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Diagnostic Performance of Rectal CT for Staging Rectal Cancer: Comparison with Rectal MRI and Histopathology

직장암 병기결정에서 직장 CT의 진단능: 직장 MRI 및 병리결과와의 비교분석

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Purpose To compare the diagnostic performance of rectal CT with that of high-resolution rectal MRI and histopathology in assessing rectal cancer.

Materials and Methods Sixty-seven patients with rectal cancer who underwent rectal CT with rectal distension using sonographic gel and high-resolution MRI were enrolled in this study. The distance from the anal verge/anorectal junction, distance to the mesorectal fascia (MRF), extramural depth (EMD), extramesorectal lymph node (LN) involvement, extramural venous invasion (EMVI), and T/N stages in rectal CT/MRI were analyzed by two gastrointestinal radiologists. The CT findings of 20 patients who underwent radical surgery without concurrent chemoradiotherapy were compared using histopathology. Interclass correlations and kappa statistics were used.

Results The distance from the anal verge/anorectal junction showed an excellent intraclass correlation between CT and MRI for both reviewers. For EMD, the distance to the MRF, presence of LNs, extramesorectal LN metastasis, EMVI, T stage, and intermodality kappa or weighted kappa values between CT and MRI showed excellent agreement. Among the 20 patients who underwent radical surgery, T staging, circumferential resection margin involvement, EMVI, and LN metastasis on rectal CT showed acceptable concordance rates with histopathology.

Conclusion Dedicated rectal CT may be on par with rectal MRI in providing critical information to patients with rectal cancer.

Index terms Rectal Cancer; Tomography, Spiral Computed; Task Performance and Analysis; Magnetic Resonance Imaging

INTRODUCTION

Accurate staging of rectal cancer is critical because the treatment choice and prognosis of rectal cancer strongly depend on its stage (1, 2). In addition, determining the circumferential resection margin (CRM) involvement of the tumor and evaluating extramural venous invasion (EMVI) and extramesorectal lymph nodes (LNs) help design a proper treatment plan (3-5). Hence, many guidelines recommend the use of a structured report form involving all information regarding T and N staging, CRM status, and EMVI during image interpretation for rectal cancer (6, 7).

The current National Comprehensive Cancer Network (NCCN) guideline states that high-resolution rectal MRI, paired with chest CT or PET/CT, is the standard of choice for staging rectal cancer (8). MRI plays an essential role in staging and predicting the prognosis of patients with rectal cancer because its excellent soft tissue contrast augments its ability to stage tumors and accurately predict clear CRM before radical surgery (9-12). On the other hand, although CT is a primary diagnostic modality in the majority of cancers in general, it plays a limited role in evaluating rectal cancer due to the weak soft tissue contrast of CT compared to MRI, as well as the limited size of the rectal space itself, especially when the rectum is collapsed (9, 13-15).

To improve the diagnostic performance of CT in evaluating rectal cancer, several attempts have been made to induce distension of the rectum with water or sonographic transmission gel as a neutral contrast (16). However, the diagnostic performance of rectal CT in rectal cancer staging in clinical practice has not yet been thoroughly investigated.

Therefore, we aimed to evaluate the diagnostic performance of rectal CT compared to that of rectal MRI, the current gold standard for assessing rectal cancer.

MATERIALS AND METHODS

PATIENT SELECTION

This retrospective study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1910-178-1074), and the requirement for informed consent was waived. The data were fully anonymized before it was provided to us.

Between June 2013 and October 2019, 324 patients underwent rectal CT at the Seoul National University Hospital. The inclusion criteria were patients with confirmed rectal adenocarcinoma and those who underwent pretreatment rectal CT and rectal MRI within a month. Accordingly, 257 patients were excluded who: 1) underwent rectal CT after treatment, such as surgery or endoscopic mucosal resection (n = 157), 2) had other rectal pathologies, such as neuroendo-

crine tumors (*n* = 16), 3) were lost to follow-up (*n* = 23), 4) had no rectal MRI (*n* = 25), or 5) no pre-CCRT rectal CT (*n* = 36). Finally, 67 patients were enrolled in the study. Of these, 47 underwent CCRT and subsequent surgery. The remaining 20 patients who underwent surgical resection without CCRT were classified into subgroups. A flowchart of the patient inclusion process is shown in Fig. 1. The baseline demographics are summarized in Table 1.

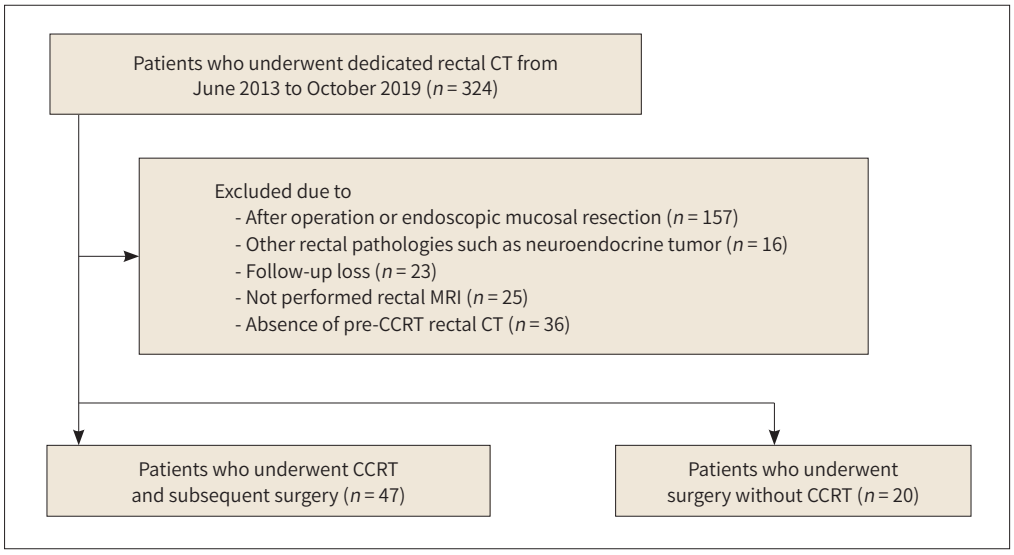
RECTAL CT AND RECTAL MR ACQUISITION

The patients were placed on the CT table in a right lateral decubitus position with their knees on their chest. A soft-tip rectal tube was inserted through the patient's rectum, and approximately 100 mL of sonography transmission gel (Supersonic; Sung Heung Medical Co., Pucheon, Korea) was administered within the range of tolerable pain. We did not perform any specific bowel cleansing or preparation before rectal CT.

