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A scoring system to support surgical decision-making for cardial submucosal tumors

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Authors

Zi-Han Geng*[1], Yan Zhu*[1], Wei-Feng Chen*[1], Shi-Yao Chen[1], Yun-Shi Zhong[1], Yi-Qun Zhang[1], Li-Li Ma[1], Wen-Zheng Qin[1], Jian-Wei Hu[1], Ming-Yan Cai[1], Li-Qing Yao[1], Quan-Lin Li[1,2], Ping-Hong Zhou[1,2]

Institutions

1 Endoscopy Center and Endoscopy Research Institute, Zhongshan Hospital, Fudan University, Shanghai, China
2 Shanghai Collaborative Innovation Center of Endoscopy, Shanghai, China

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Corresponding author

Ping-Hong Zhou, MD, FASGE, Endoscopy Center and Endoscopy Research Institute, Zhongshan Hospital, Fudan University, Shanghai, China
Fax: +86-21-64038472
zhou.pinghong@zs-hospital.sh.cn

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ABSTRACT

Background and study aims Submucosal tunneling endoscopic resection (STER) and non-tunneling techniques are two alternative options for the treatment of cardial submucosal tumors (SMTs). We aimed to establish a regression model and develop a simple scoring system (Zhongshan Tunnel Score) to help clinicians make surgical decisions for cardial submucosal tumors.

Patients and methods A total of 246 patients who suffered cardial SMTs and received endoscopic resection were included in this study. All of them were randomized into either the training cohort (n = 147) or the internal validation cohort (n = 99). Then, the scoring system was proposed based on multivariate logistic regression analysis in the training cohort and assessed in the validation cohort.

Results Of 246 patients, 97 were treated with STER and the others with non-tunneling endoscopic resection. In the training stage, four factors were weighted with points based on the β coefficient from the regression model, including irregular morphology (–2 points), ulcer (2 points), the direction of the gastroscope (–2 points for forward direction and 1 point for reverse direction), and originating from the muscularis propria (–2 points). The patients were categorized into low-score (< –4), medium-score (–4 to –3) and high-score (> –3) groups, and those with low scores were more likely to be treated with STER. Our score model performed satisfying discriminatory power in internal validation (Area under the receiver-operator characteristic curve, 0.829; 95 % confidence interval, 0.694–0.964) and goodness-of-fit in the Hosmer-Lemeshow test (*P* = .4721).

Conclusions This scoring system could provide clinicians the references for making decisions about the treatment of cardial submucosal tumors.

Introduction

Submucosal tumors (SMTs), covered by normal mucosa, originate from muscularis mucosa (MM), submucosal layer, or muscularis propria (MP), which are occasionally found in the esophagus and stomach during an upper endoscopy. Most SMTs are thought to be benign, while some have malignant potential, especially the large ones originating from the MP layer, such as gastrointestinal stromal tumors (GISTs), leiomyosarcomas, and liposarcomas [1]. For SMTs, surgical resection is an available option in patients who have dramatic symptoms or possible malignancy. However, surgical approaches carry a high risk of mor-

* These authors contributed equally

bidity and mortality. Therefore, minimally invasive surgery by endoscopic resection has become preferable during the last decade.

New endoscopic techniques, including submucosal tunneling endoscopic resection (STER) [2] and non-tunneling endoscopic resection [3, 4], were shown to be feasible, safe, and effective in treating esophageal and gastric SMTs. However, cardia, as the esophagogastric junction (EGJ), has always been considered a difficult location for endoscopic resection due to the narrow lumen and sharp angle [5].

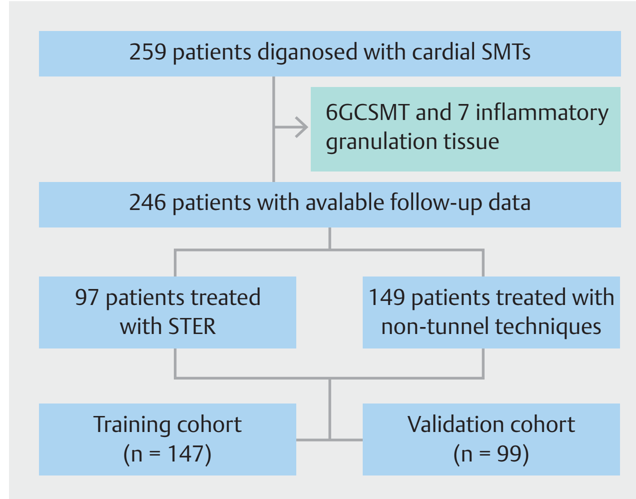
Open or laparoscopic wedge resection has usually been selected for most patients with cardial SMTs. However, resection of the gastric cardia might result in lifelong gastroesophageal reflux disease (GERD), which diminishes quality of life. Thus, STER and non-tunneling techniques (such as endoscopic submucosal dissection [ESD] and endoscopic submucosal excavation [ESE]) are minor invasive treatments for cardial SMTs without loss of curability. STER possesses multiple advantages, such as maintenance of mucosal integrity, facilitation of better rates of healing, and decreased risk of pleural/abdominal infection. However, it is difficult to identify the direction in the tunnel. Compared with STER, the non-tunnel techniques facilitate improved response to intraoperative bleeding under direct vision but cannot maintain mucosal integrity. Previous studies have compared these two endoscopic techniques. For instance, both ESE and STER have been shown to produce satisfactory therapeutic results for SMTs < 10 mm, while STER is preferable in terms of preventing air leakage symptoms for SMTs > 10 mm [6]. However, another study revealed that STER did not present overt advantages compared with ESE, and ESE is superior to STER for reduced operation time [7].

