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Determinants of Bowel Preparation Quality and Its Association With Adenoma Detection

A Prospective Colonoscopy Study

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Abstract: The predictors of poor bowel preparation in colorectal cancer screening participants have not been adequately studied, and the association between the quality of bowel preparation and adenoma detection has not been firmly established. This study examined the determinants of poor bowel preparation, and evaluated its relationship with adenoma detection.

We included subjects aged between 50 and 70 years who received colonoscopy between 2008 and 2014 in a colorectal cancer screening program in Hong Kong. The quality of the bowel preparation was assessed by colonoscopists, and the factors associated with poor bowel cleansing were evaluated by a binary logistic regression analysis. A multivariate regression model was constructed to evaluate if poor bowel preparation was associated with detection of colorectal neoplasia.

From 5470 screening participants (average age 57.7 years, SD 4.9), 1891 (34.6%) had poor or fair bowel preparation. The average cecal intubation time was 7.0 minutes (SD 5.4; range 1.22–36.9 minutes) and the average colonoscopy withdrawal time was 10.8 minutes (SD 6.9; range 6.0–107.0 minutes). Among all, 26.5% had colorectal neoplasia and 5.5% had advanced neoplasia. Older age (≥60 years; adjusted odds ratio [AOR] = 1.19–1.38, $P = 0.02$–0.04), male sex (AOR = 1.38, 95% confidence interval [CI] 1.19–1.60, $P < 0.001$), and current smoking (AOR = 1.41, 95% CI 1.14–1.75, $P = 0.002$) were significantly associated with poor/fair bowel preparation. Poorer cleansing resulted in significantly lower detection rate of neoplasia (AOR = 0.35–0.62) and advanced neoplasia (AOR = 0.36–0.50) irrespective of polyp size.

Steps to improve proper procedures of bowel preparation are warranted, especially among subjects at risk of poor bowel preparation. Strategies should be implemented to improve bowel cleansing, which is now demonstrated as a definite quality indicator.

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Abbreviations: ADR = adenoma detection rate, AGA = American Gastroenterological Association, AOR = adjusted odds ratio, APCS = Asia Pacific Colorectal Screening, ASGE = American Society of Gastrointestinal Endoscopy, BMI = body mass index, CRC = colorectal cancer, PEG = polyethylene glycol.

INTRODUCTION

Colorectal cancer (CRC) is one of the most common malignancies worldwide.[1] Many Asia Pacific countries including Korea, Japan, China, and Singapore are increasingly affected, with incidence figures comparable to that of the Western countries.[2] CRC screening tests are effective to reduce mortality by up to 33% and 56% using fecal occult blood tests and colonoscopy, respectively.[3,4] Colonoscopy is now more commonly used as a primary or follow-up screening test.[5,6] The American guidelines[7] and the updated Asia Pacific consensus statements[8] recommended colonoscopy as the preferred choice in individuals with increased risk—mainly because of its ability to detect and remove adenomatous polyps at an earlier, more treatable stage.[9,10]

According to the European guidelines for quality assurance in CRC screening and diagnosis,[11] the quality of bowel preparation is one of the auditable outcomes for every colonoscopic procedure. The ideal preparation method should reliably cleanse the colon of all fecal materials with little effect on the macroscopic appearance of the colonic mucosa to maximize the detection of adenomatous lesions.[12] Studies conducted in Western countries showed that poor bowel preparation was a major impediment to the effectiveness of colonoscopy; prolonged cecal intubation time and withdrawal time; and reduced detection of both small and large polyps.[13,14] Poor preparation quality may also increase the risk for procedure rescheduling and induce high costs.[15] According to these studies, identifying those at higher risk for poor bowel preparation is crucial to improve screening practices. Nevertheless, there is a recent study by Jover et al[16] which showed that the quality of bowel preparation did not influence the adenoma detection rate (ADR), and that withdrawal time in normal colonoscopies was the only modifiable factor related to ADR.

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We aimed to evaluate the factors independently associated with the quality of bowel preparation in a large CRC screening population. Because existing studies on the association between bowel preparation quality and ADR were almost exclusively conducted in Western countries and the conclusions are mixed,[13–16] we also tested this association based on the same Chinese screening cohort.

