European Journal of Surgical Oncology 45 (2019) 324–330

Contents lists available at ScienceDirect

European Journal of Surgical Oncology

journal homepage: www.ejso.com

Accuracy of pelvic MRI in measuring tumor height in rectal cancer patients with or without preoperative chemoradiotherapy

Eric Chung [a], Dongwon Kang [b], Hye Sun Lee [c], Eun-Suk Cho [d], Joo Hee Kim [d], Eun Jung Park [b], Seung Hyuk Baik [b], Kang Young Lee [b], Jeonghyun Kang [b, *]

[a] Yonsei University College of Medicine, Seoul, South Korea
[b] Department of Surgery, Yonsei University College of Medicine, Seoul, South Korea
[c] Biostatistics Collaboration Unit, Yonsei University College of Medicine, Seoul, South Korea
[d] Department of Radiology, Yonsei University College of Medicine, Seoul, South Korea

ARTICLE INFO

Article history:
Received 3 December 2017
Received in revised form
24 June 2018
Accepted 30 August 2018
Available online 9 October 2018

Part of this study was orally presented at the 13th Korea-Japan-China colorectal cancer symposium held in September, 2012, in Seoul, South Korea.

Keywords:
Rectal cancer
Tumor height
MRI
Rigid sigmoidoscopy
Preoperative chemoradiotherapy

ABSTRACT

Introduction: In measuring tumor height for rectal cancer, rigid sigmoidoscopy (RS) is a standard modality, and the accuracy of magnetic resonance imaging(MRI) in patients with/without preoperative chemoradiotherapy (CRT) has not been fully investigated. The aim of this study was to investigate the accuracy of MRI for measuring tumor height.

Materials and methods: Among rectal cancer patients seen between July 2006 and May 2012, the initial group (RS and MRI available at initial diagnosis) and the post-CRT group (RS and MRI available after the completion of preoperative CRT) were selected. Intra-class correlation coefficient (ICC) comparison tests were performed between RS and MRI results for each group.

Results: Ninety-nine and 29 patients were allocated into the initial group and the post-CRT group, respectively. The tumor heights measured by RS and MRI demonstrated a positive relationship in the scatter plot (linear regression; $R^2 = 0.898$; $p < 0.001$ in the initial group, $R^2 = 0.696$; $p < 0.001$ in the post-CRT group). With respect to difference of absolute value (DAV) between RS and MRI, the overall mean and standard deviation of DAV were 10.9 ± 10 mm in the initial group and 8 ± 6 mm in the post-CRT group. ICC comparison analysis revealed that inter-rater agreement of RS and MRI in the initial group was significantly better than that of the post-CRT group [ICC (95% CI) 0.946 (0.919–0.963) vs. 0.823 (0.621–0.917); $p = 0.004$)].

Conclusions: MRI can be used as a viable option to measure tumor height in rectal cancer even in patients who have undergone preoperative CRT.

Introduction

In the management of rectal cancer, the incidence of preoperative chemoradiotherapy (preop-CRT) is increasing because it can facilitate successful oncological excision and sphincter-preserving resection. According to the current guidelines, preop-CRT is recommended for patients who were diagnosed as clinically T3/4 or node-positive regardless of tumor height and location [1]. Although preop-CRT is regarded as a standard treatment for locally advanced rectal cancer, there is some controversy on applying it for upper rectal cancer due to its technical and anatomical similarity with colon cancer [2].

Tumor height measurements are clinically important in treatment perspectives. Surgical plan and preparations can differ according to preoperatively measured tumor height or tumor characteristics. From a surgeon's perspective, in the case of local excision, tumor height might be one of the most important factors to select the proper surgical approach among transanal excision, transanal endoscopic operation, transanal endoscopic microsurgery, and laparoscopic approaches.

Measuring the distance from the anal verge to a rectal tumor by rigid sigmoidoscopy (RS) has been regarded as a standard modality so far. Although colonoscopy is the gold standard detection tool for colorectal cancer, its ability to provide precise tumor localization,

* Corresponding author. Department of Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, 211 Eonju-ro, Gangnam-gu, Seoul, 06273, South Korea.
E-mail address: ravic@naver.com (J. Kang).

https://doi.org/10.1016/j.ejso.2018.08.029
0748-7983/

especially for differentiating rectosigmoid colon cancer and rectal cancer is questionable [3]. In addition, one study reported that tumor distance measured by RS and colonoscopy differ and resulted in 25% of patients changing treatment plan by adding a RS [4].

