The clinical application value of MR diffusion-weighted imaging in the diagnosis of rectal cancer
A retrospective study

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Abstract

The present study evaluated the clinical potential of magnetic resonance (MR) diffusion-weighted imaging (DWI) in the diagnosis of rectal cancer.

A total of 84 patients confirmed with rectal cancer were used as study subjects in the present study. All patients received conventional sequence MR T1WI, T2WI, and DWI examination as well as operative pathological examination. The differences between the MRI results and operative pathological results were analyzed.

The diagnosis accordance rates of conventional sequence examination in stage T1, T2, T3, and T4 were 60.00%, 82.75%, 62.85%, and 80.00%, respectively. The diagnosis accordance rates of conventional sequence combined with DWI examination in stages T1, T2, T3, and T4 were 100.00%, 100.00%, 82.85%, and 100.00% respectively. The total diagnosis accordance rates in the T staging of rectal cancer with conventional (Routinely or generally applied) sequence examination and conventional sequence combined with DWI examination were 71.42% and 92.85%, respectively.

The analysis on consistency of MR conventional sequence examination suggested that the conventional sequence combined with DWI examination is more consistent with pathological staging when compared with the convention sequence examination alone. MR DWI combined with conventional sequences reveals quite good accuracy in the T staging of rectal cancer.

Abbreviations: CT = computed tomography, DWI = diffusion-weighted imaging, HE = hematoxylin and eosin, MR = magnetic resonance, ROC = receiver operating characteristic, SPSS = statistical product and service solutions.

Keywords: diffusion-weighted imaging, examination, magnetic resonance imaging, rectal cancer

1. Introduction

Rectal cancer is one of the most common clinical malignant tumors, which accounts for about 15% of all malignant tumors. The incidence of rectal cancer ranks the third in the male cancer incidence rates and the second in the female cancer incidence rates. The incidence rate of rectal cancer is increasing rapidly every year in China.[1,2] The clinical diagnosis of rectal carcinoma is confirmed by colonoscopy, digital rectal examination, and histological examination. The tumor infiltration and diffusion degrees are indictors that are useful in staging of rectal cancer. The above indicators in turn help in the selection of proper surgical treatment schemes.[3] Imaging examinations, such as double-contrast radiography, computed tomography (CT), magnetic resonance (MR), and so on, can demonstrate tumor infiltration and diffusion degrees effectively. However, the complicated intestinal cleaning is essential before CT or double-contrast radiography leading to time consumption and discomfort to the patients.[4] On the other hand, MR has a relatively high resolution, multi-directional and multi-sequence imaging, and belongs to a non-radioactive examination. In addition, there is no need for performing frequent intestinal cleaning before examination.[5] With the continuous development of MR technology, the research of MR DWI technique on the human body has reached deeply to the micro levels.[6] Recent reports from various countries including China have confirmed the application values of MR in the differential diagnosis of rectal cancer. In this study, patients with rectal cancer received the MR conventional sequence T1WI, T2WI, and DWI examination as well as operative pathological examination. The diagnostic effects of T staging were also compared, for the better evaluation of application potential of MR technique.

2. Methods

2.1. Study subjects

A total of 84 patients with rectal cancer admitted to our hospital from July 2015 to June 2016 were randomly selected and retrospectively analyzed. Inclusion criteria were.

1. the patients were diagnosed with rectal cancer by biopsy before MR examination;

Table 1

General data of study subjects.

Item	Subjects (n = 84)
Average age, years	62.78 ± 5.54
Gender, Male/Female	48/36
Adenocarcinoma (n, %)	66 (78.57)
Mucinous adenocarcinoma (n, %)	18 (21.43)
Education degree (n, %)	17 (20.23)
Junior high school and below	
High school and technical secondary school	38 (45.23)
Junior college or above	29 (34.52)

MR = magnetic resonance.

2. patients did not receive radiotherapy or chemotherapy and other adjunctive therapies before examination, and underwent surgical treatment after examination;
3. the patients who signed the informed consent. The general data of patients were shown in Table 1.

2.2. Preparation before examination

The patients were trained both physically as well as mentally for the proper execution of the examination.

