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THE ROLE OF MRI-DETECTED EXTRAMURAL VASCULAR INVASION AS A PREDICTOR OF REGIONAL AND DISTANT METASTASIS IN LOW RECTAL CANCER

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ABSTRACT
Extramural vascular invasion (EMVI) is an adverse feature of rectal cancer that can be identified on high-resolution magnetic resonance imaging (MRI) before treatment. This study examined associations between EMVI and metastatic disease, tumor stage, nodal status, and histologic differentiation in patients with low rectal cancer. Seventy-eight patients underwent pelvic MRI and computed tomography of the chest and abdomen; 32 subsequently underwent surgery. EMVI was assessed independently by two radiologists using vascular caliber, contour, intraluminal tumor signal, and extension beyond the vessel wall. Associations were tested with Pearson's chi-square test with Yates' correction. In the full cohort, EMVI was present in 24 patients. Distant metastases occurred in 11 of 24 EMVI-positive patients and 12 of 54 EMVI-negative patients, producing a significant association between EMVI and M stage, $\chi^2(1) = 4.22$, $p = .040$. No significant association was identified between EMVI and tumor differentiation, T stage, or regional nodal metastasis. These findings support MRI-detected EMVI as a clinically relevant marker of distant metastatic risk in low rectal cancer, while the small surgical subgroup limits inference regarding local stage and histologic grade.

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Keywords: *low rectal cancer, magnetic resonance imaging, extramural vascular invasion, distant metastasis, regional lymph nodes, tumor staging.*

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Introduction

Rectal cancer remains a major oncologic problem because local anatomy, patterns of spread, and treatment-related morbidity make accurate pretreatment staging essential. Tumors arising in the lower rectum are particularly demanding. The distal mesorectum narrows as it approaches the pelvic floor, and the tumor may lie close to the mesorectal fascia, levator ani muscles, sphincter complex, or intersphincteric plane. These relationships influence both the feasibility of sphincter preservation and the risk of an involved resection margin. Consequently, imaging must provide more than a conventional TNM category; it should depict the anatomical and biological features that may alter treatment planning.

High-resolution pelvic magnetic resonance imaging (MRI) is central to local staging because it offers strong soft-tissue contrast and multiplanar assessment without ionizing radiation. MRI can delineate the depth of extramural tumor extension, the relationship of the tumor to the mesorectal fascia, involvement of the pelvic floor and sphincters, regional nodal disease, tumor deposits, and vascular invasion. Contemporary European guidance treats MRI as a structured risk-assessment examination rather than a simple method of assigning T and N categories (Beets-Tan et al., 2018; ESGAR Rectal Imaging Guideline

Group, 2026). This approach is especially relevant in low rectal cancer, where small differences in the extent and direction of spread may affect surgical strategy.

Extramural vascular invasion (EMVI) refers to tumor extension into veins beyond the muscularis propria. On MRI, EMVI is recognized when tumor signal expands or distorts an extramural vessel, produces an irregular vascular contour, or extends along a venous channel. The MRI appearance has been formalized through a five-point grading approach in which higher scores reflect increasing confidence and severity of vascular involvement. Earlier work established that high-resolution MRI can identify prognostically important features of rectal cancer before surgery (Brown et al., 2003; Smith et al., 2008). Unlike histopathologic EMVI, which becomes available only after resection, MRI-detected EMVI (mrEMVI) can contribute to risk stratification at the time treatment decisions are being made.

The prognostic relevance of mrEMVI has been repeatedly associated with metastatic spread and survival. A meta-analysis of 1,262 patients reported substantially higher rates of synchronous and subsequent metastases in mrEMVI-positive tumors than in mrEMVI-negative tumors (Siddiqui et al., 2017). A later systematic review and meta-analysis likewise found poorer overall and disease-free survival among patients with baseline mrEMVI, and persistent mrEMVI after neoadjuvant treatment was associated with worse disease-free survival than radiologic regression (Tan et al., 2021). Cohort studies have also identified mrEMVI as an independent predictor of metachronous metastasis and disease-free survival (van den Broek et al., 2020; Di Fabio et al., 2024). These findings support the view that venous invasion captures an aspect of tumor behavior not fully represented by T or N stage alone.

Even so, the relationship between EMVI and other clinicopathologic characteristics is not uniform across patient groups. Vascular invasion is more often encountered in tumors extending beyond the muscularis propria, but small samples, differences in MRI technique, treatment exposure, and pathologic verification can weaken observed associations. Histologic differentiation may also relate to metastatic behavior, although evidence specific to low rectal tumors and mrEMVI is limited. A focused evaluation of low rectal cancer is therefore useful because anatomical constraints and treatment choices differ from those for mid- and upper-rectal tumors.

