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Research Article

Study of Correlation between MRI Morphology of Primary Tumor and Extramural Vascular Invasion in Rectal Cancer

Baohua Lv,[1,2] Kai Shang,[3] Ke Wu,[2] Yuanzhong Xie,[2] Zhenghan Yang,[1] Zhenchang Wang,[1] and Erhu Jin[1]

[1]*Department of Radiology, Beijing Friendship Hospital, Capital Medical University, Beijing, China*
[2]*Department of Radiology, Taian Central Hospital, Taian, China*
[3]*Department of Orthopedic, Taian Central Hospital, Taian, China*

Correspondence should be addressed to Yuanzhong Xie; xie01088@126.com

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Introduction. In clinical settings, nodular projection (NP) and cord sign (CS) at the tumor edge and irregular nodules (IN) in the mesorectum often appeared together with extramural vascular invasion (EMVI). We aim to evaluate the diagnostic efficiency of the MRI morphology of primary tumor in predicting EMVI in patients with rectal cancer (RC). *Methods*. This retrospective study included 156 patients with RC. Clinical and imaging factors including NP at the primary tumor's edge, CS at the primary tumor's edge, maximal extramural depth (EMD), IN in the mesorectum, growth pattern, tumor length, range of rectal wall invaded (RRWI) by tumor, peritoneal reflex invasion by surgery, and pathology-proven local node involvement (PLN) were evaluated. Then, ROC curve was drawn to depict the meaningful indicators in multivariate analyses. *Results*. There were 53 (34%) patients with pathological extramural venous invasion (pEMVI). Among the clinical and imaging factors evaluated, NP, CS, IN, EMD, PLN, differentiation, and peritoneal reflex invasion were significantly associated with pEMVI. NP and PLN were independent predictors of EMVI. Areas under the ROC curve (AUC) of NP for prediction of EMVI was 0.82 (95% CI, 0.74–0.90), with a sensitivity of 73.58%, a specificity of 90.29%, a positive predictive value (PPV) of 75.59%, a negative predictive value (NPV) of 86.92%, and an accuracy of 84.62%, respectively. *Conclusions*. Patients with primary tumor with EMVI usually showed NP and CS. NP was an independent predictor of EMVI and helpful for the diagnosis of EMVI in RC patients.

1. Introduction

Tumor stage and the status of surgical margins are closely related to the survival of patients with rectal cancer [1, 2]. The other features including tumor grade, venous invasion, and perineural invasion also serve as important prognostic factors for these patients [3]. Extramural venous invasion (EMVI), defined as tumor cells found in blood vessels beyond the muscularis propria [4], has been well acknowledged as an independent predictor for local or distal recurrence [5–7], lymph node metastasis [8], and decline of overall survival (OS) [9–11]. Traditionally, EMVI is diagnosed because of the postsurgical pathology and plays no role in the preoperative treatment plans for rectal cancer patients. MRI, especially high-resolution T2-weighted imaging (HRT2WI), shows a very high resolution to soft tissues. It can clearly display the microscopic structure around the rectum without affecting the tumors and their peripheral tissues prior to surgery. Therefore, MRI is considered as an accurate and reproducible model for the preoperative identification of EMVI (mrEMVI) as well as other local prognostic features that can be helpful to treatment plans [12–18]. Nowadays, it is used as a standard for evaluating the preoperative local staging of rectal cancer and can identify EMVI in an effective manner [19].

In 1981, Talbot et al. firstly reported the effects of EMVI on the prognosis of cancer patients [7]. In 2008, Smith et al. firstly used high-resolution magnetic resonance imaging (HRMRI) to detect EMVI in rectal cancer and proposed a five-level scoring system to assess EMVI [19]. EMVI

occurred in about 17%–52% of colorectal cancer patients [19, 20]. Particularly, in those with advanced rectal cancer, the probability of vascular invasion in fat interstitial tissue around the mass showed an increased trend. One of the diagnostic criteria of EMVI is tumor signal extending into a signal void vascular structure on HRT2WI [21]. However, blood vessels do not always appear flow-void effects because of varying directions of the vessels and magnetic fields as well as different scan planes. Furthermore, the five-level scoring system on HRT2WI is not adequate for EMVI detection due to lower sensitivities (28.2% to 62%) [19, 22, 23]. Therefore, determination of EMVI based on vascular changes shows lower accuracy. In clinical settings, nodular projection (NP) and cord sign (CS) at the tumor edge and irregular nodules (IN) in the mesorectum often appeared together with EMVI. Thus, we speculated that the EMVI-positive rectal tumors may have certain morphological features. On this basis, indirect signs should also be included for the determination of EMVI. In a previous study [19], NP of rectal cancer was already mentioned by Smith, but no detailed studies were conducted afterwards on the NP, the other morphological features, and the vessels invaded by IN. In this study, we aim to investigate the correlation of MRI morphology of primary tumor in rectal cancer with EMVI on MRI.