Digital rectal examination, RS, transanal ultrasound, and pelvic magnetic resonance imaging (MRI) are frequently used tools to evaluate tumor height and accurate preoperative staging. It is well known that MRI is accurate, feasible, reproducible, and a valid standard for preoperative rectal cancer staging [5]. For this reason, pelvic MRI has been increasingly applied to evaluate rectal cancer patients. However, with respect to measuring tumor height from the anal verge, there have been no standard methods suggested to define tumor height using MRI [6–8]. Thus, it is uncertain whether pelvic MRI can substitute for RS in measuring tumor height for rectal cancer [6]. Furthermore, the usefulness of pelvic MRI in measuring tumor height has not been investigated for patients who underwent preop-CRT.

The purpose of this study was to determine whether the tumor height measured by pelvic MRI is as accurate as that evaluated by rigid sigmoidoscopy in rectal cancer patients with or without preop-CRT.

Materials and methods

Patient selection

All clinical and pathological data of patients diagnosed with rectal cancer in our hospital from July 2006 to May 2012 were obtained from our prospectively maintained database. Among 116 patients, 63 patients did not receive a preop-CRT and 53 patients underwent a preop-CRT. Although preop-CRT was initially recommended for patients with clinical stage II or III, the performance of preop-CRT was decided according to the surgeon's discretion or the patient's desire for sphincter preservation.

Fifty-nine patients with no preop-CRT group and 40 patients with the preop-CRT group were available for analysis of initial tumor staging because these patients underwent both RS and MRI at the initial diagnosis (initial group, n = 99). Among 53 patients who underwent preop-CRT, only 29 underwent both RS and pelvic MRI after completion of preop-CRT, and these patients constituted a post-CRT group (n = 29). Patients whose MRI detected no residual tumor after preop-CRT were excluded in our analysis because we cannot measure the tumor height. For the post-CRT group, all RS and pelvic MRI were measured 4–6 weeks after the completion of preop-CRT. (Fig. 1). This study was approved by the institutional review board of our hospital.

Tumor height measured by rigid sigmoidoscopy

Tumor height measured by RS was defined as the shortest distance from the anal verge to the lower border of the tumor depicted by the examiner. RS is usually performed in an outpatient setting in conjunction with a digital rectal examination, while the patients were placed in left lateral decubitus position. All RS measurements in our study were performed by three surgeons specialized in colorectal surgeries.

MRI protocol and tumor height measured by pelvic MRI

The MRI protocol was described in the previous study [9]. There was no difference of MRI protocols both concerning the staging and the restaging before surgery. Used imaging sequence were described as: T1-weighted turbo spin-echo MRI (repetition time [TR]/echo time[TE], 530/10 ms; matrix size, 448 x 358; slice thickness, 3 mm; intersection gap, 0.3 mm; and field of view, 20 × 20 cm) in the axial plane, and T2-weighted turbo spin-echo MRI (TR/TE, 3400/100 ms; matrix size, 512x180; slice thickness, 3 mm; intersection gap, 0.3 mm; and field of view, 20 × 20 cm) in all planes including axial, coronal, and sagittal. All diffusion-weighted image (DWI) studies were generated using an echo-planar sequence at three b values, 0, 500, and 1000 s/mm [2]. A 1.5-T scanner (MageneAvanto; Siemens Medical System, Erlangen, Germany) and a 3-T scanner (Achieva; Philips, Eindhoven, Netherlands) were used to obtain the images in pelvic MRI. DWI was used since 2008 in our hospital.

The tumor height measured by pelvic MRI was the shortest distance from the anal verge to the lower margin of the tumor on the imaginary longitudinal midline of the rectum in the sagittal plane (Fig. 2). As described previously, on a sagittal MR image, the distal limit is generally considered to be at the anal verge [10]. Two gastrointestinal radiologists who had 15 years and 5 years of experience in the MR imaging of the rectum independently measured the length of the rectum in the MR imaging. The measurement data by more experienced radiologist were used for further comparison to RS measurement. A less experienced radiologist performed control measurements in order to assess inter-observer variability.

Difference of absolute value (DAV)

In our study, we defined the difference of absolute value (DAV) as the absolute value between the tumor height measured by RS and that measured by MRI. According to our data, DAV showed normal gaussian distribution with mean and standard deviation as

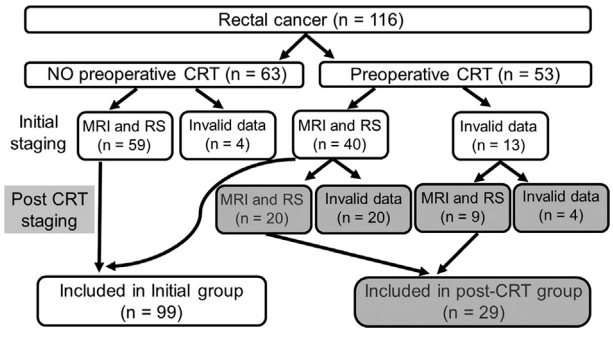

Fig. 1. Inclusion criteria.
Abbreviations: CRT: Chemoradiotherapy; MRI: Magnetic Resonance Imaging; RS: Rectosigmoidoscopy.