METHODS

Study Setting

The study setting has been previously described.[17–25] A screening center was established in Hong Kong in 2008, and invited all Hong Kong residents for CRC screening via media announcements. Eligible participants included residents aged 50 to 70 years who were asymptomatic of CRC. The screening center provides community education and free-of-charge CRC screening, and is accessible for all Hong Kong residents. We included all eligible participants who registered and selected for the screening service via telephone, fax, e-mail, or walk-in from 2008 to 2014. The study was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong (protocol CRE-2008.404). All participants provided informed consent for the study.

Study Participants

Subjects who were eligible included those who (1) were aged 50 to 70 years; (2) had no existing or previous symptoms suggestive of CRC, including hematochezia, tarry stool, anorexia or change in bowel habit in the past 4 weeks, or weight loss of >5 kg in the past 6 months; and (3) had not received any CRC screening tests in the past 5 years. Exclusion criteria included personal history of CRC, colonic adenoma, or inflammatory bowel disease. Subjects with medical disorders that were contraindications for colonoscopy (eg, cardiopulmonary insufficiency and the use of double antiplatelet therapies) were also excluded.

Study Logistics

All participants were invited to complete a self-administered survey, including details on their sociodemographic information, past medical history, and use of chronic medications. The body weight and height was measured with the participant wearing light clothing without wearing shoes, using a wall-mounted stadiometer and regularly calibrated weight scales. Subsequently, all participants attended an educational seminar, which consisted of a standard video and a health talk delivered by trained educators. The video included updates on the biological nature, risk factors, and clinical presentations of CRC, as well as the benefits of regular CRC screening. This study included all participants who received colonoscopy in the period 2008 to 2014.

Colonoscopy

Before the scheduled colonoscopy appointment, all study participants were explained about the details of colonoscopy procedures. The standard bowel cleansing regime polyethylene glycol (PEG; Klean-Prep^{R}, Helsinn Birex Pharmaceuticals Ltd, Ireland) was offered to each participant before they left the center, together with a reminder sheet on its proper use. Split dosing was recommended to the subjects, and the importance of low residue diet before colonoscopy was emphasized. Colonoscopy was performed by 3 experienced colonoscopists (3 specialists with >10 years of comparable practice experience) in 2 endoscopy centers affiliated with a major hospital. All subjects received intravenous midazolam (Groupe Panpharma, France) and meperidine (Martindale Pharmaceuticals, United Kingdom) with the doses titrated according to the subjects' level of discomfort. Air insufflation was applied, and all endoscopists aimed for cecal intubation and a withdrawal time of ≥6 minutes, which is in accordance with the current quality indicators for colonoscopy.[26] Cecal intubation is defined as passage of the colonoscope tip to a point proximal to the ileocecal valve so that the entire cecal caput, including the medial wall of the cecum between the appendiceal orifice and ileocecal valve, is visible.[26] Withdrawal time refers to the time between the moment where the cecum is reached and the moment where the scope is withdrawn.[26] As deemed appropriate by the endoscopists, lesions were removed and biopsied. The biopsied specimens were sent to a certified, accredited laboratory for gross and microscopic examination. During the procedure, the endoscopists rated the quality of bowel preparation using internationally recognized standards, and the terms included "excellent," "good," "fair," and "poor."[26] These terms were interpreted as the retained intraluminal contents that often can be removed by suctioning instead of the quality of inspection allowable after full removal of the suctionable material.[26] All colonoscopists standardized their rating of bowel preparation before all the procedures by using the guideline from the American Society of Gastrointestinal Endoscopy (ASGE)/American Gastroenterological Association (AGA) Taskforce on Quality in Endoscopy.[26] "Excellent" is typically defined as "no or minimal solid stool and only small amounts of clear fluid requiring suctioning." "Good" is "typically no or minimal solid stool with large amounts of clear fluid requiring suctioning," "Fair" refers to "collections of semisolid debris that are cleared with difficulty." "Poor" refers to "solid or semisolid debris that cannot be effectively cleared."[26] These descriptions were put up in the endoscopy room for colonoscopists' reference when they rated the quality of bowel preparation. Each colonoscopist who removed the biopsied specimens was blinded to the research question of the present study, as well as the rating of bowel preparation. The cecal intubation time and colonoscopy withdrawal time were measured by a stopwatch operated by an independent staff.

