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A comparison between the reference values of MRI and EUS and their usefulness to surgeons in rectal cancer

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Abstract. – BACKGROUND: For these patients with colorectal cancers, improving their quality of life is just as important as clearing them of their tumor burden.

AIM: To assess the reference value to surgeons of magnetic resonance imaging (MRI) and endorectal ultrasound (EUS) in local staging of rectal cancer.

PATIENTS AND METHODS: According to the criteria we set, 69 patients received MRI and 60 patients received EUS, all by senior doctors. We compared two groups in staging accuracy of depth of penetration (T), lymph nodes positive (N) and combined T and N (TN) result. Strategy one (Str1.) was chosen based on MRI or EUS staging. Strategy two (Str2.) took into account clinical parameters, such as computed tomography (CT) and colonoscopy. Strategy three (Str3.) was the best treatment strategy; this was, in part, based on analysis of patients' specimen pathological results. Compared to Str.1 and Str.2, the use of Str.3 as the reference standard separately reflected the reference values of MRI and EUS for surgeons and actual treatment accuracy.

RESULTS: EUS had higher sensitivity in T1 ($p = 0.044 < 0.05$) and specificity in T2 ($p = 0.039 < 0.05$) than MRI. MRI had higher sensitivity in N staging ($p = 0.046 < 0.05$) and was more accurate in pT1~4N1~2 ($p < 0.05$) than EUS. Reference values for surgery (comparing appropriate rates of Str.1 with Str.3) of MRI and EUS were 79.7% vs. 76. 7%, respectively $p > 0.05$). The actual treatment accuracy (comparing appropriate rates of Str.2 with Str.3) was increased up to 94.2% vs. 91.7%, respectively ($p > 0.05$).

CONCLUSIONS: EUS is good for early-stage patients but MRI for local advanced ones. Strategies both could be improved by combining clinical factors that lead to similar reference values for surgery.

Key Words:
EUS, MRI, Rectal cancer, Staging

Introduction

Nearly one million individuals are diagnosed with colorectal cancers each year and approximately 30%-40% arise from the rectum[1]. Among people under the age of 40, rectal cancer rates are increasing across races and in both sexes[2]. For these patients, improving their quality of life is just as important as clearing them of their tumor burden.

Traditional rectal cancer surgery is associated with high rates of local recurrence (5%-20%)[3]. However, with the combination of improved surgical technique using total mesorectal excision and neo-adjuvant therapy, there has been a significant reduction in local recurrence and improved survival[4,5]. The surgeon also aims to achieve a microscopic tumor free resection with minor injury as a local excision, endoscopic submucosal dissection[6], and transanal endoscopic microsurgery (TEM)[7]. Careful preoperative assessment of the tumor can identify high-risk patients that are categorized by circumferential resection margin (CRM) or basement potentially positive. Patients in the former group undergo a long course of chemoradiation prior to surgery[8,9]; those in the latter group are not considered for local resection[10].

Accurate preoperative local staging of rectal cancer is a crucial prognostic factor in rectal cancer. In addition to the size, location, and distance from the anal verge, local staging incorporates the assessment of mural wall invasion (T), CRM, and the nodal status for metastasis (N). Digital rectal examination does not have an objective criterion standard[11]. Computed tomography (CT) is useful for revealing advanced disease and distant metastases, but it is not as good at observing details[12]. More recently, magnetic resonance imaging (MRI) and endorectal ultrasound (EUS) have been used for local staging in rectal cancer due to their relatively high accuracy rates[13-15]. Comparative research between them has shown they have similar accuracy in T and N staging[16-19]. The effect of diagnosis on patients was not mentioned,

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probably because of a lack of multidisciplinary teams. The aim of this study was to determine the effect of diagnosis of MRI and EUS on rectal cancer patients by comparing them based on chosen therapy, which was determined by combined T and N (TN) staging accuracy.

Patients and MethodS

This prospective study was approved by the Institutional Review Board of Ruijin Hospital, Shanghai, China and written informed consent was obtained from all patients.

Patients

From January to December 2011, patients with proven histological primary rectal cancer and evaluated in the Departments of Surgery, Gastroenterology, or Radiology were considered for enrollment in the study. To avoid selection bias, all consecutive patients were asked to participate in this prospective investigation if they met all of the following inclusion criteria: (1) underwent colonoscopy and biopsy that proved rectal cancer; (2) no evidence of metastasis from CT; (3) underwent MRI or EUS staging; (4) first time being diagnosed; (5) resectable and had surgery in our Hospital; (6) written informed consent. Also, they must not have met and of the exclusion criteria: (1) underwent both MRI and EUS; (2) received neoadjuvant chemoradiation; (3) history of rectal surgery including endoscopically removed polyp with cancer; (4) multiple tumor in alimentary tract.

MRI/EUS Technique and Analysis

All patients had two staging results. One was done by preoperative MRI or EUS (mTN, uTN), and the other was based on pathological stage obtained after surgery (pTN). Results for T, N, and TN staging at both MRI and EUS were compared with histopathological staging of the surgical specimen, which was the reference standard (refer to AJCC Cancer Staging Manual H2010[20]).

