

Original Article

Accuracy of 128-slice multi-phase enhanced spiral computed tomography for preoperative TN staging of rectal cancer

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Abstract: This study aimed to compare the preoperative results of conventional 128-slice multi-phase enhanced spiral computed tomography (CT) and the postoperative pathological findings in patients with rectal cancer (RC) in order to investigate the application potential of 128-slice spiral CT for preoperative TN staging of RC. Thirty patients with postoperative pathologically confirmed RC underwent 128-slice spiral CT examination preoperatively. The images obtained were then analyzed for TN staging of the lesions, which were then compared with postoperative pathological TN staging to determine the accuracy of 128-slice spiral CT for preoperative TN staging of RC. For statistical analysis, the Kappa value test for concordance rate and the SPSS 17.0 statistical software were used. The consistency of the T staging results of the CT diagnosis with those of the postoperative pathological diagnosis was good (Kappa =0.543, P=0.000) but the consistency of the N staging results of the CT diagnosis with the postoperative pathological diagnosis was poor (Kappa =0.167, P=0.283). Conventional 128-slice spiral CT was reliable and exhibited significant advantages in the preoperative staging of RC patients.

Keywords: Rectal cancer, multi-slice spiral CT

Introduction

Rectal cancer (RC) is a common cancer of the digestive system, with an increasing annual incidence. The key issue in selecting the treatment program relies on correct preoperative staging of the lesions. The commonly used methods include endoscopy, transrectal ultrasonography, air-barium double-contrast radiography, computed tomography (CT), and magnetic resonance (MR) imaging. In recent years, the expanded applications of CT and MR imaging launched research studies on CT and MR virtual endoscopy and functional imaging [1-4]. Similarly, enhanced contrast examination for lesion staging also had new progresses [5-10]. The previous research studies were mainly aimed at preoperative RC staging and assessing the efficacies of combined radiotherapy and chemotherapy. Furthermore, they were more focused on assessment and efficacy for local staging [11-22]. The TNM staging of malignant

tumors not only focuses on local stages but also includes local and distant metastatic stages such as liver metastasis and peritoneal metastasis (including the omentum). Therefore, before preparing a treatment plan, whole-abdomen imaging (generally enhanced CT) should be performed. Some patients would even need to undergo whole-body positron emission tomography and computed tomography (PET-CT) examination. In order to avoid unnecessary testing costs, we retrospectively analyzed data obtained using multi-slice multi-phase enhanced spiral CT of the whole abdomen of a group of RC patients, depending on characteristics such as high resolution and isotropy of multi-slice spiral CT. Multiplanar reconstruction (MPR) technology was used to examine the values obtained using the conventional 128-slice multi-phase enhanced spiral CT, based on anatomical images, for TN staging of RC, according to the following main criteria: 1. The mesorectum is composed of the rectum, surrounding

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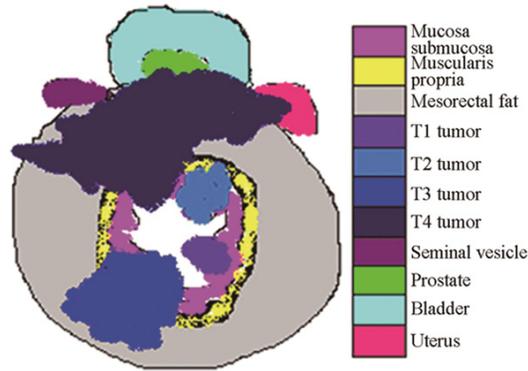


Figure 1. Sketch of T stage of rectal cancer.

mesorectal fat, and perirectal lymph nodes, which is cuffed in a thin mesorectal fascia. Mesorectal fat exhibits good anatomical contrast on the CT images; therefore, perirectal tumor invasion would be clear and easily visible. This lays the foundation for local staging. 2. The rectal wall can be divided into three layers, namely the mucosa, submucosa, and muscularis propria, from inside to outside, respectively. The mucosa is composed of the glandular epithelium with connective tissues and a mucosal muscular layer beneath being rich in blood vessels. Owing to the differences in vascular distributions on the rectal wall layers, the degree of enhancement might differ when performing contrast-enhanced CT scanning. This could lead to the identification of each structural layer under the characteristic of isotropy and high resolution of current multi-slice spiral CT imaging. In addition, most rectal malignant cancers are adenocarcinomas originating from the mucosa [14]. Thus, the gross morphological changes of tumor growth are easily displayed on high-resolution CT.

