A novel quality scoring system for the evaluation of individual colonoscopy: a multicenter retrospective study

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ABSTRACT

***Background and Aim*:** It is essential to develop a novel evaluation system for the quality of individual colonoscopy and provide guidelines on whether and when to follow up the patient after the initial colonoscopy. This study aimed to establish and validate a scoring system for the quality of individual colonoscopy in terms of the adenoma miss rate (AMR).

***Methods*:** Patients undergoing two consecutive colonoscopies within 90 days between 2009 and 2011 from different levels of hospitals in China were enrolled into this study. Potential risk factors for adenoma miss at the individual colonoscopy in a cohort of patients were evaluated in univariate and multivariate analyses. Corresponding scores for the procedure-related factors were generated based on their weights, and a scoring system was established and then validated by correlating the system with AMR.

***Results*:** A total of 2,093 patients were enrolled. Procedure-related factors at the individual colonoscopy (including bowel preparation and imaging methods), doctor experience, retroflexion and withdrawal time were identified to be independent risk factors, and each of these factors was scored from 0 to 3. Then, a novel scoring system for the quality of individual colonoscopy (ranging from 0-9) was established, which was closely correlated with the AMRs in the establishment (adjusted R^2 = 0.845) and validation databases (adjusted R^2 = 0.733).

***Conclusions*:** The developed and validated evaluation system, consisting of procedure-related independent factors, successfully assesses the quality of individual colonoscopy in terms of AMRs.

Key words: Quality evaluation; Individual colonoscopy; Adenoma miss, Risk factors

Introduction

The efficacy of colorectal cancer (CRC) screening in reducing the incidence of colorectal cancer and associated mortality is increasingly evident.[1] The quality assurance guidelines for colonoscopy have been recommended to control the quality of colonoscopy, and improve the detection of colorectal adenoma (a precancerous lesion) and thus reduce the risk of colorectal cancer. The adenoma detection rate (ADR) has been considered as one of the important measures for the quality of colonoscopy.[2, 3] Moreover, the adenoma miss rate (AMR) has become widely acknowledged and usually determined by two colonoscopies performed sequentially in a tandem protocol.[4, 5] Previous studies have demonstrated that the factors that influence ADR and AMR include bowel preparation[6-9], doctor experience and background[10, 11], withdrawal time[12, 13], sedative colonoscopy[14], and adenoma pathological characteristics.[15, 16]

However, current quality assurance systems for screening colonoscopies were established based on a general evaluation of all colonoscopies examined during a period of time. Thus, these systems are of clinical value in the assessment of the general quality of colonoscopies performed by an individual colonoscopist or at a specified medical center or hospital, but cannot be used for adequate and timely evaluation of the quality of individual colonoscopies. Currently, a quality evaluation system for individual colonoscopies is virtually lacking, and colonoscopists still face the challenges of how to manage a patient or whether and when to follow up a patient at an initial colonoscopy. Therefore, the aim of this multi-center study was to establish and validate a scoring system for evaluating the quality of individual colonoscopy, in terms of the AMRs.

Methods

Study design. A retrospective analysis of demographic, endoscopic and pathological data in patients undergoing colonoscopy collected between September 2009 and September 2011 at four hospitals at different levels was performed. The research proposal was reviewed and approved by the Research Ethical Committees at the author's institution. All patients enrolled in this study provided written informed consent. Patients who underwent two consecutive colonoscopies were enrolled with the following criteria: 1) aged more than 18 years old; 2) with complete clinical histopathology and colonoscopy records; 3) without endoscopic dye spraying for the entire colon; however, patients with regional dye spraying for suspected lesions; 4) the cecum, ileocecal valve and appendiceal orifice being clearly photographed; and 5) the images of the rectum being accurately taken during colonoscopy withdrawal. Patients with a history of colorectal cancer, polyposis syndrome, inflammatory bowel disease, or partial colonic resection and those with incomplete patient files were excluded from the study.

