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The clinical application value of multi-slice spiral CT enhanced scans combined with multiplanar reformations images in preoperative T staging of rectal cancer

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Abstract

This study aims to evaluate the diagnostic accuracy and clinical application value of multi-slice spiral CT (MSCT) enhanced scans combined with multiplanar reformations (MPRs) images compared with postoperative pathological results in preoperative T staging of rectal cancer.

One hundred sixty-eight consecutive patients with rectal cancer were admitted in our hospital between January 2013 and October 2018. Conventional MSCT plain scans, multi-phase dynamic contrast-enhanced scans, and MPRs were performed in all patients before surgical operation. The preoperative T staging of the rectal cancer lesions was evaluated using MSCT enhanced scans combined with MPRs, which was verified by postoperative pathological results. The diagnostic accuracy of MSCT enhanced scans combined with MPRs in evaluating T staging of the rectal cancer lesions were analyzed by χ^2 test and Kappa test.

Compared with postoperative pathology, T staging using MSCT enhanced scans combined with MPRs had overall accuracy of 85.7%. Consistency between MSCT enhanced scans combined with MPRs and postoperative pathological staging was effective for T staging (Kappa = 0.658, χ^2 = 4.200, P = .122).

Conventional MSCT enhanced scans combined with MPRs are simple and feasible. It is consistent with the pathological diagnosis of evaluating T staging in the rectal cancer lesions. It can provide reliable imaging evidence for the preoperative evaluation of primary rectal cancer, especially in patients with magnetic resonance imaging (MRI) contraindications, or in grass-roots hospitals due to lack of MRI equipment.

Abbreviations: MSCT = multi-slice spiral computed tomography, MPRs = multiplanar reformations, MRI = magnetic resonance imaging, TME = total mesorectal excision, EUS = endoscopic ultrasonography, APR = abdominoperineal resection, LAR = low anterior resection, DST = double-stapling technique, vLAR = very low anterior resection, ISR = intersphincteric resection, TNM = tumor-node-metastasis, NCCN = national comprehensive cancer network.

Keywords: multiplanar reformations, multi-slice spiral computed tomography, preoperative T staging, rectal cancer, TNM stage

1. Introduction

Colorectal cancer is one of the most common malignant tumors of the digestive system. In China, the incidence and mortality rates of colorectal cancer have been increasing steadily.[1] Compared with western countries, the incidence rate of rectal cancer is higher than that of colon cancer,[2,3] and 65%–70% of rectal cancer located at the low rectum in China.[4]

The treatment options of rectal cancer have changed over the last 2 decades as far as total mesorectal excision (TME), chemotherapy, and radiotherapy are concerned.[5] A standard treatment option of locally advanced mid-low rectal cancer is preoperative neoadjuvant therapy, including preoperative neo-adjuvant chemoradiotherapy or radiotherapy. It can downstage rectal tumors, improve the complete resection rates and facilitate sphincter preservation operations, and can also reduce local recurrence and minimize toxicity.[5,6] Therefore, accurate preoperative T staging is of great significance for the choice of clinical treatment, the improvement of prognosis and the accurate preoperative evaluation of the effects of neoadjuvant therapy on locally advanced rectal cancer.[7]

Imaging modalities commonly used in the staging of rectal cancer include MRI, endoscopic ultrasonography (EUS), and CT.[8–10] MRI has been recommended for routine preoperative examination of rectal cancer. But MRI technique has its own shortcomings, such as limited availability, relatively long image acquisition time, and high cost.[11] Moreover, Some patients cannot undergo MRI examinations because of claustrophobia or the presence of metal in their bodies.[12] Endorectal ultrasonography is mainly used for preoperative T staging of early rectal cancer (stage T2 and below).

MSCT enhanced scans have been commonly used in the preoperative diagnosis and staging of rectal cancer. It has the advantages of being inexpensive, fast scanning speed, volume scanning, and various of post-processing reconstruction techniques, which can further evaluate rectal cancer lesions more intuitively, precisely, and accurately. The present study aims to evaluate the diagnostic accuracy and clinical application value of MSCT enhanced scans combined with MPRs images in preoperative T staging of rectal cancer.