EUS was performed at a 3T MRI unit (GE-signa HDx3.0T, GE Medical Systems, Milwaukee, WI, USA) in both sagittal and axial planes. Two experienced technicians evaluated the MRI images. EUS was performed with a 360-degree radial echo-endoscope (Fujinon EG400, Fujinon Corp., Tokyo, Japan) and a 15MHz high-frequency ultrasound probe (SP-701, SP-702). The operators were senior gastroenterology physicians that facilitated in diagnosis and staging of rectal cancer.

For MRI, T staging was standardized based on interpretation of layer characteristics and signal intensity[21]. A node was regarded as positive if it was greater than 8 mm along the short axis, if it had spiculated or indistinct borders, or if it displayed a mottled heterogenic pattern[22-24]. The extent of wall invasion of EUS was assessed according to the criteria described by Hildebrandt and Feifel[25]. The sonographic criteria for identifying involved lymph nodes were as follows: size greater than 5 mm, heterogeneous or hypoechoic, and sharply demarcated borders[26-28] .

Treatment Analysis and Reference Standard

Reference value of MRI or EUS for surgeons remains uncertain. We adopted three treatment strategies based on NCCN clinical practice guidelines in Oncology-Rectal cancer[29] by one group including transanal excision, transabdominal resection and advised neo-adjuvant therapy.

Strategy one (Str1.) is the treatment strategy chosen by MRI or EUS staging; strategy two (Str2.) was the treatment strategy surgeons performed after it was combined with clinical parameters (digital rectal examination, CT, colonoscopy, contraindications for radiochemotherapy, and patient options); strategy three (Str3.) was the best treatment strategy for patients, and it was based on their specimen pathological results (Table I).

Str.1or Str.2 would be appropriate, over or inadequate when compared with Str.3, which was the reference standard (Table II). Reference value was defined as percentage of appropriate rate of Str.1; actual treatment accuracy was appropriate rate of Str.2 and clinical influence was found by comparing these two rates. Direct influence was agreement of stage correct and Str.1 correct plus stage wrong and Str.1 wrong. Reliability was agreement of stage correct and Str.1 correct (Figure 1).

Statistical Analysis

Statistical Package for the Social Sciences (SPSS, version 15, Inc., Chicago, IL) was used for statistical analyses. The paired samples *t*-test was performed to test whether the difference between two groups was statistically significant. Continuous variables are expressed as mean±standard deviation. Comparisons between qualitative variables were performed by using the Chi-square test with the Yates' correction when needed. Standard formulas were used in sensitivity, specificity, positive predictive value (PPV),

Table I. Standards for strategies based on.

	Strategy one (Str1.)	Strategy two (Str2.)	Strategy three (Str3.)
Transanal excision	mT1N0 or uT1N0	mT1N0 or uT1N0 without high risk features*	pT1N0 or pT1Nx without high risk features
Transabdominal resection	mT2N0 or uT2N0	m,uT2N0 or m,uT1N0 with high risk features*	pT2N0 or pT1Nx with high risk features
Transabdominal resection and advised neo-adjuvant therapy	mT1-2N1-2, mT3-4N0-2 or uT1-2N1-2. mT3-4N0-2	mT1-2N1-2, mT3-4N0-2 or uT1-2N1-2, mT3-4N0-2	pT1-2N1-2, pT3-4N0-2

*High risk features included > 30% circumference of bowel, < 3 cm in size, fixed, positive margins, lymphovascular invasion and poorly differentiated tumors.

negative predictive value (NPV), and mean overstaging and understaging rate with 95% CI calculated according to the criterion standard. Concordance was stated as follows: kappa value 0.00-0.20 poor agreement; 0.21-0.40 fair agreement; 0.41-0.60 moderate agreement; 0.61-0.80 good agreement, and 0.81-1.00 excellent agreement. $p < 0.05$ was considered statistically significant.

Results

Patient Characteristics

Patients were prospectively enrolled from January to December 2011. We reviewed the charts and database of 587 patients with rectal cancer evaluated in our hospital. A total of 202 met the inclusion criteria. Of these, 63 were excluded because of one or more exclusion criteria. That is, they underwent both MRI and EUS (n = 16), received neoadjuvant chemoradiation (n = 32), had a rectal surgery history (n = 13), had multiple tumors in the alimentary tract (n = 2), or had more than one of above (n = 2). The final study population consisted of 129 consecutive patients (MRI 69pts; EUS 60pts) with a mean age of 62 years old (range 24-88 years). Surgery was performed on all patients. The difference between the two groups was not statistically significant ($p < 0.05$) (Table III).