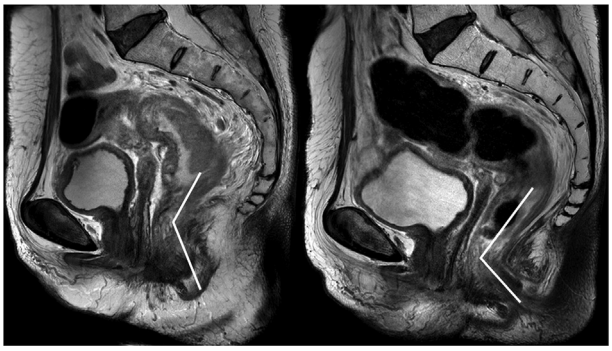

Fig. 2. Tumor height measurements. Tumor height in MRI was measured from anal verge to the lower margin of the tumor at the initial MRI (left) and after completion of preoperative chemoradiotherapy (right) in same patient.

10.9 ± 8.5 mm in the initial group. We assumed 75th percentile to be a significant DAV which was more than 15 mm. Thus, we defined a significant DAV as more than 15 mm.

Statistical analysis

All independent clinical and pathological variables were analyzed with Pearson's Chi square test, Fisher's exact test, or Students t-test depending on the distribution of the variables. The correlation between RS and pelvic MRI was analyzed by correlation analysis, linear regression analysis and scatter plots. Inter-rater agreement between RS and pelvic MRI was assessed with intra-class correlation coefficient (ICC) and Bland-Altman plots. The ICC ranges from 0 to 1, with 0 indicating no agreement and 1 indicating perfect agreement. For the Bland-Altman plot, the mean difference of zero indicates perfect agreement, while the 95% limit of agreement is the intervals within which 95% of the data line.

Inter-observer agreement analyses were performed using dedicated statistical software. The kappa statistics was used to assess inter-observer agreement with respect to scoring and was interpreted according to the guidelines of Landis and Koch [11]. We used the following definition to interpret the kappa coefficients: a kappa (κ) value of equal to or less than 0.20 indicated insignificant agreement; values from 0.21 to 0.40, median agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81–1.00, almost perfect agreement.

All independent variables were analyzed using IBM SPSS version 23.0 (SPSS Inc., Chicago, IL, USA) and Medcalc version 18.2.1 (MedCalc Software, Ostend, Belgium). A P value less than 0.05 was considered statistically significant.

Results

Ninety-nine patients and 29 patients were allocated into the initial group and the post-CRT group respectively. The characteristics of patients in each group are shown in Table 1. The majority of patients in the initial group were male, aged less than 70 years, body mass index (BMI) under 25 kg/m^2 and mid rectal tumor. In the post-CRT group, the majority of patients were aged less than 70 years, BMI under 25 kg/m^2, and low rectal tumor. The median time from initial staging MRI to surgery was 14 days (range, 2–62 days) in the no preoperative CRT group and 110 days (range, 78–178 days) in the preoperative CRT group. The median time from post CRT staging MRI to surgery was 11 days (range, 3–47 days) in the post-CRT group (Table 1).

Using paired *t*-test, there was no significant difference in the tumor height measured by RS and by MRI [RS (mean ± SD); 64 ± 29 mm and MRI (mean ± SD); 64 ± 31 mm; t(98) = − 0.543, p = 0.588] in the initial group. In addition, there was no significant difference in the tumor height measured by RS and by MRI [RS (mean ± SD); 46 ± 13 mm and MRI (mean ± SD); 47 ± 13 mm; t(28) = − 0.188, p = 0.852] in the post-CRT group.

In the initial group, the scatter plot represents the positive relationship between the tumor height distance measured by RS and the distance measured by MRI (linear regression; $R^2 = 0.745$; standardized regression coefficient = 0.862, p < 0.001). With regard to the post-CRT group, the tumor height measured by RS and MRI also exhibits a positive relationship in the scatter plot (linear regression; $R^2 = 0.376$; standardized regression coefficient = 0.613, p < 0.001) (Fig. 3).

With respect to DAV between RS and MRI, the overall mean and standard deviation of DAV were 10.9 ± 10 mm in the initial group and 8 ± 6 mm in the post-CRT group. In the initial group, in univariate analysis, mean DAV did not show any statistically significant difference according to gender, age, BMI, tumor size, tumor location, or operation method. DAV was significantly higher in T3 and T4 group compared with (y)pCR, T1, and T2 group (12.7 ± 9.4 mm vs. 9.1 ± 7.1 mm, p = 0.037). In the post-CRT group, there was no difference in mean DAV according to gender, age, tumor size, tumor location, or T stage (Table 2).