2. Materials and methods

2.1. Patients

One hundred sixty-eight consecutive patients who underwent conventional open Hartmann operation, open or laparoscopic abdominoperineal resection (APR), low anterior resection (LAR), or very low anterior resection (vLAR) with double-stapling technique (DST) anastomosis and laparoscopic intersphincteric resection (ISR) with low colorectal or coloanal anastomosis for rectal cancer located within 15 cm of the anal verge, were admitted between January 2013 and October 2018. The distance from the anal verge to the distal margin of the tumor was measured by digital rectal examination and/or colonoscopy. All cases were confirmed as adenocarcinoma of the rectum by biopsies before surgery. Operations were performed by the experienced colorectal surgeons and surgical team who were experienced in TME techniques, at the Department of Surgery of Wenzhou Central Hospital (Wenzhou, Zhejiang, PR China).

Patients that had undergone previous neoadjuvant therapy for rectal cancer, had multiple primary colorectal cancer or other cancers, had contraindications to contrast enhanced CT examination and those with insufficient CT imaging quality were excluded from the present study. Patients were also excluded if tumors had metastasized to the distant sites. The preoperative T staging of rectal cancer (The depth of rectal wall invasion) was assessed by MSCT enhanced scans combined with MPRs images. The clinical data, CT imaging features, and pathologic findings in one hundred sixty-eight cases were collected retrospectively.

This study was approved by the Institutional Review Board of Wenzhou Central Hospital, Wenzhou, Zhejiang, PR China.

2.2. CT imaging procedure

The patients were asked to fast for at least 12 hours and take 1500 to 2000 ml of water orally for inflating the intestine in 2 hours before undergoing CT examination. The patients were also asked to hold back urine and keep the bladder full before imaging and lie in the supine position.

All MSCT examinations were performed without luminal rectal contrast medium or air insufflation. All plain and contrast enhanced CT examinations including arterial, portal venous, and equilibrium phases were performed with a 64 multi-slice spiral CT scanner (SIEMENS SOMATOM Definition AS+, Muenchen, Germany). The scan delay time for arterial phase was 25 to 28 seconds, or the intelligent trigger scanning took the level of the aorta abdominalis at the top of the liver as monitoring point. The scan delay time for portal venous phase was 60 to 70 seconds and the equilibrium phase was 180 seconds, respectively.

The scan images were obtained from the diaphragm to the anal verge using the following parameters: tube voltage 120 kV; tube current was automatically assigned; rotation time 0.4 seconds; matrix 512 × 512; helical pitch 0.6; single-phase scanning time 8 to 10 seconds. Multiphasic contrast-enhanced CT images were acquired after the intravenous bolus injection of non-ionic iodinated contrast medium (Iohexol 350 mgI/ml, GE Healthcare Shanghai Co., Ltd., Shanghai, PR China; or Iopamidol 370 mgI/ml, Shanghai Bracco Sine Pharmaceutical Co., Ltd., Shanghai, PR China), according to 1.5 to 2.0 ml/kg body weight, at a rate of 3 to 4 ml/s, using a high pressure syringe injector (Ulrich Medical, Ulm, Germany). Transaxial and MPRs images (coronal and sagittal) parallel and perpendicular to the tumor axis, which were reconstructed using standard soft tissue algorithm with a scanning slice thickness of 1.0 mm and interslice interval of 1.0 mm.