2.3. MR conventional sequence examination

Siemens Magnetom Verio 3.0T Scanner (Siemens Company, Germany) was used to scan the pelvic cavity via conventional sequences:

1. Conventional cross-section T1WI (TE: 4.8 ms, TR: 106 ms, FOV: 35 cm * 35 cm, Matrix: 134×256, Thi: 8 mm, SG: 2.4 mm, and layers: 20), imaging time: 28 seconds;
2. High-resolution cross-section T2WI (TE: 124 ms, TR: 6620 ms, FOV: 20 cm * 20 cm, Matrix: 246×512, Thi:4.0 mm, SG: 0.8 mm, and layers: 19), imaging time: 4 minutes 6 seconds;
3. Sagittal T2WI (TE: 100 ms, TR:4000 ms, FOV: 20 cm * 20 cm, matrix: 230×256, Thi: 3.0 mm, SG: 0.6 mm, and Layers: 19), imaging time: 3 minutes 42 seconds;
4. Coronal T2WI (TE: 124 ms, TR: 6410 ms, FOV: 20 cm * 20 cm, matrix: 246×512, Thi: 4.0 mm, SG: 0.8 mm, and layers:19), imaging time: 5 minutes 16 seconds.

2.4. DWI examination

The patient for the proper posture of the DWI examination were guided to sit in the supine body position which is a clinical posture including holding of the head with double forearms across. Then, the location of the pelvic cavity was observed. The single shot spin echo and echo planar imaging sequences were used, and diffusion coefficient b values were 0, 600, and 1000 S/mm². The diffusion-weighted gradient fields were simultaneously exerted on 3 spatial axes, X, Y, and Z, and the relevant parameters were as follows: TR: 2500 ms, TE: 65 ms, Thi: 8.0 mm, SG: 1.0 mm, FOV: 35 cm * 35 cm, Matrix: 192×192 and imaging time: 15 minutes 4 seconds.

2.5. Operation and pathology

All patients were treated with a tumor excision. The size, morphology, and location of tumors were observed during the operation. The pathological specimens were embedded by paraffin and cut into slices, which was followed by hematoxylin and eosin (HE) staining for observation. The operations were conducted according to the instructions mentioned in the HE staining kit (Beijing Leagene Biotechnology Co., Ltd., China).

2.6. Observation index

The image analysis was as follows: First, the images were interpreted 2 times, respectively by 2 senior imaging physicians, who had more than 10 years of working experience, using double-blind method in the case of knowing the history but did not know the final diagnostic results. The diagnosis was confirmed only according to the conventional sequences T1WI and T2WI. Second, the diagnosis was identified by conventional sequences combined with DWI, which was used for preoperative T staging of rectal cancer. If the 2 physicians had different diagnostic opinions, discussions were taken until the consensus for diagnosis was reached, which finally confirmed the criteria of preoperative T staging of rectal cancer.[7] Stage T1 is defined as the tumor only invaded submucosa and the metastases of 2 to 3 regional lymph nodes occurred. Stage T2 is defined as the tumor that invaded muscle layer with no regional lymph node metastasis. Stage T3 is defined as the tumor penetrated into the muscle layer along with the metastases of 4 to 6 regional lymph nodes occurred. Stage T4 is defined as the tumor penetrated through the visceral peritoneum, along with metastases of more than 7 regional lymph nodes.

2.7. Statistical methods

The statistical product and service solutions (SPSS) 19.0 (SPSS Inc., Chicago, IL) software was used for statistical analysis. The enumeration data were expressed as a ratio and compared using the chi-square test. The consistencies between MR conventional sequences as well as conventional sequences combined with DWI and pathological staging were tested using the kappa coefficients (kappa < 0.40 represented a poor consistency; 0.40 <kappa < 0.75 represented a relatively good consistency; kappa > 0.75 represented a great consistency), The diagnostic methods of MR conventional sequences and conventional sequences combined with DWI were analyzed by the receiver operating characteristic (ROC) curve. $P < .05$ suggests that the difference was statistically significant.

