonstrated females had greater specificity (100.00% compared with males 83.60%), which can reflect differences in anatomy or differences in pelvic anatomy that influence MRI interpretation.

The stratification by duration verified that the symptoms ≤6 months group did better (95.10% diagnostic accuracy) compared with the longer duration group (79.20% diagnostic accuracy). This supports the possibility that earlier detection may be reflected in better MRI performance, either because disease was less advanced or because fewer secondary changes were confounding interpretation.

Despite our study's benefits, there were some limitations that need to be stated. One, it was conducted in one tertiary care facility, which may limit generalizability in other settings with differences in patient population or imaging resources. Second, the sample size, although suitable for evaluation, was rather small and may show rather than reflect total disease variation. Third, interobserver variation analysis was not applied in MRI readings, which may compromise reproducibility across broader clinical practices. Future multicenter studies with larger sample sizes and standardized reporting protocols are recommended to validate and expand upon these results.

CONCLUSION

This study highlights the high diagnostic accuracy of MRI in predicting circumferential resection margin and mesorectal fascia involvement in patients with locally advanced rectal cancer, using operative findings as the gold standard. MRI demonstrated strong concordance with surgical outcomes, supporting its role as a reliable preoperative imaging modality. Stratified analysis further suggested better diagnostic performance in younger patients, females, and those with shorter symptom duration. These results affirm the utility of MRI in guiding clinical decision-making and optimizing surgical planning in rectal cancer management.

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