2.3. CT imaging analysis

All of the MSCT images were evaluated independently by 2 experienced radiologist who were blinded to the pathological evaluation and clinical information. When there were some differences, they would discuss them with each other until they compromised and reached an agreement. Finally, the unified diagnoses were obtained and compared with the postoperative pathological staging according to the eighth tumor–node–metastasis (TNM) classification of the American Joint Committee on Cancer (AJCC) (pT1, tumor invades the submucosa <through the muscularis mucosa but not into the muscularis propria>; pT2, tumor invades the muscularis propria; pT3, tumor invades through the muscularis propria into perirectal tissues; and pT4, tumor invades the visceral peritoneum or invades or adheres to adjacent organ or structure) [13] on the basis of the histological findings of the surgical specimens.

Because of a limitation of MSCT for distinguishing T1 from T2 lesions. Rectal tumors on MSCT were classified by a modified TNM stage[10,14–16]: tumors confined to the bowel wall, lesions were markedly enhanced in the arterial phase, a smooth interface occurred between the serosa or the extramural layer and pararectal fat were classified as less than or equal to T2 (Fig. 1); Those with indistinct, rough, or spiculated borders between the outer rectal walls and the perirectal fats at the level of the tumor were considered as T3 (Fig. 2); Tumors that infiltrated into visceral peritoneums or adjacent organs were considered as T4 (Fig. 3).

2.4. Statistical analysis

Statistical analyses were performed using SPSS version 18.0 (Statistical Package for Social Sciences™; SPSS, Inc., Chicago, IL). The data were shown as means ± standard deviation or medians (minimum–maximum) when appropriate. Categorical data were expressed as a percentage (%). Comparison of the rate of 2 samples was then analyzed using the Chi-square test. The
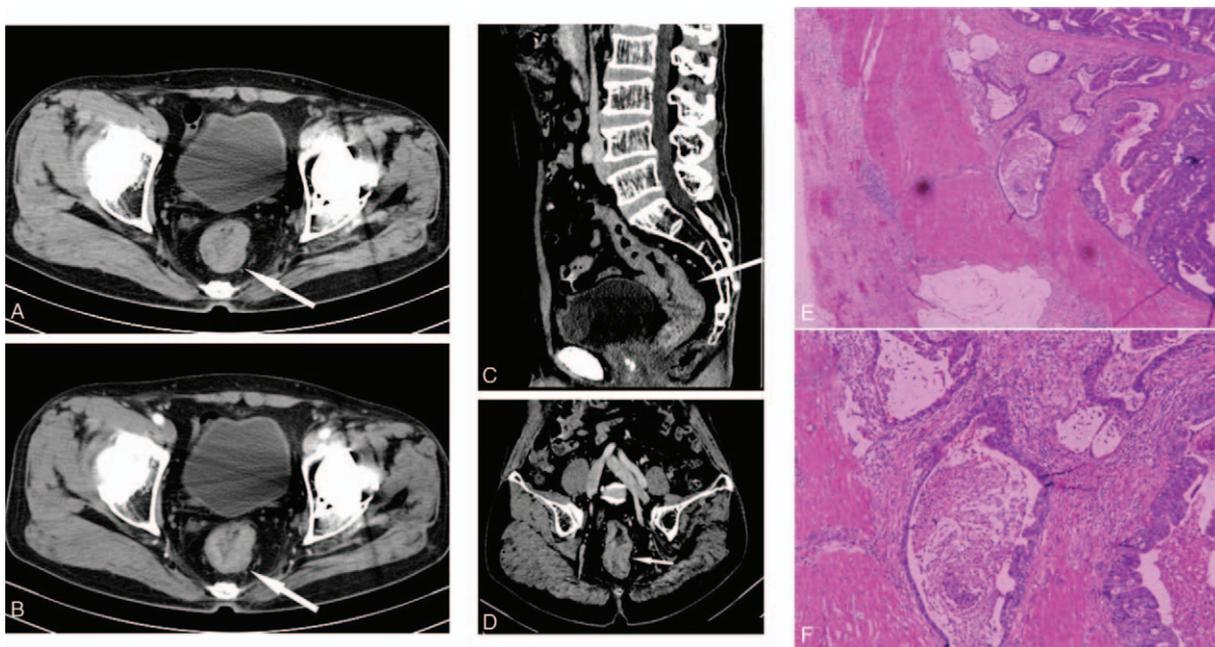
Figure 1. A 63-year-old male patient with histological stage T2 tumor. Axial MSCT (plain and enhancement scan), sagittal and oblique coronal reformatted MSCT images (A–D) showed a rectal tumor surrounding the entire intestinal lumen with smooth outer border of thickened rectal wall and a clear surrounding fat plane (long arrow) indicative of T2 stage disease. Final postoperative paraffin section (E and F) revealed ulcerative and protuberant type moderately differentiated rectal adenocarcinoma infiltrating into the deep muscular layer (Hematoxylin-eosin stain; original magnification ×80 and ×200).