Construction of adenoma miss databases from the general study population. To be eligible for the inclusion into the total adenoma miss database, the patients must also have met the following criteria: 1) two consecutive colonoscopies performed, with the first and the second examination within 90 days of the first; 2) colonoscope insertion to the cecum and good bowel preparation at the secondary colonoscopy; 3) at least one adenoma detected at the first colonoscopy, and the same or additional adenomas detected at the secondary colonoscopy; and 4) the colonoscopist for the first colonoscopy performed more than 100 intact colonoscopies at the corresponding experience level, and the colonoscopist for the second colonoscopy performed more than 1,000 colonoscopies with more than 150 cases annually during the period of the

present study. The total adenoma miss database, which was further stratified by hospital, gender and age according to the patient with missed adenoma or not, was randomly divided into two major databases at a 4:1 ratio: 1) a primary establishment database of adenoma miss, consisting of 80% patients and 2) a validation database of adenoma miss, consisting of 20% patients. In the primary establishment database of adenoma miss, a missed adenoma was randomly chosen from each adenoma-missed patient to represent the patient with missed adenoma. Similarly, a detected adenoma was also randomly chosen from each patient without a missed adenoma to represent the patient without missed adenoma. Then, all parameters of the adenomas and the corresponding patients derived from the primary establishment database were used to generate the secondary establishment database of adenoma miss as described below (Fig.1).

Establishment and validation of a scoring system. All patient-, procedure- and adenoma- related factors of the secondary establishment database of adenoma miss were entered into a multivariate logistic regression equation to generate independent factors associated with adenoma miss. After the independent factors associated with adenoma miss were concluded, all patient- and adenoma-related factors were regarded as subjective factors and thus excluded, even if they were identified as independent factors associated with adenoma miss because these factors cannot be modified at the time when the individual colonoscopy is being performed. Then, all independent procedure-related factors associated with adenoma miss were mandatorily included in a multivariate logistic regression analysis with the levels of some factors aggregated accordingly to generate the corresponding regression coefficients, and the corresponding scores according to its coefficient. Subsequently, the evaluation system for the quality of individual colonoscopy was established and validated by

determining the correlation of the scores with adenoma miss.

Statistical analysis. Statistical analyses were performed by using SPSS Statistics 17.0 (IBM, Armonk, NY). Numerical and categorical data are presented as mean ± standard deviation (SD) and percentage, respectively. A P value of less than 0.05 was considered statistically significant. The univariate analysis for all possible factors associated with adenoma miss was performed by Student's t test and Chi-square test. Moreover, factors with $P < 0.100$ in univariate analysis were further tested in multivariate logistic regression analysis. Procedure-related factors in the whole independent risk factors were mandatorily put into a multivariate logistic regression analysis again with the levels of some factors aggregated at the discretion of their odds ratio (OR) and generated the corresponding regression coefficients. The corresponding scores for procedure-related independent factors were calculated as the regression coefficient of each parameter divided by the smallest coefficient and rounded off, and then a scoring system was formed for evaluating the quality of individual colonoscopy. The scoring system was validated as follows: first, each colonoscopy in both the establishment and validation databases get a score according to the scoring system, then different score values and their respective per-adenoma AMRs were entered into linear regression analysis for evaluating the relationship by their coefficient and R^2, and finally the difference and linear trends between different score ranges and their respective AMRs were analyzed by an R×C table.

Results

Patients included in the database. Between September 2009 and September 2011, a total of 4,567 patients underwent two consecutive colonoscopies. Of these patients, 2,474 (54.2%) patients were excluded due to colorectal cancer (n = 44, 1.8%), colon resection (n = 163, 6.6%), inflammatory bowel disease (n = 186, 7.5%) colon

polyposis syndrome (n = 67, 2.7%), poor colonoscopic images and incomplete data (n = 1473, 59.5%), inadequate bowel preparation and inexperienced colonoscopist at the second colonoscopy (n = 378, 15.3%), colonoscope not reaching the ileocecal valve (n = 21, 0.8%) and interval time more than 90 days (n = 142, 5.7%). Therefore, 2,093 patients were finally included in the adenoma miss database; 1,673 and 420 patients were respectively allocated into the establishment database of adenoma miss and validation database of adenoma miss (Fig.1). Of these 2,093 patients, 124 (6%) had a family history of colorectal cancer, 475 (23%) a history of adenoma, 129 (6%) a history of diverticulum, and 150 (7%) a history of abdominal surgery. The adenoma size ranged from 3-66 mm with a mean of 8.8 mm. Patient-, procedure- and adenoma-related factors in patients included in the adenoma miss database in relation to the different levels of hospitals are shown in Table 1.