Outcome Variables and Covariates

For the primary objective, the outcome was the bowel preparation quality and the covariates included age, sex, educational level, marital status, occupation, monthly household income, self-perceived health status, self-perceived risk for CRC, family history of CRC, smoking habits, alcohol drinking, and perceived necessity of CRC screening for people aged ≥50 years. For the secondary objective, the outcome is ADR, which has been proposed as a quality benchmark and a reportable quality measure.[26] It is defined as the proportion of screening colonoscopies performed by a physician that detect at least one histologically confirmed colorectal adenoma or cancer.[27] We included colorectal neoplasia and advanced neoplasia in separate analyses. Advanced neoplasia is defined as CRC, any colorectal adenoma or sessile serrated polyp which has a size of ≥10 mm in diameter, high grade dysplasia, villous or tubulovillous histologic characteristics, or any combination thereof. The covariate for ADR included the Asia Pacific Colorectal Screening (APCS) score,[28] body mass index (BMI), alcohol drinking, self-reported hypertension, and diabetes, as well as the

bowel preparation quality, cecal intubation time, and colonoscopy withdrawal time. The APCS scoring system is a validated instrument which risk stratifies symptomatic subjects based on age, sex, smoking history, and family history of CRC. Subjects were divided into average risk (scored 0–1), moderate risk (scored 2–3), and high risk (scored 4–7).[28]

Statistical Analyses

The sociodemographic details of the study participants were descriptively presented. A binary logistic regression analysis was performed with poor/fair bowel preparation as the outcome variable (vs good/excellent preparation), and all the covariates were entered into the regression model. To address the secondary objective, 2 separate binary logistic regression models were constructed with detection of adenoma and advanced neoplasia as the outcome variable, respectively. The variable tested for association was the quality of bowel preparation. Previous studies found that longer withdrawal time was associated with higher ADR,[29–31] and procedures in poorly prepared patients were longer.[14,15] Colonoscopy withdrawal time was therefore not included as a covariate in the regression analyses as it could be affected by the detection of adenoma and the quality of bowel preparation. Owing to the different experiences of colonoscopists and the interphysician effect on the ADR, we also incorporated individual endoscopist as a covariate in sensitivity analysis. All P values <0.05 in the multivariate regression analysis were regarded as statistically significant.

RESULTS

Participant Characteristics

A total of 5470 eligible participants were included (Table 1). There were only 8 colonoscopies which were incomplete or abandoned because of poor bowel preparation, which were excluded from the regression analyses. Their average age was 57.7 years (SD 4.9), and 47.0% were male subjects. Their average BMI was 23.5 kg/m^2 (SD 3.2), and 14.2% had family history of CRC in a first-degree relative. The proportion of current smokers and current drinkers was 7.7% and 9.6%, respectively. The most common comorbidities included hypertension (22.9%), diabetes (7.5%), and gastroesophageal reflux disease (5.1%). Among them, 4.7% used Non-steroidal anti-inflammatory drugs (NSAIDs) and 2.5% used aspirin. Majority was classified as having moderate risk (79.2%) and 20.8% was classified as high risk. The proportion of participants having poor, fair, good, and excellent bowel preparation was 5.8%, 28.8%, 52.5%, and 12.9%, respectively. The average cecal intubation time was 7.0 minutes (SD 5.4; range 1.22–36.9 minutes), and the average colonoscopy withdrawal time was 10.8 minutes (SD 6.9; range 6.0–107.0 minutes). Among all, 26.5% had colorectal neoplasia and 5.5% had advanced neoplasia. The distribution of these lesions was shown in Table 1. Among those with colorectal neoplasia, the proportion having diameters of <5 and 5 to 9 mm was 60.2% and 39.8%, respectively, whereas for those with advanced neoplasia, the proportion having diameters of <5, 5 to 9, and ≥10 mm was 3.3%, 17.0%, and 79.7%, respectively.

