Constipation, Diabetes, and Split-Dose Regimen Are Associated With Suboptimal Bowel Preparation in Young Patients

Lexin Liu

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Jingbin Wang (✉ gzzydxszyypwbk@163.com)

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Yingzhe Lai

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Li Liu

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Guoxin Huang

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Pengli Ma

Shenzhen Hospital of Guangzhou University of Chinese Medicine

Research Article

Keywords: bowel preparation, colonoscopy, mannitol, polyethylene glycol electrolyte solution

Posted Date: August 20th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-797075/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

An increase in the incidence of colorectal cancer in young patients has been observed. However, there is little research investigating the factors associated with suboptimal bowel preparation focusing on young patients compared to patients > 50 years.

Aims

We aimed to evaluate the factors associated with a suboptimal bowel preparation in young patients (age ≤ 50 years) using the Boston Bowel Preparation Scale (BBPS).

Methods

This retrospective study analyzed 1,980 patients who underwent complete colonoscopy from June 2017 to September 2020. Data regarding demographic and clinical characteristics and bowel preparation adequacy were collected. Furthermore, factors associated with suboptimal bowel preparation were analyzed.

Results

Among our participants, 17.8% demonstrated suboptimal bowel preparation. After adjusting for several factors, multivariate analysis showed that diabetes (OR:0.28; 95% CI, 0.14–0.56, $P = .000$), constipation (OR:0.20; 95% CI, 0.13–0.29, $P = .000$), and split-dose bowel preparation (OR:1.69; 95% CI, 1.28–2.23, $P = .000$) were independent predictors of suboptimal bowel preparation. Additionally, constipation was significantly associated with poor bowel preparation in all colonic segments; on the other hand, diabetes and split-dose bowel preparation were significant on right side of the colon.

Conclusions

Constipation, diabetes and split-dose bowel preparation were significantly associated with suboptimal bowel preparation in young patients.

Introduction

According to global cancer statistics, colorectal cancer (CRC) is the third most common type and second leading cause of cancer-related deaths worldwide. [1] In China, CRC ranks third in terms of incidence regardless of sex. [2] However, a recent epidemiologic study showed that over the past few decades the

increased number of colonoscopy screenings has led to an increase in the incidence of CRC in younger patients (< 50 years old) compared to a slight decline in older patients. [3] Currently, colonoscopy is the standard approach to evaluate patients' colon status since it can directly visualize mucosal abnormalities, perform mucosal biopsies, and remove precancerous adenomas, [4] which reduces the progression of CRC. Furthermore, the success of colonoscopy depends on the quality of bowel preparation. A relationship has been found between suboptimal bowel preparation with increased procedure time and decreased detection rate of adenoma and other high-risk lesions. [5] Regarding bowel preparation, multiple studies have found factors associated with suboptimal bowel preparation including male sex, increased age, tricyclic antidepressant use, obesity, socioeconomic status, and patient comprehension of bowel preparation agent instructions. [6–9]

The implementation of cancer prevention policy and increased awareness of the importance of early detection have led to the increased popularity of spontaneous cancer screening in urban areas among younger individuals. [10, 11] However, no study has investigated the risk factors associated with suboptimal bowel preparation in the young patients. Therefore, we aimed to investigate the risk factors for a suboptimal bowel preparation in young patients (age $\leq$ 50 years) in a large-scale retrospective cohort.

Methods

2.1 Subjects

This retrospective study included young patients who underwent colonoscopy and completed a questionnaire at the Shenzhen Hospital of Guangzhou University of Chinese Medicine between June 2017 and September 2020. The following characteristics excluded patients from participation: >50 years-old; history of CRC, inflammatory bowel disease, and cecal intubation failure; and incomplete questionnaire. Among 6,436 patients, 1,980 were included in the final analysis. The flow of patient selection is detailed in Fig. 1.