Although the previously mentioned studies compared tumor characteristics, procedure details, and clinical outcomes of these two methods, there are no clinical rules that can help clinicians make choices for cardial SMTs. Therefore, we built a regression model and designed a scoring system to support surgical decision-making. After that, we also evaluated the scoring system in an independent cohort. This system could be used to categorize patients with cardial SMTs before endoscopic resection, and it is expected to assist junior endoscopists in making surgical decisions case by case to improve overall clinical outcomes.

Patients and methods

Patients

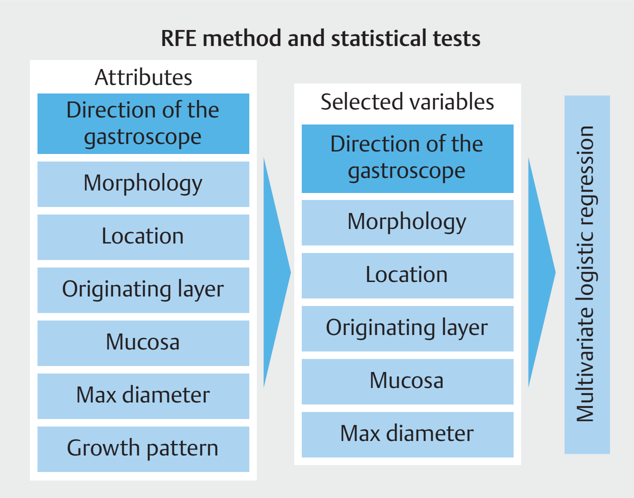
We conducted a single-center, retrospective study of 259 consecutive patients diagnosed with cardial SMTs who were treated with endoscopic resection (STER or non-tunnel techniques) in the Endoscopy Center, Zhongshan Hospital Fudan University (Shanghai, China) from July 2017 to March 2021. Thirteen patients were excluded because pathology revealed GCSMT (gastric cancer presenting as a submucosal tumor) in six cases and inflammatory granulation tissue in seven cases. Patients with available follow-up data and complete demographic and clinical information (n = 246) were included in this study and were randomized into either the training cohort (n = 147) or the internal validation cohort (n = 99). A flowchart is shown in ▶ **Fig. 1**. The surgical technique for cardial SMTs was chosen by four experts (PHZ, YSZ, YQZ, MDX) who had experience with >1000 cases of STER and non-tunnel techniques for the upper gastrointestinal tract. They made the surgical decisions based on experience with previous cases involving various SMT characteristics. In our endoscopy center, STER and non-tunnel techniques matured during this period. Thus, the decision-making for each technique did not change a lot during the study period. for non-tunneling techniques, operators cut the mucosa, dissected the submucosal layer, and peeled the tumor after locating the lesions [3, 4]. In comparison, with the STER technique, a submucosal tunnel was created to expose and resect SMTs under direct endoscopic visualization [2, 8]. This study was approved by the Ethics Committee of Zhongshan Hospital, in accordance with the Declaration of Helsinki (B-2018–222). We obtained written consent from all patients.



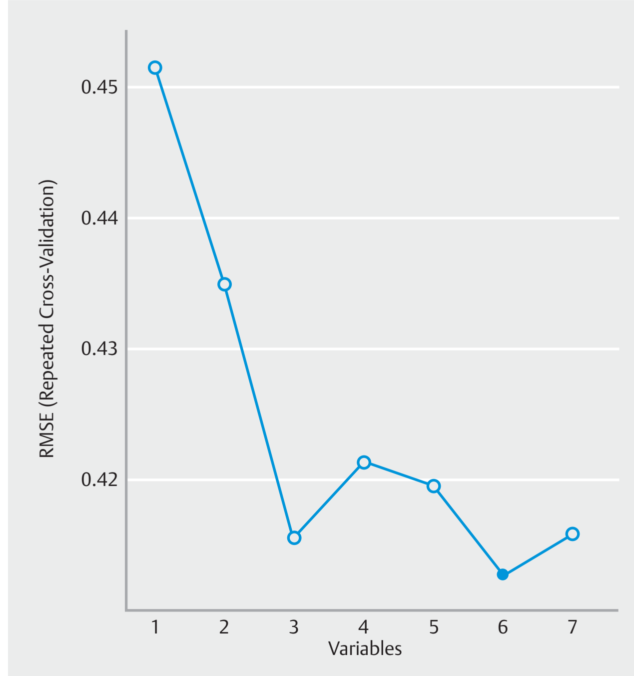
▶ **Fig. 1** The filter and group of patients. A total of 246 patients diagnosed with cardial SMTs and treated with endoscopic resection (STER or non-tunnel techniques) were randomly separated into a training cohort and a validation cohort. SMTs, submucosal tumors; GCSMT, gastric cancer presenting as a submucosal tumor; STER, submucosal tunneling endoscopic resection.