3. Results

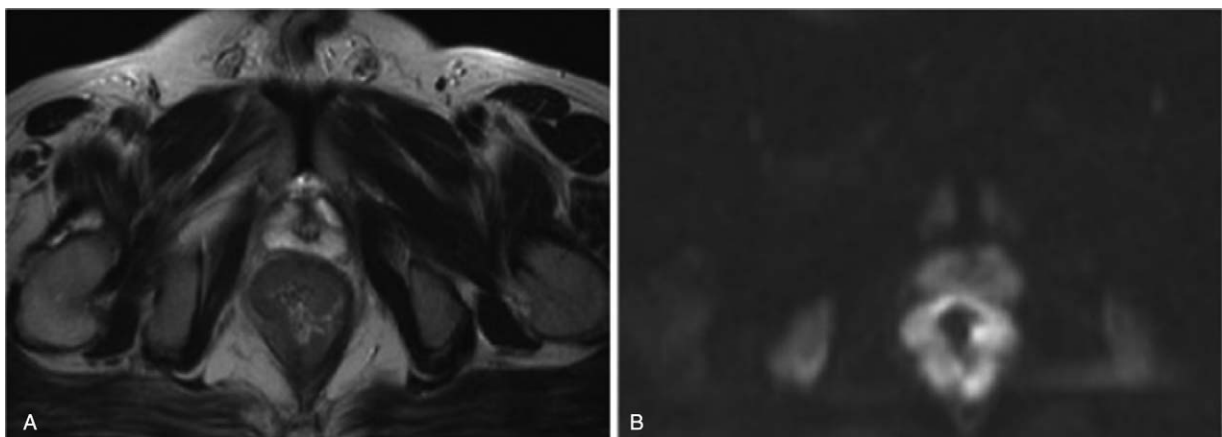### 3.1. MR conventional sequence and DWI examinations for patients with rectal cancer

As shown in Figure 1, the tumor infiltration and diffusion degrees were distinct at different stages. In the T2 stage, high-resolution T2WI displayed that the rectal wall of the patient was non-uniformly thickened, the muscle layer was discontinuous, and the interface between the muscle layers and the surrounding fat were clear (Fig. 1a). On the other hand, DWI displayed that the lesion showed a high signal (Fig. 1b). In the T3 stage, T2WI suggested that the rectal wall of patients was uniformly thickened, and the mass was annularly infiltrated into the intestinal wall. The interface between the muscle layers and surrounding fat was indistinct (Fig. 2a). However, DWI displayed that the lesion showed a significantly high signal (Fig. 2b). In the T4 stage, high-resolution T2WI displayed the rectal wall with non-uniform thickness (Fig. 3a). Further, MR imaging DWI (Fig. 3b) displayed significantly high signal.
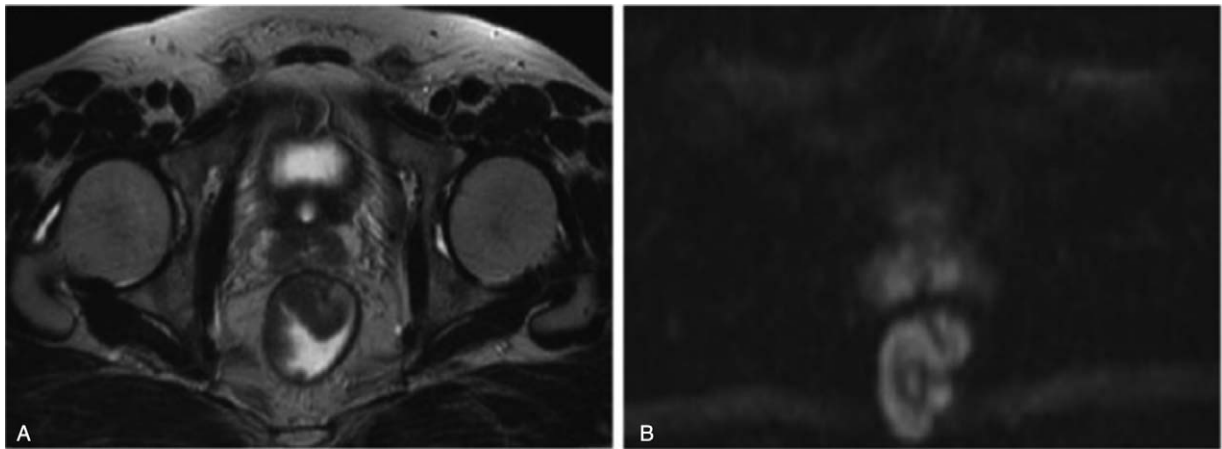
Figure 1. MR conventional sequence and DWI examinations for patients with rectal cancer in stage T2. High resolution T2WI in preoperative stage T2 (a); DW (Ib = 1000 S/mm^2) in preoperative stage T2 (b).
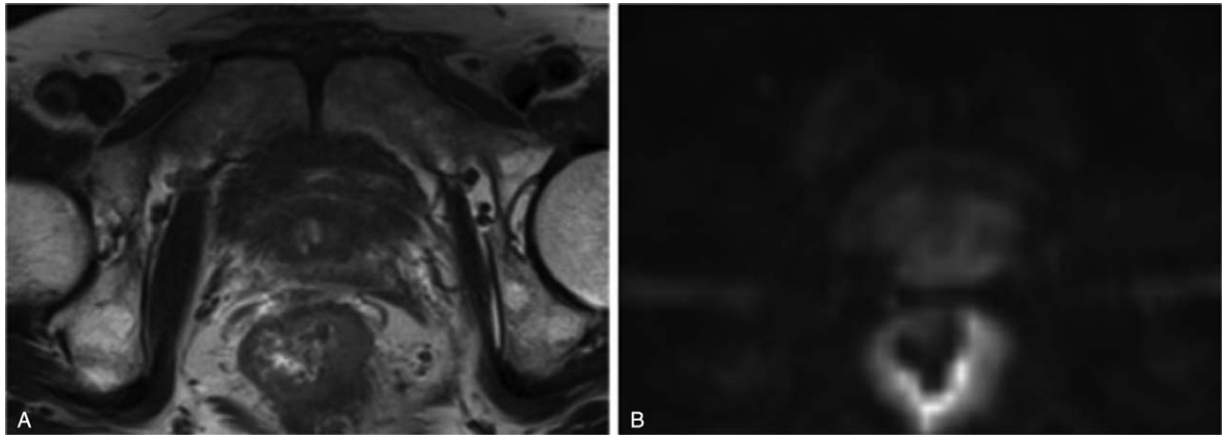
Figure 2. MR conventional sequence and DWI examinations for patients with rectal cancer in stage T3. T2WI in preoperative stage T3 (a); b: DWI in preoperative stage T3 (b).