Potential factors associated with adenoma miss from establishment database of adenoma miss. The quality of bowel cleanliness was assessed by the colonoscopist at the time of colonoscopy and graded as being excellent, adequate or poor as previously described[17]. Excellent and adequate bowel cleanliness was defined as good quality. The proficiency of the colonoscopists was defined by the cumulative cases of colonoscopy as four levels as follows: 1) more than 2,000; 2) between 1,000 and 2,000; 3) between 500 and 1,000; and 4) less than 500 cases. The cumulative cases of colonoscopy for one colonoscopist were calculated as the sum of all cases of colonoscopy before this study and during this study and graded into the corresponding experience groups. The withdrawal time was defined as the time of colonoscopy withdrawal to the rectum minus the time of colonoscopy insertion to the cecum based on the times recorded on the images. The withdrawal time of the colonoscopy for a particular colonoscopist with a certain level of experience was represented by the

average time of at least 100 normal total colonoscopy procedures (i.e., no lesions were detected) performed by that colonoscopist with the experience level at that time, which may change according to the advancement of the experience level of the colonoscopist.

The univariate analysis showed that age, bowel preparation, doctor experience, imaging methods (dye spraying and/or narrow band imaging), withdrawal time and adenoma characteristics, such as morphology, adenoma site, adenoma pathology, adenoma IEN, adenoma risk and adenoma size, were significant factors in predicting adenoma miss (Table 2). Moreover, the multivariate logistic regression analysis further confirmed that bowel preparation, imaging methods, doctor experiences, retroflexion and withdrawal time were independent procedure-related factors associated with "per-patient" miss rate (Table 3).

Establishment of the scoring system based on AMR. The levels of some independent procedure-related factors above were aggregated at the discretion of their OR after they were mandatorily entered into the multivariate logistic regression analysis again. Withdrawal time for individual colonoscopy was graded into three groups: ≤ 4 minutes, > 4 and < 6 minutes, and ≥ 6 minutes. Doctor experience was classified into two groups: more than 1,000 cases and less than 1,000 cases. Bowel preparation was divided into two groups: good and poor. Imaging methods were classified as dye spraying and/or narrow band imaging and no dye spraying and/or marrow band imaging. Retroflexion was classified as no retroflexion, rectum retroflexion only and ascending colon retroflexion (or with rectum). Table 4 provides an example of calculation of the individual score for the five independent factors. Accordingly, the total score for predicting the quality of the individual colonoscopy was nine; a higher value of the total score was correlated with a lower AMR.

According to the range of AMRs, the scores were divided into three grades: grade 1 (score 0-2), grade 2 (score 3-6) and grade 3 (score 7-9) based on the "per-adenoma" AMR from the establishment database (Table 4).

Validation of the scoring system in terms of "per-adenoma" AMR. The performances of the scoring system in the establishment and validation databases of adenoma miss are shown in Table 5. The values of the score were significantly correlated with the AMRs either in the establishment or in the validation databases of adenoma miss with the coefficients of 0.929 and 0.873, respectively. The R^2 for linear regression in the establishment database and in the validation database was 0.845 and 0.733, respectively. There were significant differences in the linear trends between the different score ranges and the AMRs through R×C table analysis (Pearson χ^2 = 93.433, $P < 0.001$ and linear-by-linear association value = 93.398, $P < 0.001$ in the establishment database of adenoma miss; Pearson χ^2 = 56.445, $P < 0.001$ and linear-by-linear association value = 55.291, $P < 0.001$ in the validation database of adenoma miss).