2. Methods

2.1. Patients. Rectal cancer patients admitted to the Radiology Department of Beijing Friendship Hospital between June 2014 and April 2018 were included in this study. The rectal cancer was diagnosed based on postoperative pathology. All patients had undergone surgical resection within 6 weeks after preoperative MRI. The exclusion criteria were as follows: (i) patients with rectal mucinous adenocarcinoma, (ii) those with a time interval of more than 6 weeks between surgery and MRI, (iii) those received palliative surgery for the treatment, (iv) those with incomplete pathologic data or MRI data, and (v) those with blurry images. Written informed consent was waived as this was a retrospective study. The study protocols were approved by the Institutional Review Board of Capital Medical University.

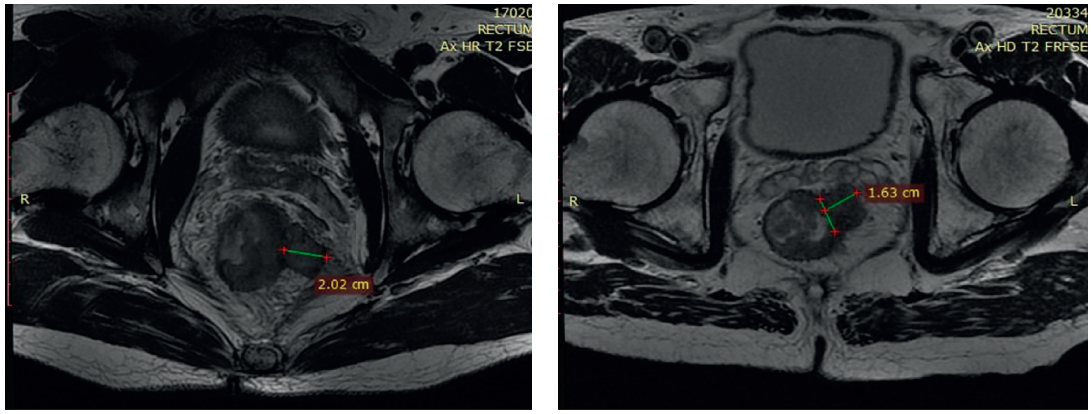
2.2. MRI Scan. MRI was performed using a 3.0 T system (Signa Excite HD 3.0 T, GE Healthcare, Milwaukee, WI, USA) equipped with a phased-array surface coil. The procedures comprised of bowel preparation and intravenous contrast enhancement, and intravenous antispasmodic agents were not mandatory. For the observation of pulse sequences, fast spin-echo sagittal HRT2WI was given with a thickness of 4 mm, an intersection gap of 1 mm, and a TR/TE of 4,000 ms/102 ms, in the absence of fat saturation. The matrix size was 320×256. The ETL was 16, and NEX was 4. In addition, axial (perpendicular to the long axis of the rectum) HRT2WI was performed with a contiguous section thickness of 3 mm, TR/TE of 4,000 ms/102 ms as well as FOV of 16×16 cm without fat saturation. The matrix size was 320×256. The ETL and NEX were 16 and 4, respectively. For dynamic contrast-enhanced MRI (DCE-MR), a LAVA/LAVA-XV sequence was performed in the presence of fat saturation, a thickness of 3 mm, FOV of 36×36 cm, matrix size of 256×192, flip angle of 15°, and 40 consecutive phases. A bolus of Gd-DTPA (0.1 mmol/kg, Magnevist, Bayer Schering, Germany) was injected at a rate of 2 mL/s intravenously, followed by a saline flush before enhanced sequencing.

2.3. Imaging Interpretation. To detect morphology of primary tumor including NP, CS and growth pattern, IN, EMD, tumor length, the range of rectal wall invaded by tumor (RRWI) and relation with peritoneal reflex, the images from HRT2WI were mainly reviewed by two radiologists with 8 and 13 years of experience in abdominopelvic MRI, respectively. In cases of any disputes, the third experienced physician in gastrointestinal imaging joined in the communication until final consensus. All radiologists were informed about the inclusion criteria for this study, but they were blinded to the pathologic stages or pEMVI status of the patients.

2.4. Confirmation of Tumor Morphology in HRT2WI. NP was defined as tumor breaking through the muscular layer, leading to the formation of at least one nodule in the surrounding adipose tissues. CS referred to a cord extending from the mass into the surrounding adipose tissues, which was characterized by an irregularly thickened spiculation with coarse edges, and its diameter at the junction with the rectal wall was greater than 1 mm. The growth pattern of tumor was mainly circular infiltration and local growth. Local growth was defined as presence of tumor in a round-like or oval profile. Meanwhile, irregular mass and involvement of less than half of the rectal wall by tumor, together with a maximal width of more than half of the long diameter were also defined as local growth. IN was defined as presence of irregular nodules in the mesorectum presenting irregular forms, rough edges, lobulated appearance, or burrs in HRT2WI.