The present study examined whether EMVI was associated with distant metastasis, regional nodal metastasis, T stage, and histologic differentiation in patients with low rectal cancer. A further objective was to assess the clinical value of EMVI identified during the initial MRI examination as a marker that could complement conventional staging. The analysis was based on the original cohort and contingency tables reported in the study; no attempt was made to infer unreported outcomes or to replace the observed data with estimates from external literature.

Materials and Methods

The study included 78 patients with low rectal cancer at different stages of disease. The mean age was 62.2 years (SD = 9.3); 47 patients (60.3%) were men and 31 (39.7%) were women. Histologic diagnosis was established from biopsy material obtained during colonoscopy or rectosigmoidoscopy. Moderately differentiated adenocarcinoma was identified in 57 patients, poorly differentiated adenocarcinoma in 13, and well-differentiated adenocarcinoma in 8. Thirty-two patients subsequently underwent surgical treatment and constituted the subgroup used for analyses requiring postoperative or surgical-pathologic information.

All patients underwent pelvic MRI and computed tomography (CT) of the chest and abdomen as part of comprehensive staging. Pelvic MRI was performed on a GE Optima MR450w GEM system using surface and integrated table-mounted coils. The protocol included T2-weighted sequences in the axial, sagittal, and coronal planes with 3-mm section thickness, an axial T1-weighted sequence, and axial diffusion-weighted imaging with b values of 500 and 1,000 s/mm². CT examinations were performed on a Siemens SOMATOM Emotion 6 scanner with bolus administration of nonionic iodinated contrast material.

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The combined examinations were used to assess local tumor extent, regional nodes, and distant metastatic disease.

Two radiologists independently evaluated the imaging findings. The study retained findings when both readers agreed on the relevant diagnostic feature. MRI criteria for EMVI included tumor-equivalent signal within the lumen of an extramural venous structure, venous dilatation, wall thickening or irregularity, intravascular tumor deposits, and tumor extension through the vascular wall into surrounding pararectal tissue. These criteria are consistent with the morphologic concept underlying established mrEMVI assessment, in which expansion, irregularity, and replacement of a vessel by tumor signal increase confidence that venous invasion is present (Smith et al., 2008).

For the surgical subgroup, the distribution by histologic differentiation was 24 moderately differentiated, 4 poorly differentiated, and 4 well-differentiated adenocarcinomas. The T-stage distribution was T1 in 1 patient, T2 in 2, T3 in 19, and T4 in 10. Histopathologic examination of surgical specimens was used to verify vascular invasion where such confirmation was available, while biopsy specimens established tumor morphology. The source dataset reports several EMVI counts across different analytic subsets; therefore, the statistical analyses below follow the denominators and cell counts specified in each original contingency table rather than treating those subsets as interchangeable.

Associations were examined with Pearson's chi-square test using Yates' continuity correction for 2 × 2 tables. For the analysis of differentiation, well-differentiated tumors were excluded because no EMVI-positive cases occurred in that category, leaving 28 moderately or poorly differentiated tumors. For the T-stage analysis, T1 and T2 tumors were excluded because no EMVI-positive cases occurred in those groups. Statistical significance was interpreted at $p < .05$. Because the available dataset did not provide confidence intervals, multivariable models, or time-to-event outcomes, the analysis was limited to the reported cross-sectional associations.

Results

Among the 32 surgically treated patients, moderately differentiated adenocarcinoma accounted for 75.0% of tumors, whereas well- and poorly differentiated adenocarcinomas each accounted for 12.5% (Table 1). Most surgically treated tumors were locally advanced: 19 patients (59.4%) had T3 disease and 10 (31.2%) had T4 disease; only 3 patients had T1 or T2 tumors (Table 2).

The differentiation analysis included 28 patients with moderately or poorly differentiated adenocarcinoma. EMVI was present in 6 of 24 moderately differentiated tumors and 3 of 4 poorly differentiated tumors (Table 3). Pearson's chi-square test with Yates' correction yielded $\chi^2(1) = 1.97$, $p = .160$. Thus, the observed distribution did not provide evidence of an association between EMVI and histologic differentiation in this surgical subset. The marked numerical difference in proportions should be interpreted cautiously because the poorly differentiated group contained only four patients.

For T stage, the contingency analysis included 19 T3 and 10 T4 tumors. EMVI was recorded in 5 T3 and 4 T4 cases, while EMVI was absent in 14 and 6 cases, respectively (Table 4). The association was not statistically significant, $\chi^2(1) = 0.11$, $p = .740$. The exclusion of the three T1–T2 cases and the modest number of EMVI-positive observations restricted the ability to detect differences between T3 and T4 disease.