Materials and methods

Patients' data

The CT scanning data of the 30 patients with RC confirmed in the postoperative pathological examination were collected. The median age of the patients was 45 years. Of the patients, 17 were men with a median age of 51 years, 13 were women with a median age of 40 years. The clinical manifestations were abdominal pain, repeated diarrhea, bloody stools, weight loss and changes in stool characteristics, repeated constipation and repeated bloody

mucus, among others. The minimal disease history was 10 days, while the longest was up to 1 year. All the patients underwent surgery within 2 weeks after the examination, the post-operative pathological report confirmed adenocarcinoma. This study was retrospective, no declaration or informed consent was needed.

Pre-examination preparation

A week before the examination, gastrointestinal tract examination using a contrast agent was not to be performed and no metal-containing drugs were used. On the night before the examination, 500 mL of 20% mannitol was orally administered at 8:00 pm, which was diluted with 5% glucose solution to 1000 mL prior to oral administration. A total of 500-1000 mL of warm water was orally administered at 60-90 min before scanning, over 3 or 4 times, at time intervals of 15 min, and administered before the final scanning. Warm water (500-800 mL) was used for enema after positioning and before scanning.

Scanning technology

A Siemens SOMATOM Definitions AS 64-row 128-slice spiral CT scanner was used, with the following scanning parameters: tube voltage, 120 kV; tube current, 210 mAs; pitch, 0.6; scanning collimation, 128 × 0.6 mm; frame speed, 0.5 s; reconstructed layer thickness and interlayer spacing, 1.0 and 0.7 mm, respectively. Total abdominal CT conventional scanning, enhanced arterial phase scanning (approximately 30 sec), and portal venous phase scanning (60 sec) were performed. The contrast medium used was iopamidol injection (370 g/L), injected through the elbow vein at a dose of 1.5 mL/kg body weight and rate of 4.5 mL/s.

Diagnostic criteria

The pathological TN staging criteria were as follows: T1 stage, tumor invasion of the submucosa; T2 stage, tumor invasion of the muscularis propria; T3 stage, tumor invasion from the muscularis propria through the subserosa or perirectal tissues; T4 stage, direct invasion of other organs or structures by the tumor and/or perforation of the visceral peritoneum (**Figure 1**). In N0 stage, no lymph node or a lymph node in the mesorectal fat space with short diameter

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Table 1. Pathological TN staging criteria of RC

T staging	Appearance	N staging	Appearance
T1	Tumor invaded submucosa	N0	Without lymph node or lymph short diameter <8 mm
T2	Tumor invaded muscularis propria	N1	1-3 lymph nodes
T3	Tumor broke through muscularis propria while not involved in fascia	N2	≥4 lymph nodes
T4	Tumor broke through fascia or invaded adjacent organs		