T and N Staging

T, N and TN staging result showed for 69 patients (total 19 overstaged and 8 understaged), MRI correctly assessed 55 for T, 53 for N, and 42 for TN. For 60 patients in the EUS group (total 13 overstaged, and 12 understaged), there were 50 for T, 42 for N, and 35 for TN correct (Table IV, Figure 2). T accuracy of MRI vs. EUS was 79.7% vs. 83.3% ($p > 0.05$), respectively. For N, it was 76.8 vs. 70.0% ($p > 0.05$), respectively, which was similar to other publications [16-19, 30]. Combined TN staging accuracy was 60.9% and 58.3% in MRI and EUS ($p > 0.05$), respectively (Table V). It was much lower than T or N alone and caused higher over and under staging rates.

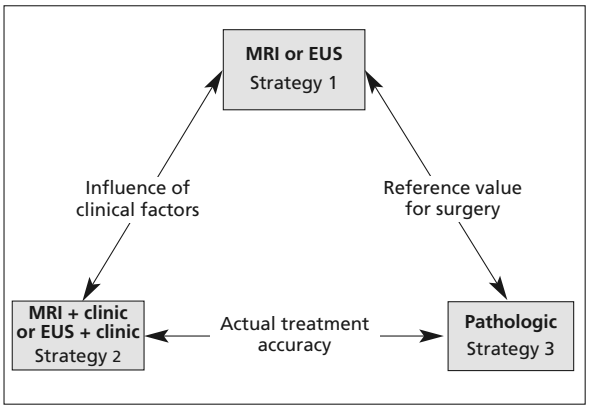

Figure 1. Design of the research.

Table II. Criterion for strategies.

		Str.1 or Str.2		
		Transanal excision	Transabdominal resection	Neoadjuvant therapy
Str.3	Transanal excision	Appropriate	Over	Over
	Transabdominal resection	Inadequate	Appropriate	Over
	Advice neoadjuvent therapy	Inadequate	Inadequate	Appropriate

Table III. Patient and tumor characteristics.

Characteristics	Value
Age (years)	
Mean ± SD	62 ± 14
Range	24-88
Sex-no. (%)	
Male	77 (59.7%)
Female	52 (40.3%)
Range from anus-no. (%)	
Below peritoneal reflection	59 (45.7)
Above peritoneal reflection	70 (52.3)
Median interval between exam and surgery	
Mean ± SD	1 ± 2
Range	1-5
Type of pathological-no. (%)	
Adenocarcinoma	126 (97.7%)
Mucinous carcinoma	2 (1.55%)
Squamous cell carcinoma	1 (0.78%)
Type of tumor differentiation-no. (%)	
Well	14 (10.9%)
Media	93 (72.1%)
Low	21 (16.3%)
Undifferentiated	1 (0.78%)
Gross type of tumor-no. (%)	
Protruded	68 (52.7%)
Infiltrating	24 (18.6%)
Ulceration	37 (28.7%)
pT-no. (%)	
T1	28 (21.7%)
T2	32 (24.8%)
T3	38 (29.5%)
T4	31 (24.0%)
pN-no. (%)	
N0	83 (64.3%)
N1~2	46 (35.7%)

Accuracy between these two methods had no statistical significance.

Inner groups, sensitivity, and PPV were higher in pT3-4 than in pT1-2 in MRI ($p < 0.05$). This difference was not observed in EUS. Comparing the two groups, EUS had higher sensitivity in T1 ($p = 0.044 < 0.05$) and specificity in T2 ($p = 0.039 < 0.05$). MRI had higher sensitivity in N staging ($p = 0.046 < 0.05$) and higher accurate in staging pT1~4N1~2 ($p < 0.05$) (Table VI). Statistical results were similar to the meta analysis previously reported[41-43]. MRI and EUS had their own characters.

Clinical Relevance

Reference values for surgery of MRI and EUS was 79.7% vs. 76.7% $p > 0.05$), respectively. 3 and 4 cases might be under treated in MRI and EUS, while 11 and 10 might be over treated. The actual treatment accuracy increased to 94.2% vs. 91.7% ($p > 0.05$). 2 cases were under treated and 2 were over treated in both groups. MRI and EUS had similar reference values and actual treatment accuracy for patients (Figure 3).

Combined clinical factors showed statistically significant differences (MRI $p = 0.021 < 0.05$, EUS $p = 0.047 < 0.05$). 14.7% (total 19) of patients avoided being mistreated. All changes occurred in pT1~2N0~2, and accuracy increased from 51.9% to 88.9% in MRI (10 cases, 7 in T1N0-2; 3 in T2N0-2) and from 60.6% to 87.9% in EUS (9 cases, 4 cases in T1N0-2; 5 cases in T2N0-2). Appropriate rates of Str.1 and Str.2 in pT3~4N0~2 was higher than in pT1~2N0~2 in both groups ($p < 0.01$). The reference values of MRI and EUS can be significantly improved upon by clinical factors (Figure 3).