2.2 Data collection

A predetermined questionnaire was used by a research assistant to collect the data of patients scheduled for colonoscopy regarding age, sex, hospital status, constipation, bowel preparation agents, family history of gastrointestinal tumors, prior experience of colonoscopy, medical conditions (including diabetes and hypertension), use of mosapride, and method of bowel preparation (split-dose or same-day). Additionally, polyp detection rate was recorded by the colonoscopy specialist. This study was approved by the Ethics Committee of Shenzhen Hospital of Guangzhou University of Chinese Medicine (approval number: 616) and performed in accordance with the ethical guidelines established following the 2013 Declaration of Helsinki. The need for informed consent was waived due to the retrospective nature of the study.

2.3 Bowel preparation

Upon setting the appointment, a nurse instructed all patients regarding the manner of preparation and consumption of bowel preparation agents with dietary restrictions. All patients were instructed to avoid food rich in fiber such as vegetables, fruits, and seaweeds for three consecutive days and to maintain a liquid diet the day before colonoscopy. Patients were randomly allocated to two groups according to manner of receiving bowel preparation agents as either full single or two split doses. In this study, the bowel preparation agents used included polyethylene glycol (PEG)-electrolyte solution and mannitol.

For the same-day cohort, the patients were prepared with glycol (PEG)-electrolyte solution (WanHe Pharmaceutical Co., Shenzhen, China) dissolved in 3 L of water; additionally, 6 hours before the examination, patients were administered 3L of PEG solution (three bags of PEG) at a rate of 250 ml every 15 minutes. Additionally, patients received mannitol (No.4 Pharmaceutical Co., Shijiazhuang, China) in a dose of 250 ml of 20% mannitol 6 hours before colonoscopy; they were then instructed to drink 1000 ml of water within an hour, this was followed by repeated ingestions of 250 ml of mannitol and 1 L of water.

For the split-dose bowel preparation, patients were instructed to begin ingesting one third of the bowel preparation (1L of PEG solution (one bag of PEG) or 250 ml of mannitol with 1 L of water) at 22:00 and repeated ingesting the same amount at 23:00, on the day prior to colonoscopy. The one third of the bowel preparation left was required to be consumed within 4 hours before the scheduled colonoscopy.

2.4 Efficacy of bowel preparations

Bowel preparation efficacy was evaluated by the colonoscopy specialist according to the Boston Bowel Preparation Scale (BBPS), which is consistent with previous literature regarding bowel preparation evaluation. [12] The BBPS scores ranged from 0 to 9 in each of the three parts of colon: left side of the colon (LC), transverse colon (TC), and right side of the colon (RC); higher values were indicative of optimal preparation. Suboptimal cleansing was defined as total BBPS < 6, or sub-score < 2 in one or more colon segments. The bowel preparation quality efficacy was recorded on four grades: poor (0–2 points in total), fair (3–5 points in total; or 6-7 points in total but sub-score < 2 in one or more colon segments), good (6–7 points in total, and each colon segment score ≥ 2), and excellent (8 ± 9 points in total). [13, 14] Excellent or good were classified as optimal while fair or poor were defined as suboptimal for the analysis.

2.5 Statistical analysis

All statistical analyses were performed using Statistical Package for the Social Sciences 17.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were described as means $\pm$ standard deviations (SDs) and analyzed using Student's t-test. On the other hand, categorical variables were described as frequency (%) and was analyzed using the chi-square test or Fisher's exact test. Logistic regression was used to estimate relative risks for suboptimal bowel preparation as odds ratios (ORs) with 95% confidence intervals (CI). To investigate risk factors for suboptimal bowel preparation in the whole and each colonic segment, a multivariable logistic regression model was fitted including all variables. Statistical significance was set at $p < 0.05$.

