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Original Article

Value of magnetic resonance imaging in evaluating TNM stage of rectal cancer

Hui Luan[1*], Hua Zhang[2*], Jinyong Yang[3], Man Li[4], Zhenhua Zhang[5]

[1]Department of Radiology, Yantai Municipal Laiyang Central Hospital, Yantai, Shandong Province, China; [2]CT Room, Dezhou Traditional Chinese Medicine Hospital, Dezhou, Shandong Province, China; [3]Medical Imaging Center, Shandong Medical Imaging Research Institute, Ji'nan, Shandong Province, China; [4]Operating Room, [5]Department of Medical Imaging, Maternity and Child Health Care of Zaozhuang, Zaozhuang, Shandong Province, China. [*]Equal contributors and co-first authors.

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Abstract: Objective: To discuss the value of magnetic resonance imaging (MRI) in preoperative tumor node metastasis (TNM) staging of rectal cancer. Methods: A total of 60 patients with rectal cancer confirmed by both surgical and pathological approaches were enrolled from September 2017 to April 2019. The preoperative MRI results of all patients were collected for TNM staging; results of which were later compared with the staging results of postoperative pathological specimens, and the correlation analysis was performed. Results: The overall accuracy of preoperative TNM staging of rectal cancer was 86.67%, with a Kappa value of 0.760 (P=0.020). Pearson correlation analysis showed a significant correlation between the data from TNM staging and from pathological staging (P<0.05). The area under the receiver operating characteristic curve was 0.726 (P=0.001). Conclusion: MRI shows a high accuracy in preoperative TNM staging of rectal cancer, which is conducive to the development of it in therapeutic regimens.

Keywords: Rectal cancer, magnetic resonance imaging, TNM staging, pathological staging

Introduction

Rectal cancer is malignant, with high morbidity and mortality in various countries; showing an increasing incidence year by year, and a younger trend in onset age, with a 5-year survival rate of 41%-49% [1, 2]. The current preoperative diagnostic methods for rectal cancer include rectoscopy, double development of the large intestine, computed tomography, rectal ultrasound, and magnetic resonance imaging (MRI). Both rectoscopy and double development of the large intestine cannot clearly see the invasion and lymph node metastasis around tumor. Results of computed tomography can show both rectal lesions and invasion locations, but it performs with insufficient accuracy in preoperative staging [3, 4]. Both MRI and rectal ultrasound have high staging accuracy but results of rectal ultrasound are greatly affected by the subjective judgment of the examiner, and it is difficult to perform in patients with upper rectal cancer or intestinal stenosis [5, 6]. MRI has few problems in these respects. It is convenient in pre- and post-treatment comparison, showing a significant diagnostic accuracy for local lymph node metastasis compared with rectal ultrasound, a high resolution of soft tissues, multidirectional imaging; which better shows the size, morphology and growth mode of tumors, and has the advantage of non-invasiveness [7]. Previous studies mostly focused on the postoperative review of rectal cancer. The value of MRI in preoperative staging of rectal cancer is still divergent. This study was performed in patients with rectal cancer who underwent preoperative MRI for tumor node metastasis (TNM) staging, so as to provide clinicians with information on the tumor stage before surgery, benefiting the development of treatment regimens.

Materials and methods

Baseline data

A total of 60 patients with rectal cancer in the Maternity and Child Health Care of Zaozhuang

Table 1. Pulse sequence and parameters of MRI

Pulse sequence	TR/TE (msec)	FOV (cm)	NSA	Section thickness/interval (mm/mm)
Suvery	shortest/shortest	400×400	1	5/0
Axi T1	400/10	260×340	2	5/0
Axi T1 F/S	400/10	260×340	2	5/0
Axi T2	shortest/85	260×340	4	5/0
Sag T2	shortest/85	240×340	4	3/0
O-Axi T2	shortest/85	230×290	4	2/2
O-Cor T2	shortest/85	200×200	4	3/0
DWI (0-800)	2100/shortest	340×420	4	5/0

Note: MRI = magnetic resonance imaging.