Regional nodal status was also not significantly associated with EMVI in the surgical group. Regional lymph node metastases were present in 4 of 9 EMVI-positive patients and in 8 of 23 EMVI-negative patients (Table 5). The corrected chi-square statistic was $\chi^2(1) = 0.21$, $p = .647$. These data do not show that EMVI status and regional nodal metastasis were statistically dependent within the available sample.

A different pattern was observed for distant metastasis in the full cohort of 78 patients. M1 disease was present in 11 of 24 patients with EMVI and 12 of 54 patients without EMVI; M0 disease was present in 13 and 42 patients, respectively (Table 6). The association between EMVI and M stage reached statistical

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significance, $\chi^2(1) = 4.22$, $p = .040$. Descriptively, distant metastatic disease was therefore more frequent among patients classified as EMVI-positive on the study's imaging assessment.

The detailed metastatic distribution further showed liver and pelvic nodal metastases in four EMVI-positive and three EMVI-negative patients, pulmonary metastases in two EMVI-positive patients, combined liver and lung metastases in two EMVI-positive patients, and prostatic metastases in three EMVI-positive patients. Five EMVI-negative patients had pelvic nodal metastases without the distant patterns listed in the table. No distant metastases were recorded in 13 of 24 EMVI-positive patients and 46 of 54 EMVI-negative patients (Table 7). These category counts are descriptive and were not subjected to separate inferential tests in the source analysis.

Discussion

The principal finding was the significant association between EMVI and distant metastatic disease. In contrast, EMVI was not significantly associated with histologic differentiation, T3 versus T4 stage, or regional nodal metastasis in the analyzed subsets. This pattern is clinically plausible because EMVI represents direct access of tumor to extramural venous channels, a route that can facilitate hematogenous dissemination. The result also aligns with published evidence in which mrEMVI has shown a strong relationship with synchronous and metachronous metastasis (Siddiqui et al., 2017; Sohn et al., 2015). The present data should not be taken to show that EMVI causes metastasis, but they support its use as a marker of a phenotype associated with systemic spread.

The magnitude and consistency of prior findings strengthen the relevance of the observed M-stage association. Siddiqui et al. (2017) reported that mrEMVI-positive rectal cancers were more likely to present with metastatic disease and to develop metastases during follow-up. In a Dutch cohort, van den Broek et al. (2020) found that mrEMVI remained a significant predictor of metachronous metastasis after consideration of several other MRI features. More recent work has similarly linked MRI-predicted tumor deposits and EMVI with disease-free survival after resection (Di Fabio et al., 2024). The current study is smaller and focused on low rectal cancer, yet its direction of association is consistent with this broader literature.

The absence of a significant relationship between EMVI and nodal metastasis deserves separate consideration. Nodal spread and venous invasion are distinct routes of tumor dissemination, and MRI assessment of lymph nodes is itself imperfect because size alone does not reliably distinguish benign from malignant nodes. Contemporary MRI guidance therefore uses morphology, location, and patient-level patterns rather than a single size criterion for mesorectal nodal staging (ESGAR Rectal Imaging Guideline Group, 2026). In this study, 4 of 9 EMVI-positive patients and 8 of 23 EMVI-negative patients had regional nodal metastases. With these small cell counts, a nonsignificant result cannot establish equivalence between groups; it indicates only that the available sample did not demonstrate a statistically reliable association.

A similar limitation applies to T stage. EMVI generally requires tumor extension beyond the muscularis propria and is consequently most relevant in T3–T4 disease. However, once analysis is restricted to advanced T categories, a simple comparison of T3 with T4 may not capture the biologic variation that determines venous invasion. Extramural depth, vessel caliber, tumor deposits, mesorectal fascia involvement, and treatment exposure may all add information that is lost in a two-category table. MRI studies have long emphasized the prognostic importance of features beyond categorical T stage, including circumferential resection margin status and depth of extramural extension (MERCURY Study Group, 2007; Taylor et al., 2014).

Histologic differentiation showed a pronounced descriptive imbalance—EMVI in 3 of 4 poorly differentiated tumors compared with 6 of 24 moderately differentiated tumors—but the corrected chi-square test was not significant. The small poorly differentiated subgroup makes the estimate unstable, and exclusion of well-differentiated tumors further narrows inference. A larger cohort would be needed to

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determine whether grade contributes independently to EMVI risk in low rectal cancer. Future analyses could retain all differentiation categories and use exact or regression-based methods when sparse cells are present.