2.5. Measurement of the Maximal Extramural Depth (EMD) and RRWI. EMD was defined as the maximal distance from tumor to the muscularis propria of the rectum (Figure 1(a)). In cases of unrecognized muscularis propria, the distance between the line of the residual muscularis propria and the distal part of the mass and the outermost boundary of the tumor was measured on HRT2WI (Figure 1(b)) [24, 25]. Tumor length referred to the length between the upper and lower of tumor measured on sagittal T2WI along the midline of the bowel (Figure 2). The range of RRWI was measured in the circumference of the intestinal lumen on HRT2WI.

2.6. Other Imaging Factors. Three location relationships were available between primary tumor and peritoneal reflex. Upper was defined as the primary tumor located above peritoneal reflex. Middle was defined as the primary tumor



(a) (b)

Figure 1: Illustration of measurement of the tumor maximal extramural depth. (a) HRT2WI obtained from a 56-year-old male patient with rectal cancer (PT4N1) showed that the distance from the outermost boundary of the tumor to the residual muscularis was 2.02 cm. (b) HRT2WI obtained from a 69-year-old male patient with rectal cancer (PT3N0) showed that the distance between the attachment in the two muscularis propria breakthroughs and the outermost boundary of the tumor was 1.63 cm.

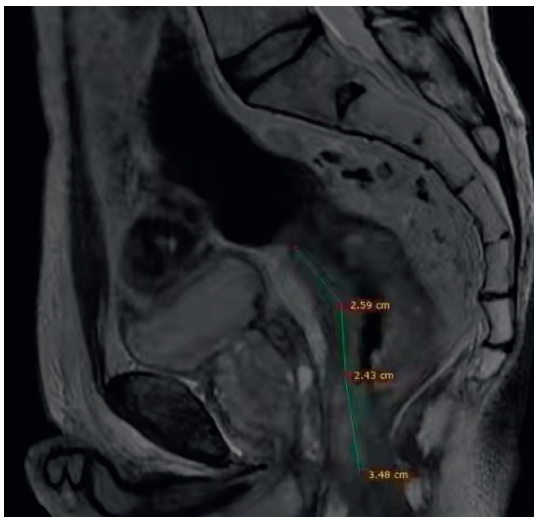


Figure 2: Illustration of measurement of tumor length. Sagittal T2-weighted imaging of a 65-year-old male patient with rectal cancer (PT3N1) showed that the tumor length was 8.50 cm.

with the same height of peritoneal reflex. Lower was defined as the primary tumor located beneath the peritoneal reflex [26].

2.7. Surgical and Clinicopathological Assessment. Radical surgery was performed within 6 weeks after MRI scan according to the principles of total mesorectal excision. After surgery, the specimens were fixed in formalin (10%) for at least 48 h before transverse slicing (i.e., perpendicular to the long axis of the rectum) at a thickness of 3 μm. Clinicopathologic factors were determined including T stage (behalf of local invasion depth), nodal status, differentiation, tumor size, and pEMVI. Tumor staging was performed according to the seventh edition of the TNM system [11], which was classified into well, moderately, or poorly differentiated stages. Tumor size was recorded as the longest diameter of the whole specimen. The presence of EMVI was confirmed when tumor tissue was present within an extramural space or within a tubular structure that was lined by endothelial cells, smooth muscles, or elastic fibers [10]. A pathologist experienced in colorectal pathology conducted the histopathologic examinations.

2.8. Statistical Analysis. All statistical analyses were performed using the SPSS 23.0 software. The chi-square test or t-test was used to analyze the correlations of clinical factors (i.e., age, gender, and PLN) and imaging features (i.e., NP, CS, IN, tumor length, growth pattern, relation with peritoneal reflex, peritoneal reflex invasion, differentiation, and EMD) with EMVI. Statistically significant variables from the univariate analysis were evaluated using multivariate logistic regression to identify independent predictors for EMVI. Receiver operating characteristics (ROC) curve analysis was used to determine the diagnostic performance of NP for predicting EMVI. Corresponding areas under the ROC curve (AUC), sensitivities, specificities, and overall accuracies with 95% confidence intervals (CIs) were calculated. $p < 0.05$ was statistically significant.

3. Results

3.1. Patient Characteristics. In total, 156 patients (male: 103; female: 53) with rectal cancer were included in this study. The baseline characteristics are presented in Table 1. The mean age was 64 years (33–89 years). All patients underwent radical surgery within 6 weeks after the MRI scan.

3.2. Pathologic Results. Among the 156 patients, 53 (34%) were confirmed to be pEMVI-positive according to pathological and immune histochemistry results. The other 103 cases were EMVI-negative. There were 47 cases of PLN, 17 of which were from the EMVI-positive group and 30 of which were from the EMVI-negative group. EMVI was correlated

Table 1: Characteristics of the primary tumor and pEMVI results.