Discussion

Our study is the first to establish and validate a scoring system for the quality of individual colonoscopy in terms of AMR, using multivariate analysis for thousands of patients. First, patient-, procedure- and adenoma- related factors were, for the first time, analyzed together in a multivariate model to identify the independent risk factors of adenoma miss. Second, all independent procedure-related risk factors that were identified, such as bowel preparation, imaging methods, doctor experiences, retroflexion and withdrawal time were extracted and analyzed again using the logistic equation and given an item score to establish the scoring system for individual colonoscopy. The scoring system established in the present study appeared to be

correlated very well with AMRs in both the establishment and validation databases. Although this scoring system does not allow the colonoscopist to inform the patient of detailed AMR during individual colonoscopy, an increase in the scores was significantly associated with a decrease in AMRs. Thus, the scoring system could be used to determine the likelihood that an adenoma has been missed in an individual patient to some degree and assess the quality of individual colonoscopy.

Currently, AMR and ADR vary among different studies and geographic regions[2, 3, 5] and the variations may be partially caused by lack of a well-established evaluation system for the quality of individual colonoscopy. Thus, there is a need to establish an objective and reliable system to evaluate individual colonoscopy, especially in terms of AMR. In this study, a scoring system consisting of a few major easily obtainable procedure-related factors was established and confirmed that higher scores of this system corresponded with lower AMRs of individual colonoscopy. Since the scores were cumulatively calculated according to the procedure-related factors during individual colonoscopy, they can provide a useful signal to indicate whether there is a risk of adenoma misses for individual colonoscopy and whether a follow-up procedure is required. In the setting of screening/surveillance, the evaluation for the quality of individual colonoscopy could also improve the ADR and reduce the incidence of CRC in the general population, although further studies are required to verify these assumptions. Therefore, the evaluation for the quality of individual colonoscopy should be paid more attention in clinical practice and incorporated into the guidelines of decision-making on whether a follow-up and re-examination is needed, especially for patients with a high risk of CRC.

There are some unique features and advantages in the design of the present study. First, patients were enrolled from four different levels of hospitals in the setting of

adenoma screening and diagnosis, with strict inclusion and exclusion criteria. So, our scoring system appears to be reliable and could be used in the different levels of hospitals. Second, previous studies showed that colonoscopist experience[18] and withdrawal time[19, 20] were correlated with the AMRs. In the present study, the experience of a colonoscopist was graded according to the numbers of colonoscopies he/she performed, which would advance to higher levels with the numbers of colonoscopies accumulated. For a colonoscopist, he/she would have different average withdrawal times for negative colonoscopies (i.e., colonoscopy without adenoma) in his/her different experience levels during the period of this study. It is justifiable and reliable to calculate different withdrawal times of a colonoscopist in his/her different experience levels during a rather long study period in comparison with that of others.[20] Third, all factors that are known to be related to adenoma miss, such as patient-, procedure- and adenoma- related factors were entered into one analytical model to achieve a more reliable conclusion. However, only one factor or the same kind of factors associated with adenoma miss have been previously assessed in one model.[21-23]

One of the limitations in this study was the retrospective nature. Some complex parameters related to the colonoscopy examination, such as examining the proximal sides of flexures, folds and valves, adequacy of distention and cleaning and suctioning of the bowel, were not be able to be collected and included into our scoring system, because they were acquired by real-time and continuous investigation or detailed video evaluation and performed by specific experts. The second limitation is that the withdrawal time was defined as the time of colonoscopy withdrawal to the rectum minus the time of colonoscopy insertion to the cecum in this retrospective study. However, the reaching of the endoscope to the cecum and the withdrawing of the

endoscope to the cecum were performed well and withdrawal time was justifiably calculated in this study.

In conclusion, a scoring system for the quality of individual colonoscopy consisting of procedure-related independent factors was successfully developed and validated. The scoring system is a reliable and valid evaluation system to assess the quality of individual colonoscopy, in terms of AMRs; however, independent validation of this system is required before it can be used in clinical practice to minimize or avoid the incidence of colorectal cancer by reducing adenoma miss.

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Conflict of interest:

The authors have no conflicts to disclose.

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Table 1. Patient-, procedure- and adenoma- related factors in patients included in the total adenoma miss database in relation to the different levels of hospitals.