From an imaging perspective, the findings reinforce the value of deliberately reporting EMVI at baseline MRI. A structured report should document EMVI status alongside tumor height, T category, mesorectal fascia relationship, sphincter and pelvic-floor involvement in low tumors, nodal disease, and relevant tumor deposits. Current ESGAR recommendations explicitly include EMVI within primary staging and restaging frameworks (ESGAR Rectal Imaging Guideline Group, 2026). Consistent reporting is important because EMVI can be visible before treatment and may change after neoadjuvant therapy. Meta-analytic evidence suggests that persistent mrEMVI after treatment carries an adverse prognosis compared with radiologic regression (Tan et al., 2021).

Several limitations constrain interpretation. First, the full cohort comprised 78 patients, but only 32 underwent surgery, leaving small analytic groups for morphology, T stage, and nodal comparisons. Second, the study used univariable chi-square analyses; potential confounding by tumor size, extramural depth, mesorectal fascia status, treatment, or other risk features could not be addressed. Third, the source dataset reports EMVI counts for different subsets that are not numerically identical. The present revision therefore preserves the denominators of the original contingency tables and avoids combining them into a single derived estimate. Fourth, interobserver agreement was handled by requiring concordance between two radiologists, but a kappa statistic or other reproducibility measure was not reported. Finally, the cross-sectional M-stage analysis does not distinguish synchronous disease from metastases arising during longitudinal follow-up.

These limitations also indicate practical directions for further research. A prospective design with a prespecified MRI protocol, structured EMVI scoring, blinded readers, histopathologic correlation, and longitudinal surveillance would permit stronger evaluation of diagnostic and prognostic performance. Multivariable models could test whether mrEMVI adds information beyond T category, nodal status, mesorectal fascia involvement, tumor deposits, and histologic grade. Reporting effect sizes with confidence intervals would also be more informative than significance testing alone. In low rectal cancer specifically, analyses should consider the anatomical relationship to the sphincter complex and pelvic floor, because these features influence local management even when the principal prognostic question concerns systemic dissemination.

Conclusion

In this cohort of patients with low rectal cancer, EMVI was significantly associated with distant metastatic disease but not with histologic differentiation, T3 versus T4 stage, or regional nodal metastasis. The result supports the inclusion of EMVI in baseline MRI assessment as a marker that may identify patients with a greater burden of systemic risk. The finding should be interpreted within the limits of the small surgical subgroup, univariable analysis, and inconsistent EMVI denominators across source subsets. Larger prospective studies with standardized MRI scoring, reproducibility analysis, and longitudinal outcomes are needed to establish the independent prognostic contribution of mrEMVI and to clarify how it should be integrated with other MRI risk features in treatment planning.

Tables

Table 1

Distribution of Surgically Treated Patients by Histologic Differentiation

Histologic differentiation	n	%
Well differentiated	4	12.5
Moderately differentiated	24	75.0
Poorly differentiated	4	12.5
Total	32	100.0

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Table 2

Distribution of Surgically Treated Patients by T Stage

T stage	n	%
T1	1	3.1
T2	2	6.3
T3	19	59.4
T4	10	31.2
Total	32	100.0

Table 3

Association Between EMVI and Histologic Differentiation in the Surgical Subgroup

EMVI status	Moderately differentiated	Poorly differentiated	Total
Present	6	3	9
Absent	18	1	19
Total	24	4	28

Note. $\chi^2(1) = 1.97$, $p = .160$.

Table 4

Association Between EMVI and T Stage in the Surgical Subgroup

EMVI status	T3	T4	Total
Present	5	4	9
Absent	14	6	20
Total	19	10	29

Note. $\chi^2(1) = 0.11$, $p = .740$.

Table 5

Association Between EMVI and Regional Lymph Node Metastasis

EMVI status	Nodes present	Nodes absent	Total
Present	4	5	9
Absent	8	15	23
Total	12	20	32

Note. $\chi^2(1) = 0.21$, $p = .647$.

Table 6

Association Between EMVI and Distant Metastasis in the Full Cohort

EMVI status	M0	M1	Total
Present	13	11	24
Absent	42	12	54
Total	55	23	78

Note. $\chi^2(1) = 4.22$, $p = .040$.

Table 7

Distribution of Metastatic Findings by EMVI Status

Characteristic	EMVI present (n = 24)	EMVI absent (n = 54)
Liver and pelvic lymph node metastases	4	3
Pulmonary metastases	2	0
Liver and lung metastases	2	0
Prostatic metastases	3	0
Pelvic lymph node metastases	0	5
No distant metastases	13	46
Total	24	54

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