consistency between the 2 staging methods was evaluated using the Kappa statistic. Kappa (κ) value greater than 0.75 was considered excellent agreement, 0.40 to 0.75 was fair to good and below 0.40 was poor. Statistical significance was denoted by $P < .05$.

3. Results

The clinicopathological data of 168 patients were summarized in Table 1. Histopathologic examination revealed stages of ≤pT2 tumors in 44 patients, pT3 tumors in 123 patients, and pT4 tumor stage in 1 patient with infiltration into the uterus.
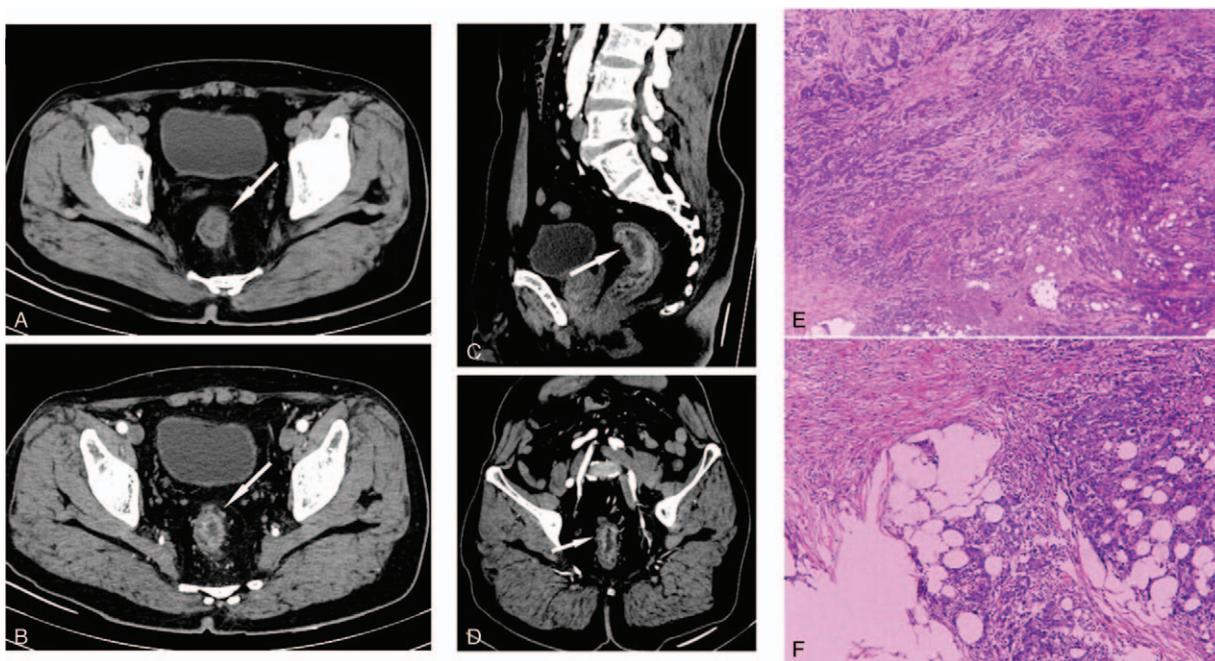
Figure 2. A 65-year-old male patient with histological stage T3 tumor. Axial MSCT (plain and enhancement scan), sagittal and oblique coronal reformatted MSCT images (A–D) showed a rectal tumor with a rough edge and spiculations extending into the peri-rectal fat (long arrow) indicative of stage T3 disease. Final postoperative paraffin section (E and F) revealed ulcerative type of a poorly differentiated rectal adenocarcinoma infiltrating into the entire intestinal wall and extramural fibrous adipose tissue. (Hematoxylin-eosin stain; original magnification ×80 and ×200).