Another reason for high appropriate treatment rates with relatively poor TN staging accuracy was that some stages had the same treatment strategy. Direct influence was 81.16% in MRI

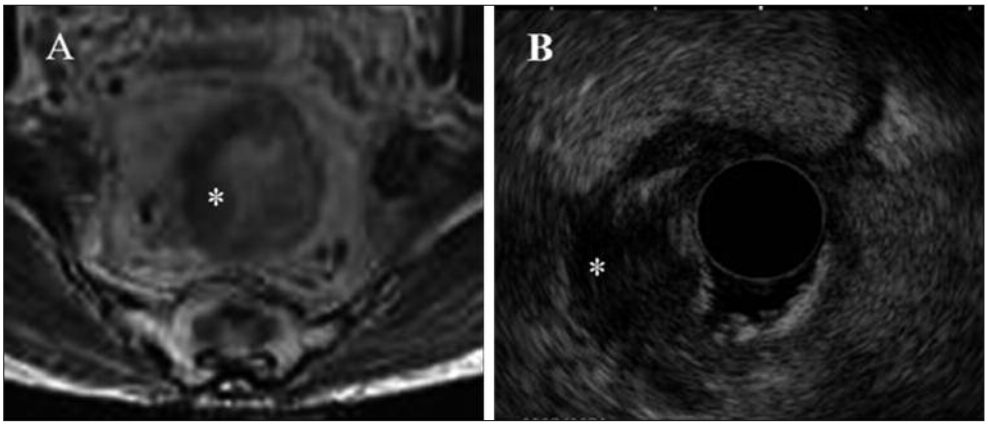

Figure 2. T3 malignant tumor stranding in MRI and EUS.T3 tumor located in the left side that penetrated the rectal wall and invaded perirectal fat (*). ***A,*** MRI view, showed more details. ***B,*** EUS view.

Table IV. T and N stage results by MRI and EUS contrasted to pathological stage.

		MRI					EUS				
		T1	T2	T3	T4	Total	T1	T2	T3	T4	Total
Pathological stage	T1	6	0	0	0	6	14	1	0	0	15
	T2	6	12	3	0	21	1	14	1	0	16
	T3	0	3	21	1	25	0	2	11	3	16
	T4	0	0	1	16	17	1	0	1	11	13
	Total	12	15	25	17	69	16	17	13	14	60
		MRI			EUS						
		N0	N1-2	Total	N0	N1-2	Total				
Pathological stage	N0	31	4	35	31	9	40				
	N1-2	12	22	34	9	11	20				
	Total	43	26	69	40	20	60				
	T stage										
		MRI				EUS					
		Under	Correct	Over	Total	Under	Correct	Over	Total		
N stage	Under	0	4	0	4	0	8	1	9		
	Correct	4	42	7	53	5	35	2	42		
	Over	0	9	3	12	0	7	0	9		
	Total	4	55	10	69	5	50	5	60		

and 81.67% in EUS ($p > 0.05$). The reliability of MRI was 60.87% and 58.33% for EUS ($p > 0.05$). It was much lower than the reference value ($p < 0.05$) (Figure 4).

Discussion

Endorectal ultrasound (EUS) has long been the only imaging method for staging rectal cancer. In our research, EUS had higher sensitivity in T1 ($p = 0.044 < 0.05$) and specificity in T2 ($p = 0.039 < 0.05$) than MRI. We suggest that early-stage patients undergo EUS, especially in preoperative staging of T1 patients who can be avoided from unnecessary TME (total mesorectal excision).

Early reports show that MRI has not been able to accurately predict T-stage unless an endorectal coil is used[31,32]. With the development of the technique, MRI can achieve almost the same accuracy as EUS[33,34]. Based on our MRI data, we found that sensitivity and PPV (pay-per-view) were higher in pT3-4 than in pT1-2 ($p < 0.05$)

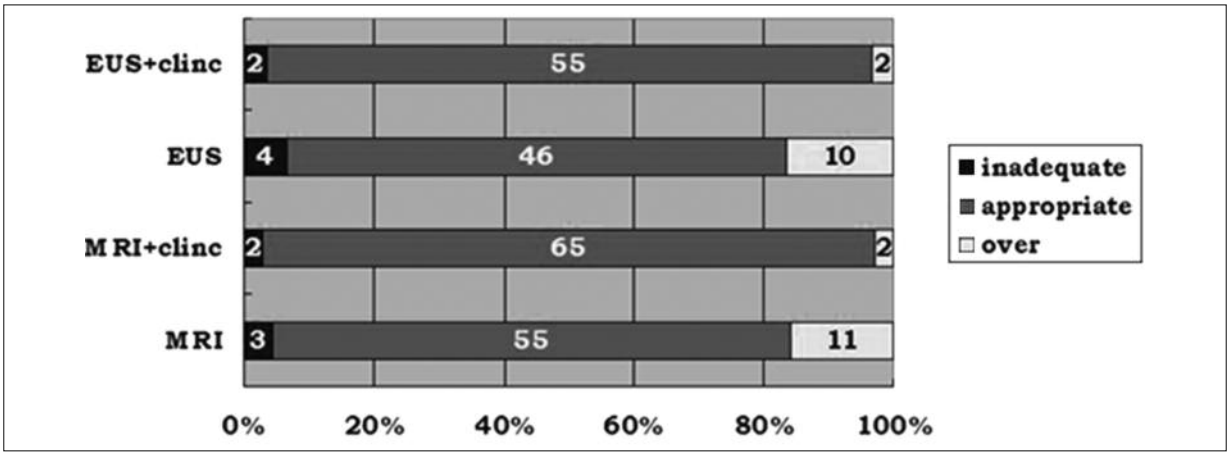

Figure 3. Mean over and inadequate treatment rates for MRI and EUS.