Study design

To avoid redundancy and over-fitting problems, we selected several top attributes by a Recursive Feature Elimination (RFE) method, as illustrated in ▶ **Fig. 2**. RFE, like stepwise regression, is a backward selection method that estimates a model on all features, computes importance scores, and removes the least important ones [9]. Seven potential factors for surgical decision-making included direction of the gastroscope (both vs reverse vs forward), morphology (regular vs irregular), location (anterior wall and greater curvature vs posterior wall and lesser curvature vs cardia near the lower esophagus), originating layer (MM and submucosa vs MP), mucosa (smooth vs ulcerative), maximum diameter (≤ 2 vs > 2 cm), and growth pattern (intraluminal vs extraluminal). The result indicated that six variables (direction of the gastroscope, morphology, location, originat-



▶ **Fig. 2** Graphical description of the variable selection process. Six factors were selected and investigated by multivariate logistic regression. RFE, recursive feature elimination.



▶ **Fig. 3** RMSE of the different number of variables. Six variables (direction of the gastroscope, morphology, location, originating layer, mucosa, and max diameter) could achieve the minimal root mean squared error (RMSE). RMSE, root mean squared error.

ing layer, mucosa, and max diameter) could achieve the minimal root mean squared error (RMSE) (▶ **Fig. 3**). Furthermore, statistical tests also showed that there were significant differences between STER and non-tunnel techniques in the previously mentioned six variables.

After selecting proper variables, we established a scoring system to predict the determination of endoscopic resection for cardial SMTs in the training phase and then validated the scoring system. At first, six explanatory variables were considered in the multivariate logistic regression using training cohort data. The β coefficients from the logistic regression model were exploited to create the scoring system (the score was rounded to the nearest integer of the β coefficients). Only β coefficients of variables with $P<.05$ were adopted in this system. The total score for each participant was calculated by adding variable scores, and patients could be classified into high-, medium-, or low-score groups. The rates of STER and non-tunneling endoscopic resection could be calculated for each score and group level. In this study, the R package "caret" was applied to the logistic regression model and the parameters for model performance were fine-tuned through the 10-fold cross-validation technique.

Clinical characteristics

Using medical records and endoscopic findings, we collected information on patient demographics, tumor characteristics, and clinical outcomes. Tumor characteristics consisted of morphology, location, originating layer, max diameter, growth pattern, mucosal state, and histologic evaluation. We also recorded the direction of the gastroscope where SMTs could be observed directly. Clinical outcomes mainly consisted of procedure duration, length of hospital stay, en bloc resection rate, rates of complications (perforation and postoperative bleeding), and rates of local recurrence. The procedure duration was measured from mucosal incision to wound closure. The en bloc resection rate was defined as the proportion of completely resected tumors without apparent residual tumors assessed macroscopically by the endoscopist at the resection site and with negative margins (both lateral and basal resection margins) on pathologic examination (histologically complete resection).

Patients received regular follow-up for evaluation of local recurrence with esophagogastroduodenoscopy (EGD) or telephone interviews. Detailed telephone interviews were performed by trained physicians with patients who were unwilling to return for follow-up. The interviews included questions about examinations and treatments at other hospitals. The last follow-up was in April 2021.

Statistical analysis

Continuous variables are presented as means ± standard deviation (SD) N ~ (μ, σ2), and categorical variables are shown as numbers with percentages. We conducted univariable analysis to compare clinical characteristics between STER and non-tunnel techniques using the Student *t* test, the chi-squared test, the Fisher exact test, or the likelihood ratio test (LRT). We selected several variables for the multivariate model, according to results of the RFE method and univariate analysis (variables with $P<.05$). Clinical characteristics also were compared between the two cohorts to explore data distribution. A multivariable logistic regression model was used to identify independent factors associated with surgical decision-making and the results are presented as odds ratios (ORs), 95 % confidence intervals (Cis), β coefficients, and P values. The goodness-of-fit was evaluated with the Hosmer-Lemeshow test. The β coefficients

▶ Table 1 Clinical characteristics and procedural outcomes of patients.

	STER (n = 97)	Non-tunnel technique (n = 149)	*P* value
Male, n (%)	52 (53.6)	63 (42.3)	0.082
Age (years), mean ± SD	49.6 ± 11.6	52.3 ± 12.5	0.086
Growth pattern, n (%)			0.941
▪ Intraluminal growth	92 (94.8)	141 (94.6)	
▪ Extraluminal growth	5 (5.2)	8 (5.4)	
Morphology, n (%)			0.000[1]
▪ Regular	28 (28.9)	94 (63.1)	
▪ Irregular	69 (71.1)	55 (36.9)	
Mucosa, n (%)			0.007[1]
▪ Smooth	95 (97.9)	132 (88.6)	
▪ Ulcerative	2 (2.1)	17 (11.4)	
Max diameter (cm), mean ± SD	2.6 ± 1.5	2.2 ± 1.5	0.049[1]
Location, n (%)			0.000[1]
▪ Anterior wall and greater curvature	43 (44.3)	80 (53.7)	
▪ Posterior wall and lesser curvature	17 (17.5)	60 (40.3)	
▪ Cardia near the lower esophagus	37 (38.1)	9 (6.0)	
Direction of the gastroscope, n (%)			0.000[1]
▪ Both	44 (45.4)	52 (34.9)	
▪ Reverse	18 (18.6)	89 (59.7)	
▪ Forward	35 (36.1)	8 (5.4)	
Layer, n (%)			0.040[1]
▪ Muscularis mucosa and submucosa	3 (3.1)	15 (10.1)	
▪ Muscularis propria	94 (96.9)	134 (89.9)	
Surgery time (min), mean ± SD	58.7 ± 32.0	48.3 ± 29.1	0.009[1]
En bloc resection rate, n (%)	91 (93.8)	143 (96.0)	0.642
Hospital stay (day), mean ± SD	3.8 ± 1.9	3.8 ± 1.6	0.942
Histopathologic evaluation, n (%)			0.196
▪ Leiomyoma	85 (87.6)	114 (76.5)	
▪ GIST	9 (9.3)	28 (18.8)	
▪ Lipoma	1 (1)	3 (2.0)	
▪ Cyst	2 (2.1)	3 (2.0)	
▪ Neurofibroma	0 (0.0)	1 (0.7)	
Complications, n (%)	3 (3.1)	8 (5.4)	0.597
Recurrence, n (%)	3 (3.1)	0 (0.0)	0.117