TABLE 1. Characteristics of the Study Participants (N = 5470)

Age, y, mean (SD)	57.71 (4.88)
Age, n (%)	
≤54	1683 (30.8)
55–59	1902 (34.8)
60–64	1312 (24.0)
65–70	573 (10.5)
Male sex, n (%)	2571 (47.0)
BMI, kg/m^2, mean (SD)	23.54 (3.16)
Family history present for a first-degree relative, n (%)	775 (14.2)
Ever smoking, n (%)	423 (7.7)
Alcohol consumption, n (%)	527 (9.6)
Diabetes mellitus, n (%)	408 (7.5)
Hypertension, n (%)	1255 (22.9)
IHD/heart disease, n (%)	93 (1.7)
COPD, n (%)	38 (0.7)
Stroke, n (%)	32 (0.6)
Cirrhosis, n (%)	7 (0.1)
GERD, n (%)	280 (5.1)
Use of nonsteroidal anti-inflammatory drugs, n (%)	256 (4.7)
Use of aspirin, n (%)	135 (2.5)
APCS scores, n (%)	
Average risk	0 (0)
Moderate risk	4331 (79.2)
High risk	1139 (20.8)
Bowel preparation, n (%)	
Poor	315 (5.8)
Fair	1576 (28.8)
Good	2872 (52.5)
Excellent	707 (12.9)
Cecal intubation time (min; mean/SD)	7.00 ± 5.35
Colonoscopy withdrawal time (min; mean/SD)	10.79 ± 6.88
Colorectal neoplasia, n (%)	1448 (26.5)
Proximal	579 (40.0)
Distal	638 (44.1)
Proximal and distal	231 (16.0)
Colorectal advanced neoplasia or CRC*, n (%)	301 (5.5)
Proximal	115 (38.2)
Distal	171 (56.8)
Proximal and distal	15 (5.0)
Size of colorectal neoplasia detected (diameter), n (%)	1448 (26.5)
<5 mm	871 (60.2)
5–9 mm	577 (39.8)
Size of colorectal advanced neoplasia detected (diameter), n (%)#	301 (5.5)
<5 mm	10 (3.3)
5–9 mm	51 (17.0)
≥10 mm	239 (79.7)

APCS = Asia Pacific Colorectal Screening, BMI = body mass index, COPD = chronic obstructive pulmonary disease, GERD = gastroesophageal reflux disease, IHD = ischemic heart disease.

* ''Distal'' is defined as the location distal to the splenic flexure, including the descending colon, the rectosigmoid, and the rectum.

1 missing data.

Factors Associated With Poor or Fair Bowel Preparation

From binary logistic regression analysis with poor or fair bowel preparation as an outcome, it was found that subjects aged ≥60 years (adjusted odds ratio [AOR] for 60–64 years = 1.19, 95% confidence interval [CI] 1.01–1.41, $P = 0.04$; AOR for 65–70 years = 1.38, 95% CI 1.19–1.60, $P = 0.02$); male subjects (AOR = 1.38, 95% CI 1.19–1.60, $P < 0.001$); and current smokers (AOR = 1.41, 95% CI 1.14–1.75, $P = 0.002$) were significantly more likely to present with poor or fair bowel preparation (Table 2).

TABLE 2. Factors Associated With Poor/Fair Bowel Preparation (N = 5470)