Significant DAV was not associated with gender, age, BMI, tumor size, tumor location, or depth of invasion in either the initial group or the post-CRT group (Table 3).

ICC comparison analysis revealed that the inter-rater agreement of RS and MRI in the initial group was significantly better than that of the post-CRT group [ICC (95% CI), 0.946 (0.919–0.963) in the initial group vs. 0.823 (0.621–0.917) in the post-CRT group; p = 0.004)] (Fig. 4)(see Table 4).

Table 1
Patient baseline characteristics according to group.

		Initial group (N = 99) N (%)	Post-CRT group (N = 29) N (%)
Gender	Male	62 (62.6)	16 (55.2)
	Female	37 (37.4)	13 (44.8)
Age (years)	≤70	75 (75.8)	26 (89.7)
	>70	24 (24.2)	3 (10.3)
BMI (kg/m^2)	≤25	72 (72.7)	27 (93.1)
	>25	27 (27.3)	2 (6.9)
Tumor size (cm)	≤4	54 (54.5)	20 (69)
	>4	34 (34.3)	5 (17.2)
	No data	11 (11.1)	4 (13.8)
Tumor location[a]	Low	42 (42.4)	18 (62.1)
	Mid	47 (47.5)	11 (37.9)
	Upper	10 (10.1)	0
Operation[b]	LAR	89 (89.9)	28 (96.6)
	APR	1 (1)	1 (3.4)
	Transanal excision	9 (9.1)	0
(y)pT[c]	(y)pCR, T1, T2	50 (50.5)	14 (48.3)
	T3, T4	49 (49.5)	15 (51.7)
Days from initial staging MRI to surgery	No preoperative CRT group, median (range)	14 (2–62)	
	Preoperative CRT group, median (range)	110 (78–178)	
Days from post CRT staging MRI to surgery			11 (3–47)

Abbreviations; CRT: chemoradiotherapy; BMI: Body Mass Index.
[a] Defined by the distance from anal verge using rigid sigmoidoscopy, Low − less than or equal to 5 cm, Mid − greater than 5 cm to less than or equal to 10 cm, Upper − greater than 10 cm to less than or equal to 15 cm.
[b] LAR - Low anterior resection; APR - Abdominoperineal resection.
[c] y prefix indicates those cases in which classification is performed during or following multimodality therapy.

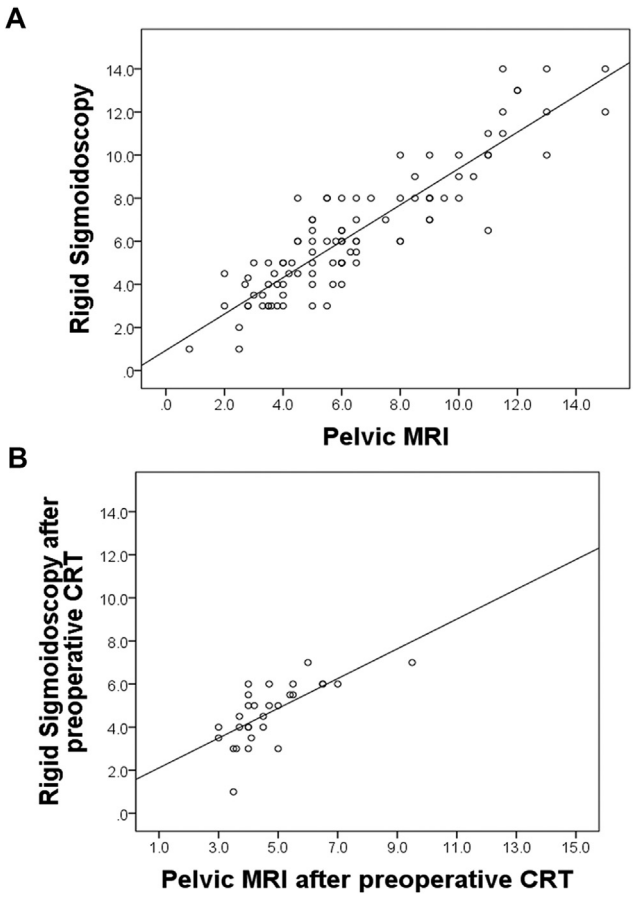

Fig. 3. Correlation between rigid sigmoidoscopy and pelvic MRI. **A.** The scatter plot represents the positive relationship between distance measured by rigid sigmoidoscopy and distance measured by pelvic MRI (Initial group) (linear regression; $R2 = 0.745$; standardized regression coefficient = 0.862, $p < 0.001$). **B.** The scatterplot represents the positive relationship between distance measured by rigid sigmoidoscopy and distance measured in pelvic MRI after preoperative chemoradiotherapy (post-CRT group) (linear regression; $R2 = 0.376$; standardized regression coefficient = 0.613, $p < 0.001$).