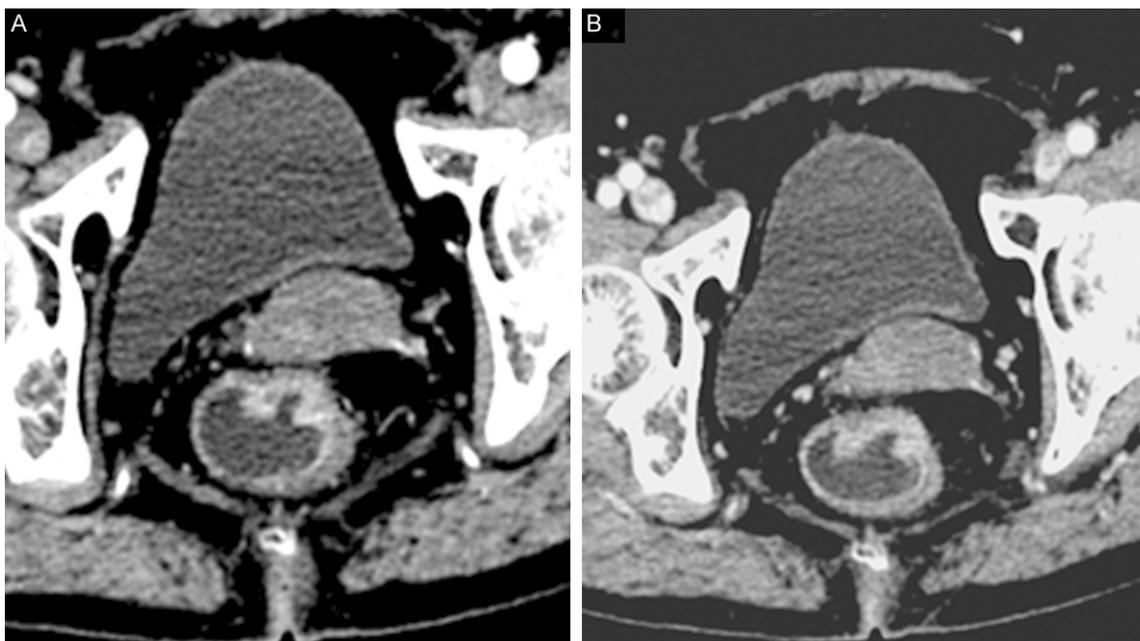


Figure 2. T1-2 tumor of rectum. A. Arterial phase. The lesion appeared remarkable contrast enhancement in arterial phase. The mucosa side demonstrated more remarkable than the muscularis propria side in the extent of contrast enhancement. The border between the mucosa and the muscularis propria was blur. The border between the adjacent normal mucosa and muscularis propria was clear. The outline of the rectum was smooth. The mesorectal fat was clear. B. Portal venous phase. The lesion demonstrate more remarkable contrast enhancement and homogeneous than the arterial phase. The border between the mucosa and the muscularis propria was blur. The outline of the rectum was still smooth. In some cases, the submucosal edema was seen in the transitional area of the normal and abnormal tissues, which made the border of the mucosal and submucosal be recognized. The mesorectal fat was intact.

of <8 mm was involved. In N1 stage, 1-3 lymph nodes were involved. In N2 stage, 4 or more lymph nodes in the mesorectal fat space were involved (**Table 1**).

The CT diagnostic criteria were based on the existing literatures and our own experience. Because most patients in this study exhibited indiscernible lesions in T1 and T2 staging, T1 and T2 staging were thus classified as “T1-2 staging”. On the arterial phase and portal venous phase images, because the lesion adjacent to the normal intestinal mucosa or that in the transition region exhibited significant enhancement than the muscular layer and the submucosal edema might occur in some patients, all layers of the intestinal wall were rec-

ognizable; thus, T staging of the lesion could be performed. In the T1-2 stage lesions, the tumor had invaded the muscularis propria but did not penetrate the muscular layer. When partial muscular layer was involved, the superficial muscular layer and lesions were poorly defined, but the deep surface of the muscular layer still shifted like the normal muscular layer. The outline of the outer edge was smooth, and no invasion could be seen within the mesorectal fat space (**Figure 2A, 2B**). In the T3 stage lesions, the tumor had invaded the muscularis propria but did not involve the rectal fascia. The normal muscular layer, which was weakened, migrated to and fused with the lesions. Its border was unclear, as well as the muscular layer at the

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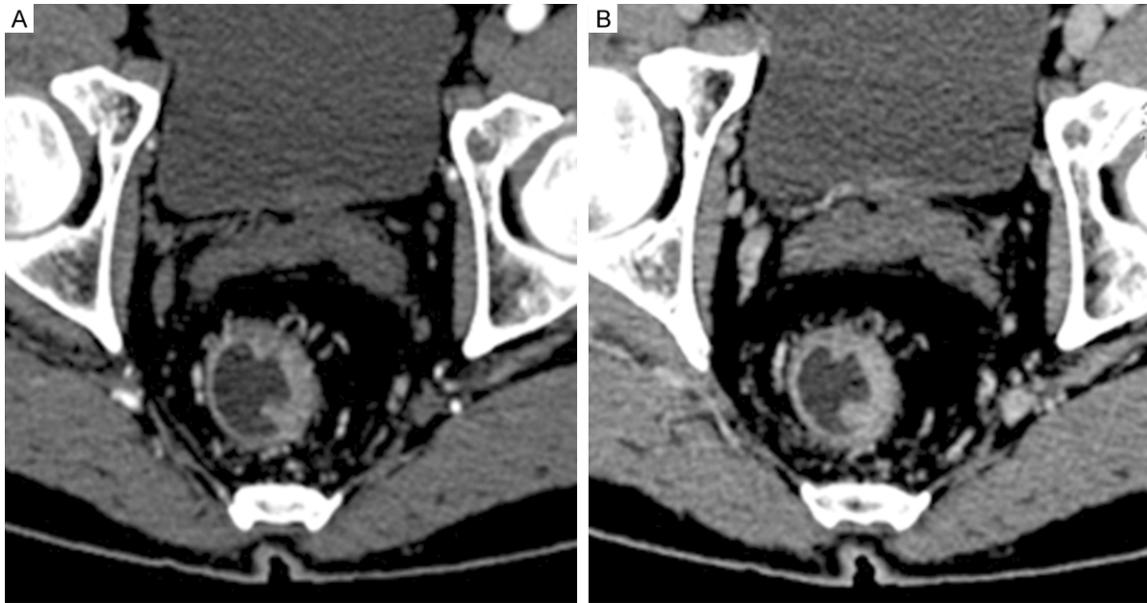