For all CT examinations, 16-320 channel multidetector CT scanners were used (sensation 16 [*n* = 6], definition [*n* = 5], force [*n* = 1]; Siemens Healthineers, brilliance 64 [*n* = 2], ingenuity [*n* = 26]; Philips Healthcare, Discovery; GE Healthcare, [*n* = 24], Aquilion ONE; Canon Medical Systems [*n* = 3]).

The acquisition parameters for rectal CT were as follows: detector configuration, 0.625–1.25 mm; pitch, 0.797–1; rotation time, 0.5–0.75 ms; tube voltage, 100–120 kVp; tube current, 150–250 mAs; slice thickness 2–3 mm; and reconstruction interval, 2–3 mm. Precontrast, arterial, and portal phase CT images were obtained for all CT scans. After the acquisition of precontrast CT images, 370 mg·I/mL of iodinated contrast agent was injected by an automatic power injector at a dose of 1.5 mL/kg and a rate of 3–5 mL/s for a fixed 30 s. A saline chase was performed at the same rate for 10 s. For the arterial phase images, a 35 s delay was used after the aorta reached 100 Hounsfield units using the bolus tracking method. For the portal phase, a fixed 70 s delay was used after contrast administration. For all three phases, CT scanning was performed from the dome of the liver to the upper thigh to sufficiently include

Fig. 1. Flow chart of patient enrollment.



CCRT = concurrent chemoradiation therapy

Table 1. Baseline Demographics of the 67 Patients Included

Factors	Values
Age (year)	60.93 ± 9.57
Sex (male:female)	49:18
Body mass index (kg/m^2)	23.89 ± 3.22
Neoadjuvant treatment	
None	20 (30)
Concurrent chemoradiation therapy	44 (66)
Chemotherapy + tyrosine kinase inhibitor	3 (5)
Operation	
Anterior resection	0 (0)
Low anterior resection	39 (58)
Ultra-low anterior resection	18 (27)
Intersphincteric resection	4 (6)
Abdominoperineal resection	2 (3)
Transanal local excision	4 (6)

Data are presented as mean ± standard deviation or *n* (%).

the anal verge (AV). After CT scanning, orthogonal coronal and sagittal reconstructions with a 2 mm reconstruction interval were performed (17). Additional oblique coronal and axial reconstruction images were obtained for all patients, similar to the MRI.

For rectal MRI, a bisacodyl suppository (Dulcolax, Boehringer Ingelheim) was used for bowel preparation at least 3 h prior to the examination. Unless contraindicated, all participants received 20 mg of scopolamine butylbromide (Buscopan, Boehringer Ingelheim) to reduce bowel motion. Before the examination, adequate rectal distention was achieved with 80–100 mL of sonography transmission gel (Supersonic). The use of endorectal filling in rectal MRI remains controversial. Indeed, although the use of endorectal filling is not routinely advised, there is no concrete consensus in both the European Society of Gastrointestinal and Abdominal Radiology (ESGAR) and Society of Abdominal Radiology (SAR) consensus meetings (6, 18). Therefore, the SAR panelists stated that personal and institutional preferences seemed to guide their choice of endorectal filling. As we believe that filling the rectal lumen with sonographic gel facilitates the detection of small tumors, our institute used 80–100 mL of sonographic gel to distend the rectum during rectal MRI.

MRI examinations were performed using a 3T Superconducting System (Ingenia; Philips Healthcare [*n* = 61], Discovery MR 750w; GE Healthcare [*n* = 3]) for 64 patients and a 1.5T MR scanner (Signa HDX; GE Healthcare) for three patients. A 16-channel torso coil was used. Rectal MRIs included T2-weighted (T2W) fast spin-echo (FSE) sequences in the sagittal, oblique axial, and oblique coronal planes, T1-weighted (T1W) spin-echo sequences in the axial plane, diffusion-weighted images (DWI), and apparent diffusion coefficient maps. Two-dimensional (2D) sagittal and coronal T2W FSE sequences were performed using the following parameters: relaxation time (TR), 3761 ms; echo time (TE), 110 ms; field of view (FOV), 24 × 24 cm; slice thickness, 3 mm with a 0.3 mm gap, acquisition matrix, 336 × 252; and number of signal averages (NSA), 3. Coronal T2W images were scanned perpendicularly to the rectum

with the tumor. The oblique axial T2W high-resolution sequence was planned perpendicularly to the rectum with the tumor with the following parameters: TR 3865 ms, 100 ms; FOV, 14 × 14 cm; slice thickness, 3 mm; a 0.3 mm gap, and acquisition matrix, 232 × 228. An oblique axial DWI scan perpendicular to the tumor was implemented using single-shot echo-planar imaging with the following parameters: TE/TR 76/6000 ms, FOV 20 × 30 cm, slice thickness 5 mm with a 0.2 mm gap, acquisition matrix 292 × 304, NSA 6, and two b values (0 and 1000 s/mm^2).

CT AND MR IMAGE ANALYSIS

All rectal CT and MR scans were independently reviewed by two abdominal radiologists (with seven and 12 years of experience in rectal MRI, respectively). They were blinded to each other's evaluations of the scans, previous clinical reports, and the patients' clinical information. They analyzed the CT images first, and then the MRI scans with at least a one-month interval in a random order to minimize recall bias.

For both CT and MRI, the following parameters were analyzed: distance (cm) from the AV and from the anorectal junction to the lower margin of the tumor, extramural tumor depth (EMD, mm), T stage, shortest distance (mm) from the tumor to the mesorectal fascia (MRF), EMVI, and N stage. The AV refers to the most distal aspect of the anal sphincter complex and is located at the lower margin of the subcutaneous external sphincter muscle, which is clearly visualized on CT or MRI in the para-midline sagittal plane (7). The upper border of the puborectalis muscle was used as the anorectal junction. The EMD of the tumor invasion was measured in millimeters from the outer border of the longitudinal proper muscle layer to the deepest part of the tumor invasion perpendicular to the rectal wall. The MRF also referred to as the fascia propria of the rectum, is identified as a thin, highly attenuated structure on CT and a low signal intensity structure on MRI that envelops the rectum and surrounding perirectal fat. To evaluate CRM status, the shortest tumor distance (mm) from the MRF was measured. EMVI refers to the presence of cancer cells within veins beyond the muscularis propria of the rectal wall. EMVI was determined to be present when enhanced tumor density on CT or intermediate tumor signal intensity on MRI was observed within extramural vessels contiguous to the primary tumor (19).

The T and N stages of the tumors were evaluated based on the colorectal cancer staging guidelines of the AJCC 8th edition (20). According to the 8th edition of the AJCC on Cancer staging system, T0, Tis, T1, T2, T3, T4a, and T4b tumors were defined as having no evidence of primary tumor, intraepithelial or invasion of the lamina propria, invasion of the submucosa, invasion of the muscularis propria, invasion of the muscularis propria into the perirectal tissue, penetration to the surface of the visceral peritoneum, or direct invasion of other organs or structures, respectively (20). For T3 tumors, subcategorization was performed, that is, T3a, T3b, T3c, and T3d for extramural invasions of < 1, 1–5, > 5–15, and > 15 mm, respectively.