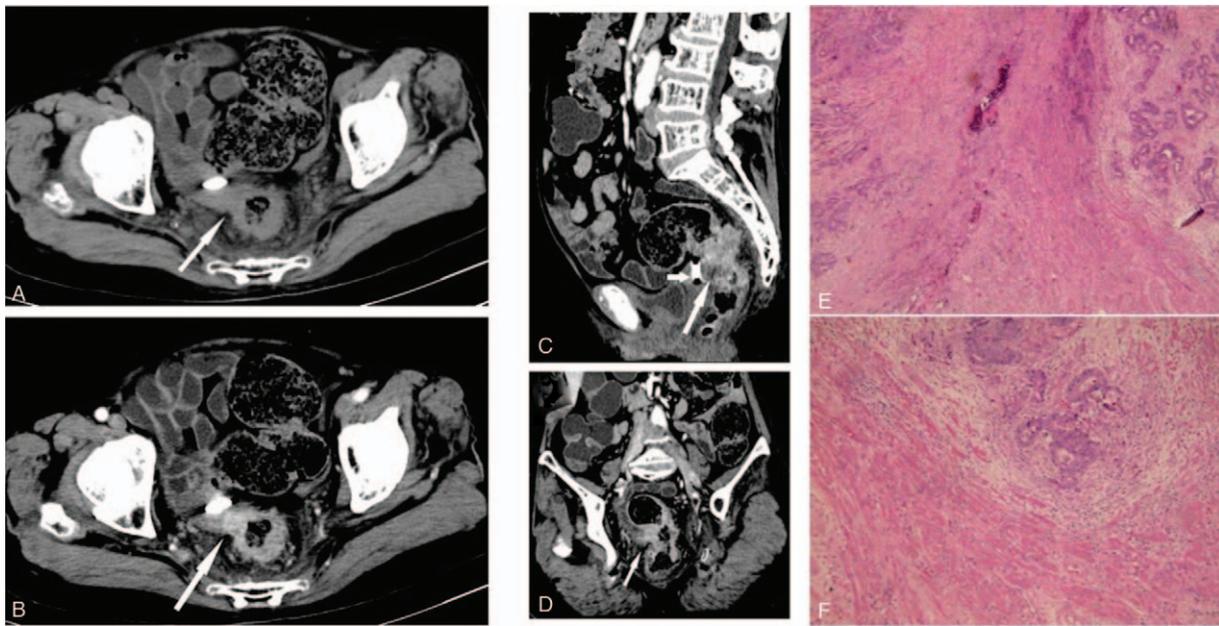
Figure 3. A 78-year-old female patient with histological stage T4 tumor. Axial MSCT (plain and enhancement scan) and sagittal reformatted MSCT images (A– C) showed a rectal tumor surrounding the entire intestinal lumen with infiltration into peri-rectal fat and the obliteration of the fat plane between the rectal tumor and the posterior uterine wall indicative of T4 stage disease (long arrow). The intrauterine device was clearly visible (short arrow). Oblique coronal reformatted image (D) also showed the tumor as an irregular mural thickening of the rectal wall with spiculations extending into the peri-rectal fat (arrow). Final postoperative paraffin section (E and F) revealed ulcerative type moderately differentiated rectal adenocarcinoma infiltrating into the extramural layer and myometrium of the uterus (Hematoxylin-eosin stain; original magnification ×80 and ×200).