Variables	$N = 156$	pEMVI		P value
		Negative ($n = 103$) N (%)	Positive ($n = 53$) N (%)	
Age (year)	63.69 ± 10.68	64.18 ± 10.99	62.76 ± 10.08	0.198
Gender				
Male	103 (66)	70 (68)	33 (32)	0.48
Female	53 (34)	33 (62.3)	20 (37.7)	
RRWI				
≤1/3	11 (7.1)	9 (81.8)	2 (18.2)	0.139
1/3–2/3	55 (35.3)	38 (69.1)	17 (30.9)	
≥2/3	90 (57.6)	56 (62.2)	34 (37.8)	
NP	49 (31.4)	10 (20.4)	39 (79.6)	<0.001
CS	53 (34)	15 (28.3)	38 (71.7)	<0.001
IN	42 (26.9)	10 (23.8)	32 (76.2)	<0.001
Growth pattern				
Limited mass	75 (48.1)	53 (70.7)	22 (29.3)	0.239
Circum wall	81 (51.9)	50 (61.7)	31 (38.3)	
Relation with peritoneal reflex				
Upper	53 (34)	36 (67.9)	17 (32.1)	
Middle	73 (46.8)	45 (61.6)	28 (38.4)	0.491
Lower	30 (19.2)	22 (73.3)	8 (26.7)	
Peritoneal reflex invasion				
Negative	145 (92.9)	101 (64.7)	44 (35.3)	<0.001
Positive	11 (7.1)	9 (81.8)	2 (18.2)	
Tumor length (cm)	5.26 ± 2.27	5.31 ± 2.51	5.16 ± 1.70	0.371
PLN	47 (30.1)	17 (36.2)	30 (63.8)	<0.001
Differentiation				0.033
Well	8	0	8	
Moderately	131	44	87	
Poorly	17	9	8	
EMD (mm)	4.82 ± 5.00	2.78 ± 3.25	8.78 ± 5.44	<0.001

pEMVI: pathologic extramural vascular invasion; RRWI: range of rectal wall invaded by tumor; NP: nodular projection at the primary tumor's edge; CS: cord sign at the primary tumor's edge; IN: irregular nodules in the mesorectum; PLN: pathology-proven local node involvement; EMD: maximal extramural depth.

with tumor differentiation level. The worse the differentiation of tumor was, the higher the probability of EMVI was. Eleven (11/156, 7.1%) cases were confirmed with peritoneal reflex invasion by pathology, including 9 (9/11, 81.8%) cases from the positive group. Other pathologic results are summarized in Table 1.

3.3. Results of Univariate Analysis. As shown in Table 1, MRI features, including NP, CS, IN, and EMD were significantly associated with pEMVI ($p < 0.05$). Among the 156 patients, there were 49 (49/156, 31.4%) cases of NP, including 39 (39/49, 79.6%) cases from the positive group (Figure 3(a)–3(d)) and 10 cases from the negative group. There were 53 (53/156, 34%) cases of CS, including 38 (38/53, 71.7%) cases from the positive group (Figures 4(a) and 4(b)) and 15 cases from the negative group (Figures 4(c)–4(e)). There were 42 (42/156, 27%) cases of IN, including 32 (32/42, 76.2%) cases from the positive group (Figures 5(a) and 5(b)) and 10 (10/42, 23.8%) cases from the negative group.

3.4. Independent Predictors for EMVI. As shown in Table 1, NP, CS, IN, and EMD were significantly associated with pEMVI ($p < 0.001$). Among them, NP was an independent predictor for pEMVI, with an odds ratio of 11.57 (Table 2).

3.5. The Diagnostic Performance of NP for EMVI Prediction. The ROC curve for NP predictor of EMVI is shown in Figure 6. The diagnostic predictive value of NP is shown in Table 3. The AUC of NP for prediction of EMVI was 0.82 (95% CI, 0.74–0.90), with a sensitivity of 73.58%, a specificity of 90.29%, a positive predictive value (PPV) of 75.59%, a negative predictive value (NPV) of 86.92%, and an accuracy of 84.62%, respectively.

4. Discussion

EMVI is crucial for the establishment of treatment plans and prognosis of rectal cancer patients. It has been proven as an independent predictor of local and distant recurrence and low OS in patients with rectal cancer [13–15]. In the latest guidelines proposed by the Society for Medical Oncology (ESMO), mrEMVI is considered as a significant risk factor for rectal cancer [12]. Meanwhile, it is also an independent factor for predicting neoCRT effects [15, 19]. At present, diagnostic criteria of EMVI on MRI is based on five-scoring levels, which is mainly used to observe and analyze the changes of vascular morphologic and signals in the tumor area on HRT2WI or CET1WI [7, 20]. However, the technique showed lower sensitivity and a large variance (28%–62%). Nowadays, it is still a challenge to improve the