For N staging, the presence (N+) or absence (N0) of metastatic LNs was determined. For metastatic LNs, size criteria such as ≥ 8 mm in the short-axis diameter, as well as morphologic criteria, such as irregular margins or mixed-density or signal intensity, were used (7). If extra-mesorectal LN involvement was suspected, the reviewers recorded the location of the LNs, including the internal iliac, external iliac, common iliac, inguinal, and para-aortic chains.

For EMD, CRM status, and T staging, subcategorization was performed to compare CT and MRI results. For the EMD, the tumors were subcategorized into ≤ 5 mm and > 5 mm. For the CRM status, the shortest tumor distance of < 2 mm from the MRF on CT or MRI was used as the criterion to predict CRM involvement. For T staging, the tumors were subcategorized into ≤ T3b and ≥ T3c.

The above analyses were also performed on oblique coronal and axial reconstructed CT images.

PATHOLOGIC ANALYSIS

For patients who had not undergone neoadjuvant CCRT before surgery, the pathological information obtained during surgery was also recorded from the patient's electronic medical record. The pathologic findings analyzed were diagnosis, degree of differentiation, pathologic EMD, T and N stages, tumor involvement in the CRM, pathologic EMVI, and the presence of extramesorectal LN involvement. All data were recorded using a standardized histopathological report form.

STATISTICAL ANALYSIS

For all continuous variables, the intraclass correlation coefficient (ICC) was used to compare the results between rectal CT and MRI and between the two reviewers. The agreement was considered poor for ICC values less than 0.40, fair for values between 0.40 and 0.59, good for values between 0.60 and 0.74, and excellent for values between 0.75 and 1.0. EMD and the shortest distance to the MRF were compared between rectal CT and MRI using kappa values. For T staging, EMVI, and LN evaluation, kappa or weighted kappa values were used to compare the results between rectal CT and MRI and between the two reviewers. Kappa values of ≥ 0.81 indicated excellent, 0.61–0.80 substantial, 0.41–0.60 moderate, 0.21–0.40 fair, and ≤ 0.20 poor agreement.

In 20 patients who underwent surgery without CCRT, the concordance rates between CT or MRI and histopathology were used to evaluate the diagnostic performance.

All statistical analyses were performed using SPSS (version 25.0; IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

RESULTS

COMPARATIVE RESULTS BETWEEN RECTAL CT vs. RECTAL MRI

DISTANCE FROM THE AV AND ANORECTAL JUNCTION

A comparison of the recorded distance from the AV to the lower margin of the tumor between CT and MRI showed excellent intraclass correlation for both reviewers (correlation coefficients, 0.972 and 0.953) ($p < 0.001$). In addition, the recorded distance from the anorectal junction to the lower margin of the tumor between both modalities showed excellent intraclass correlation for both reviewers (correlation coefficients, 0.955 and 0.912) ($p < 0.001$) (Fig. 2). The mean ± standard deviation of the differences between the recorded distances from the AV to the tumors in CT and MRI was 0.192 ± 0.733 mm and 0.020 ± 0.889 mm for the two reviewers,

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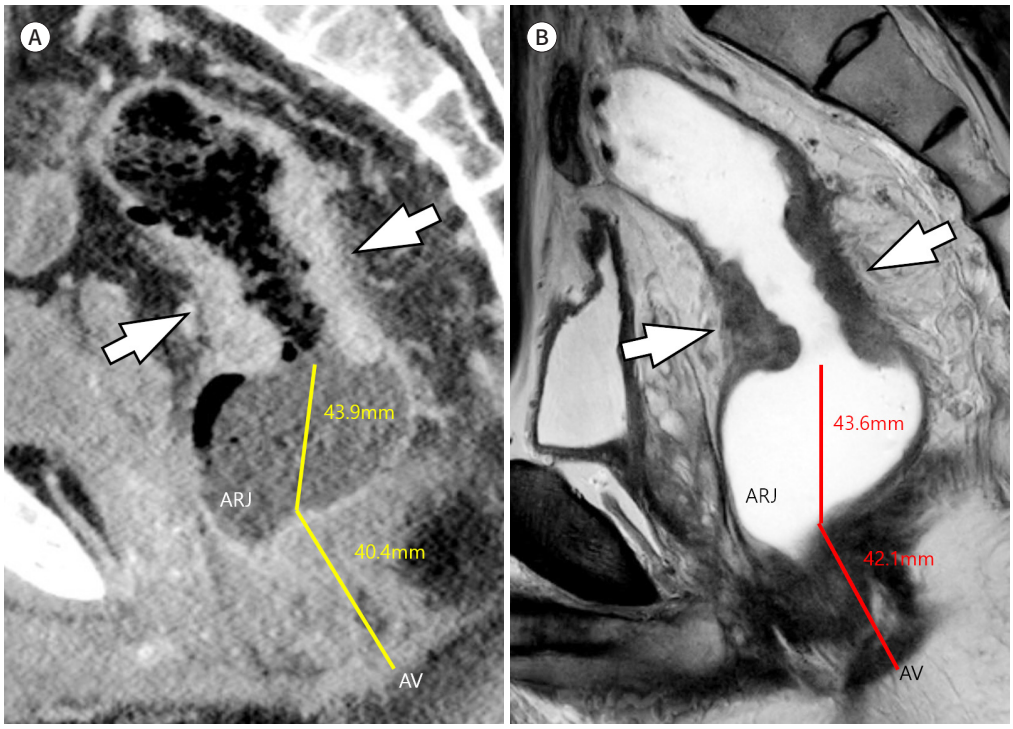
Fig. 2. A 50-year-old male with rectal cancer.
A. Sagittal image of the rectal CT. A tumor (arrows) can be seen 8.4 cm and 4.4 cm above the AV and ARJ, respectively.
B. Sagittal image of the rectal MRI. The distances of the tumor (arrows) from the AV and ARJ are measured as 8.6 cm and 4.4 cm, respectively.
ARJ = anorectal junction, AV = anal verge



respectively. The inter-observer reliability of the CT reported distance from the AV to the tumor was also excellent (correlation coefficient, 0.928) ($p < 0.001$) compared to that of MRIs (correlation coefficient, 0.965) ($p < 0.001$).