Figure 3. MR conventional sequence and DWI examinations for patients with rectal cancer in stage T4. High resolution T2WI in preoperative stage T4 (a); DW (Ib = 1000 S/mm^2) in preoperative stage T4 (b).

3.2. Results of MR conventional sequence examination

The diagnosis accordance rates of the conventional sequences in stage T1, T2, T3, and T4 were 60.00%, 82.75%, 62.85%, and 80.00%, respectively. The total diagnosis accordance rate was 71.42% (Table 2). As demonstrated in Table 3, after compared the findings between MR conventional sequence examination and operative pathological staging, it was found that of the MR conventional sequence examination were basically consistent with the pathology detection (kappa = 0.587, P <.001).

Table 2

Comparison between MR conventional sequence examination and operative pathology in the T staging of rectal cancer.

Examination mode	Stage T1	Stage T2	Stage T3	Stage T4	Total diagnose accordance rate
MR conventional sequences	6 (60.00)	24 (82.75)	22 (62.85)	8 (80.00)	60 (71.42)
Operation and pathology	10 (100.00)	29 (100.00)	35 (100.00)	10 (100.00)	84 (100.00)
χ^2	2.813	3.505	13.067	0.556	35.908
P	.093	.061	.001	.456	<.001

Table 3

Comparison between MR conventional sequence examination and operative pathological staging (n).

MR examination	Pathological staging				Total
	Stage T1	Stage T2	Stage T3	Stage T4	
Stage T1	6	3	0	0	9
Stage T2	4	24	8	0	36
Stage T3	0	2	22	2	26
Stage T4	0	0	5	8	13
Total	10	29	35	10	84
P	.091	.062	.001	.451	<.001.

The test of the consistency between MR conventional sequence examination and pathological staging: kappa = 0.587, P <.001. MR = magnetic resonance.

3.3. Results of MR conventional sequence combined with DWI examination

The diagnosis accordance rates of conventional sequence combined with DWI examination were further evaluated. It was indicated that the diagnosis accordance rates in stage T1, T2, T3, and T4 were 100.00%, 100.00%, 82.85%, and 100.00%, respectively. However, the misdiagnosis rate in stage T4 was 37.50%. The total diagnosis accordance rate was 92.85% (Table 4). As shown in Table 5, the results of the conventional sequence combined with DWI examination, were more consistent with the pathology detection rates (kappa = 0.898, P <.001).