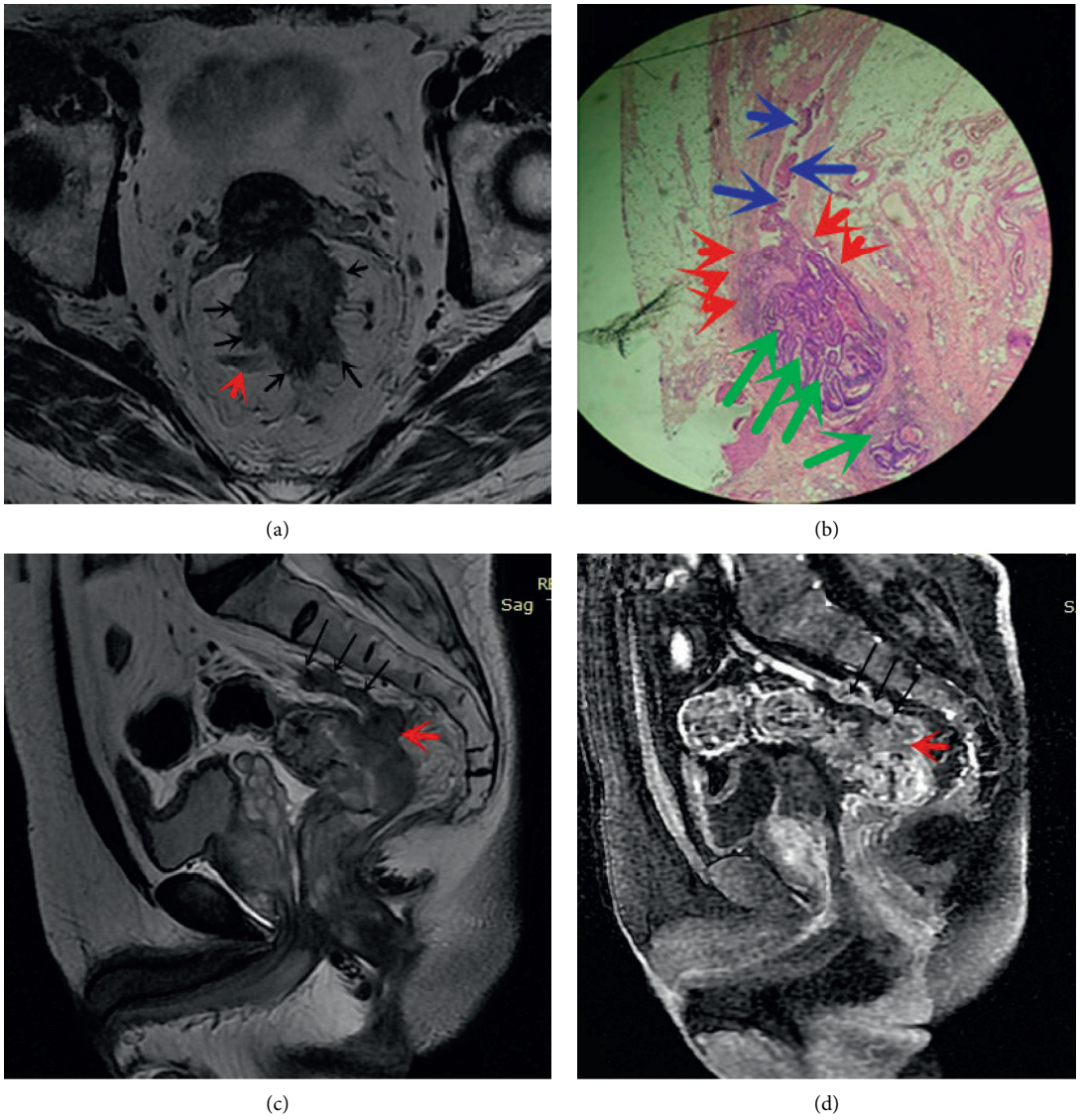


Figure 3: Examples of nodular projection (NP) at the primary tumor's edge on MRI. (a, b) HRT2WI of a 70-year-old female patient with rectal cancer (PT3N0) demonstrated multiple NP (black arrows) and an irregular thickened blood vessel (red arrow); nodules (green arrows) invaded the vascular cavity, and irregular distension (red arrows) was noticed in the vascular root. There was cord-like cancer embolus (blue arrows) in the vascular cavity. (c, d) Sagittal T2-weighted imaging and gadolinium-enhanced sagittal T1-weighted imaging of a 55-year-old man with rectal cancer (PT4N2) showed NP (red arrows) in the posterior wall protruding into the adjacent vessel. Besides, multiple cancerous emboli (multiple black arrows) were found in the superior rectal vein.

detection rate and diagnostic accuracy of EMVI. Besides, it is not adequate to only observe the extramural vessels of the rectum, and some indirect signs should be included in the diagnostic category.

In this study, we demonstrated a significant correlation between pEMVI and the morphological characteristics of the primary rectal tumor (NP and CS), IN, peritoneal reflex invasion, and EMD as well as PLN. Our data showed that NP was predictive for EMVI. The differentiation of cancer cells at the margins were various, with different growth velocities. Cancer cells penetrating the tuberal regions of the external membrane were poorly differentiated, and the growth velocity was quick with strong invasive capacity, which was prone to affect the peripheral vessels. In addition, the vascular permeability of the neoplasm was high. The cancer cells would leak to the vascular cavity. Meanwhile, the cancer cells may produce matrix metalloproteinase (MMP) and degrade the extracellular matrix (ECM) and the basement membrane (BM). This would promote the dissemination of cancer cells, which contributed to the invasion and metastasis [27]. The tumor with no NP may be a well-differentiated adenocarcinoma which grows more slowly, allowing the possibility of inflammation in the peripheral of the invaded vessels. This reaction could reduce the incidence of metastases and venous invasion [28]. Meanwhile, the appearance of NP contributed to the enlargement of tumor volume and area, which provided the basis for the invasion of tumor to the peripheral vessels. In addition, part of NP