STER, submucosal tunneling endoscopic resection; SD, standard deviation.
[1] Statistically significant.

▶ **Table 2** Clinical characteristics and procedural outcomes of the training (n = 147) and validation (n = 99) cohorts.

	Training cohort	Validation cohort	*P* value
STER, n (%)	63 (42.9)	34 (34.3)	.180
Male, n (%)	66 (44.9)	49 (49.5)	.479
Age (years), mean ± SD	50.2 ± 12.0	52.9 ± 12.4	.091
Growth pattern, n (%)			.304
▪ Intraluminal growth	141 (95.9)	92 (92.9)	
▪ Extraluminal growth	6 (4.1)	7 (7.1)	
Morphology, n (%)			.125
▪ Regular	67 (45.6)	55 (55.6)	
▪ Irregular	80 (54.4)	44 (44.4)	
Mucosa, n (%)			.753
▪ Smooth	135 (91.8)	92 (92.9)	
▪ Ulcerative	12 (8.2)	7 (7.1)	
Max diameter (cm), mean ± SD	2.3 ± 1.4	2.4 ± 1.6	.614
Location, n (%)			.185
▪ Anterior wall and greater curvature	70 (47.6)	53 (53.5)	
▪ Posterior wall and lesser curvature	44 (29.9)	33 (33.3)	
▪ Cardia near the lower esophagus	33 (22.4)	13 (13.1)	
Direction of the gastroscope, n (%)			.074
▪ Both	57 (38.8)	39 (39.4)	
▪ Reverse	58 (39.5)	49 (49.5)	
▪ Forward	32 (21.8)	11 (11.1)	
Layer, n (%)			.903
▪ Muscularis mucosa and submucosa	11 (7.5)	7 (7.1)	
▪ Muscularis propria	136 (92.5)	92 (92.9)	
Surgery time (min), mean ± SD	53.8 ± 31.9	50.5 ± 28.7	.417
En bloc resection rate, n (%)	140 (95.2)	94 (94.9)	1.000
Hospital stay (day), mean ± SD	3.8 ± 1.7	3.8 ± 1.7	.958
Histopathologic evaluation, n (%)			.080
▪ Leiomyoma	117 (79.6)	82 (82.8)	
▪ GIST	23 (15.6)	14 (14.1)	
▪ Lipoma	1 (0.7)	3 (3.0)	
▪ Cyst	5 (3.4)	0 (0.0)	
▪ Neurofibroma	1 (0.7)	0 (0.0)	
Complications, n (%)	6 (4.1)	5 (5.1)	.963
Recurrence, n (%)	1 (0.7)	2 (2.0)	.729

STER, submucosal tunneling endoscopic resection; SD, standard deviation.

▶ **Table 3** Multivariate logistic regression analysis of factors for surgical decision-making in the training cohort and scoring system.

Factors	Multivariate analysis			
	OR [95 % CI]	β coefficient	*P* value	Point assigned
Morphology				
▪ Regular	1			
▪ Irregular	0.180 [-0.739 – 0.062]	–1.715	0.001*[1]	–2[1]
Mucosa				
▪ Smooth	1			
▪ Ulcerative	9.379 [1.521 – 183.808]	2.238	0.044*[1]	2[1]
Location				
▪ Anterior wall and greater curvature	1			
▪ Posterior wall and lesser curvature	1.866 [0.685 –5.262]	0.624	0.227	
▪ Cardia near the lower esophagus	2.108 [0.316 – 17.914]	0.746	0.449	
Direction of the gastroscope				
▪ Both	1			
▪ Reverse	2.871 [1.091 – 7.916]	1.055	0.036[1]	1[1]
▪ Forward	0.090 [0.009 – 0.647]	–2.403	0.022[1]	–2[1]
Layer				
▪ Muscularis mucosa and submucosa	1			
▪ Muscularis propria	0.138 [0.015 – 0.797]	–1.980	0.043[1]	–2[1]
Max diameter (cm), mean±SD	1.332 [0.933 – 1.944]	0.287	0.122	

OR, odds ratio; CI, confidence interval.
[1] Statistically significant.

of significant variables ($P<.05$ was considered statistically significant) were used to construct a scoring model. The performance of the scoring system was assessed with an area under the curve (AUC) with 95 % CI. Calculations were performed with SPSS statistical software version 26.0 and R version 4.0.2.