Figure 3. T3 tumor of rectum. A. Arterial phase. The lesion demonstrate remarkable enhancement in arterial phase. The border between the mucosa and the muscularis propria was blur. The exterior margin of the rectum appeared blur with concex and umsmooth outline. B. Portal venous phase. The lesion demonstrate more remarkable contrast enhancement and homogeneous than the arterial phase. The border between the mucosa and the muscularis propria was blur. The exterior margin of the rectum appeared blur with concex and unsmooth outline.

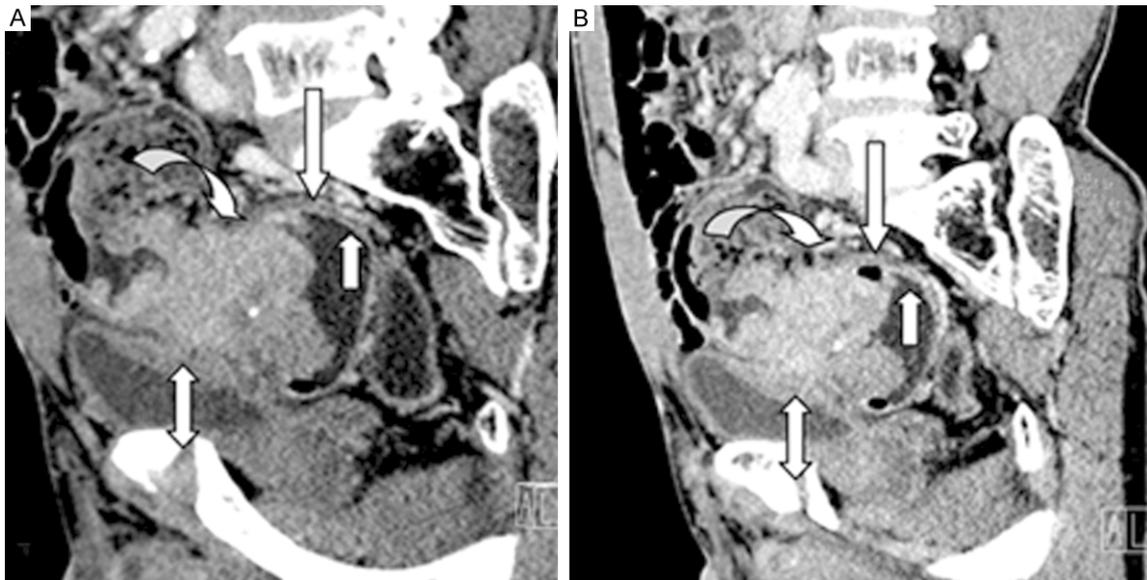


Figure 4. T4 tumor of rectum. A. Arterial phase. The mucosa adjacent to the lesion demonstrated clear with contrast enhancement (short arrow), the muscularis propria appeared clear (long arrow) too. However, the muscularis propria of the lesion area appeared blur with the same extent of the contrast enhancement as the lesion. The focal rectal wall was shrink (curved arrow). The lesion invaded the bladder anteriorly (double arrow). B. Portal venous phase. The lesion appeared further contrast enhancement, more homogeneous than arterial phase. The mucosa (short arrow) and the muscularis propria (long arrow) adjacent to the lesion appeared well-defined. The lesion demonstrated ill-defined with the bladder. The muscularis propria of the lesion was blur with the local wall shrinked (curved arrow). The lesion invaded the bladder anteriorly (double arrow).

lesion site, with an outline convex and serrated surface. The mesorectal fat gap exhibited

streak-like soft tissue attenuation, and the rectal fascia was intact (**Figure 3A, 3B**). In the T4