Inter-observer agreement of tumor height measurements

Overall, there was good agreement [$\kappa = 0.653$, Confidence Interval (CI): 0.525–0.779] between the two gastrointestinal radiologists. In detail, cases of initial group [$\kappa = 0.727$, CI:0.576–0.878] showed good agreement. Cases of post-CRT group showed moderate agreement [$\kappa = 0.447$. CI: 0.196–0.697].

Discussion

Our study demonstrated that the difference in tumor height measured by pelvic MRI and RS was not significant, and that pelvic MRI could be a viable option to measure tumor height for rectal cancer even in patients who have undergone preoperative chemoradiotherapy.

In the management of rectal cancer, surgery remains one of the most important treatment modalities. Tumor height, defined as the distance from the anal verge to the lower edge of the tumor, is one of the most important variables used to determine surgical methods. Until now, rigid sigmoidoscopy has been regarded as the gold standard to measure the tumor height in rectal cancer patients.

RS is easy to perform even in out-patient clinic. The complication rate of RS is very low. Also, it is still warranted for obtaining tumor tissue or for identifying the tumor circumstances more accurately than an MRI would permit. The economic benefit of RS is another merit in comparison to MRI. Even with these substantial advantages, we cannot omit some weaknesses. Patients experience moderate to severe discomfort from the preparation, the positioning, and the insertion during RS. Practically, RS is contraindicated for tumor with stenosis. The relationship between the tumor and peritoneal reflection could affect decisions regarding performance of preop-CRT or surgical treatment. Some guideline suggested to add tumor location in relation to peritoneal reflection such as below (mesorectal fascia invasion) or above in structured MRI reporting form [12]. It is very difficult to accurately detect peritoneal reflection by RS, which seems to be one possible reason of decreasing use of RS [13].

Pelvic MRI has been used widely in the management of rectal

Table 2
Difference of absolute value between rigid sigmoidoscopy and pelvic MRI according to variables.

		Initial group (N = 99)		Post-CRT group (N = 29)	
		difference of absolute value (mm) (Mean ± SD)	P	difference of absolute value (mm) (Mean ± SD)	P
Gender	Male	11.1 ± 9.2	0.681	6.8 ± 5.7	0.318
	Female	10.4 ± 7.2		9.5 ± 8.5	
Age (years)	≤70	10.6 ± 8.2	0.549	7.5 ± 6.5	0.244
	>70	11.8 ± 9.4		12.6 ± 12.5	
BMI (kg/m^2)	≤25	11.3 ± 8.7	0.432	8.6 ± 7	<0.001
	>25	9.8 ± 7.8		0	
Tumor size (cm)	≤4	10.6 ± 8.4	0.209[d]	9 ± 7.8	0.420[d]
	>4	12.5 ± 9.4		7.6 ± 5.1	
	No data	7.3 ± 4.4		3.7 ± 4.7	
Tumor location[a]	Low	8.9 ± 1.0	0.134[d]	6.8 ± 6.7	0.279
	Mid	12.5 ± 9.6		9.9 ± 7.8	
	Upper	11.5 ± 9.1		N/A	
Operation[b]	LAR	11.4 ± 8.6	0.181[d]	6.5 ± 1.2	0.013
	APR	2 ± 0		25 ± 0	
	Transanal excision	6.8 ± 5.5		N/A	
(y)pT[c]	(y)pCR, T1, T2	9.1 ± 7.1	0.037	7.5 ± 8.4	0.706
	T3, T4	12.7 ± 9.4		8.5 ± 6.0	

Abbreviations; CRT: chemoradiotherapy; BMI: Body Mass Index.
[a] Defined by the distance from anal verge using rigid sigmoidoscopy, Low – less than or equal to 5 cm, Mid – greater than 5 cm to less than or equal to 10 cm, Upper – greater than 10 cm to less than or equal to 15 cm.
[b] LAR - Low anterior resection; APR - Abdominoperineal resection.
[c] y prefix indicates those cases in which classification is performed during or following multimodality therapy.
[d] One-way ANOVA.

Table 3
Univariate analysis of factors associated with significant absolute difference value between rigid sigmoidoscopy and pelvic MRI.