Results

Comparison between STER and non-tunnel techniques for managing cardial SMTs

A total of 97 STER and 149 non-tunnel technique procedures were performed during this study. As shown in ▶ **Table 1**, there were no significant differences in patient characteristics (age and gender), tumor growth pattern, pathological types, en bloc resection rate, hospital stay, complications, and recurrence ($P>.05$) between the STER and non-tunnel interventions. The surgery time for non-tunnel techniques was shorter than for STER (non-tunnel vs STER, 48.3 ± 29.1 min vs 58.7 ± 32.0 min, $P<.05$). Six tumor characteristics – direction of the gastroscope, morphology, location, originating layer, mucosa, and max diameter – differed significantly.

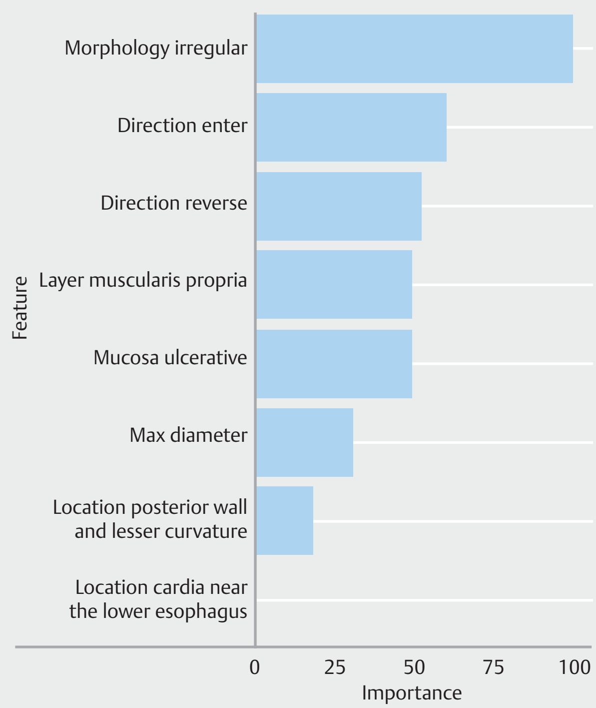
Clinical characteristics and procedural outcomes of the training and validation cohorts

The clinical characteristics and procedural outcomes in the training and validation cohort are shown in ▶ **Table 2**. A total of 246 patients were included, 147 in the training cohort and 99 in the validation cohort. The two cohorts were comparable regarding clinical characteristics and procedural outcomes.

Design of the score system to support surgical decision-making

Multivariate analysis (10-fold cross-validation) demonstrated that morphology, the direction of the gastroscope, originating layer, and mucosa were significant factors for the model (▶ **Table 3**). ▶ **Fig. 4** shows the variable importance based on sensitivity analysis. Our regression model fitted well in the Hosmer-Lemeshow test ($P=.4721$).

We applied a scoring system (ZhongshanTunnel Score) that was convenient for predicting surgical decisions by assigning –2 points to irregular morphology, 2 points to ulcer, 1 point to reversing direction, –2 points to forward direction, and –2 points to MP layer (▶ **Table 3**). A total score was calculated for each patient in the training cohort by adding the points corresponding to each individual factor (▶ **Table 4**). Patients were



▶ **Fig. 4** Variable importance in the sensitivity analysis.

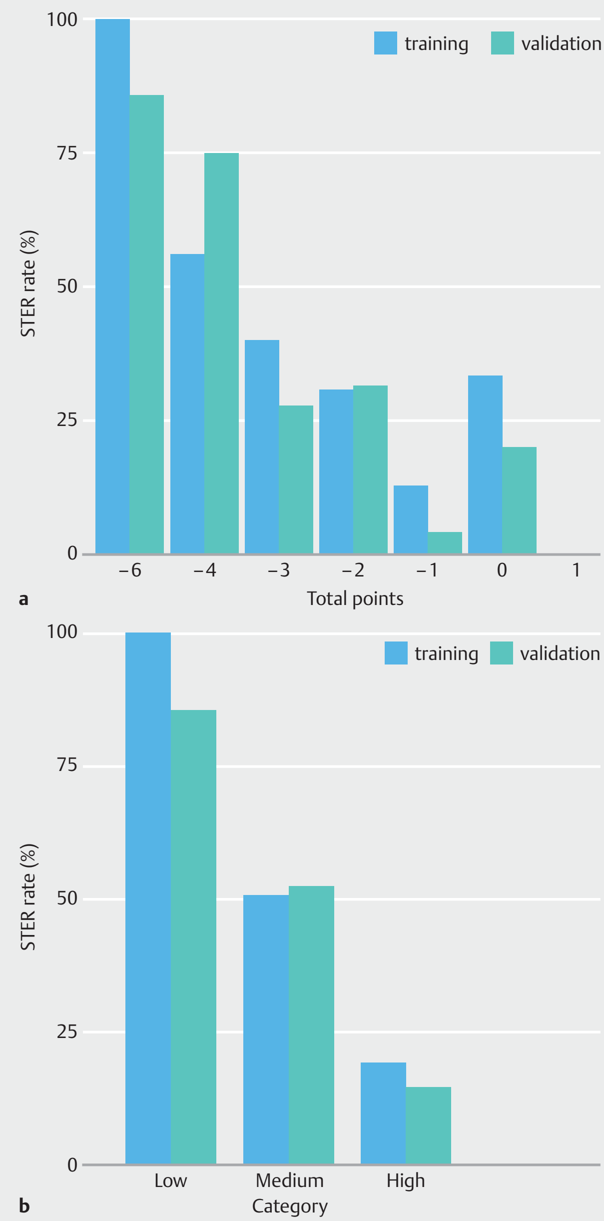
categorized into low-score (<–4), medium-score (–4 to –3) and high-score (>–3) groups. The STER rate was 100 % in the low-score group, 50.8 % in the medium-score group, and 19.4 % in the high-score group (▶ **Table 5**). In the training cohort, patients with low scores were more likely to be treated and vice versa.