	Hospitals				Total	*P* value
	1	2	3	4		
No. of patients	999	576	307	211	2093	
Age (years)						< 0.001
Mean (SD)	53.3 (12.4)	56.5 (12.8)	58.9 (13.0)	63.3 (14.0)	56.0 (13.1)	
Range	23-80	21-81	23-90	29-91	21-91	
Sex						0.328
Male	640	374	214	140	1,368	
Female	359	202	93	71	725	
Symptom						0.001
Symptom-free	305	80	44	43	472	
Abdominal pain	205	165	78	43	493	
Bloody stool	229	165	107	66	567	
Fecal property	196	128	63	42	429	
Weight loss	62	38	15	17	132	
Family history of colorectal cancer						0.01
Yes	76	26	12	17	131	
No	923	550	295	194	1,962	
Family history of adenoma						
Yes	199	143	65	68	475	0.001
No	800	433	242	143	1,618	
Abdominal surgery history						0.388
Yes	78	38	23	10	149	
No	921	538	284	201	1,944	
Diverticulum history						0.001
Yes	67	26	7	23	123	
No	932	550	300	188	1,970	
Doctor experience (cases)						0.001
> 2000	339	190	42	52	623	
1000-2000	307	219	75	80	681	
500-1000	250	114	140	51	555	
< 500	103	53	50	28	234	
Doctor specialty						0.001
Endoscopist	114	167	98	104	483	
Gastroenterologist	885	409	209	107	1,610	
Colonoscopy						0.001
Single manipulation	999	323	133	110	1,565	
Double manipulation	0	253	174	101	528	

Sedative colonoscopy						<0.001
Yes	159	167	90	106	522	
No	840	409	217	105	1,571	
Bowel preparation						0.619
Excellent	262	167	73	58	560	
Adequate	565	315	183	112	1,175	
Poor	172	94	51	41	358	
Dye spraying and/or narrow band imaging						< 0.001
Yes	510	193	68	30	801	
No	489	383	239	181	1,292	
Retroflexion						< 0.001
No	747	362	213	125	1,447	
Rectum only	201	190	83	68	542	
Ascending colon (or with rectum)	51	24	11	18	104	
Withdrawal time (SD, min)	5.3 (1.1)	4.8 (1.6)	4.1 (0.7)	4.8(1.9)	4.9 (1.4)	< 0.001
Mean time since last colonoscopy (SD, day)	21.2(24.0)	19.1 (20.8)	13.8 (18.1)	15.2 (21.0)	18.9 (22.2)	< 0.001
No. of adenoma detected	2,197	1,298	718	419	4,632	
Adenoma site	1,750	1,033	552	330	3,665	0.047
Rectum	414	297	119	90	920	
Sigmoid colon	578	324	187	113	1,202	
Descending colon	172	104	61	26	363	
Splenic flexure colon	18	10	4	3	35	
Transverse colon	250	141	94	34	519	
Hepatic flexure colon	42	24	7	5	78	
Ascending colon	229	112	61	50	452	
Cecum	47	21	19	9	96	
Morphology						< 0.001
Slightly elevated	135	67	11	16	229	
Flat	66	46	3	7	122	
LST	77	46	21	15	159	
Sessile	582	349	122	58	1,111	
Subpedunculated	463	232	157	84	936	
Pedunculated	427	293	238	150	1,108	
Adenoma pathology						0.432
Tubular	1,454	835	440	268	2,997	
Villous	45	24	10	11	90	
Villotubular	234	161	96	47	538	
Serrated	17	13	6	4	40	
Adenoma IEN						0.022

Low grade	1,650	944	509	311	3,414	
High grade	100	89	43	19	251	
Adenoma risk						< 0.001
Low risk	1,133	734	340	211	2,418	
High risk	617	299	212	119	1,247	
Adenoma size (SD, mm)	8.8 (6.0)	8.8 (5.8)	8.9 (4.8)	8.7 (4.4)	8.8 (5.7)	0.957

Note: Hospital 1, Nanfang Hospital (affiliated with Southern Medical University); Hospital 2, Wuxi City People's Hospital (affiliated with Nanjing Medical University); Hospital 3, Mianyang Central Hospital in Mianyang city; Hospital 4, Longgang Central Hospital in Shenzhen city. LST, laterally spreading tumors; IEN, intraepithelial neoplasia.

Table 2. Association between individual characteristics and adenoma miss in univariate analysis.