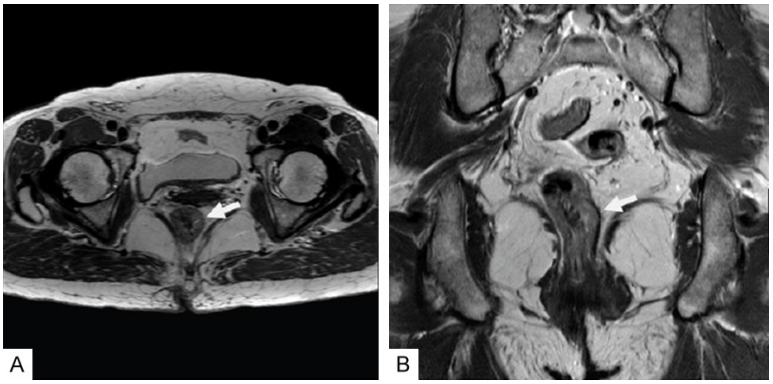

Figure 1. T1: The tumor did not break through the muscle layer. The white arrows indicated tumor in submucosa. A. High-resolution T2WI axial image; B. High-resolution T2WI coronal image.

from September 2017 to April 2019 were enrolled, including 40 males, aged 38-82 years old, with an average age of 63.5±7.9 years; 20 females, aged 40-80 years, with an average age of 63.7±8.0 years. Patients were eligible if they were diagnosed with rectal cancer by biopsy; were 18 years old or elder; and received surgical treatment within 2 weeks after the biopsy. Patients were excluded if they had recurrent rectal cancer, tumor metastasis from other sites, or rectal invasion; received any intervention before the examination and radical operation; had metal implants in their body; had liver or kidney dysfunction, or high fever; or had poor clarity of image due to a small tumor diameter.

Methods

In this study, 3.0 Tesla MRI (Achieva X-serise, Phillips, Holland) with a 32-channel cardiac coil was used. During the examination, patients were requested to lie down and were informed about health advice, the process, and the inspection time. The ultrafast magnetic spin-echo sequences (Turbo Field Echo, TFE) used in this study are shown in **Table 1**. The total inspection time was about 21 min.

Staging criteria

Three radiologists with more than 10 years of experience analyzing MRI results were responsible for image interpretation, observation of location of rectal tumors and surrounding tissues, as well as tumor TNM staging [8]. The staging criteria were as follows, T1: the tumor invaded the submucosa; T2: the tumor invaded the muscle layer; T3: the tumor invaded through the muscle layer to the serosa layer, or to the large intestine and surrounding rectum without peritoneum; T4: the tumor invaded directly into other organs or structures, and/or to the organ layer throughout the peritoneum. When there were different opinions, a consistent conclusion was made after discussion and research. Pathological staging criteria of rectal cancer referred to the American Joint Committee on Cancer and International Union Against Cancer TNM classification system for rectal cancer (7th edition) [9, 10]. The accuracy rate of staging = (number of pathological staging cases - cases with overestimation or underestimation staging)/number of cases underwent MRI staging * 100.00%.

Statistical analyses

Statistical analysis software IBM SPSS version 21.0 was used for data analyses in this study. Receiver operating characteristic (ROC) curve and diagnostic consistency analyses were performed to calculate the sensitivity, specificity, positive predictive rate, negative predictive rate, kappa value, and area under the curve, respectively. Pearson product-moment correlation coefficient (Pearson's r) was used to explore the correlation between results of pre-

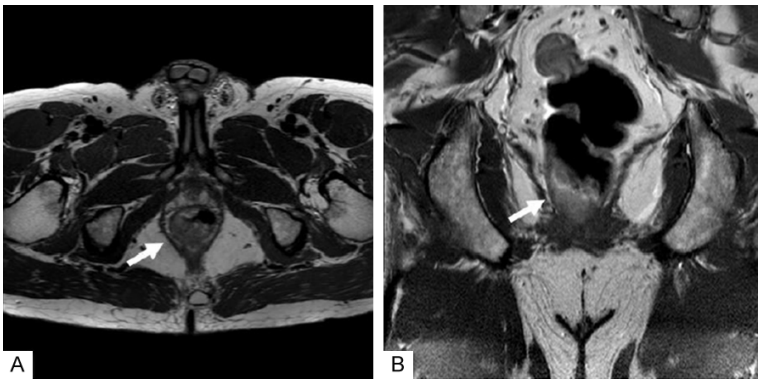

Figure 2. T2: The tumor did not break through the outer edge, with uniform surrounding fat signal. The white arrows indicated the disappearance of peripheral black line, and invasion in the muscle layer. A. High-resolution T2WI axial image; B. High-resolution T2WI coronal image.