The mean ± standard deviation of the differences between the recorded distances from the anorectal junction to the tumor in CT and MRI was 0.168 ± 0.865 mm and -0.177 ± 1.099 mm for the two reviewers, respectively. The inter-observer reliability of CT in reporting the distance from the anorectal junction to the tumor was also excellent (correlation coefficient, 0.888) ($p < 0.001$) compared with that of MRI (correlation coefficient, 0.963) ($p < 0.001$).

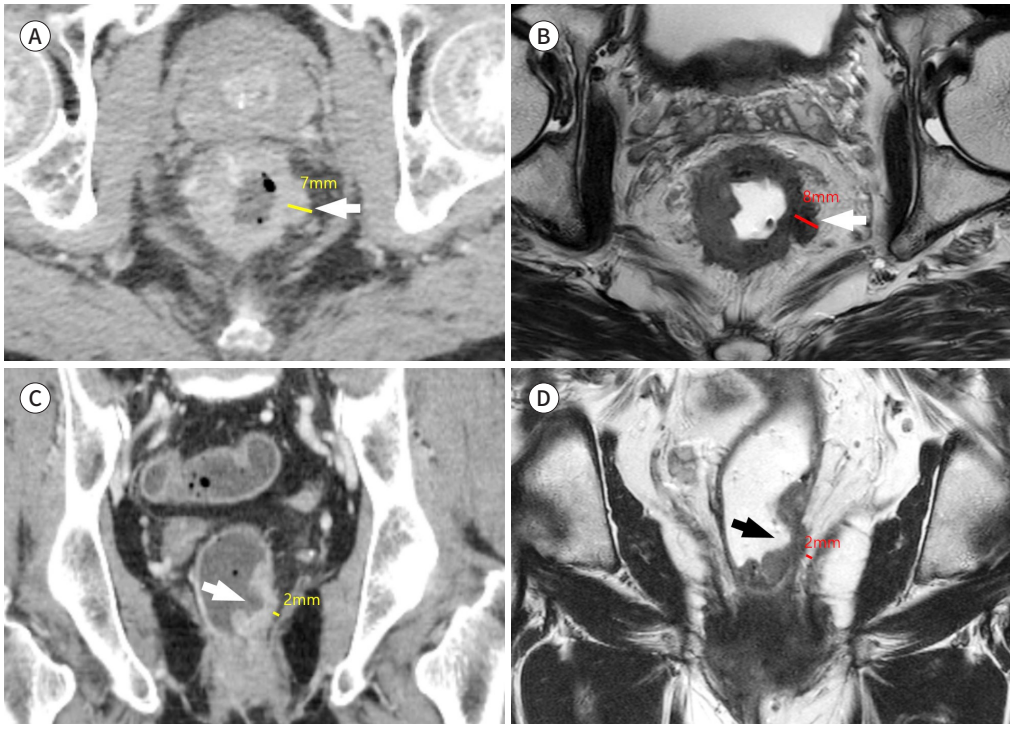
EMD

An excellent correlation was found between rectal CT and MRI in measuring the EMD for both reviewers (correlation coefficients, 0.973 and 0.869) ($p < 0.001$) (Fig. 3). When the patients were categorized into two groups using a cutoff value of 5 mm, the kappa values between CT and MRI for the two reviewers were 0.931 and 0.676, respectively ($p < 0.001$). The inter-observer reliability of CT when measuring EMD was fair (correlation coefficient, 0.594) ($p < 0.001$) compared to that of MRI (correlation coefficient, 0.670) ($p < 0.001$).

SHORTEST DISTANCE FROM MRF

CT and MRI showed excellent correlation in measuring the shortest distance from the tu-

Fig. 3. A 72-year-old male with rectal cancer.
A, B. Measurement for EMD in a 72-year-old male with rectal cancer. (A) Axial image of the rectal CT shows an exophytic extension of the tumor to the mesorectal fat at 3 o'clock. The EMD of the tumor (arrow) invasion is measured as 7 mm on the CT. (B) On an axial image of the rectal MRI, the EMD of the tumor (arrow) is concordantly measured as 8 mm.
C, D. Measurement for the shortest distance to the MRF in a 63-year-old female with rectal cancer. (C) Coronal image of the rectal CT shows that the distance between the tumor (arrow) and MRF is 2 mm. (D) On a coronal rectal MRI, the distance is also measured as 2 mm (arrow).
EMD = extramural depth, MRF = mesorectal fascia



mor to the MRF for both reviewers (correlation coefficients, 0.809 and 0.844) ($p < 0.001$) (Fig. 3). When the patients were categorized into two groups using a cutoff value of 2 mm, the kappa values between CT and MRI for the reviewers were 0.944 and 0.582, respectively ($p < 0.001$). In terms of inter-observer reliability, the ICCs of CT and MRI were 0.687 and 0.561, respectively (fair-to-good correlation) ($p < 0.001$).

T STAGING

The intermodality agreement between CT and MRI for determining the T staging is shown in Table 2. Rectal CT and MRI showed excellent agreement in determining the T stage for both reviewers (weighted kappa values, 0.954 and 0.926) ($p < 0.001$). Regarding inter-observer reliability, there was substantial agreement for both CT and MRI (weighted kappa values, 0.766 and 0.773) ($p < 0.001$).

EMVI

The intermodality agreement in determining EMVI between CT and MRI was excellent for both reviewers using a 5-point scale (weighted kappa value, 0.884 and 0.896) ($p < 0.001$) (Table 3).

Table 2. Intermodality Comparative Results of the Two Reviewers for T Staging

		MR									Weighted Kappa Value
		T1	T2	T3a	T3b	T3c	T3d	T4a	T4b	Total	
Reviewer 1											0.954 (p < 0.001)
CT	T1	0	0	0	0	0	0	0	0	0	
	T2	1	6	1	0	0	0	0	0	8	
	T3a	0	2	6	0	0	0	0	0	8	
	T3b	0	2	3	24	1	0	0	0	30	
	T3c	0	0	0	0	8	1	0	0	9	
	T3d	0	0	0	0	0	4	0	0	4	
	T4a	0	0	0	0	0	0	2	0	2	
	T4b	0	0	0	0	0	0	0	6	6	
	Total	1	10	10	24	9	5	2	6	67	
Reviewer 2											0.926 (p < 0.001)
CT	T1	0	0	0	0	0	0	0	0	0	
	T2	0	14	0	0	0	0	0	0	14	
	T3a	0	0	1	0	0	0	0	0	1	
	T3b	0	3	3	19	5	0	0	0	30	
	T3c	0	1	0	1	9	0	0	0	11	
	T3d	0	0	0	0	0	2	0	0	2	
	T4a	0	0	0	0	0	0	2	0	2	
	T4b	0	0	0	0	0	0	1	6	7	
	Total	0	18	4	20	14	2	3	6	67	

Table 3. Intermodality Comparative Results of the Two Reviewers for Extramural Venous Invasion