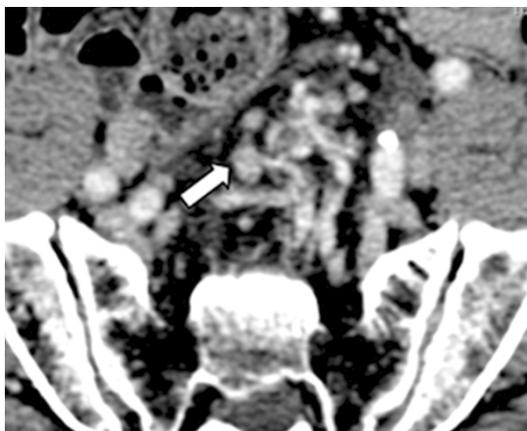


Figure 5. CT appearance of the metastatic lymph node. The short diameter ≥ 8 mm. Portal venous phase demonstrate heterogeneous enhancement (arrow).

stage lesions, the tumor invaded the rectal fascia and adjacent organs (**Figure 4A, 4B**). The criterion for N staging was a short lymph node diameter of ≥ 8 mm (**Figure 5**).

Image analysis

Image analysis was performed by two CT experts. The CT volume data acquired were performed by using the MPR technology for multiplanar and multi-angle observation and analysis of lesions, including tumor shape, size, invasion depth, surrounding tissue invasion, and pelvic lymph node metastasis, followed by further tumor staging and comparison with pathological findings. When the two image readers disagreed with each other, consensus was obtained through a discussion. The Kappa value test was used to analyze the consistency between the results of the CT TN staging and those of the postoperative pathological TN staging. A $P < 0.05$ was considered statistically significant. The SPSS 17.0 statistical software package was used for the analysis.

Results

Pathological TN staging

Among the 30 RC patients, there were one case of T1 stage, 7 cases of T2 stage, 11 cases of T3 stage and 11 cases of T4 stage disease. For pathological N staging, there were 14 patients with N0 stage; 14 with N1 stage and 2 with N2 stage disease.

CT TN staging

Among the 30 RC patients, there were 7 cases of T1-2 stage, 16 cases of T3 stage and 7 cases of T4 stage result from CT scan. The CT results also indicated N0 stage in 14 patients, N1 stage in 14 and the N2 stage in 2.

Consistency test between the CT and pathological T staging results

In this study, because the T1 and T2 staging results of the 30 RC patients diagnosed using CT was summarized as T1-2 staging (**Figure 2**), the corresponding pathological results also summarized the T1 and T2 staging as T1-2 staging for the statistical analysis. The consistency test between the CT and pathologic T staging results of the 30 RC patients revealed good consistency between the two diagnostic methods (Kappa = 0.543, $P=0.000$).

Consistency test between the CT and pathological N staging results

The consistency test between the CT and pathological N staging results of the 30 RC patients revealed poor consistency between the two diagnostic methods (Kappa = 0.167, $P=0.283$; **Table 2**).

Discussion

The annual incidence of RC had been increasing, and RC had become a common major lethal tumor. The disease is usually diagnosed in the late stage. Because of the risks of local recurrence and metastasis, RC is associated with a poor prognosis. Even after accurate resection, the local recurrence rate is about 3%-32%. Surgical resection plus appropriate neoadjuvant therapy had become the main treatment method for RC. In total mesorectal excision, the entire mesorectal fascia and anterior structures are resected, thereby achieving the effects of complete tumor resection. If accompanied with radiotherapy, the overall recurrence rate of RC could be reduced to less than 10% [23]. Therefore, in order to select the appropriate treatment, completely remove lesions and improve the survival rate and quality of life of patients, accurate preoperative staging before or after neoadjuvant treatment is essential [4, 24] and was also reported as an important prognostic factor [23].

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Table 2. Results of CT TN staging and pathologic TN staging of the 30 RC patients

T staging	CT diagnosis			T staging	Postoperative pathologic diagnosis		
	N staging				N staging		
	N0	N1	N2		N0	N1	N2
T1-2 (n=7)	6	1	0	T1-2 (n=8)	6	2	0
T3 (n=16)	7	9	0	T3 (n=11)	5	6	0
T4 (n=7)	1	4	2	T4 (n=11)	3	6	2