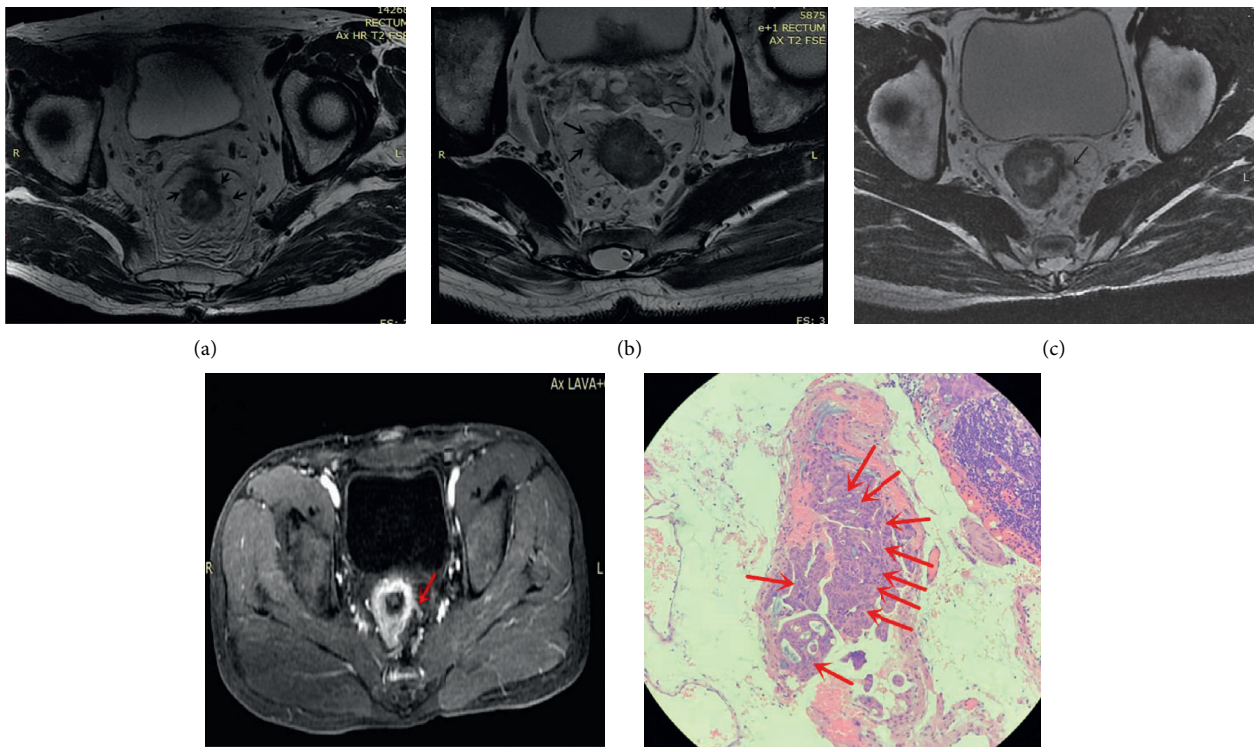


Figure 4: Examples of cord sign (CS) at the primary tumor's edge on MRI. (a, b) Axial HRT2WI of a 69-year-old male patient with rectal cancer (pT3N1) and a 58-year-old woman with rectal cancer (PT3N0) showed multiple CS (arrow) with uneven caliber and coarse edge. (c, d) HRT2WI of a 49-year-old male patient with rectal cancer (PT3N1) demonstrated intermediate signal intensity tumor in an extramural vessel in the left wall of the rectum. The caliber of the vessel was expanded with coarse edges, and its intensity in enhanced T1WI showed a decline to some extent, which was in line with the intensity of the tumor on gadolinium-enhanced T1-weighted imaging (CET1WI). (e) Corresponding micrograph of the same patient with (c, d) showing cancer thrombus in a vessel (red arrows).