		MR								MR		
		1	2	3	4	5	Total			Absent	Present	Total
Reviewer 1												
CT	1	48	0	0	2	0	50	CT	Absent	51	6	54
	2	1	2	0	1	0	4					
	3	0	0	0	1	0	1		Present	1	12	13
	4	0	1	0	3	3	7					
	5	0	0	0	0	5	5		Total	52	15	67
	Total	49	3	0	7	8	67					
Weighted Kappa value				0.884 (p < 0.001)				Kappa value		0.820 (p < 0.001)		
Reviewer 2												
CT	1	1	0	0	0	0	1	CT	Absent	31	2	33
	2	15	1	0	0	0	16					
	3	8	6	1	1	0	16		Present	3	31	34
	4	0	1	3	8	2	14					
	5	0	0	0	0	7	7		Total	34	33	67
	Total	24	10	13	11	9	67					
Weighted Kappa value				0.896 (p < 0.001)				Kappa value		0.851 (p < 0.001)		

When patients were classified into two dichotomous groups (1 or 2 for absent versus 3–5 for present), the kappa values between CT and MRI were 0.820 and 0.851 for the two reviewers, respectively ($p < 0.001$). The inter-observer agreement between the two reviewers was moderate for both CT and MRI (weighted kappa values: 0.430 for CT and 0539 for MRI) ($p < 0.001$).

MESORECTAL AND EXTRAMESORECTAL LN STAGING

The intermodality agreement between CT and MRI was excellent for differentiating N0 from ≥ N1 for both reviewers (kappa value, 1.000 and 0.879) ($p < 0.001$) (Table 4). In addition, excellent to substantial agreement was found in detecting extramesorectal LN metastasis between both reviewers (kappa values, 0.892 and 0.765, respectively) ($p < 0.001$). Regarding the inter-observer agreement, substantial-to-moderate agreements were shown between the two reviewers for CT and MRI for both mesorectal (kappa values, 0.565 and 0.533) and extramesorectal LN staging (kappa values, 0.589 and 0.624) ($p < 0.001$).

DIAGNOSTIC PERFORMANCE OF OBLIQUE CORONAL AND AXIAL RECONSTRUCTION CT IMAGES

For the EMD evaluation of all 67 patients, oblique reconstruction CT showed a similar correlation with rectal MRI when compared with orthogonal reconstruction CT (correlation coefficient: 0.964 for reviewer 1 and 0.840 for reviewer 2) ($p < 0.001$). Dividing by a 5 mm cutoff value, the kappa values between oblique reconstruction CT and MRI were also substantial-to-excellently correlated (kappa values: 0.895 for reviewer 1 and 0.640 for reviewer 2). For T staging, the weighted kappa values for oblique CT and rectal MRI were 0.933 and 0.835, respectively. Inter-observer agreement between the two radiologists was excellent, with a weighted kappa value of 0.862, which was higher than that of the orthogonally reconstructed CT (weighted kappa value: 0.766). For MRF evaluation using a 2 mm cutoff value, the agreement between oblique reconstruction CT and MRI improved from moderate (kappa value: 0.582) to substantial (kappa value: 0.611) for reviewer 2.

Table 4. Intermodality Comparative Results of Lymph Node Staging

	Reviewer 1					Reviewer 2				
			MR					MR		
			N0	≥ N1	Total			N0	≥ N1	Total
Mesorectal lymph node	CT	N0	9	0	9	CT	N0	8	1	9
		≥ N1	0	58	58		≥ N1	9	49	58
		Total	9	58	67		Total	17	50	67
	Kappa value		1.000 ($p < 0.001$)			Kappa value		0.879 ($p < 0.001$)		
	Reviewer 1					Reviewer 2				
			MR					MR		
			-	+	Total			-	+	Total
Extramesorectal lymph node	CT	-	46	3	49	CT	-	47	1	48
		+	0	18	18		+	5	14	19
		Total	46	21	67		Total	52	15	67
	Kappa value		0.892 ($p < 0.001$)			Kappa value		0.765 ($p < 0.001$)		

Regarding EMVI, the agreement between oblique reconstruction CT and MRI was improved by reviewer 2 for both the 5-point scoring system (weighted kappa value: from 0.896 to 0.897) and dichotomization (kappa value: from 0.851 to 0.910) when compared to orthogonally reconstructed CT. Inter-observer agreement of oblique reconstruction CT between the two radiologists (kappa value: 0.529) was also improved compared to orthogonally reconstructed CT (kappa value: 0.43).

COMPARATIVE RESULTS BETWEEN RECTAL CT AND HISTOPATHOLOGY

In the 20 patients who underwent surgery without CCRT, the final histopathology revealed one pTis, three pT1, six pT2, nine pT3 (three pT3a, three pT3b, two pT3c, and one pT3d), and one pT4b. For N staging, nine patients were N1, and the remaining 11 were N0. The average time (± standard deviation) from rectal CT or rectal MRI to surgery was 19.2 ± 12.7 days and 15.4 ± 8.6 days, respectively.

CRM INVOLVEMENT

The rectal CT results were concordant with histopathology for evaluating the CRM involvement in 75% (15/20) of the patients evaluated by reviewer 1 and 65% (13/20) by reviewer 2. Two and four patients were misinterpreted as having threatened the CRM (shortest distance to MRF, ≤ 2 mm) on rectal CT by reviewers 1 and 2, respectively. Histology confirmed sufficient CRMs (shortest distance to the MRF > 2 mm) in these six patients. In contrast, three patients were understaged with sufficient CRMs on CT by both reviewers; however, the pathology revealed a threatened CRM in these three patients.

T STAGING

The comparative results of rectal CT and histopathology for T staging are presented in Table 5. Rectal CT showed excellent agreement with histopathology in determining T staging for reviewer 1 (weighted kappa value, 0.848) ($p < 0.001$) and moderate agreement for reviewer 2 (weighted kappa value, 0.569) ($p = 0.005$) (Fig. 4). When the 20 patients were dichotomized into two groups into ≤ T3b and ≥ T3c, rectal CT showed a high concordance rate with histopathology for both reviewers (concordance rate, 90% [18/20]). For reviewer 1, patients with pT3b and pT3c were overstaged and understaged as cT3c and cT3b, respectively. According to reviewer 2, two patients with pT3c and pT4b were understaged as cT3b.

EMVI

When the patients were dichotomized into two groups based on ctEMVI- (confidence score, 1 or 2) and ctEMVI+ (confidence score, 3–5) on CT, rectal CT showed high concordance rates with histopathology for both reviewers 1 (90%, 18/20) and 2 (70%, 14/20) (Fig. 5). Reviewers 1 and 2 overcalled ctEMVI as positive in two and six patients who had negative EMVIs on pathology, respectively.