3.4. Diagnosis for T staging of rectal cancer

The area under the curve of the MR conventional sequence examination was 0.753 (P <.05), while the sensitivity and the specificity were 81.2% and 76.7%, respectively (Fig. 4a). The

area under the curve of the MR conventional sequence combined with DWI examination was 0.925 (P <.05), while the sensitivity and the specificity were 93.6% and 82.5%, respectively (Fig. 4b).

4. Discussion

Rectal cancer usually occurs at the juncture of the dentate line and sigmoid, which is mainly treated with a surgical resection in supplementation with radiotherapy, chemotherapy, immunotherapy, and Chinese medicine treatment.[8] According to relevant statistics, the 5-year survival rates of rectal cancer in stage 2 and 3 treated by surgery are about 70% and 30%, respectively.[9] Previous studies found that chronic inflammation in the local rectum leads to the production of long-term adverse stimuli. According to epidemiological studies, low residue diet, high fat diet, benign adenoma (papillary adenoma and familial multiple polyposis) cancer are all risk factors in rectal

Table 4

Comparison between MR conventional sequence combined with DWI examination and operative pathology in T staging of rectal cancer.

| Examination mode	Stage T1	Stage T2	Stage T3	Stage T4	Total diagnose accordance rate
MR combined with DWI examination	10 (100.00)	29 (100.00)	29 (82.85)	10 (100.00)	78 (92.85)
Operation and pathology	10 (100.00)	29 (100.00)	35 (100.00)	10 (100.00)	84 (100.00)
χ^2	—	—	4.560	—	4.327
P	—	—	.032	—	.037

DWI = diffusion-weighted imaging, MR = magnetic resonance.

Table 5

Comparison between MR conventional sequence combined with DWI examination and operative pathological staging (n).

MR conventional sequence combined with DWI examination	Pathological staging				Total
	Stage T1	Stage T2	Stage T3	Stage T4	
Stage T1	10	0	0	0	10
Stage T2	10	0	0	0	10
Stage T3	0	0	29	0	29
Stage T4	0	0	6	10	16
Total	10	29	35	10	84

The test of the consistency between MR conventional sequence combined with DWI examination and pathological staging: kappa = 0.898, P <.001. DWI = diffusion-weighted imaging, MR = magnetic resonance.
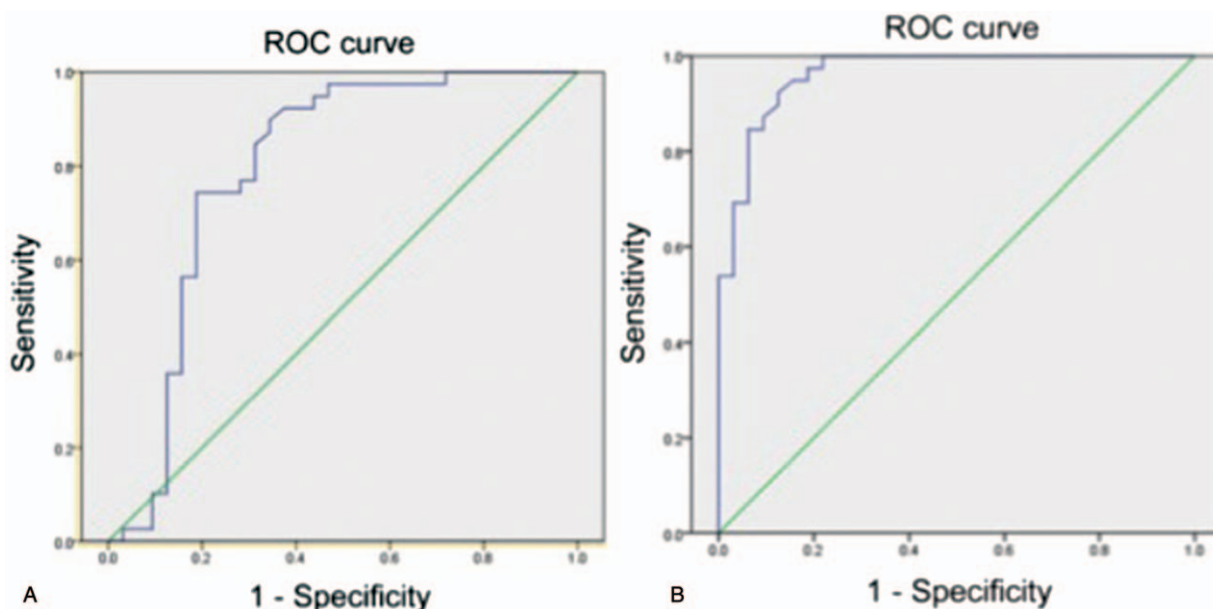
Figure 4. Diagnosis for T staging of rectal cancer. ROC curve of MR conventional sequence examination (a); Roc curve of MR conventional sequence examination combined with DWI examination (b).