		Initial group (N = 99)		Post-CRT group (N = 29)	
		Significant DAV N (%)	P	Significant DAV N (%)	P
Gender	Male	22 (35.5)	0.506	2 (12.5)	0.632*
	Female	10 (27)		3 (23.1)	
Age (years)	≤70	23 (30.7)	0.618	4 (15.4)	0.446*
	>70	9 (27.5)		1 (33.3)	
BMI (kg/m^2)	≤25	26 (36.1)	0.232	5 (18.5)	1.0*
	>25	6 (22.2)		0	
Tumor size (cm)	≤4	20 (37)	0.223	5 (25)	0.441*
	>4	11 (32.4)		0	
	No data	1 (9.1)		0	
Tumor location*	Low	10 (23.8)	0.134	2 (11.1)	0.339*
	Mid and Upper	22 (38.6)		3 (27.3)	
Operation†	LAR	30 (33.7)	0.806*	4 (14.3)	0.172*
	APR	0		1 (100)	
	Transanal excision	2 (22.2)			
(y)pT‡	(y)pCR, T1, T2	14 (28)	0.395	3 (21.4)	0.651
	T3, T4	18 (36.7)		2 (13.3)	

*: Fisher's exact test.
Significant difference of absolute value (DAV) was defined as DAV value more than 15.

cancer due to various advantages. MRI is a feasible and reproducible equivalent to histopathologic results regarding the preoperative prediction of tumor spread [5]. MRI is most reliable technique to help determine circumferential resection margin involvement, presence of extensive extramural vascular invasion, and relationship with surrounding organ, which could predict surgical difficulties or long-term outcomes for rectal cancer [14,15]. MRI limits the overutilization of preop-CRT in patients with low-risk disease to avoid the radiation induced morbidity and cost of preop-CRT [16]. Despite these benefits of MRI, replacing RS with pelvic MRI to measure tumor height is still controversial.

There are several ways to measure tumor height in rectal cancer. Digital rectal exam (DRE) is easy to perform and provides tumor fixity and the exact intraluminal location of tumor. However, it is a subjective measure and cannot assess most upper rectal cancers; hence, the information obtained via DRE, compared with other modalities, is limited. Furthermore, it can miss early rectal cancers. Flexible colonoscopy is one of the most frequently used tools in diagnosing and treating colorectal cancers. Flexible colonoscopy gives more information, including the overall shape, size, and intraluminal status of tumor or polyp. In this point, practitioners prefer flexible colonoscopy than RS [13]. However, measuring tumor height by flexible colonoscopy could be inaccurate as it is subjective, and not easily reproducible, depending on how much of the rectum is redundant. Recently Jacobs and colleagues, comparing flexible colonoscopy and MRI, demonstrated that there were severe discrepancies between the two modalities. They recommended MRI, instead of a flexible colonoscopy, to define tumor height due to MRI's high inter-observer or intra-observer correlations [13]. There have been several studies comparing RS and MRI [6–8,17]. Among them, three retrospective studies concluded that MRI cannot substitute RS [6,7,17]. However, there might be some limitations in Meylemans and colleagues study, because they compared CT and MRI images (not solely MRI images) with RS and included patient number was relatively low [17]. With regard to those two other studies [6,7], it should be noted that the definition of tumor height by MRI differed between the two studies. Baatrup and colleagues measured tumor height from puborectalis [6], while Keller and colleagues measured it from anal verge [7]. According to the Keller and colleagues study, whether the measurement starts in the anal verge or anorectal junction might be one of the most important reason of difference among MRI defined tumor heights [14]. Although recent consensus guideline recommended anorectal ring as the starting point in MRI measurement [12], RS