N STAGING

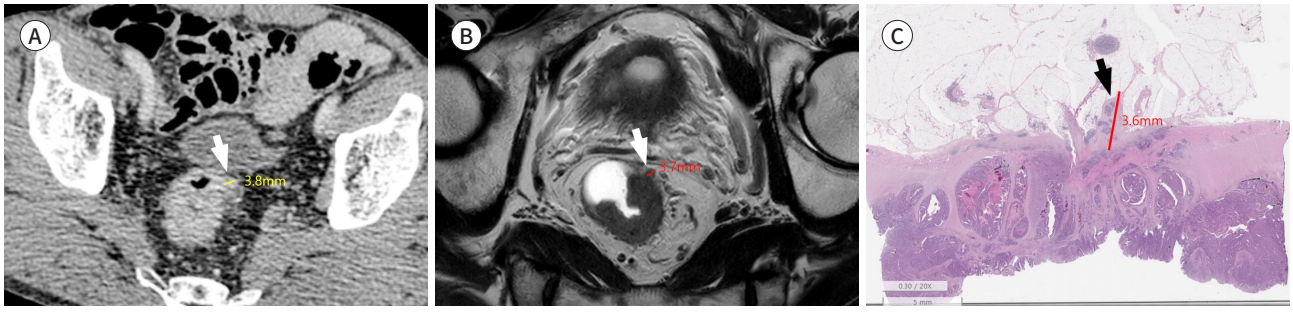
Rectal CT showed relatively low concordance rates with histopathological findings for both reviewers (60% [12/20]) for reviewer 1 and 65% [13/20] for reviewer 2). Both reviewers frequent-

Table 5. Comparative Results between Rectal CT and Histopathology for T Staging

		Histopathology									
		≤ T1*	T2	T3a	T3b	T3c	T3d	T4a	T4b	Total	Weighted Kappa Value
CT	Reviewer1										0.848 (p < 0.000)
	T1	0	0	0	0	0	0	0	0	0	
	T2	4	3	1	0	0	0	0	0	8	
	T3a	0	1	2	0	0	0	0	0	3	
	T3b	0	2	0	2	1	0	0	0	5	
	T3c	0	0	0	1	0	0	0	0	1	
	T3d	0	0	0	0	1	1	0	0	2	
	T4a	0	0	0	0	0	0	0	0	0	
	T4b	0	0	0	0	0	0	0	1	1	
	Total	4	6	3	3	2	1	0	1	20	
	Reviewer 2										0.569 (p = 0.005)
	T1	0	0	0	0	0	0	0	0	0	
	T2	2	5	2	0	0	0	0	0	9	
	T3a	1	0	0	0	0	0	0	0	1	
	T3b	1	1	1	3	1	1	0	0	8	
	T3c	0	0	0	0	0	0	0	1	1	
	T3d	0	0	0	0	1	0	0	0	1	
	T4a	0	0	0	0	0	0	0	0	0	
	T4b	0	0	0	0	0	0	0	0	0	
	Total	4	6	3	3	2	1	0	1	20	

*Pathologic ≤ T1 stage includes pTis and pT1 stages.

Fig. 4. A 63-year-old male with rectal cancer.
A, B. On axial CT (A) and MR (B) images, a nodular tumor extension can be seen at 1 o'clock of the tumor (arrows). The EMD of the tumor invasion is measured as 3.8 mm on CT (A) and 3.7 mm on MRI; (B) therefore, the tumor was staged as cT3b on both CT and MRI.
C. The patient underwent low anterior resection without neoadjuvant treatment. On a microscopic image (hematoxyling and eosin stain, × 40), the EMD of the tumor (arrow) is measured as 3.6 mm and finally staged as pT3b by histopathology.
EMD = extramural depth



ly overcalled the N stage as positive for 12 patients who were node-negative (N0) on pathology (seven patients by reviewer 1 and five patients by reviewer 2) (Fig. 6).

DIAGNOSTIC PERFORMANCE OF OBLIQUE CORONAL AND AXIAL RECONSTRUCTION CT IMAGES

For the 20 patients with oblique coronal and axial reconstruction CT images similar to

Fig. 5. A 73-year-old male with rectal cancer.
A, B. On coronal rectal CT (A) and MR (B) images, a tubular and serpentine extension of the tumor (arrows) with similar attenuation or signal intensity to the main tumor is well demonstrated. Therefore, two radiologists reported EMVI positivity on CT and MRI.
C. The patient received low anterior resection without neoadjuvant treatment because he refused neoadjuvant concurrent chemoradiation therapy. On a microscopic image (hematoxyling and eosin stain, × 40), multiple tumor droplets (arrows) can be seen within the extramural veins. Histology confirmed the presence of EMVI.
EMVI = extramural venous invasion

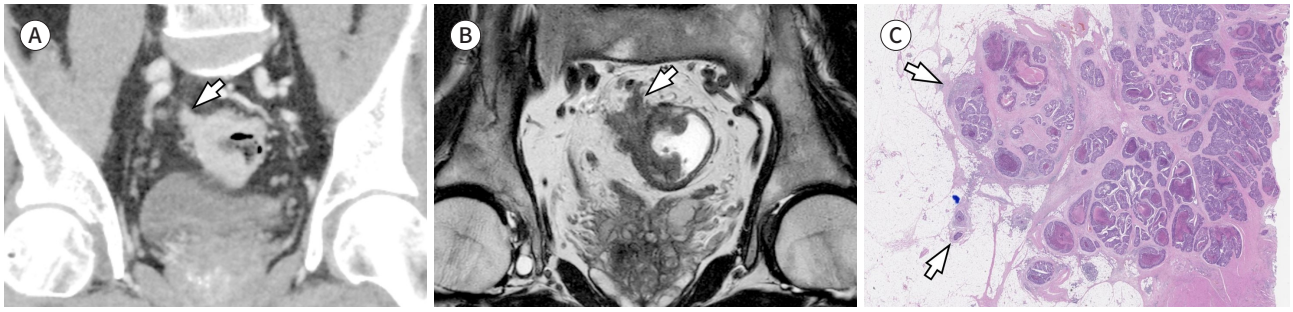
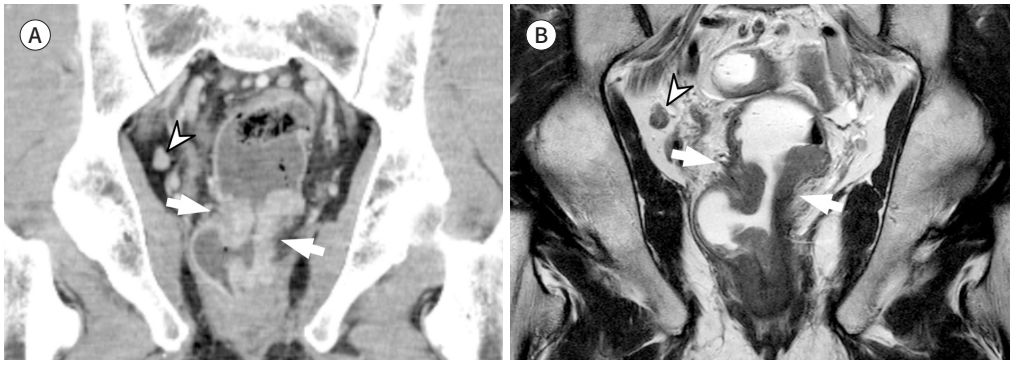