cancer.[10,11] The pathogenesis of rectal cancer is usually considered to be influenced by both the diet and environment and its mechanism has not yet been completely determined.

Conventional MR examination has been used for the diagnosis of rectal cancer since the 1980s, which is characterized by multi-parameter imaging, high resolution with no radiation hazards.[12] Using conventional MR examination, Rectal cancer manifests as diffuse or localized thickening of the rectal wall, mass formation, and signal abnormality.[13,14] The final conclusion about MRI in the staging of rectal cancer has not yet been identified. However, an effective imaging diagnosis for mass location, degree of invasion, and regional lymph nodes by cross-sectional T1WI, cross-sectional T2WI, coronal T2WI and sagittal T2WI can directly display the rectal wall structures including mucous layer, submucosa and muscular layer.[15,16] The results of conventional sequence diagnosis and pathological diagnosis in 84 cases with rectal cancer provides the evidence that following conventional sequence diagnosis there are 6 cases (60.00%) in stage T1, 24 cases (82.75%) in stage T2, 22 cases (62.85%) in stage T3, and 8 cases (80.00%) in stage T4. There were 60 cases in total diagnostic accordance (71.42%), which were greatly consistent with the pathological diagnostic staging.

MR diffusion-weighted imaging (DWI), through the utilization of MR special sequence to give prominence to scattered phases caused by diffusion, reflects the micro-diffusion process of water molecule in tissues in macro-imaging.[17] DWI was firstly used in the clinical diagnosis of acute cerebral infarction and now has been widely applied in the diagnosis of nervous system diseases.[18] DWI adopts a planar echo imaging technology, which has advantages of simple operation, no contrast agent, rapid imaging and less artifacts caused by movement. Limited literature is available for the diagnosis of rectal cancer through the use of DWI, in view of the fact that tumor cells have a small gap and relatively high density. So, a signal change of tumor tissue on DWI is higher than that of normal tissue.[19] In this study, DWI shows high signals in 84 patients with rectal cancer,

which reflects the characteristics of small diffusion of water molecules in the tumor tissues of rectal cancer. Therefore, it provides an option for a noninvasive effective examination method for preoperative T staging of rectal cancer.

In addition, the results of this study indicate that in 84 rectal cancer patients with their diagnosis using conventional sequence combined with DWI examination there are 10 cases (100.00%) in stage T1, 29 cases (100.00%) in stage T2, 29 cases (82.85%) in stage T3 and 10 cases (100.00%) in stage T4. So, there are 78 cases in total diagnostic accordance, indicating the high consistence between conventional sequence combined with DWI examination, and pathological diagnosis examination. Moreover, compared to single conventional sequence examination, the diagnosis accordance rate of was enhanced from 71.42% to 92.85%, conventional sequence combined with DWI examination, confirming that the diagnostic accuracy of MR conventional sequence combined with DWI examination for preoperative T staging of rectal cancer is higher. In clinical practice, although MR conventional sequence examination can clearly display a rectal wall bulge or significantly thickened lesions, the diagnosis for relatively small masses and early rectal cancer is quite difficult. Therefore, it needs to combine with a high signal on the DWI sequence in the diagnosis of rectal cancer.[5] The ROC curve analysis indicates that the areas under the ROC curves of single MR conventional sequence examination and MR conventional sequence combined with DWI examination for rectal cancer are 0.753 and 0.925, respectively, indicating the diagnostic accuracy of the latter examination.

5. Conclusion

In conclusion, compared to MR conventional sequence examination, DWI combined with MR conventional sequence examination will improve the accuracy of T staging diagnosis to a certain extent, which can be utilized for primary qualitative assessment on rectal cancer.

Author contributions

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