Table V. Accuracy, overstaging, understaging, kappa and agreement for T and N staging by MRI or EUS according to pathological stage.

	T			N			TN		
	MRI	EUS	(*p*)	MRI	EUS	(*p*)	MRI	EUS	(*p*)
Accuracy (%)	79.7	83.3	NS	76.8	70.0	NS	60.9	58.3	NS
95% CI (%)	(70.2-89.2)	(73.8-92.7)		(66.8-86.8)	(54.0-81.6)		(49.4-72.4)	(45.8-70.8)	
Overstaging (%)	8.3	8.3	NS	17.4	15.0	NS	27.5	20.0	NS
Understaging(%)	5.8	8.3	NS	5.8	15.0	NS	11.6	21.4	NS
Kappa	0.721	0.778		0.535	0.325		0.562	0.514	
Agreement	Good	Good		Moderate	Fair		Moderate	Moderate	

NS: not significant.

Table VI. Sensitivity, specificity, positive and negative predictive values for T1-4 and N staging by MRI or EUS according to pathological stage.

	T1			T2			T3			T4			N		
	MRI	EUS	(*p*)	MRI	EUS	(*p*)	MRI	EUS	(*p*)	MRI	EUS	(*p*)	MRI	EUS	(*p*)
Sensitivity (%)	50	87.5	0.044	80	77.8	NS	84.0	84.6	NS	94.1	78.6	NS	84.6	55.0	0.046
Specificity (%)	100	97.7	NS	83.3	97.6	0.039	90.9	89.4	NS	98.1	95.7	NS	72.1	77.5	NS
PPV (%)	100	93.3	NS	57.1	87.5	NS	84.0	68.8	NS	94.1	84.6	NS	64.7	55.0	NS
NPV (%)	90.5	95.6	NS	93.8	93.2	NS	90.9	95.5	NS	98.1	93.6	NS	64.7	77.5	NS

NS: not significant.

and MRI had higher sensitivity in N staging ($p = 0.046 < 0.05$) and was more accurate in diagnosis of pT1~4N1~2 ($p < 0.05$). Thus, we suggest MRI for local advanced patients that may benefit from more intensive preoperative treatments.

The way to improve staging accuracy is important and suffering. Only extremely experienced diagnosticians, with a large case volume of rectal carcinoma patients, can accurately read MRI or EUS data and translate that into therapy-relevant decisions. T1 patients may under treated cause unaware of nodal metastasis before local resection. As reported, lymph node involvement in T1 is 2-20%[33]. Survival after transanal endoscopic microsurgery (TEM) for T1 rectal cancer is limited mainly because of recurrence[34]. Diffusion-weight-

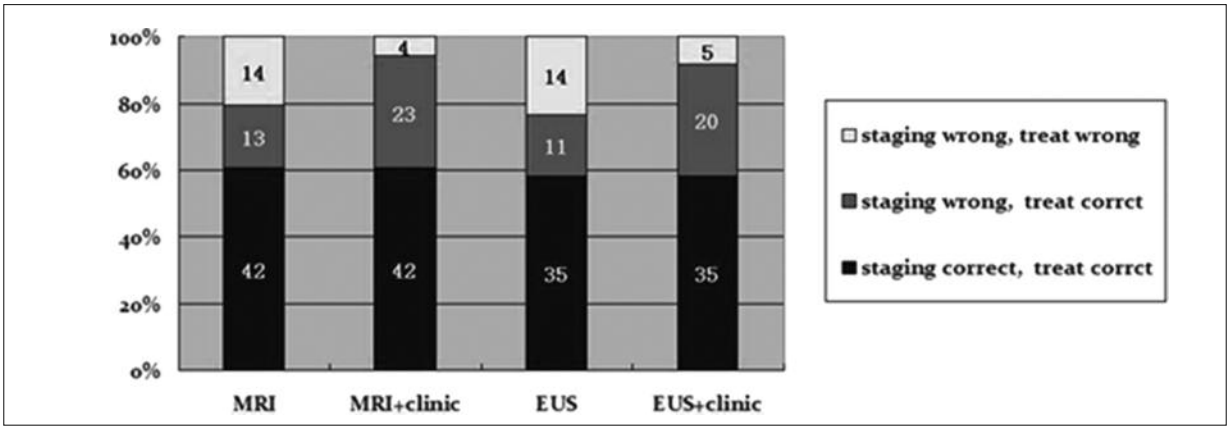

Figure 4. Relationship between staging and treatment.

ed MRI, three dynamic contrast-enhanced MRI, and EUS-guided lymph node fine needle punctures are being taken to improve the accuracy of N staging[35,36]. In the clinic, the diagnostic accuracy of EUS in staging rectal carcinoma does not recapitulate the extremely good results reported in the literature[37]. The main reason for this lower performance is the operator dependency of EUS. MRI is reported to overstage T from 15% to 30%[38]. In our study, it was slightly lower, and this might be due to the fact that our readers had a stable and consistent learning curve.