The results of preoperative T staging using MSCT enhanced scans combined with MPRs images in 168 patients were summarized in Table 2, which were as follows: an overall accuracy was 85.7%; the accuracy was 79.5% for ≤T2 tumors, in 9 (20.5%) patients the extent of the disease was overstaged; in

particular, the accuracy for T3 tumors was high at 87.8%, in 4 (3.3%) patients the extent of the disease was overstaged and 11 (8.9%) cases were understaged; the accuracy was 100% (only 1 case) for T4 tumor. There were no statistically significant differences in the T staging between MSCT enhanced scans combined with MPRs and postoperative pathological results (McNemar-Bowker Test, $\chi^2 = 4.200$, Kappa = 0.658, $P = .122$).

4. Discussion

In Asian Chinese patients, rectal cancer accounts for the greatest number of all colorectal cancers. Environmental factors were thought to be associated with the high incidence of rectal cancer. Some studies had found that the polluted surface water sources were risk factors for rectal cancer.[17]

Preoperative staging of rectal cancer was critical in order to provide the optimal treatment pathway for patients with rectal cancer.[16] MSCT scans had been used conveniently in patients with rectal cancer. Combined with three-phase dynamic contrast-enhanced scans and MPRs, MSCT could provide more accurate and reliable imaging massages than conventional spiral CT in the evaluation of the tumor invasion of the rectal wall and surrounding organs. In our study, all patients underwent plain and three-phase dynamic contrast-enhanced scans of MSCT before surgical operation. MPRs were performed on a picture archiving and communication system (PACS) workstation. Contrast-enhanced scans could reflect the characteristics of the blood supply of the rectal cancers and the extent of the tumor size more objectively. With multiplanar reconstruction technique the reconstructed images could be displayed in any plane or arbitrary orientation, they could also be aligned parallel or perpendicular to the axises of the tumors which were similar to MRI. Thus it

Table 1

Patients' clinical-pathological parameters (n = 168).

	n
Gender (Male/Female)	103/65
Age (yr) (range)	67.4 ± 10.4* (41–89)
BMI (kg/m2) (range)	21.88 ± 3.35* (14.02–32.03)
Tumor location from anal verge (cm) (range)	7.5 ± 3.3* (1.5–15.0)
The maximum diameter of the tumor (cm) (range)	4.2 ± 1.4* (1.5–8.0)
Surgical procedure	
Open Hartmann operation	2
APR	24
LAR or vLAR	59
Laparoscopic APR	15
Laparoscopic LAR or vLAR	65
Laparoscopic intersphincteric resection (ISR)	3
Pathological T staging (tumor invasive depth)	
T1	8
T2	36
T3	123
T4	1
Tumor staging	
I	36
II	48
III	84

APR = abdominoperineal resection, LAR = low anterior resection, vLAR = very low anterior resection.
* mean ± standard deviation.

Table 2

T-staging results of MSCT enhanced scans combined with MPRs images in comparison with postoperative pathology (n=168).

Pathologic staging	MSCT with MPRs for preoperative staging (No.)			Total	Accuracy (%)
	≤T2	T3	T4		
≤T2	35	9	0	44	79.5 (35/44)
T3	11	108	4	123	87.8 (108/123)
T4	0	0	1		100 (1/1)
Total	46	117	5	168	85.7 (144/168)

McNemar–Bowker Test, $\chi^2 = 4.200$, Kappa = 0.658, $P = .122$.

could evaluate the morphological characteristics of rectal lesions more comprehensively and provide greater accuracy in preoperative staging of rectal cancer.[14,16]