Fig. 6. A 58-year-old male with rectal cancer.
A, B. On coronal rectal CT (A) and MR (B) images, a huge annulo-constricting mass (arrows) in the rectum can be seen. Note an 8 mm round, enlarged LN (arrowheads) at the right internal iliac chain, suggesting extramesorectal LN metastasis. The patient underwent intersphincteric resection with extramesorectal LN dissection without neoadjuvant treatment. However, no metastatic LNs were apparent on final histopathology, confirming N0 stage.
LN = lymph node



those of the MR images, the concordance rates for evaluating CRM involvement between rectal CT and histopathology were 80% (16/20) for reviewer 1 and 70% (14/20) for reviewer 2. For T staging, the weighted kappa values were 0.903 and 0.847, respectively. Dividing by ≤ T3b or ≥ T3c, the concordance rates between rectal CT and histopathology were 95% (19/20) for reviewer 1 and 95% (19/20) for reviewer 2. Regarding EMVI, when the patients were dichotomized into two groups by ctEMVI- (confidence score, 1 or 2) and ctEMVI+ (confidence score, 3–5) on CT, the concordance rates were 95% (19/20) and 80% (16/20), respectively. For N staging, the concordance rate between both reviewers was 55% (11/20). Except for N staging, oblique reconstruction CT images showed better concordance rates with histopathology than orthogonal reconstruction CT images.

COMPARATIVE RESULTS BETWEEN RECTAL MRI AND HISTOPATHOLOGY

For CRM involvement, the concordance rates between rectal MRI and histopathology were

75% (15/20) and 65% (13/20) for reviewers 1 and 2, respectively. For T staging, the weighted kappa values were 0.872 and 0.505. When the 20 patients were dichotomized into two groups, ≤ T3b and ≥ T3c, the concordance rates between rectal MRI and histopathology were 90% (18/20) for reviewer 1 and 75% (15/20) for reviewer 2. Regarding EMVI, when patients were dichotomized into two groups based on mrEMVI- (confidence score, 1 or 2) and mrEMVI+ (confidence score, 3–5) on MRI, rectal MRI showed acceptable concordance rates (80%, 16/20 for reviewer 1, and 70%, 14/20 for reviewer 2) with histopathology for both reviewers. Regarding N staging, rectal MRI showed a better concordance rate with histopathology than rectal CT, according to reviewer 2 (60% [12/20] for reviewer 1 and 75% [15/20] for reviewer 2).

DISCUSSION

In this study, we found excellent correlations between rectal CT and MRI and between the two reviewers in localizing the longitudinal tumor extent. Identifying lower rectal cancer, defined as when the distal margin of the tumor is located within 5–6 cm of the AV (21-23), is important because its management and prognosis differ from those of upper or middle rectal cancer. Therefore, we believe that the exact localization of rectal tumors using rectal CT may have an impact on clinical practice. In this study, a slightly lower ICC (0.888) was obtained for the inter-observer correlation between rectal CT and MRI (0.963). Compared to the prominently and clearly visualized horizontal portion of the external anal sphincter on CT or MRI as an anatomical landmark of AV, the puborectalis sling, which is an anatomic landmark of the anorectal junction, is less prominent on rectal CT than on MRI (21-23). This might be responsible for the lower ICC value of rectal CT compared with rectal MRI when measuring the distance from the anorectal junction to the tumor.

In terms of measuring the EMD or shortest distance to the MRF, excellent correlations were achieved between rectal CT and MRI by both reviewers. This is an interesting and encouraging result because this information is critical for determining the treatment plans and prognosis of patients with rectal cancer. We initially expected that CT, even rectal CT, might have results discrepant from rectal MRI in providing detailed information in millimeter units, owing to the weak soft tissue contrast of CT. We thought that the better spatial resolution of CT (usually 0.4 mm × 0.4 mm × 2 mm) compared to high-resolution rectal MRI (0.6 mm × 0.6 mm × 3.3 mm) might compensate for the worse soft tissue contrast of CT. Furthermore, adequate distention of the rectum using sonographic gel prior to CT examination may have partially contributed to the favorable result because well-delineated rectal cancer through rectal distention may have facilitated the identification of rectal cancer as well as the deepest extramural extension of the tumor. In the same context, rectal CT provided acceptable concordance rates (65% [13/20] and 75% [15/20]) with histopathology for both reviewers to determine the CRM status in 20 patients who underwent surgery without CCRT. Because high-resolution CT using a 1024 × 1024 matrix has recently been introduced with thin-section reconstruction, we hope that it may further improve the spatial resolution of CT by up to 0.2 mm × 0.2 mm × 1 mm and improve the concordance rates of rectal CT with histopathology. There have been conflicting results regarding the effect of rectal distention on the distance between rectal cancer and MRF. Slater et al. (24) insisted that the distance could be underestimated due to the effect

of compression by the endorectal gel or water. However, other authors have reported no significant difference in the distance between a tumor and the MRF on non-distended and distended MR images (25-27). This may be because tumor invasion and desmoplastic reactions can stiffen adjacent tissues against the effects of compression, and the amount of mesorectal fat compression is insufficient to push the tumor close to the MRF. Therefore, further prospective studies with larger study populations are warranted to address these conflicting issues.

Regarding T staging, we observed encouraging results on rectal CT. Rectal CT showed excellent agreement with MRI for both reviewers (weighted kappa values, 0.954 and 0.926) and substantial agreement (weighted kappa values, 0.766) in terms of inter-observer reliability. Compared to histopathology, a high concordance rate (90%, 18/20) was achieved by both reviewers for differentiating between $\leq$ pT3b and $\geq$ pT3c. We thought this was an important observation because patients with $\leq$ pT3b have a favorable outcome compared to patients with $\geq$ pT3c. Our results are noteworthy because the exact prognosis is critical in patients with rectal cancer. Traditionally, CT is regarded as an inferior modality for determining T staging compared to MRI because of poor soft tissue contrast. Indeed, several researchers have reported a lower T staging accuracy (79%–90%) of CT compared to that of rectal MRI using a phase array coil and 3T scanner (86%–95%) (28-31). We believe that the excellent agreement in T staging between dedicated rectal CT and MRI in our study may be due to the combined use of sonographic gel and oblique axial CT reconstruction images.