An advance in preoperative assessment through accurate staging is a solid base for multidisciplinary team (MDT). Although not completely equal to a multidisciplinary approach, MRI or EUS staging proved to significantly improve the outcomes of patients with rectal malignancy[39,40]. If we only consider MRI or EUS, 79.7% or 76.7% of patients, respectively, would receive the appropriate therapy ($p > 0.05$). Considering clinical factors such as patient tumor history, family history, health condition, digital rectal examination by experienced surgeons, and other tests, the actual treatment strategy increased to 94.2% in MRI and 91.7% in EUS ($p > 0.05$). Both could lead to similar reference values for surgery and could be significantly improved upon by combining clinical factors.

There are some researches about clinical relevance of MRI. One report states that MRI analysis of CRM predict survival outcomes for good and poor responders provides an opportunity for MDT to offer additional treatment options before planning definitive surgery[21,41]. Another report supports an anatomically based MRI staging system for low rectal cancer to predict the planes of surgical excision[42]. These differ from our research since they report either on local advanced patience or whether or not anus preserve excision (APE) surgery. Thus they are not suitable for comparison.

Limitations

We used either MRI or EUS staging for two reasons. One was strategies could not be made if patients took both of them and had different staging results. The other was to reduce patients cost. The diagnosis of these two methods in one patient is our next avenue of research. According to preoperative staging, we recommend that locally advanced patients should take adjuvant therapy. However, not all did. But this has no influence in comparing treatment strategy. Taylor et al[43] also state that Stages I, II, and III rectal cancers may be best managed by surgery alone if staged by high-resolution magnetic resonance imaging. More researches should be done to normalize neo-adjuvant therapy.

Conclusions

EUS is good for early-stage patients but MRI for local advanced patients. Combined TN staging accuracy in MRI and EUS are similar in that both could lead to similar reference values for surgery. Furthermore, both of them can be significantly improved upon by combining clinical factors.

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References

1) Boyle P, Leon ME. Epidemiology of colorectal cancer. Br Med Bull 2002; 64: 1-25.
2) Meyer JE, Narang T, Schnoll-Sussman FH, Pochapin MB, Christos PJ, Sherr DL. Increasing incidence of rectal cancer in patients aged younger than 40 years: an analysis of the surveillance, epidemiology, and end results database. Cancer 2010; 116: 4354-4359.
3) Phillips RK, Hittinger R, Blesovsky L, Fry JS, Fielding LP. Local recurrence following 'curative' surgery for large bowel cancer: I. The overall picture. Br J Surg 1984; 71: 12-16.
4) Hospers GA, Punt CJ, Tesselaar ME, Cats A, Havenga K, Leer JWH, Marijnen CA, Jansen EP, Van Krieken HH, Wiggers T, Van de Velde CJ, Mulder NH. Preoperative chemoradiotherapy with capecitabine and oxaliplatin in locally advanced rectal cancer. A phase I-II multicenter study of the Dutch Colorectal Cancer Group. Ann Surg Oncol 2007; 14: 2773-2779.
5) Yeh CH, Chen MF, Lai CH, Huang WS, Lee SP, Chen WC. Comparison of treatment results between surgery alone, preoperative short-course radiotherapy, or long-course concurrent chemoradiotherapy in locally advanced rectal cancer. Int J Clin Oncol 2012; 17: 482-490.
6) Hon SS, Ng SS, Chiu PW, Chan FK, Ng EK, Li JC, Lee JF, Leung KL. Endoscopic submucosal dissection versus local excision for early rectal neoplasms: a comparative study. Surgical endoscopy. Surg Endosc 2011; 25: 3923-3927.
7) Allaix ME, Rebecchi F, Giaccone C, Mistrangelo M, Morino M. Long-term functional results and quali-

ty of life after transanal endoscopic microsurgery. Br J Surg 2011; 98: 1635-1643.

8) Taylor F, Quirke P, Heald R, Moran B, Blomqvist L, Swift I, St Rose S, Sebag-Montefiore D, Tekkis P, Brown G; MERCURY study group. One millimetre is the safe cut-off for magnetic resonance imaging prediction of surgical margin status in rectal cancer. Br J Surg 2011; 98: 872-879.

9) Martijnse IS, Dudink RL, Kusters M, Vermeer TA, West NP, Nieuwenhuijzen GA, van Lijnschoten I, Martijn H, Creemers GJ, Lemmens VE, van de Velde CJ, Sebag-Montefiore D, Glynne-Jones R, Quirke P, Rutten HJ. T3+ and T4 rectal cancer patients seem to benefit from the addition of oxaliplatin to the neoadjuvant chemoradiation regimen. Ann Surg Oncol 2012; 19: 392-401.