Factors	Patients without missed adenoma (n=1,220)	Patients with missed adenoma (n=453)	Total (n=1,673)	*P* value[†]
Bowel preparation				0.001
Excellent	350	108	458	
Good	686	242	928	
Poor	184	103	287	
Hospital				0.754
1	586	205	791	
2	335	128	463	
3	178	73	251	
4	121	47	168	
Adenoma family history				0.014
Yes	958	329	1,280	
No	269	124	393	
Symptom				0.769
Symptom-free	273	102	375	
Abdominal pain	292	101	393	
Bloody stool	329	122	451	
Fecal property	239	100	339	
Weight loss	87	28	115	
Doctor experience (cases)				
> 2000	374	115	489	0.002
1000-2000	412	135	547	
500-1000	318	136	454	
< 5000	116	67	183	
Doctor specialty				0.808
Endoscopist	287	104	391	
Gastroenterologist	933	349	1,282	
Sex				0.779
Male	799	300	1,100	
Female	421	153	573	
Inpatients				0.642
Yes	729	265	994	
No	491	188	679	
Dye spraying and/or narrow band imaging				0.003
Yes	725	305	1,030	
No	495	148	643	
Sedative colonoscopy				0.746
Yes	917	337	1,254	
No	303	116	419	

Retroflexion				0.08
No	818	329	1,147	
Rectum only	335	106	441	
Ascending colon (or with rectum)	67	18	85	
Adenoma site				< 0.001
Rectum	321	49	370	
Sigmoid colon	363	167	530	
Descending colon	117	49	166	
Splenic flexure colon	11	12	23	
Transverse colon	172	66	238	
Hepatic flexure colon	33	25	58	
Ascending colon	149	60	209	
Cecum	54	25	79	
Morphology				< 0.001
Slightly elevated	122	145	267	
Flat	47	76	123	
LST	81	7	88	
Sessile	256	142	398	
Subpedunculated	294	66	360	
Pedunculated	420	17	437	
Adenoma pathology				< 0.001
Tubular	935	434	1,369	
Villous	61	1	62	
Villotubular	209	15	224	
Serrated	15	3	18	
Adenoma IEN				< 0.001
Low grade	1,093	446	1,539	
High grade	127	7	134	
Adenoma risk				<0.001
Low risk	723	428	1,151	
High risk	497	25	522	
Abdominal surgery history				0.977
Yes	1,137	422	1,559	
No	83	31	114	
Family history of colorectal cancer				0.296
Yes	1,153	422	1,575	
No	67	31	98	
Diverticulum history				0.887
Yes	1,145	426	1,571	
No	75	27	102	
Colonoscopy manipulation				0.140
Single manipulation	304	129	433	
Double manipulation	916	324	1,240	

Age, Years (SD)	54.7 (13.3)	59.7 (12.5)	< 0.001
Mean time since last colonoscopy (SD, day)	18.9 (22.0)	20.0 (23.4)	0.393
Withdrawal time (SD, min)	5.0 (1.3)	4.8 (1.4)	0.024
No. of adenoma with first detection	1.7 (0.9)	2.0 (1.3)	< 0.001
Adenoma size (SD, mm)	10.0 (6.3)	5.8 (3.1)	< 0.001

†, *P* value generated from the univariate analysis is indicated in parentheses.

Hospital 1, Nanfang Hospital (affiliated with Southern Medical University); Hospital 2, Wuxi City People's Hospital (affiliated with Nanjing Medical University); Hospital 3,Mianyang Central Hospital in Mianyang city; Hospital 4,Longgang Central Hospital in Shenzhen city. LST, laterally spreading tumors; and IEN, intraepithelial neoplasia.

Table 3. Multiple logistic regression analysis of independent influential factors associated with adenoma miss.