	n	%	Adjusted Odds Ratio (95% CI)	*P*
Age, y				
≤54	541	32.1	1.0 (referent)	
55–59	639	33.6	1.061 (0.919–1.225)	0.42
60–64	483	36.8	1.193 (1.010–1.409)	0.04
65–70	228	39.8	1.376 (1.187–1.595)	0.02
Sex				
Male	997	38.8	1.376 (1.187–1.595)	<0.001
Female	894	30.8	1.0 (referent)	
Educational level				
Primary or below	476	35.2	1.0 (referent)	
Secondary	1087	34.3	0.907 (0.787–1.044)	0.17
Tertiary or above	328	34.7	0.846 (0.694–1.032)	0.10
Marital status				
Married	1616	34.5	1.0 (referent)	
Single/divorced/ widowed/others	275	35.2	1.166 (0.984–1.381)	0.08
Occupational status				
Full time	735	34.8	1.0 (referent)	
Part time or retired	680	37.3	1.059 (0.910–1.232)	0.46
Housewife and others	476	31.0	1.013 (0.849–1.209)	0.89
Monthly household income ($US)				
<1285$	522	34.8	1.0 (referent)	
1285$–2571$	542	34.7	1.041 (0.889–1.218)	0.62
2571$–3856$	289	34.2	1.018 (0.843–1.230)	0.85
3856$–5141$	127	31.8	0.914 (0.715–1.173)	0.48
>5142$	134	36.9	1.155 (0.885–1.508)	0.29
Refused to answer	277	34.8	1.092 (0.905–1.318)	0.36
Self perceived overall health status				
Very good or good	703	36.0	1.0 (referent)	
Fair	1083	33.6	0.923 (0.816–1.044)	0.20
Poor or very poor	95	36.1	1.000 (0.760–1.317)	0.99
Self-perceived risk of CRC				
At risk	1377	35.4	1.104 (0.969–1.257)	0.14
Not at risk	514	32.6	1.0 (referent)	
Family history of CRC				
Absent	1375	34.5	1.0 (referent)	
First-degree relatives	275	35.5	1.026 (0.870–1.210)	0.76
Second-degree relatives	241	33.8	0.991 (0.836–1.176)	0.92
Nonsmokers/ex-smokers	1698	33.6	1.0 (referent)	
Smokers	193	45.6	1.409 (1.136–1.747)	0.002
Nondrinkers/ex-drinkers	1694	34.3	1.0 (referent)	
Alcohol drinkers	197	37.4	0.919 (0.754–1.120)	0.40
Patient perception of the necessity of CRC screening for people aged ≥50 y				
Not very necessary or unnecessary	49	33.8	1.0 (referent)	
Not sure	219	33.2	0.981 (0.667–1.443)	0.92
Very or quite necessary	1623	34.8	1.054 (0.740–1.501)	0.77

$US = US dollars, CI = confidence interval, CRC = colorectal cancer, p = p-value, y = years.

The Association Between Bowel Preparation Quality and Detection of Lesions

Poorer bowel preparation quality was associated with longer cecal intubation time and longer colonoscopy withdrawal time (both $P < 0.001$; Table 3). The detection of colorectal neoplasia and advanced neoplasia was used as the outcome measure controlling for the recognized risk factors of CRC (Table 4). Compared with subjects with excellent bowel preparation, those with good (AOR = 0.354, 95% CI 0.270–0.464, $P < 0.001$) and fair or poor (AOR = 0.406, 95% CI 0.303–0.545, $P < 0.001$) bowel cleansing were significantly less likely to have colorectal neoplasia detected. The same applied to colorectal advanced neoplasia and neoplastic lesions sized ≥5 mm in diameter (Table 5).

Sensitivity Analysis

Each study participant was assigned to the principal endoscopist responsible for the colonoscopy procedure. When

TABLE 3. The Cecal Intubation Time and Colonoscopy Withdrawal Time According to the Quality of Bowel Preparation

Bowel Preparation Quality	Cecal Intubation Time, min (mean/SD)	*P*	Colonoscopy Withdrawal Time, min (mean/SD)	*P*
Excellent	5.67 (4.91)	<0.001	9.87 (5.74)	<0.001
Good	6.93 (5.03)		10.58 (6.71)	
Fair	7.63 (6.02)		11.49 (7.58)	
Poor	7.43 (5.04)		11.25 (6.79)	

**P* values compared the cecal intubation time and colonoscopy withdrawal time among subjects with different bowel preparation quality. The range of cecal intubation time and colonoscopy withdrawal time was 1.2 to 36.9 minutes and 6 to 107 minutes, respectively.

the endoscopist was used as a covariate in all the regression models performed above (ie, with bowel preparation and detection of neoplastic lesions as outcomes), all the associated factors remained unchanged. There were no difference in adenoma detection, cecal intubation time, and colonoscopy withdrawal time among the endoscopists. There exists no multicollinearity of the regression analyses, implying robustness of the modeling techniques.

DISCUSSION

It was found that the level of poor or fair bowel preparation was 34.6%. Older age, male sex, and smoking were associated with poorer bowel cleansing, which was associated with lower ADR for any neoplasia or neoplasia ≥5 mm. Poor preparation may obscure the colonoscopy field, thus rendering identification of colonic lesions more difficult.