Internal validation of the risk-scoring system

The total score for each patient in the validation cohort was calculated and categorized in the same way as in the training cohort (▶ **Table 4**, ▶ **Table 5**). In the validation cohort, the STER rate was 85.7 % in the low-score group, 52.6 % in the medium-score group, and 14.8 % in the high-score group. ▶ **Fig. 5** shows the rate of STER declined with increasing scores. This trend was also found in all patients (▶ **Fig. 6**). Our prediction scoring system showed discriminatory performance in the validation cohort (AUC, 0.829; 95 % CI, 0.694–0.964) (▶ **Fig. 7**).

Surgical outcomes of STER and non-tunnel technique in the high-score and middle-score group

We compared surgical outcomes for the two techniques in the high-score patients (▶ **Table 6**). Complication ($P=0.030$) and recurrence rates ($P=0.029$) for STER were higher than for non-tunneling techniques in the high-score group. En bloc resection rate, surgery time, and length of hospital stay were not significantly different between STER and non-tunnel resection. In the middle-score group, surgical outcomes were no different for the two techniques (▶ **Table 7**).



▶ **Fig. 5** **a** Rate of STER for the score model and **b** the three categories in the training and validation cohorts. STER, submucosal tunneling endoscopic resection.

Discussion

With constant advances in endoscopic techniques, STER and non-tunnel techniques have gained popularity for resection of cardial SMTs. In previous studies, these two techniques have been compared and a few factors have been proposed that might influence the surgical decision. However, the optimal way to select a surgical method for cardial SMTs still remains to be determined. Compared to non-tunnel techniques, the time it takes to perform STER is longer due to the significant skill and experience required. Complication rates also were not statistically significantly different between the two methods,

▶ **Table 4** Distribution of scores for surgical decision-making in the training and validation cohorts.

Total points	Training cohort			Validation cohort		
	Patients (n = 147)	STER (n = 63)	STER rate (%)	Patients (n = 99)	STER (n = 34)	STER rate (%)
–6	19	19	100.0	7	6	85.7
–4	41	23	56.1	20	15	75.0
–3	20	8	40.0	18	5	27.8
–2	26	8	30.8	19	6	31.6
–1	31	4	12.9	24	1	4.2
0	3	1	33.3	5	1	20.0
1	7	0	0.0	6	0	0.0

STER, submucosal tunneling endoscopic resection.

▶ **Table 5** Classification for surgical decision-making in the training and validation cohorts.

Category	Total points	Training cohort			Validation cohort		
		Patients (n = 147)	STER (n = 63)	STER rate (%)	Patients (n = 99)	STER (n = 34)	STER rate (%)
Low	< –4	19	19	100.0	7	6	85.7
Medium	-4 to –3	61	31	50.8	38	20	52.6
High	> –3	67	13	19.4	54	8	14.8

STER, submucosal tunneling endoscopic resection

▶ **Table 6** Surgical outcomes of STER and non-tunnel technique in the high-score group.