Because EMVI is a poor prognostic factor in patients with rectal cancer, the exact identification of EMVI on imaging is critical for patient prognosis (19). Our study found that rectal CT showed excellent to substantial agreement with rectal MRI findings, according to both reviewers. Furthermore, moderate agreement with a weighted kappa value of 0.430 was observed for inter-observer reliability. Compared to histopathology, rectal CT showed high concordance rates for both reviewers (90% [18/20] and 70% [14/20], respectively). For eight patients showing discrepant results between CT and histology, both reviewers called ctEMVI-positive for all eight patients who eventually had negative EMVIs on pathological examination. We suggest that the exact differentiation of EMVI from tumor infiltration might be difficult using CT in these patients due to the poor soft tissue contrast of CT.

We also found that the intermodality agreement for N staging was excellent to substantial for both mesorectal and extramesorectal LNs. However, the inter-observer agreement for CT and MRI between the two reviewers was not sufficiently high. Furthermore, relatively low concordance rates were observed between rectal CT and histopathology (60% [12/20] and 65% [13/20], respectively) for N staging. Compared to rectal MRI, in which signal intensity and LN margins are used in addition to LN size for characterizing the nodes (32, 33), radiologists usually use size alone in CT to determine LN status. This limited information related to node size may be responsible for the low concordance rates between CT and histopathological findings. Indeed, the reviewers overcalled the LN status on CT in most patients (12/14) who were misinterpreted as LN staging. Recently, forward-looking trials have been conducted to improve the characterization of LN metastases in colorectal cancers using CT (34, 35), in which internal heterogeneity and border irregularity of LNs on CT could predict LN metastasis. Therefore, further studies that add morphological criteria to LN staging using CT are warranted to improve the diagnostic performance of rectal CT for LN staging.

Regarding the analysis of oblique reconstruction CT, the inter-observer agreement between the two radiologists improved for the evaluation of EMD and EMVI compared with orthogonal reconstruction CT. Furthermore, the agreement between CT and MRI also improved regarding the measurement of the distance between the tumor and the MRF and EMVI for reviewer 2 when oblique reconstructed CT images were used. More importantly, for subgroup analysis, concordance rates between oblique reconstruction CT and histopathology were improved in CRM involvement, T staging, and EMVI compared to the comparative results between orthogonal CT and histopathology. However, oblique reconstruction perpendicular to the rectal centerline might positively influence the correlation and agreement between CT and MRI and the concordance rate between rectal CT and histopathology. Through oblique axial reconstruction, the relationship between the muscularis propria and the tumor can be more accurately evaluated without blurring (36). Similarly, oblique coronal reconstruction images may contribute to the precise evaluation of the invasion of adjacent structures, such as the anal sphincter complex (10). Therefore, further prospective studies with a larger number of patients and oblique reconstruction CT are warranted to validate our results.

Our study has several limitations. First, the sample size (n = 67) was not sufficiently large, particularly for patients who underwent surgery without CCRT (n = 20). Therefore, further studies with larger populations are required to verify our results. Second, the image quality of the obliquely reconstructed CT images was not perfect because oblique reconstruction was retrospectively performed with already orthogonally reconstructed axial CT images, owing to the absence of source CT data. Therefore, although we obtained slightly optimistic results with oblique reconstruction CT, further prospective studies with a larger number of patients and prospectively acquired oblique reconstruction CT images should be conducted to validate our results. Furthermore, we believe that high-resolution reconstruction with a matrix of 1024 × 1024 and adjusted reconstruction perpendicular to the tumor may improve the diagnostic performance of rectal CT. Third, only two reviewers were recruited for the performance study. Considering that the interpretation of rectal imaging is influenced by the expertise of radiologists, recruiting many reviewers with different levels of experience could help to better reflect actual clinical practice.

In conclusion, rectal CT with rectal distention using sonographic gel may provide critical information on par with rectal MRI in patients with rectal cancer.

Author Contributions

Conceptualization, S.S.Y., S.Y.S., K.S.H.; data curation, all authors; formal analysis, all authors; funding acquisition, K.S.H.; investigation, S.S.Y., S.Y.S., K.S.H.; methodology, S.S.Y., S.Y.S., K.S.H.; project administration, S.S.Y., S.Y.S., K.S.H.; resources, S.Y.S., K.S.H.; software, S.Y.S., K.S.H.; supervision, S.Y.S., K.S.H.; validation, S.Y.S., K.S.H.; visualization, S.Y.S., K.S.H.; writing—original draft, S.S.Y., S.Y.S., K.S.H.; and writing—review & editing, S.Y.S., K.S.H.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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직장암 병기결정에서 직장 CT의 진단능: 직장 MRI 및 병리결과와의 비교분석

손석윤[1] · 서윤석[2] · 윤정희[2] · 허보윤[3] · 배재석[2] · 김세형[2,4]*

목적 직장암 병기결정에서 직장 CT의 진단능을 고해상도 직장 MRI 및 병리결과와 비교분석하였다.

대상과 방법 초음파 젤을 이용하여 직장을 팽창시킨 후 얻은 직장 CT와 고해상도 직장 MRI를 촬영한 66명의 직장암 환자가 포함되었다. 두 명의 위장관 영상의학과 의사가 직장 CT와 MRI에서 항문피부선/항문직장경계까지의 거리, 직장간막근막까지의 거리, 벽외침범 깊이, 직장간막외 림프절 침범, 벽외정맥침범, 및 T/N 병기를 평가하였다. 동시화학방사선요법을 시행 받지 않고 근치적 수술을 시행한 20명의 환자의 CT 소견을 병리결과와 비교하였다. 급내상관분석 및 카파 분석을 이용하여 통계 분석하였다.

결과 항문피부선/항문직장경계까지의 거리 측정에서 두 명의 영상의학과 의사 모두 CT와 MRI 간에 높은 상관관계를 보였다. 벽외침범 깊이, 직장간막근막까지의 거리, 림프절의 유무, 직장간막외 림프절 침범, 벽외정맥침범, T 병기 결정에서 CT와 MRI 간의 높은 일치도를 보였다. 수술을 시행받은 20명의 환자에서 T 병기, 측방절제연 침범, 벽외정맥침범, 림프절 전이 결정에서 CT는 병리결과와 만족할만한 일치율을 보였다.

결론 직장암 전용 CT는 직장암 환자의 병기 결정에 중요한 정보를 제공하며, 진단능은 고해상도 직장 MRI와 유사하다.

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