10) Nash GM, Weiser MR, Guillem JG, Temple LK, Shia J, Gonen M, Wong WD, Paty PB. Long-term survival after transanal excision of T1 rectal cancer. Dis Colon Rectum 2009; 52: 577-582.

11) Yeung JMC, Ferris NJ, Lynch AC, Heriot AG. Preoperative staging of rectal cancer. Future Oncol 2009; 5: 1295-1306.

12) Lupo L, Angelelli G, Pannarale O, Altomare D, Macarini L, Memeo V. Improved accuracy of computed tomography in local staging of rectal cancer using water enema. Int J Colorectal Dis 1996; 11: 60-64.

13) Siddiqui AA, Fayiga Y, Huerta S. The role of endoscopic ultrasound in the evaluation of rectal cancer. Int Semin Surg Oncol 2006; 3: 36.

14) Assenat E, Thézenas S, Samalin E, Bibeau F, Portales F, Azria D, Quenet F, Rouanet P, Aubert BS, Senesse P. The value of endoscopic rectal ultrasound in predicting the lateral clearance and outcome in patients with lower-third rectal adenocarcinoma. Endoscopy 2007; 39: 309-313.

15) Klessen C, Rogalla P, Taupitz M. Local staging of rectal cancer: The current role of MRI. Eur Radiol 2007; 17: 379-389.

16) Fuchsjäger MH, Maier AG, Schima W, Zebedin E, Herbst F, Mittlböck M, Wrba F, Lechner GL. Comparison of transrectal sonography and double-contrast mr imaging when staging rectal cancer. Am J Roentgenol 2003; 181: 421-427.

17) Brown G, Davies S, Williams G, Bourne M, Newcombe R, Radcliffe A, Blethyn J, Dallimore N, Rees B, Phillips C, Maughan TS. Effectiveness of preoperative staging in rectal cancer: digital rectal examination, endoluminal ultrasound or magnetic resonance imaging? Br J Cancer 2004; 91: 23-29.

18) Balena V, Martino D, Lorusso F, Martino T, Valerio P. Endorectal ultrasound and magnetic resonance imaging (MRI) scan in rectal cancer: a comparative study. Arch Ital Urol Androl 2010; 82: 259-261.

19) Fernández-Esparrach G, Ayuso-Colella JR, Sendino O, Pagés M, Cuatrecasas M, Pellisé M, Maurel J, Ayuso-Colella C, González-Suárez B, Llach J. Eus and magnetic resonance imaging in the staging of rectal cancer: A prospective and comparative study. Gastrointest End 2011; 74: 347-354.

20) Greene FL. Ajcc cancer staging manual. Springer Verlag; 2002.

21) Patel UB, Taylor F, Blomqvist L, George C, Evans H, Tekkis P, Quirke P, Sebag-Montefiore D, Moran B, Heald R. Magnetic resonance imaging-detected tumor response for locally advanced rectal cancer predicts survival outcomes: MERCURY experience. J Clini Oncol 2011; 29: 3753-3760.

22) Koh DM, Chau I, Tait D, Wotherspoon A, Cunningham D, Brown G. Evaluating mesorectal lymph nodes in rectal cancer before and after neoadjuvant chemoradiation using thin-section T2-weighted magnetic resonance imaging. Int J Radiat Oncol Biol Phys 2008; 71: 456-461.

23) Lambregts DMJ, Beets GL, Maas M, Kessels AG, Bakers FC, Cappendijk VC, Engelen SM, Lahaye MJ, de Bruïne AP, Lammering G, Leiner T, Verwoerd JL, Wildberger JE, Beets-Tan RG. Accuracy of gadofosveset-enhanced mri for nodal staging and restaging in rectal cancer. Ann Surg 2011; 253: 539-545.

24) Kim DJ, Kim JH, Ryu YH, Jeon TJ, Yu JS, Chung JJ. Nodal staging of rectal cancer: High-resolution pelvic MRI versus 18F-FDGPET/CT. J Comput Assist Tomogr 2011; 35: 531-534.

25) Hildebrandt U, Feifel G. Preoperative staging of rectal cancer by intrarectal ultrasound. Dis Colon Rectum 1985; 28: 42-46.

26) Harewood GC, Wiersema MJ, Nelson H, Maccarty RL, Olson JE, Clain JE, Ahlquist DA, Jondal ML. A prospective, blinded assessment of the impact of preoperative staging on the management of rectal cancer. Gastroenterology 2002; 123: 24-32.

27) Koh DM, Brown G, Temple L, Raja A, Toomey P, Bett N, Norman AR, Husband JE. Rectal cancer: mesorectal lymph nodes at MR imaging with USPIO versus histopathologic findings–initial observations. Radiology 2004; 231: 91-99.