	B	S.E.	Wald χ^2	df	*P* value	OR (95% CI)
Doctor experiences			20.874	3	< 0.001	
> 2000 case						1
1000-2000 cases	-1.001	0.255	15.426	1	< 0.001	0.368 (0.223-0.606)
500-1000 cases	-0.673	0.249	7.297	1	0.007	0.510 (0.313-0.831)
< 500 cases	-0.297	0.248	1.433	1	0.231	0.734 (0.457-1.208)
Age	0.035	0.006	36.870	1	< 0.001	1.035 (1.024-1.047)
Bowel preparation			23.245	2	< 0.001	
Excellent						1
Adequate	-1.058	0.231	20.984	1	< 0.001	0.347 (0.221-0.546)
Poor	-0.871	0.202	18.527	1	< 0.001	0.419 (0.282-0.622)
Withdrawal time	-0.127	0.053	5.767	1	0.016	0.881 (0.794-0.977)
Adenoma site			59.288	7	< 0.001	
Rectum						1
Sigmoid colon	1.373	0.219	36.390	1	< 0.001	3.947 (2.571-6.060)
Descending colon	1.173	0.285	16.925	1	< 0.001	3.231 (1.848-5.649)
Splenic flexure colon	2.115	0.547	14.982	1	< 0.001	8.293 (2.841-24.204)
Transverse colon	1.140	0.253	20.272	1	< 0.001	3.127 (1.904-5.136)
Hepatic flexure colon	2.383	0.404	34.791	1	< 0.001	10.842 (4.911-23.937)
Ascending colon	1.296	0.271	22.842	1	< 0.001	3.645 (2.148-6.216)
Cecum	0.824	0.345	5.696	1	0.017	2.280 (1.159-4.486)
Adenoma morphology			124.527	5	< 0.001	
Slightly elevated						1
Flat	0.623	0.258	5.835	1	0.016	1.8643 (1.125-3.089)
LST	-0.820	0.586	1.958	1	0.162	0.440 (0.140-1.389)
Sessile	-0.778	0.192	16.445	1	< 0.001	0.459 (0.315-0.669)
Subpedunculated	-1.557	0.225	47.762	1	< 0.001	0.211 (0.136-0.328)
Pedunculated	-2.969	0.337	77.482	1	< 0.001	0.051 (0.027-0.099)
Adenoma size	-0.243	0.035	58.056	1	< 0.001	0.784 (0.732-0.839)

Dye spraying and /or narrow band imaging	-0.920	0.156	34.660	1	< 0.001	0.399 (0.293-0.541)
Retroflexion			7.357	2	0.025	
No						1
Rectum only	-0.326	0.167	3.829	1	0.050	0.722 (0.521-1.001)
Ascending colon (or with rectum)	-0.724	0.340	4.542	1	0.033	0.485 (0.249-0.943)
Constant	1.1212	0.563	3.969	1	0.046	3.067

B, partial coefficient; S.E., standard error; df, degree of freedom; OR, odds ratio; CI, confidence interval; LST, laterally spreading tumors

Table 4. The scoring system for predicting the quality of individual colonoscopy based on "per-adenoma" adenoma miss.

Factors	B	Score
Dye spraying and/or narrow band imaging		
No		0.00
Yes	0.189	1.00
Retroflexion		
No		0.00
Rectum only	0.163	1.00
Ascending colon (or with rectum)	0.159	1.00
Withdrawal time (minutes)		
< 4		0.00
≥ 4 and < 6	0.152	1.00
≥ 6	0.326	2.00
Bowel preparation		
Poor		0.00
Good	0.430	3.00
Doctor experience (cases)		
≤ 1000		0.00
> 1000	0.357	2.00

B, partial coefficient.

Table 5. Validation of the scoring system for predicting the likelihood of "per-adenoma" adenoma miss.

Score	No. of patients	No. of adenomas with first detection	No. of adenomas with second detection	AMR (%)	Score grade
Validation in the establishment database of adenoma miss (n=1,673)					
0	30	64	95	33	1
1	37	45	82	45	1
2	71	90	129	30	1
3	138	274	363	25	2
4	259	383	527	27	2
5	270	480	622	23	2
6	338	506	638	21	2
7	291	568	670	15	3
8	197	444	500	11	3
9	42	101	108	6	3
Total	1,673	2,955	3,734		
Validation in the validation database of adenoma miss (n=420)					
0	3	5	7	29	1
1	14	17	31	45	1
2	16	22	34	35	1
3	33	41	67	39	2
4	61	78	104	25	2
5	68	120	165	27	2
6	80	126	163	23	2
7	82	155	170	9	3
8	54	122	131	7	3
9	9	24	26	8	3
Total	420	710	898		