This is thus far the first large-scale study in the Asia Pacific region which addressed the association between bowel preparation and ADR among asymptomatic screening CRC participants. The study design is prospective; endoscopists were blinded to our research questions; and the data recording is complete. However, some limitations should be addressed. First, the screening participants were self-referred, and it is possible that they were more health conscious than the general population. It is nevertheless impractical to recruit screening subjects by a population-based, random sampling strategy because the anticipated refusal rate would be high. Second, this study allows inferences with respect to associations but not causality because of its observational nature. The present findings should be cautiously interpreted as we reported that the quality of bowel preparation was associated with, but not directly influencing adenoma detection. In addition, we have only tested PEG as the bowel preparation of interest. Other formularies such as oral sodium phosphate, sodium picosulfate, magnesium citrate, and MiraLAX/Gatorade have been reported in the literature as having different efficacy, patient tolerability, and adverse effects.[32–35] Nonetheless, PEG is one of the most commonly used bowel preparation regimen, and has been recognized as a fast, effective, and well-tolerated method for bowel cleansing.[36] In addition, it should be noted that the perception of preparation quality is inevitably subjective.

TABLE 4. Factors Associated With Detection of Colorectal Neoplasia and Advanced Neoplasia of Any Size

	Any Colorectal Neoplasia				Any Colorectal Advanced Neoplasia			
	n	%	AOR (95% CI)	*P*	n	%	AOR (95% CI)	*P*
APCS (score)								
0–3	1086	25.1	1.0 (referent)		207	4.8	1.0 (referent)	
4–7	362	31.8	1.253 (1.077–1.458)	0.003	94	8.3	1.361 (1.027–1.805)	0.03
Alcohol drinking (nondrinker)	1281	25.9	1.0 (referent)		256	5.2	1.0 (referent)	
Ex-drinker/current drinker	167	31.7	1.146 (0.933–1.409)	0.20	45	8.5	1.395 (0.975–1.996)	0.07
Body mass index, kg/m^{2*}								
<23	598	24.3	1.0 (referent)		100	4.1	1.0 (referent)	
≥23 (overweight or obesity)	827	28.1	1.109 (0.974–1.262)	0.12	196	6.7	1.335 (1.021–1.745)	0.04
Diabetes mellitus	1303	25.7	1.0 (referent)		270	5.3	1.0 (referent)	
Yes	145	35.5	1.360 (1.078–1.716)	0.009	31	7.6	0.876 (0.565–1.359)	0.554
Hypertension	1087	25.8	1.0 (referent)		199	4.7	1.0 (referent)	
Yes	361	28.8	0.984 (0.843–1.148)	0.84	102	8.1	1.534 (1.159–2.030)	0.003
Bowel preparation								
Excellent	195	27.6	1.0 (referent)		24	3.4	1.0 (referent)	
Good	743	25.9	0.354 (0.270–0.464)	<0.001	156	5.4	0.388 (0.220–0.685)	0.001
Fair or poor	510	27.0	0.406 (0.303–0.545)	<0.001	121	6.4	0.504 (0.274–0.929)	0.03

AOR = adjusted odds ratio, APCS = Asia Pacific Colorectal Screening. The cutoff of 23 kg/m^2 was used to define overweight/obesity (recommended for Asians).

TABLE 5. Factors Associated With Detection of Colorectal Neoplasia and Advanced Neoplasia ≥5 mm