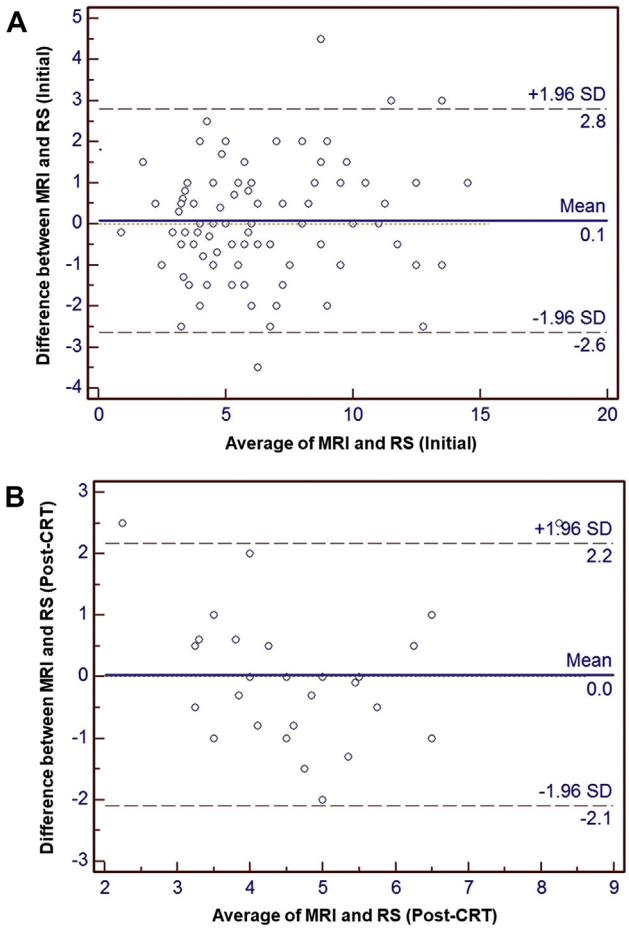

Fig. 4. Bland-Altman plot demonstrating the differences between the rigid sigmoidoscopy and pelvic MRI of the initial group (A) and post-CRT group (B). Differences are plotted against the mean of two measures. The solid line indicated the mean of the difference; the dotted lines do the upper and lower 95% limits of agreement. ICC comparison analysis revealed that inter-rater agreement of RS and MRI in initial group was significantly better than that of post-CRT group [ICC (95% CI) 0.946(0.919–0.963) vs. 0.823 (0.621–0.917); p = 0.004)].

Table 4
Published data on comparison between the modalities in measuring tumor height of rectal cancer.

Study	Year	Nation	Comparison	No.	MRI definition of tumor height	Major findings	Conclusions
Jacobs et al. [13]	2018	Netherlands	MRI vs. colonoscopy	211	anorectal junction to lower margin	measuring tumor height: MRI ≠ colonoscopy	MRI is recommended to define tumor height than colonoscopy.
Meylemans et al. [17]	2014	Belgium	CT/MRI vs. Colonoscopy/RS/ERUS	66	anal verge to lower margin	measuring tumor height: MRI ≠ RS	Radiology based tumor height is reproducible.
Keller et al. [7]	2014	USA, Norway	MRI vs. RS	50	anal verge to lower margin	measuring tumor height: MRI ≠ RS	Standardized method in measuring MRI tumor height is warranted.
Baatrup et al. [6]	2009	Norway	MRI vs. RS	144	puborectalis muscle to lower margin	measuring tumor height: MRI ≠ RS	MRI and RS are not interchangeable.
Paparo et al. [18]	2014	Italy	MRI vs. RS	66	anal verge to lower margin	1)determining the intra- and extraperitoneal location of rectal cancer: similar between MRI and RS 2)measuring tumor height: similar MRI and RS	MRI could substitute RS.
Schoellhammer et al. [4]	2008	USA	RS vs. Colonoscopy	53	N/A	RS changed treatment modality initially planned by colonoscopy in 25% of patients.	RS should be performed on all patients for accurate localization of a cancer thought to be in the rectosigmoid or rectum.
This study		Korea	MRI vs. RS	99 (Initial)	anal verge to lower margin	measuring tumor height: similar MRI and RS	MRI could substitute RS.
				29 (After preop-CRT)	anal verge to lower margin	measuring tumor height: similar MRI and RS	MRI could substitute RS.

N/A: Not available.

measurement usually started from the anal verge, not anorectal ring. Thus, we believe that this point should be discussed between surgeons and radiologists. In contrast, Paparo and colleagues reported that MRI measured tumor height correlated well with that obtained by RS [18]. This result is in par with our results. In addition, one of the most unique finding of our study might be the accuracy of MRI persisted even in patients who underwent preop-CRT.

Van der Paardt MP and colleagues reported diagnostic accuracy of restaging with MRI after preop-CRT showed poor mean sensitivity and negative likelihood ratios. They explained differentiating fibrosis from residual tumor and accurate nodal staging were some of the challenges. In addition, they demonstrated that adding diffusion weighted image or evaluation by experienced observers could give better results [19]. We hypothesized in our study that preop-CRT might hamper accurate measurement of tumor distance in MRI because fibrosis and peritumoral infiltration caused by preop-CRT contributed to overestimation of staging or confusion in tumor location especially in MRI evaluation [20,21], of which subject was not studied yet as far as we know. One of the interesting findings in our study was that the inter-rater agreement of RS and MRI in the initial group was significantly better than that of the post-CRT group. From a statistical standpoint, this difference originated from the relatively small number of patients in the post-CRT group compared to the initial group. In this study, diffusion weighted image was applied to all patients in post-CRT group. The high inter-rater agreement of RS and MRI in the post-CRT group, although lower than the initial group, can be derived partially by adding DWI. Further studies are warranted to clarify this issue.

We are aware that our study has some limitations. The measured tumor height using RS might be dependent on the examiner. Although all RS measurements were performed by three surgeons specialized in colorectal cancer surgery, these situations could not diminish the possibility of difference between the measurements. Practically, it was impossible for us to obtain measurements for RS repeatedly in the same individual. In the same sense, although tumor height in MRI were evaluated by expert radiologist using standardized protocol, there might be inter-observer difference. In literature, inter-observer or intra-observer agreement of MRI for measuring rectal cancer height was known to be very high [13,17]. In our study, inter-observer agreement was good when measured in the initial stage. In contrast, it is not so high when measured after preop-CRT. Although an insufficient number of patients, especially after preop-CRT could cause some selection bias, this might reflect the difficulties in measuring tumor height after preop-CRT. Inter-observer agreement in MRI might be an interesting and important issue, which should be validated in further research especially for patients who underwent preop-CRT.