28) Gleeson FC, Clain JE, Papachristou GI, Rajan E, Topazian MD, Wang KK, Levy MJ. Prospective assessment of eus criteria for lymphadenopathy associated with rectal cancer. Gastrointest Endosc 2009; 69: 896-903.

29) Engstrom PF, Arnoletti JP, Benson AB 3rd, Chen YJ, Choti MA, Cooper HS, Covey A, Dilawari RA, Early DS, Enzinger PC, Fakih MG, Fleshman J Jr, Fuchs C, Grem JL, Kiel K, Knol JA, Leong LA, Lin E, Mulcahy MF, Rao S, Ryan DP, Saltz L, Shibata D, Skibber JM, Sofocleous C, Thomas J, Venook AP, Willett C; National Comprehensive Cancer Network. NCCN Clinical Practice Guidelines in Oncology: colon cancer. J Natl Compr Canc Netw 2009; 7: 778-831.

30) Bianchi P, Ceriani C, Palmisano A, Pompili G, Passoni GR, Rottoli M, Cappellani A, Montorsi M. A prospective comparison of endorectal ultrasound and pelvic magnetic resonance in the preoperative staging of rectal cancer. Ann Ital Chir 2006; 77: 41-46.

31) Blomqvist L, Machado M, Rubio C, Gabrielsson N, Granqvist S, Goldman S, Holm T. Rectal tumour staging: MR imaging using pelvic phased-array and endorectal coils vs endoscopic ultrasonography. Eur Radiol 2000; 10: 653-660.

32) Hünerbein M, Pegios W, Rau B, Vogl TJ, Felix R, Schlag PM. Prospective comparison of endorectal ultrasound, three-dimensional endorectal ultrasound, and endorectal mri in the preoperative evaluation of rectal tumors. Preliminary results. Surg Endosc 2000; 14: 1005-1009.

33) Kim SH, Lee JM, Lee MW, Kim GH, Han JK, Choi BI. Diagnostic accuracy of 3.0-Tesla rectal magnetic resonance imaging in preoperative local staging of primary rectal cancer. Invest Radiol 2008; 43: 587-593.

34) Winter L, Bruhn H, Langrehr J, Neuhaus P, Felix R, Hänninen LE. Magnetic resonance imaging in suspected rectal cancer: determining tumor localization, stage, and sphincter-saving resectability at 3-Tesla-sustained high resolution. Acta Radiol 2007; 48: 379-387.

35) Doornebosch PG, Ferenschild FT, de Wilt JH, Dawson I, Tetteroo GW, de Graaf EJ. Treatment of recurrence after transanal endoscopic microsurgery (TEM) for T1 rectal cancer. Dis Colon Rectum 2010; 53: 1234-1239.

36) Mizukami Y, Ueda S, Mizumoto A, Sasada T, Okumura R, Kohno S, Takabayashi A. Diffusion-weighted magnetic resonance imaging for detecting lymph node metastasis of rectal cancer. World J Surg 2011; 35: 895-899.

37) Marusch F, Ptok H, Sahm M, Schmidt U, Ridwelski K, Gastinger I, Lippert H. Endorectal ultrasound in rectal carcinoma–do the literature results really correspond to the realities of routine clinical care? Endoscopy 2011; 43: 425-431.

38) Chun HK, Choi D, Kim MJ, Lee J, Yun SH, Kim SH, Lee SJ, Kim CK. Preoperative staging of rectal cancer: comparison of 3-T high-field MRI and endorectal sonography. Am J Roentgenol 2006; 187: 1557-1562.

39) Swellengrebel HA, Peters EG, Cats A, Visser O, Blaauwgeers HG, Verwaal VJ, van Velthuysen ML, Cense HA, Bruin SC, Marijnen CA. Multidisciplinary discussion and management of rectal cancer: a population-based study. World J Surg 2011; 35: 2125-2133.

40) Du CZ, Li J, Cai Y, Sun YS, Xue WC, Gu J. Effect of multidisciplinary team treatment on outcomes of patients with gastrointestinal malignancy. World J Gastroenterol 2011; 17: 2013-2018.

41) Hunter CJ, Garant A, Vuong T, Artho G, Lisbona R, Tekkis P, Abulafi M, Brown G. Adverse features on rectal MRI identify a high-risk group that may benefit from more intensive preoperative staging and treatment. Ann Surg Oncol 2012; 19: 1199-1205.

42) Shihab OC, How P, West N, George C, Patel U, Quirke P, Heald RJ, Moran BJ, Brown G. Can a novel MRI staging system for low rectal cancer aid surgical planning? Dis Colon Rectum 2011; 54: 1260-1264.

43) Taylor FG, Quirke P, Heald RJ, Moran B, Blomqvist L, Swift I, Sebag-Montefiore DJ, Tekkis P, Brown G; MERCURY study group. Preoperative high-resolution magnetic resonance imaging can identify good prognosis stage I, II, and III rectal cancer best managed by surgery alone: a prospective, multicenter, European study. Ann Surg 2011; 253: 711-719.