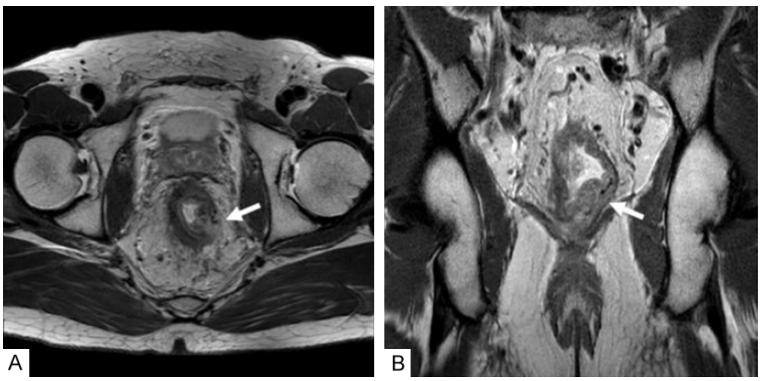

Figure 3. T3: The tumor invaded the serosal layer, or irregular protrusions were seen in the fat outside the intestinal wall. The white arrows indicated irregular shape of tumors and invasion in serosal layer. A. High-resolution T2WI axial image; B. High-resolution T2WI coronal image.

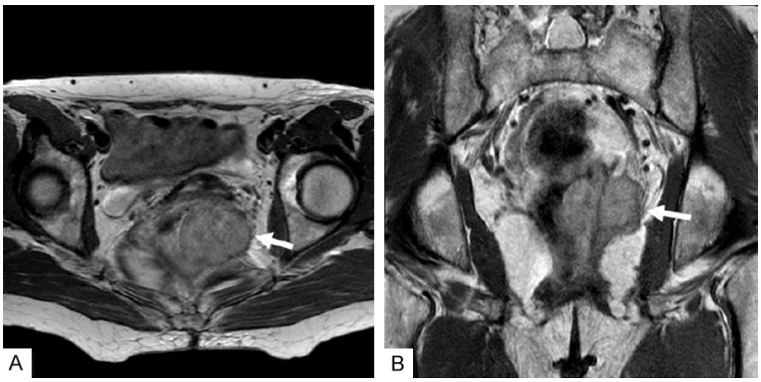

Figure 4. T4: The tumor invaded throughout the serosal layer to adjacent organs or structures. The white arrows indicated the invasion throughout the intestinal wall to adjacent organs. A. High-resolution T2WI axial image; B. High-resolution T2WI coronal image.

operative TNM staging by MRI and results of postoperative pathological staging. $P<0.05$ indicated a statistically significant difference.

Results

Basic data, MRI staging, and pathological staging

The MRI images of 60 patients were the basis for preoperative staging of rectal cancer. The images of T1 to T4 stages according to the TNM staging are shown in **Figures 1**-**4**. T1: The rectal circular muscle showed a uniform signal on the T2-weighted imaging (T2-WI) sequence. The circle was complete in structure, and the tumor did not break through the muscular layer. See O-AXI in **Figure 1A** and O-COR in **Figure 1B**. Tumors can be seen on the submucosa indicated by the white arrows. T2: The structure of the circular muscle was invaded but not to the outer edge, with uniform surrounding fat signal. See O-AXI in **Figure 2A** and O-COR in **Figure 2B**. The disappearance of the peripheral black line (see the white arrows) indicated that the muscle layer was invaded by tumor. T3: The circular structure and the serosal layer were invaded, or irregular protrusions could be seen in the fat outside the intestinal wall. See O-AXI in **Figure 3A** and O-COR in **Figure 3B**. The white arrows indicated irregular shape of tumors and invasion in serosal layer. T4: The tumor invaded throughout the serosal layer to adjacent organs or structures. See O-AXI in **Figure 4A** and O-COR in **Figure 4B**. The white arrows indicated the invasion throughout the intestinal wall to adjacent organs. The basic data as well as MRI and pathological staging of 60 patients are shown in **Table 2**. The T staging of pathological specimens