In conclusion, our study demonstrated that pelvic MRI could be a viable option to measure tumor height for rectal cancer even in patients who have undergone preoperative chemoradiotherapy. However, a standard method to define tumor height by MRI examination is needed.

References

[1] Benson 3rd AB, Venook AP, Bekaii-Saab T, et al. Rectal cancer, version 2.2015. J Natl Compr Canc Netw 2015;13(6):719–28. quiz 28.

[2] Park JS, Sakai Y, Simon NS, et al. Long-term survival and local relapse following surgery without radiotherapy for locally advanced upper rectal cancer: an international multi-institutional study. Medicine (Baltimore) 2016;95(22). e2990.

[3] Piscatelli N, Hyman N, Osler T. Localizing colorectal cancer by colonoscopy. Arch Surg 2005;140(10):932–5.

[4] Schoellhammer HF, Gregorian AC, Sarkisyan GG, Petrie BA. How important is rigid proctosigmoidoscopy in localizing rectal cancer? Am J Surg 2008;196(6):904–8. discussion 8.

[5] Group MS. Extramural depth of tumor invasion at thin-section MR in patients with rectal cancer: results of the MERCURY study. Radiology 2007;243(1):132–9.
[6] Baatrup G, Bolstad M, Mortensen JH. Rigid sigmoidoscopy and MRI are not interchangeable in determining the position of rectal cancers. Eur J Surg Oncol 2009;35(11):1169–73.
[7] Keller DS, Paspulati R, Kjellmo A, et al. MRI-defined height of rectal tumours. Br J Surg 2014;101(2):127–32.
[8] Sato S, Kato T, Tanaka JI. Defining the distal margin of rectal cancer for surgical planning. J Gastrointest Oncol 2017;8(1):194–8.
[9] Kim DJ, Kim JH, Ryu YH, Jeon TJ, Yu JS, Chung JJ. Nodal staging of rectal cancer: high-resolution pelvic MRI versus (1)(8)F-FDGPET/CT. J Comput Assist Tomogr 2011;35(5):531–4.
[10] Kim DJ, Kim JH, Lim JS, et al. Restaging of rectal cancer with MR imaging after concurrent chemotherapy and radiation therapy. Radiographics 2010;30(2):503–16.
[11] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33(1):159–74.
[12] Beets-Tan RGH, Lambregts DMJ, Maas M, et al. Magnetic resonance imaging for clinical management of rectal cancer: updated recommendations from the 2016 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. Eur Radiol 2018;28(4):1465–75.
[13] Jacobs L, Meek DB, van Heukelom J, et al. Comparison of MRI and colonoscopy in determining tumor height in rectal cancer. Unit Eur Gastroenterol J 2018;6(1):131–7.
[14] Beets-Tan RG, Beets GL. Rectal cancer: review with emphasis on MR imaging. Radiology 2004;232(2):335–46.
[15] dePrisco G. MRI local staging and restaging in rectal cancer. Clin Colon Rectal Surg 2015;28(3):194–200.
[16] Brown G, Davies S, Williams GT, et al. Effectiveness of preoperative staging in rectal cancer: digital rectal examination, endoluminal ultrasound or magnetic resonance imaging? Br J Canc 2004;91(1):23–9.
[17] Meylemans D, Penninckx F, Vanbeckevoort D, Wolthuis AM, Fieuws S, D'Hoore A. Endoscopic versus radiology-based location of rectal cancer. Acta Chir Belg 2014;114(6):364–9.
[18] Paparo F, Puppo C, Montale A, et al. Comparison between magnetic resonance imaging and rigid rectoscopy in the preoperative identification of intra- and extraperitoneal rectal cancer. Colorectal Dis 2014;16(11):O379–85.
[19] van der Paardt MP, Zagers MB, Beets-Tan RG, Stoker J, Bipat S. Patients who undergo preoperative chemoradiotherapy for locally advanced rectal cancer restaged by using diagnostic MR imaging: a systematic review and meta-analysis. Radiology 2013;269(1):101–12.
[20] Chen CC, Lee RC, Lin JK, Wang LW, Yang SH. How accurate is magnetic resonance imaging in restaging rectal cancer in patients receiving preoperative combined chemoradiotherapy? Dis Colon Rectum 2005;48(4):722–8.
[21] Kuo LJ, Chern MC, Tsou MH, et al. Interpretation of magnetic resonance imaging for locally advanced rectal carcinoma after preoperative chemoradiation therapy. Dis Colon Rectum 2005;48(1):23–8.