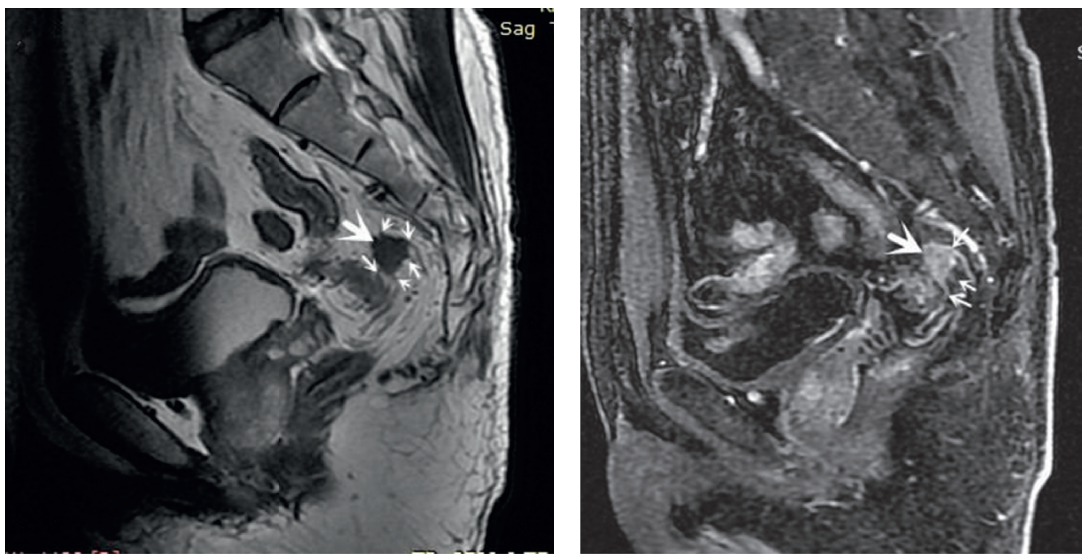


Figure 5: Examples of irregular nodules (IN). (a, b) Sagittal T2-weighted imaging and gadolinium-enhanced sagittal T1-weighted imaging of a 55-year-old male patient with rectal cancer (PT3N1) presented an irregular nodule (big white arrow) with a lobulated appearance behind the upper rectum. Meanwhile, the multiple vessels attached to the nodules showed irregular dilation and their signal on enhanced sagittal T1-weighted imaging showed reduction compared to the adjacent normal vessels.

Table 2: Results of imaging and pathologic factors in multivariate logistic regression analysis.

Independent predictor	Odds ratio	95% CI	*P* value
NP	11.566	3.00–44.65	<0.001
PLN	7.027	1.62–30.55	<0.001

95% CI: 95% confidence interval; NP: nodular projection at the primary tumor's edge; PLN: pathology-proven local node involvement.

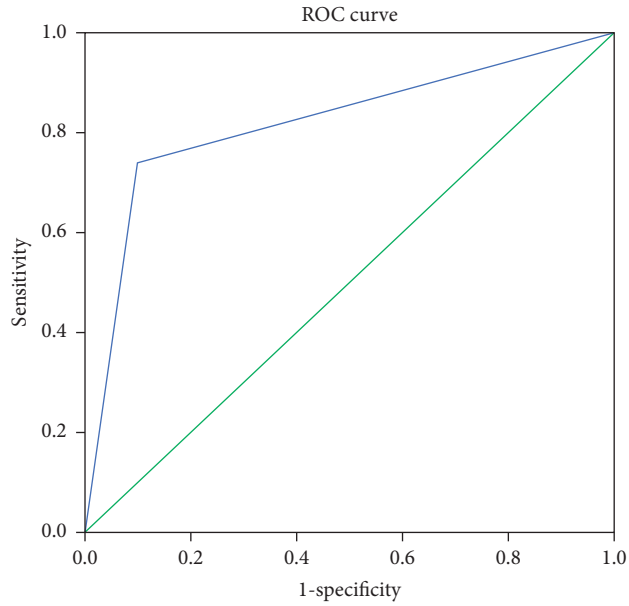


Figure 6: Receiver operating characteristic (ROC) curves of NP for extramural vascular invasion (EMVI) predicting.

Table 3: Diagnostic predictive values of NP for prediction of EMVI from ROC.

Diagnostic values	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
NP	0.82	73.58	90.29	79.59	86.92	84.62

NP: nodular projection at the primary tumor's edge; AUC: area under the receiver operating characteristics curve; PPV: positive predictive value; NPV: negative predictive value.

may be derived from tumor tissues invading into the vascular lumen at the junction with the rectal wall, or the tumor thrombus in the vascular root cavity that was attached to the primary mass with a broad base. Furthermore, the NP may derive from the fusion of TDs near the tunica adventitia near the rectum and the primary tumor mass. The origin of TDs was closely related to the vessels. Therefore, TDs would affect the peripheral vessels. This would explain the correlation between NP and EMVI.

Rectal cancer can provoke a desmoplastic reaction, defined as a host reaction in which fibrous tissue is formed around the tumor [29, 30]. Also, radiotherapy can induce fibrosis in normal tissue and in areas with tumor necrosis. In this study, in order to partially exclude the influence of the fiber strand around the rectum, the diameter of CS must be greater than 1 mm, and its edge should be rough and uneven. The diameter of the majority of fiber strands was relatively small, and the edges were generally smooth, which was not the same as CS defined in this study. About 25% of the cord shadows near the colorectal cancer was induced by inflammatory reactions [31]; therefore, most of the CS on MRI was probably EMVI, lymphangitis carcinomatosa [32], and cancerous cords. Cancer-associated fibroblasts (CAFs) would alternate the heterogeneity of cancer cells through various individual regulations [33]. Recent studies indicated that CAFs were crucial for the cancer infiltration and metastasis, which were considered the independent risk factors for poor prognosis. The diffused profibrous stromal reaction was considered the well-acknowledged feature for malignancy [34]. In general, CS was closely related to the biological behavior of the malignancies. On HRT2WI or gadolinium contrast-enhanced T1-weighted magnetic resonance imaging (CET1WI), MRI is effective to distinguish blood vessels from fibrous cords, but it cannot reliably distinguish between fibrosis with and without tumor cells [35]. Therefore, we could not exclude the inflammatory fiber cords, which may affect the sensitivity of CS.