In the present study we assessed the diagnostic capability of MSCT enhanced scans combined with MPRs images in tumor invasion depth (T-staging) of rectal cancer, as compared with postoperative pathological results as reference standard.[10–12,14–16] In our study, histopathologic examination revealed stages of ≤pT2 tumors in 44 patients (8 patients were staged as pT1 while 36 were staged as pT2), pT3 tumors in 123 patients and pT4 tumor stage in 1 patient with infiltration into the uterus. Sinha et al[16] reported an overall accuracy of T-staging on MSCT/MPRs was 87.1%, and an accuracy of 84.2% for ≤T2 tumors, 80.7% for T3 tumors and 96.5% for T4 tumor. Dar et al[18] reported the diagnostic accuracy of MSCT/MPRs for ≤T2, T3, and T4 lesions was 77%, 86.5%, and 100%, respectively. Ahmetoğlu et al[19] reported the overall accuracy in T-staging was 86%, and an accuracy of 86% for ≤T2 tumors, 86% for T3 tumors and 100% for T4 tumor. Filippone et al[20] reported the overall accuracy in T staging was 83% when transverse images were evaluated in combination with MPRs, and an accuracy of 93% for ≤T2 tumors, 90% for T3 tumors and 98% for T4 tumor. Matsuoka et al[21] reported the concordance rate with the postoperative pathological results in T staging was 100%. In our series of 168 patients a high diagnostic quality was achieved for MSCT enhanced scans combined with MPRs images, obtaining an overall accuracy of 85.7% in T-staging, an accuracy of 79.5% for ≤T2 tumors, 87.8% for T3 tumors, and 100% for T4 tumor, which were similar to previous reports in the literatures.[16,18–21]

It is difficult to differentiate T1 from T2 tumors on MSCT, because the layers of the rectal wall cannot be clearly differentiated by MSCT.[12,18,20] Therefore in preoperative T-staging of rectal tumors, T1 and T2 tumors were classified as ≤T2 tumors by MSCT. This is an intrinsic limitation of MSCT, however, the differentiation between T1 and T2 tumors is of little clinical value for the choice of clinical treatment plans.[18,20]

Differentiation of T2 tumors from T3 tumors are very important because T3 tumors could benefit from chemoradiotherapy.[18–19] Tumor infiltration of the perirectal fat or the serosa is the crucial criterion for differentiating T2 from T3 tumors.[14,18–20] In this study, the accuracy of MSCT was 79.5% for ≤T2 tumors, in 9 (20.5%) patients the extent of the disease was overstaged. The possible cause of this problem is that peritumoral fibrosis, inflammation, or congestive changes, and this can lead to overstaging.[16,19] The accuracy of MSCT was 87.8% for T3 tumors, in 4 (3.3%) patients the extent of the disease was overstaged and 11 (8.9%) cases were understaged. Misdiagnosing minimal T3 infiltration as T2 stage is possibly of minor consequence for patient treatment, because patients with minimal T3 tumor infiltration are at low risk of surgical failure from circumferential excision margin involvement.[16,20,22]

In the differentiation of T3 and T4 tumors infiltration, the main CT criterion was the obliteration of fat planes between tumor and adjacent organ.[19,20] Some previous studies had reported the combination of axial and MPRs images were more accurate than axial images alone in the staging of T4 tumors.[14,16,20] Because the number of patients with T4 tumor infiltration in our study is only a single case, studies with larger T4 sample sizes are needed to ascertain our results further.

Pelvic MRI has been routinely recommended to assess T stage of the primary rectal tumor internationally, especially in the differentiation between T2 and T3 tumors.[23,24] The present findings indicate that MSCT enhanced scans combined with MPRs is also of great value in the preoperative diagnosis of the ≤T2 stage and T3 stage of rectal cancer. Moreover, MSCT examination costs were significantly lower than the MRI. Therefore, MSCT examinations were currently widely used in patients with rectal cancer because of their relatively inexpensive costs and convenience.

5. Conclusions

Our findings indicate that conventional MSCT enhanced scans combined with MPRs are simple and feasible. It is consistent with the pathological diagnosis of evaluating T staging in the rectal cancer lesions. It can provide reliable imaging evidence for the preoperative evaluation of primary rectal cancer, especially in patients with magnetic resonance imaging (MRI) contraindications, or in grass-roots hospitals due to lack of MRI equipment.

Author contributions

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