	Colorectal Neoplasia ≥5 mm				Colorectal Advanced Neoplasia ≥ 5mm			
	n	%	AOR (95% CI)	*P*	n	%	AOR (95% CI)	*P*
APCS (score)								
0–3	410	9.5	1.0 (referent)		198	4.6	1.0 (referent)	
4–7	167	14.7	1.448 (1.183–1.773)	<0.001	92	8.1	1.396 (1.050–1.858)	0.02
Alcohol drinking (nondrinker)	500	10.1	1.0 (referent)		246	5.0	1.0 (referent)	
Ex-drinker/current drinker	77	14.6	1.297 (0.989–1.700)	0.06	44	8.3	1.423 (0.991–2.043)	0.06
Body mass index, kg/m^{2*}								
<23	247	10.0	1.0 (referent)		98	4.0	1.0 (referent)	
≥23 (overweight or obesity)	324	11.0	0.954 (0.794–1.147)	0.62	187	6.3	1.279 (0.975–1.678)	0.08
Diabetes mellitus	510	10.1	1.0 (referent)		260	5.1	1.0 (referent)	
Yes	67	16.4	1.434 (1.063–1.934)	0.02	30	7.4	0.869 (0.557–1.354)	0.53
Hypertension	417	9.9	1.0 (referent)		189	4.5	1.0 (referent)	
Yes	160	12.7	1.152 (0.932–1.423)	0.19	101	8.0	1.633 (1.231–2.166)	0.001
Bowel preparation								
Excellent	80	11.3	1.0 (referent)		24	3.4	1.0 (referent)	
Good	269	9.4	0.428 (0.295–0.621)	<0.001	148	5.2	0.363 (0.205–0.643)	0.001
Fair or poor	228	12.1	0.619 (0.420–0.911)	0.02	118	6.2	0.497 (0.269–0.918)	0.03

AOR = adjusted odds ratio, APCS = Asia Pacific Colorectal Screening.
* The cutoff of 23 kg/m^2 was used to define overweight/obesity (recommended for Asians).

Although the terms in rating the quality of bowel preparation have been regarded as reasonable guides to the appropriate use of bowel descriptors by the ASGE and AGA,[26] there might still be interobserver bias influencing its reliability. In addition, the colonoscopy withdrawal time and cecal intubation time were measured including the time of lesion removal, and the lesion removal time per se was not specifically measured. Lastly, the present study has not arranged follow-up procedures to ascertain the actual incidence rates of colorectal neoplasia among patients in different bowel preparation groups. These follow-up procedures could be considered in future studies.

There are few studies which addressed the determinants of colon-cleansing quality in the Western countries. In a multicenter European trial, Froehlich et al[14] found that subjects aged >65 years and those who had poorer health status were associated with lower quality of preparation. Ness et al[37] recruited patients attending for colonoscopy at a University hospital in Indianapolis, and found that the determinants of inadequate preparation for colonoscopic procedures included male sex, a later colonoscopy starting time, failure to follow preparation instructions, inpatient status, procedural indications for constipation, use of tricyclic antidepressants, and a history of cirrhosis, stroke, or dementia. However, the majority of subjects in both studies were mostly symptomatic, and the number of asymptomatic subjects who attended for screening was modest. The reasons why older patients, male subjects, and smokers were more likely to present with poorer preparation remained speculative. These individuals might have poorer tolerability to the regimen, or failed to follow the preparation schedule completely due to the relatively lower health consciousness—notably among males and smokers.

Some previous studies evaluated the association between bowel preparation quality and ADR, or the efficiency of colonoscopy with mixed results.[13–16] The range of inadequate or poor bowel preparation ranged from 12.5% to 25.8%. One prospective, multicenter study identified that poorer cleansing quality resulted in lower detection of polyps of any size, and also polyps >10 mm in size.[14] Another retrospective database analysis showed that adequate preparation led to identification of ''nonsignificant'' lesions (≤9 mm), but not ''significant'', mass lesions (>9 mm).[13] Yet another multicenter, prospective observational study found that bowel cleansing was not associated with higher ADR.[16] Findings from these studies are inconclusive with respect to the impact of bowel cleansing on ADR. Hence, given the large sample size of the present study, our findings supported the hypothesis that poor bowel preparation was associated with lower detection rates of colonic lesions among asymptomatic screening participants.

As one of the implications from this study, subjects at higher risk for inadequate cleansing should have more intensive preparation protocols. They are also individuals where steps to improve patient understanding of and compliance with bowel preparation are warranted. ADR has been inversely associated with the risks of interval CRC, advanced-stage interval cancer, and fatal interval cancer.[27,38] Previous evidence on the significance of bowel preparation was not strong, and these findings are compatible with bowel preparation being a quality indicator for colonoscopy. The low ADR among those with poor bowel cleansing found in this study alerts the need for emphasizing strategies to improve it in continuous quality improvement programs. Future studies should evaluate the reasons underlying poor bowel preparation, and devise targeted interventions to enhance the cleansing procedure.

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