AMR, adenoma miss rate

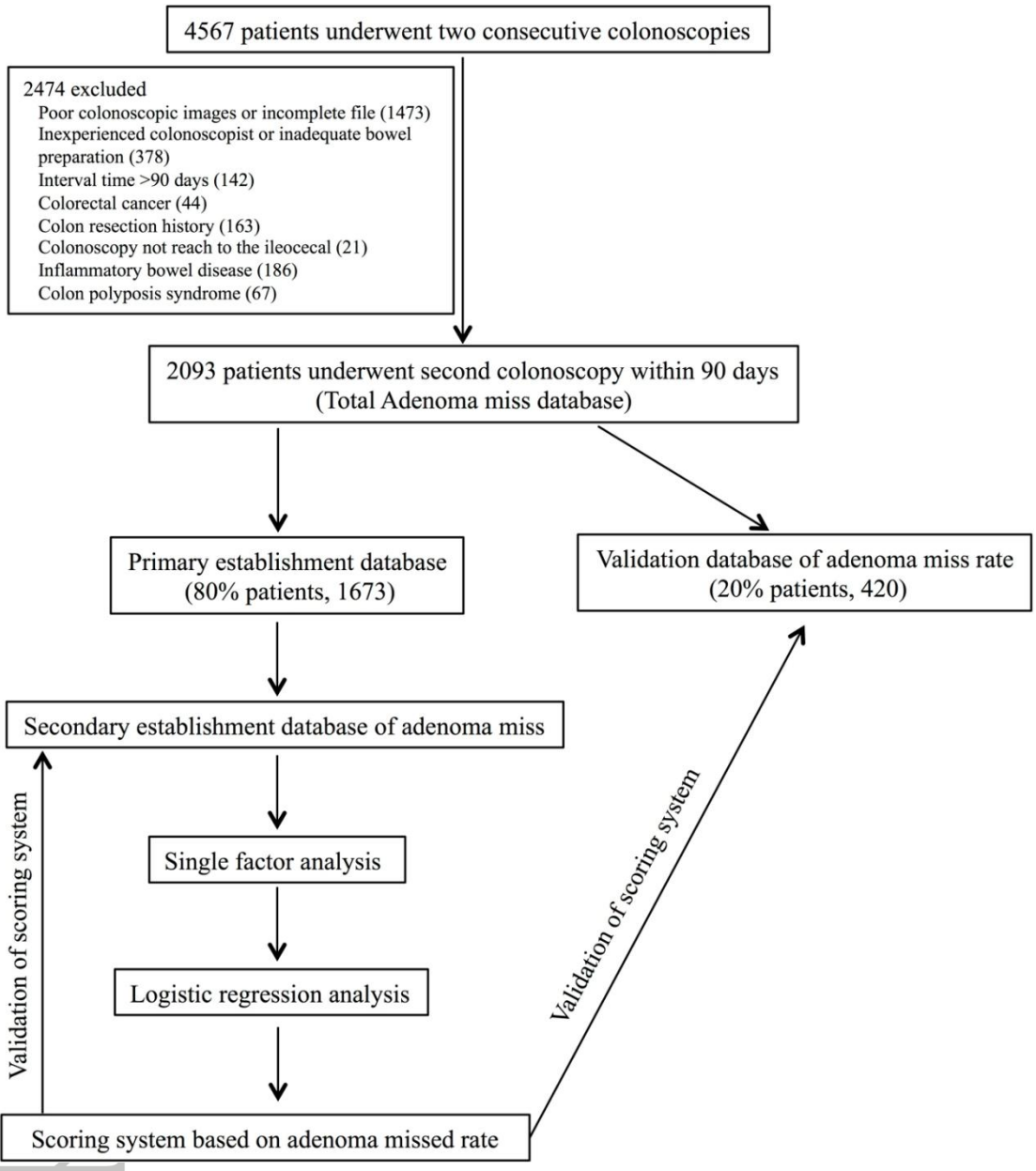

Figure 1. Flowchart for the study design.