In this study, we defined IN as nodules with irregular shapes, which may mainly include metastatic lymph nodes and tumor deposition (TD). In the previous studies

[22, 36–38], local lymph node metastasis and EMVI were mutual risk factors [22, 36–38]. Our data confirmed that local lymph node metastasis was an independent predictor for EMVI. It may be related to the lymphatic or microvascular obstruction, lymphatic fluid, or block of microcirculation reflux caused by metastatic lymph nodes or intravascular cancer emboli. Thus, cancer cells were stuck in lymphatic or microvascular, which triggered in lymphatic or microvascular invasion and subsequent extramural vascular invasion. Since the twentieth century, fatty tissues around the colorectum in colorectal cancer have been recognized as TDs [39]. They are small bits of tumor in the adipose tissues outside the colon or rectum not in lymph nodes. The American Joint Committee on Cancer Staging Manual 7th Edition (AJCC 7th TNM) and College of American Pathologist cancer protocol have defined tumor deposition as pericolic or perirectal fats with discontinuous tumor spread, extravascular spread with venous invasion, or totally replaced lymph nodes [40, 41]. The incidence of TDs is not low, from 17% to 55% in the colon and 6% to 64% in CRC [42–45]. The origin of the TDs was related to venous invasion, lymphatic invasion, nerve sheath infiltration, and continuous growth [43–45]. The emergence of the TDs may also indicate that the tumor is poorly differentiated and highly invasive, while TDs also frequently invaded blood vessels adjacent. On this basis, it is reasonable to speculate that there might be a correlation between TDs and EMVI. However, it is hard to identify the metastatic lymph nodes and the TDs by MRI. On this basis, we only monitored the MR morphology of the nodules, rather than conducting a deep investigation of the pathological components.

The correlation of peritoneal reflex invasion and EMD with EMVI was similar to NP and EMVI. The EMD and peritoneal reflex invasion were correlated with tumor characteristics, such as a more aggressive profile [46]. Additionally, in the presence of increased EMD, a larger tumor volume indicated more contact of tumor to the blood vessels, leading to higher probability of vascular invasion. In cases of peritoneal reflex invasion, the blood vessels between the peritoneal reflex and the anterior rectal wall may have been invaded by the tumor [47].

Indeed, there are some limitations in this study. Firstly, this was a retrospective analysis, and it was hard to perform accurate comparisons between the MRI and pathological findings. We did not investigate the EMVI using MR and only analyzed the imaging morphologies of the cancer. Meanwhile, some patients received neoadjuvant chemotherapy, which may lead to changes in cancer morphology. This would affect the results of our study. Secondly, some samples were obtained from rectal cancer patients at stage T2, who were pEMVI-positive. Tumors with NP, CS, and IN were almost at the T3 or T4 stage. Specifically, NP only appeared in the tumor with T3 or T4 stage. This reduced the predictive value and diagnostic effectiveness of these indicators. If patients at the T2 stage were excluded, the diagnostic value of CS and IN may increase. Thirdly, a time interval of more than 1 month was generated between MRI and surgery in some patients who underwent preoperative chemoradiotherapy, which was long enough to change the tumor status and presented a negative effect on evaluations of the diagnostic performance of the primary tumor morphology. Fourthly, the EMVI was unequivocal on MRI in many patients, but their pathological results were negative. Although pEMVI is the gold standard, both pathological preparation and film reading process may affect the assessment. Moreover, pathologists can only evaluate small samples of tumor tissues, not all tumor tissues. Therefore, if the pathological diagnosis is completely dependent, the detection rate of mrEMVI may be underestimated. The advantages of MRI are obvious as it can display the rectal tumor tissue and surrounding tissues causing no effects on the perienteral tissue structure. Due to the destruction of the vessel wall, only an extramural tumor deposit without any endothelial cell lining was seen in the pathology slide. Some locally advanced tumors with high-grade venous invasion or extensive vascular invasion may lead to injury of blood vessel walls and normal venous cellular structure, together with some difficulties in identification of vessels. These may not be reported by pathologists, which then increase the false-negative ratio.

In summary, NP may be used as an independent predictor for EMVI. It is helpful in the diagnosis of EMVI in patients with rectal cancer and facilitates treatment decision-making in patients with rectal cancer.

Data Availability

The datasets used in the current study are available upon reasonable request from the corresponding author.

Ethical Approval

The study protocols were approved by the Institutional Review Board of Capital Medical University and Taian Central Hospital.

Conflicts of Interest

The authors affirm that there are no potential conflicts of interest in relation to this study.

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