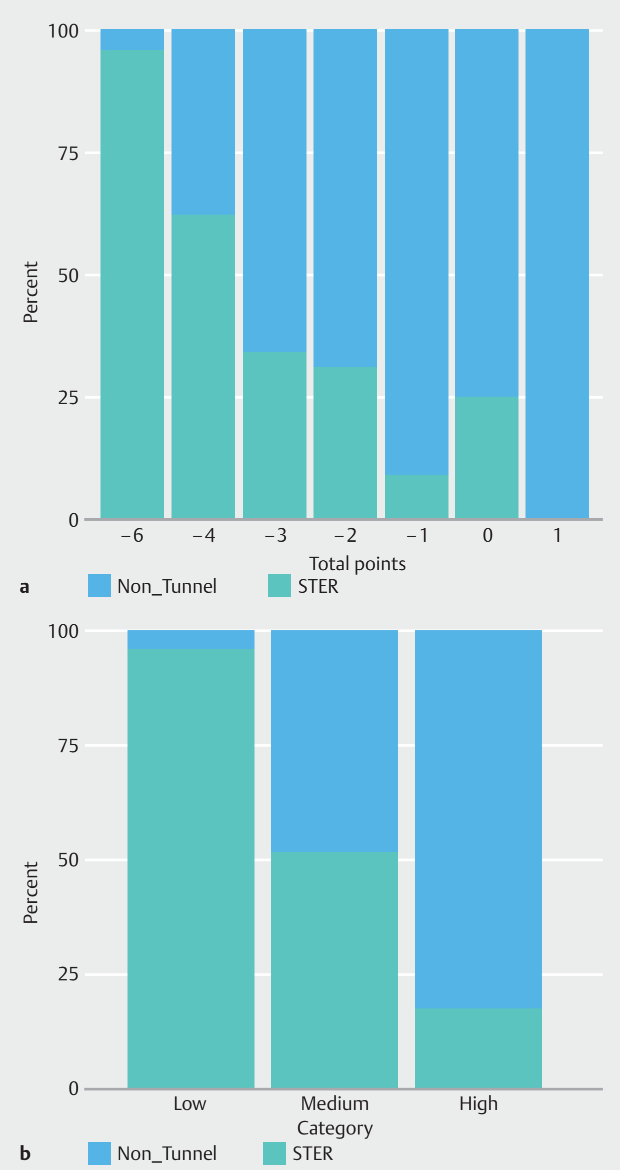
	STER (n = 21)	Non-tunnel technique (n = 100)	*P* value
Surgery time (min), mean ± SD	53.1 ± 30.8	46.3 ± 29.0	0.338
En bloc resection rate, n (%)	21 (100.0)	97 (97.0)	1.000
Hospital stay (day), mean ± SD	4.3 ± 1.9	3.8 ± 1.5	0.163
Complications, n (%)	3 (14.3)	3 (3.0)	0.030[1]
Recurrence, n (%)	2 (9.5)	0 (0.0)	0.029[1]

STER, submucosal tunneling endoscopic resection; SD, standard deviation.
[1] Statistically significant.

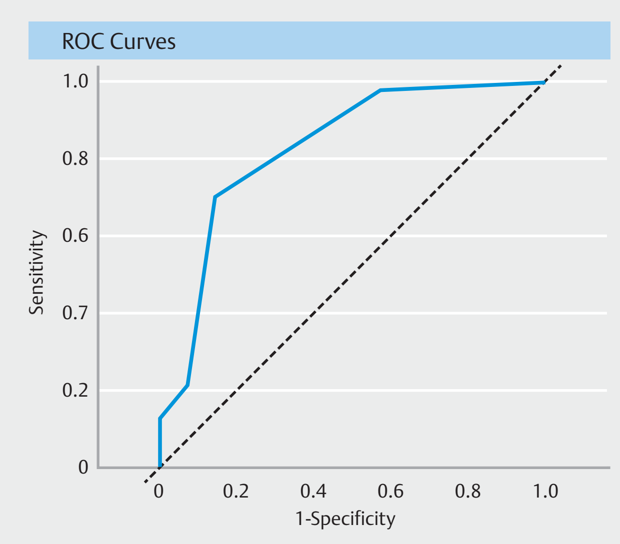
but there was a trend toward more with the non-tunnel techniques (non-tunnel vs STER, 8 cases vs 3 cases). It has been known that non-tunnel techniques have a high risk of perforation and difficulty with subsequent endoscopic closure. In comparison, STER is associated with a reduced risk of postoperative gastrointestinal tract leakage and secondary infection. If perforation happens, it should be easier to close under the tunnel.

We found that several factors (maximum diameter, morphology, mucosa, originating layer, direction of the gastroscope, and location) had a significant impact on the surgical decision-making, which is consistent with conclusions from previous studies. Lu [6] demonstrated that both ESE and STER produced satisfactory therapeutic results for SMTs < 10 mm and STER was a preferable choice for SMTs > 10 mm, especially when perforation was likely to happen. Inoue [10] reported that SMTs < 3.0 cm from the esophagus and cardia might be the appropriate application for STER. A study by Chen [11] revealed that implementation of STER for SMTs with a long diameter ≤ 5.0 cm and a transverse diameter ≤ 3.5 cm could facilitate a high en bloc resection rate. However, Wang [12] considered that even when for tumors > 3.5 cm, STER still appears to be a feasible and effective method for SMTs in the upper gastrointestinal tract. To conclude, the upper limit of the tumor diameter for a successful STER remains controversial.

Irregular morphology of SMTs was an independent risk factor for failure of en bloc resection [13]. It has been reported



▶ **Fig. 6** **a** Probability of STER and non-tunnel techniques for the score model and **b** the three categories in all patients. STER, submucosal tunneling endoscopic resection.



▶ **Fig. 7** AUC for the scoring system in the validation cohort. AUC, area under the receiver-operator characteristic curve.

that SMTs with irregular margins are associated with risk of malignancy and should not be treated with STER [12, 14]. Chen [11] then reported that STER was feasible for large tumors with irregular shapes in the deep MP layer but associated with a relatively high likelihood of piecemeal resection and complications. Given the specific anatomical structure of the EGJ, SMTs located in the cardia are often irregular. As a result, accurate preoperative evaluation is more difficult and piecemeal resection sometimes is inevitable. Although STER for cardial SMTs is more challenging than for esophageal SMTs, the en bloc resection rates are comparable [15].