Table 2. Basic data, TNM staging by MRI, and pathological staging

No.	Age (year)	Sex	Preoperative TNM staging	Postoperative pathological staging
1	48	M	T4	T4
2	59	M	T2	T1
3	64	F	T4	T4
4	70	M	T2	T1
5	65	F	T2	T2
6	53	F	T2	T1
7	58	M	T2	T1
8	60	M	T2	T2
9	64	F	T3	T2
10	50	M	T4	T4
11	49	M	T2	T2
12	51	M	T2	T2
13	72	M	T3	T2
14	53	F	T3	T3
15	61	M	T4	T4
16	58	M	T3	T3
17	70	F	T3	T3
18	48	M	T3	T3
19	49	F	T3	T3
20	38	M	T3	T3
21	42	M	T3	T3
22	82	F	T4	T4
23	72	M	T3	T3
24	65	M	T3	T3
25	43	M	T3	T3
26	58	F	T3	T3
27	65	F	T4	T4
28	62	M	T3	T3
29	53	M	T3	T3
30	59	F	T3	T3
31	67	M	T3	T3
32	64	F	T3	T3
33	48	M	T3	T3
34	59	M	T3	T3
35	64	F	T3	T3
36	70	M	T2	T2
37	65	F	T2	T2
38	53	F	T3	T3
39	58	M	T3	T3
40	60	M	T3	T3
41	64	F	T3	T3
42	50	M	T3	T3
43	49	M	T3	T3
44	51	M	T3	T3
45	72	M	T3	T3
46	53	M	T3	T3
47	61	M	T3	T3
48	58	M	T3	T3
49	70	M	T3	T3
50	48	M	T3	T3
51	49	F	T3	T3
52	38	M	T3	T3
53	42	M	T3	T3
54	82	F	T4	T4
55	72	M	T3	T3
56	65	M	T3	T3
57	43	M	T3	T3
58	58	F	T3	T3
59	65	F	T4	T4
60	62	M	T3	T3

Note: MRI = magnetic resonance imaging; TNM = tumor node metastasis.

showed 4 cases of T1, 8 cases of T2, 40 cases of T3, and 8 cases of T4; TNM staging by MRI showed 0 case of T1, 10 cases of T2, 42 cases of T3, and 8 cases of T4.

Accuracy of staging by MRI comparing with pathological staging

Compared with the pathological staging, the total accuracy of TNM staging by MRI was 86.67%, and the accuracy rates in T2, T3, and T4 were 60.00%, 90.48%, and 100.00%, respectively. There were 2 cases of T2 and 2 cases of T3 that were overestimated by MRI staging. See **Table 3**.

Correlation between MRI staging and pathological staging

Pearson's product-moment correlation coefficient showed a significant correlation between MRI staging and pathological staging ($P<0.001$). See **Table 4**.

TNM staging by MRI and results of pathological reports

MRI showed a sensitivity of 0%, a specificity of 0%, a positive predictive rate of 0%, and a negative predictive rate of 0% in T1 staging; a sensitivity of 60.00%, a specificity of 75.00%, a positive predictive rate of 75.00%, and a negative predictive rate of 60.00% in T2 staging; a sensitivity of 95.20%, a specificity of 100.00%, a positive predictive rate of 100.00%, and a negative predictive rate of 50.00% in T3 stag-

Table 3. Accuracy of TNM staging by preoperative MRI (n=60)

Postoperative pathological staging	Accuracy (%)	Overestimation of stage (n)	Underestimation of stage (n)
T1 (n=4)	0 (0)	0	4
T2 (n=8)	60.00 (10)	2	0
T3 (n=40) (T3$^{\Delta}$ and T3*)	90.48 (42)	2	0
T4 (n=8)	100.00 (8)	0	0
Total (n=60)	86.67	4	4

Note: $^{\Delta}$The tumor invaded the fat layer while not involved in the fiber layer, with a low metastasis rate; *The tumor broke through the fat layer and tended to invade the fiber layer, with a high metastasis rate. MRI = magnetic resonance imaging; TNM = tumor node metastasis.

Table 4. Correlation between preoperative TNM staging and post-operative pathological staging

Item	Pathological results	
	r	P
Preoperative TNM staging	0.923	<0.001

Note: TNM = tumor node metastasis.

Table 5. TNM staging by MRI and results of pathological reports

MRI staging	T1	T2	T3	T4
Sensitivity	0	60.00%	95.20%	100.00%
Specificity	0	75.00%	100.00%	100.00%
Positive predictive rate	0	75.00%	100.00%	100.00%
Negative predictive rate	0	60.00%	50.00%	100.00%

Note: MRI = magnetic resonance imaging; TNM = tumor node metastasis.