The traditional inspection techniques include clinical examination (digital rectal examination), biochemical tests (e.g., carcinoembryonic antigen detection), endoscopy, air-barium double contrast radiography and transrectal ultrasound examination. These inspection techniques could not accurately show tumor invasion depth and lymph node metastasis and therefore inadequate to guide disease staging. Conventional CT and low-slice spiral CT have relatively low spatial resolution and cannot achieve isotropic images, so their staging accuracies are limited. The new-generation multi-slice spiral CT has thinner collimation, so the spatial resolution was increased to a submillimeter degree, the scanning coverage area was increased and the isotropic images could be achieved. Combined with MPR, the staging accuracy for different tumors could be improved [25]. In order to achieve accurate staging, CT and MR are routine examination methods for RC patients [26, 27]. Both imaging modalities not only provide conventional anatomic imaging methods but also expand functional imaging methods of CT or MR imaging, such as virtual endoscopy, dynamic perfusion and diffusion through the application of new technologies [3, 4, 28-31]. Thus, they enable staging, identification of biological behaviors and provide tumor information from different perspectives for exploration and selection of the exact tumor treatment program and prognosis assessment method.

The mesorectum is composed of the rectum, surrounding mesorectal fat and perirectal lymph nodes, which is cuffed in a thin mesorectal fascia. Mesorectal fat exhibits good anatomical contrast on CT and MR images; therefore, perirectal tumor invasion would be clear and easily visible. CT and MR imaging had become the preferred examination modalities for RC staging. The literatures published within the

last 5 years show that high-resolution MR imaging is more often used in imaging of anatomical structures for RC staging [27], whereas the applications of CT anatomical imaging are rare [25, 32]. RC patients should be examined not only for local staging but also for distant metastasis such as liver and lung metastases. Thus, enhanced CT examination is considered as an indispensable screening method for RC patients. In this study, 64-row 128-slice multi-phase enhanced spiral CT (arterial and portal venous phases) had high spatial resolution and could obtain isotropic images. Meanwhile, because the blood supply differed between the intestinal mucosa and muscular layer, the difference in the enhancement of the rectal mucosa and muscular layer in the different phases could be used to distinguish the mucosa and muscular layer. In addition, mesenteric fat structures also result in good natural contrast, and are thus conducive to demonstrate local lymphadenopathy and surrounding structural invasion. Therefore, enhanced CT scanning could be useful for TN staging of RC. In this study, because the mucosa of the normal intestinal wall or lesions and the mucosa in the transitional region of the normal intestinal wall appeared significant enhancement in the arterial and portal venous phases, whereas the muscular layer exhibited a relatively low degree of enhancement, as well as edema of some lesions adjacent to the submucosa, the structures of the different intestinal layers could be identified on the CT images. However, when the submucosa did not show edema, distinguishing between the mucosa and submucosa was difficult. Hence, the author combined T1 and T2 stages into T1-2 stage for the purpose of research and discussion. In this study, 5 of 7 patients had correct CT T1-2 staging, 9 of 16 patients had correct CT T3 staging, and all 7 patients had correct CT T4 staging. In 2 of 11 patients, T3 stage lesion was underestimated as T1-2 stage. The possible reasons are that these 2 patients demonstrated a smooth outer edge of the intestine, that the enhancement of muscular lesions in arterial phase was low, and that the enhancement of the lesions in the muscular layer in the portal venous phase was lower than that in the mucosa. Thus, the lesions were misdiagnosed because of the absence of invasion to the deep muscular layer. In 3 of 7 patients, T1-2 stage was overestimated as T3 stage. The possible reason is that the enhanced

small blood vessels in the mesenteric fat space were misjudged as invasion of the intestinal wall and surrounding structures. In 4 of 11 patients, T4 stage was underestimated as T3 stage. The possible reason is that the lesion caused fibrosis of the surrounding tissues, pulling the perirectal fascia; thus, it was mistakenly judged as an invasion. As for CT N staging, this study exhibited poor consistency with pathological N staging. The possible reason is that the standard threshold of lymph node metastasis (shorter axis of ≥ 8 mm) was set too high, while that in 30%-50% of the patients with lymph node metastasis was < 5 mm (8).

Above all, the use of conventional 128-slice dual-phase enhanced CT was reliable and advantageous for preoperative staging of RC. Because of the advantages of abdominal CT, local staging of RC could be performed and the presence of distant metastasis (e.g., liver metastasis) could be better detected. Therefore, it can provide comprehensive assessments of the overall condition of RC patients.

The limitation of this study was the poor consistency between the CT results and the pathologic results for lymph node metastasis. This should be further investigated in future studies, with the criterion for lymph node metastasis reduced to 5 mm.

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Disclosure of conflict of interest

None.

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