It is essential that STER not be recommended for patients who have SMTs with ulcers because the integrity of the mucosa cannot be maintained. Also, the deep MP layer where SMTs originate is a risk factor associated with perforation [16]. In addition to the above factors associated with SMTs, our study indicated that the direction of the gastroscope also contributed to determining endoscopic methods. The direction of the gastroscope in which SMTs were observed could help endoscopists estimate the maneuverable space and direction of endoscopic instruments.

According to the above analyses, our study established and validated a novel and simple-to-use scoring system for evaluating methods before endoscopic resection. The scoring system comprises four factors: irregular morphology, ulcer, gastroscope direction, and location in the MP layer. The scoring system with an AUC = 0.829 is excellent for discrimination (0.8–0.9) [17]. Categorizing patients based on the scoring system could guide endoscopists in choice of STER or non-tunnel techniques. STER may be a better choice for patients with scores < −4, and non-tunnel techniques may be more suitable for patients in the high-score (> −3) group. For patients with medium scores (−4 to −3), STER and non-tunnel techniques are both feasible.

We found that clinical results were worse when STER was attempted with high-point lesions in our study. When SMTs could only be observed in the reverse direction, and there were ulcers on the mucosal surface (high-point lesions), the visual range of the operating area and the operable space for endoscopic instruments were much more limited than that in the forward direction, and the mucosal integrity could not be guaranteed. In such a scenario, complications such as bleeding and perforation would be more likely with STER. Therefore, failure of and complications associated with endoscopic surgery may be linked with inappropriate operation selection. The appropriateness of each technique for cardial SMTs, based on tumor-specific factors, is summarized in (▶**Table 8**), and the experts in our Endoscopy Center follow these empirical rules.

▶ **Table 7** Surgical outcomes of STER and non-tunnel technique in the middle-score group.

	STER (n = 51)	Non-tunnel technique (n = 48)	*P* value
Surgery time (min), mean ± SD	60.0 ± 32.8	51.5 ± 28.9	0.178
En bloc resection rate, n (%)	48 (94.1)	45 (93.8)	1.000
Hospital stay (day), mean ± SD	3.7 ± 1.4	3.9 ± 1.7	0.681
Complications, n (%)	0 (0.0)	3 (6.3)	0.220
Recurrence, n (%)	1 (2.0)	0 (0.0)	1.000

STER, submucosal tunneling endoscopic resection; SD, standard deviation.

▶ **Table 8** Appropriateness of STER and non-tunnel techniques for cardial SMTs based on different tumor factors.

Factors	STER	Non-tunnel	Suggestions
Morphology			
▪ Regular	Yes	Yes	Both
▪ Irregular	Yes	Yes	STER
Mucosa			
▪ Smooth	Yes	Yes	STER
▪ Ulcerative	No	Yes	Non-tunnel
Location			
▪ Anterior wall and greater curvature	Yes	Yes	Non-tunnel
▪ Posterior wall and lesser curvature	Yes	Yes	Non-tunnel
▪ Cardia near the lower esophagus	Yes	Yes	STER
Direction of the gastroscope			
▪ Both	Yes	Yes	STER
▪ Reverse	No	Yes	Non-tunnel
▪ Forward	Yes	Yes	STER
Layer			
▪ Muscularis mucosa and submucosa	Yes	Yes	Non-tunnel
▪ Muscularis propria	Yes	Yes	STER

STER, Submucosal tunneling endoscopic resection; SMT, submucosal tumor.

Our scoring system has may be helpful in training young endoscopists about how to make surgical decisions. With it rates of surgical failure and complications can be reduced. For example, if an SMT is located in the superficial layer (muscularis mucosa and submucosa) of the esophagus, accompanied by ulcers on the mucosal surface, and can only be observed in the reversing direction, ESD (non-tunneling techniques) is suggested. In this situation, STER (tunneling techniques) may lead to mucosal injury on the surface of a tunnel, and therefore, ESD should be chosen. On the other hand, if an SMT is located in the deep layer (muscularis propria) of the esophagus, the mucosal surface is smooth, and it is visible in the forward direction, STER is suggested because with it, the integrity of the SMT's mucosal surface is preserved and risk of perforation is reduced.

The advantages of our scoring system are as follows. First, this system is based on clinical characteristics that are readily ascertainable. Thus, it is appropriate to adopt the scoring system in clinical settings and helpful for junior endoscopists to make surgical decisions. Moreover, we applied a 10-fold cross-validation technique to fine-tune the parameters for model performance, and our scoring system showed discriminatory performance. Applying the scoring system to the validation cohort also confirmed its feasibility. The predicted results correlated well with observations in the low- and high-score groups.

There are also several limitations of this study. First, we only performed internal validation to assess our scoring system. Cases from external sources are needed to improve the generalizability of the system. Second, our study was retrospective with potential bias. Hence, prospective studies are anticipated in the future.

Conclusions

In conclusion, our scoring system provides endoscopists with references for surgical decisions about cardial SMTs and it is expected to reduce the risk of severe complications and recurrence due to misjudgment about endoscopic techniques.

Competing interests

The authors declare that they have no conflict of interest.

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CORRECTION

A scoring system to support surgical decision-making for cardial submucosal tumors

Zi-Han Geng, Yan Zhu, Wei-Feng Chen et al.

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In the above-mentioned article in **Fig. 1** the word “techniques” was added. **In Fig. 2** and **Fig. 6** several changes were made.

This was corrected in the online version on Mai 23 2022.