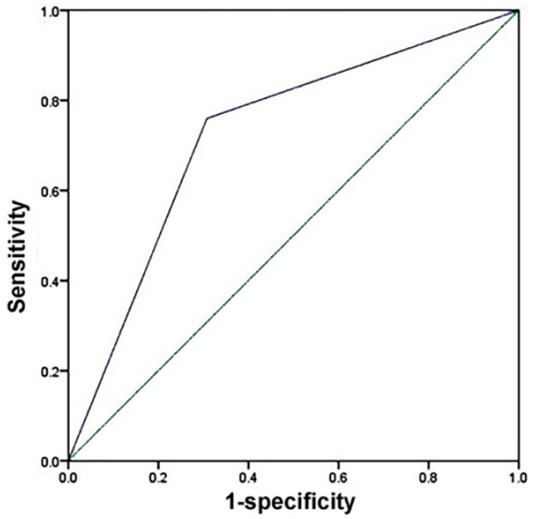

Figure 5. Receiver operating characteristic curve.

ing; a sensitivity of 100.00%, a specificity of 100.00%, a positive predictive rate of 100.00%, and a negative predictive rate of 100.00% in T4 staging. The Kappa value was 0.760, and P=0.020 (**Table 5**). The area under the ROC curve was 0.726, and P=0.001 (**Figure 5**).

Discussion

T2WI can clearly show the contrast between the anatomical structure of the pelvic cavity and the fat around the rectum, it also can accurately provide the signs of tumors. Most research suggests using the non-fat-suppressed T2WI instead of the fat-suppressed T2-WI [11-13]. Diffusion-weighted imaging as one of the main imaging sequences of MRI, can reflect the state of human tissue struture at a molecular level, that is, diffusion-weighted imaging shows the change in corresponding tissue structure and water molecules simultaneously when the human body undergoes pathological chanes. The quantitative index is the apparent diffusion coefficient (ADC) value, which is positively related to the cell density. The rectal cancer cells grow fast and are arranged closely, and the diffusion of extracellular water molecules is clearly limited, resulting in a decrease in its ADC value, so that the ADC value can be used to identify the nature of tumors [14-16]. The muscle layer is the main structure of the intestinal wall. Its low signal at T2WI indicates damage or invasion in the muscle layer, which is the divergence between T1 and T2.

Of the 60 patients in this study, 4 patients who were confirmed as T1 in postoperative pathological staging were overestimated as T2 in preoperative TNM staging. The specific reasons are presumably the different degrees of intestinal contraction or expansion or the submucosal and muscular layers of the intestinal wall were oppressed by the tumor, which caused the

ambiguous boundary of the muscular layer, leading to overestimation in patients at T1 and T2. As a result, the accuracy of T1 staging in this study was low. Li et al. reported 100% overestimation of T1 tumors in the study of TNM staging by MRI and pathological staging, which is similar to our findings [17, 18]. The majority of patients with rectal cancer in this study were at T2 or T3, while the treatment regimens for the two are greatly different, thus the main task in TNM staging by MRI is to distinguish T2 and critical T3.

In this study, two patients at T2 were overestimated as T3 in preoperative TNM staging, which can be attributed to the tumor-like invasion signs at intestinal wall and surrounding structures caused by local fibrosis, inflammation, infection, or vasculopathy [19, 20]. The combination of observing both parallel and vertical sections of the tumor in MRI can be helpful to reduce the mis-staging. Therefore, the distinguishment of T2 and T3 is sufficient to meet most clinical needs. MRI can clearly show the mucosal and muscular layers of the rectum, as well as the tumors, fat around the rectum and organs, which makes it an indispensable examination in the diagnosis of rectal cancer. The TNM staging is currently an ideal method for preoperative staging of rectal cancer, which provides a favorable diagnosis and treatment basis for clinicians. Although deviations may occur, our results are similar to the findings of Qin et al. in terms of sensitivity, specificity, and positive and negative predictive rates of TNM staging of rectal cancer by MRI [21]. Pearson's correlation coefficient showed significant correlation between TNM staging by MRI and pathological staging, and the area under the ROC curve was between 0.7-0.9, indicating that MRI was a reliable method for TNM staging of rectal cancer.

In summary, the accuracy of rectal cancer staging by MRI is promising, and the results were significantly correlated with the pathological analyses, indicating that MRI can reflect the detailed and accurate TNM staging information in patients with rectal cancer, and contribute to the development of treatment regimens, so that the patients can have a favorable prognosis. With the improvement of film reading and the development of imaging technology, high-resolution MRI will have increasing advantages in preoperative TNM staging of rectal cancer. However, the sample size in this study was limited, so a larger sample size is required for further in-depth research in order to draw reliable and repeatable conclusions.

Disclosure of conflict of interest

None.

Address correspondence to: Zhenhua Zhang, Department of Medical Imaging, Maternity and Child Health Care of Zaozhuang, Fuyuan Third Road, Xuecheng District, Zaozhuang 277800, Shandong Province, China. Tel: +86-0632-8791116; E-mail: zhangzhenhuafy1h@163.com

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