Results

3.1 Baseline characteristics of the study population

The demographic and clinical characteristics of the 1,980 participants who underwent complete colonoscopy and completed questionnaires are described in Table 1. Among the 1,980 participants, 1,011 (51.06%) were male and 969 (48.94%) were female with a mean age of 39.50 ± 7.54 years. Furthermore, 368 (18.6%) were inpatient, 455 (23.0%) had previously undergone colonoscopy, 243 (12.3%) had a family history of gastrointestinal tumors, and 156 (7.9%) had constipation. Medical conditions included hypertension ($n = 81$, 4.1%), diabetes mellitus ($n = 53$, 2.7%). Polyps were detected in 30.9% of this cohort. In this study, 868 (43.8%) and 1112 (56.2%) used PEG and mannitol as bowel regimen, respectively. Among the 1980 participants, 329 (16.6%) were classified as “excellent,” 1299 (65.6%) as “good,” 352 (17.8%) as “fair,” and 0 (0%) as “poor,” according to the BBPS. Overall, 1,628 (82.2%) and 352 (17.8%) patients achieved optimal and suboptimal bowel preparation, respectively.

Table 1
Demographic and clinical characteristics of the study population.

Entire cohort (n = 1980)	
Age (years)	39.50 ± 7.54
Gender, male,n (%)	1011 (51.06%)
Hospital status,n (%)	
Inpatient	368 (18.6%)
Outpatient	1610 (81.4%)
Experience of colonoscopy, n (%)	455 (23.0%)
Bowel preparation agents, n (%)	
Polyethylene glycol (PEG)-electrolyte / Mannitol	868 (43.8%) / 1112 (56.2%)
Family history of gastrointestinal tumors, n (%)	243 (12.3%)
Medical conditions, n (%)	
Hypertension	81 (4.1%)
Diabetes	53 (2.7%)
Constipation	156 (7.9%)
Colonoscopy results, n (%)	
Polyp detection	612 (30.9%)
BBPS Excellent/Good/Fair	329 (16.6%) / 1299 (65.6%) / 352 (17.8%)
Note: Values are presented as number (%), mean ± SD, or Median.BBPS = Boston Bowel Preparation Scale.	

3.2 Factors associated with suboptimal bowel preparation on bowel preparation

The comparison of characteristics between the optimal and the suboptimal bowel preparation groups is shown in Table 2. Significant differences were observed regarding the sex, bowel preparation method, diabetes, and constipation between the two groups ($p < .05$); particularly, male, split-dose bowel preparation, and the presence of diabetes or constipation were more prevalent in the suboptimal bowel preparation group. Other variables were not significantly different between the two groups.

Table 2
Factors Associated with Bowel Preparation efficacy.

	Optimal (n = 1628)	Suboptimal (n = 352)	p value
Age (years)	39.51 ± 7.53	39.44 ± 7.61	0.887
Gender, male, n (%)	811 (49.8%)	200 (56.8%)	0.019*
Hospital status, n (%)			
Inpatient	313 (19.2%)	55 (15.6%)	0.131
Outpatient	1315 (80.8%)	297 (84.4%)	
Experience of colonoscopy, n (%)	387 (23.8%)	68 (19.3%)	0.081
Bowel preparation agents, n (%)			
Polyethylene glycol (PEG)-electrolyte	708 (43.5%)	160 (45.5%)	0.515
Mannitol	920 (56.5%)	192 (54.5%)	
Family history of gastrointestinal tumors	194 (11.9%)	49 (13.9%)	0.324
Medical conditions, n (%)			
Hypertension	62 (3.8%)	19 (5.4%)	0.181
Diabetes	29 (1.8%)	24 (6.8%)	< 0.001*
Constipation	80 (4.9%)	76 (21.6%)	< 0.001*
Use of mosapride, n (%)	50 (3.1%)	12 (3.4%)	0.736
Ways of bowel preparation, n (%)			
Split-dose	638 (39.2%)	188 (53.4%)	< 0.001*
Same-day	990 (60.8%)	164 (46.6%)	
Note: Values are presented as number (%), mean ± SD, or Median.*p < 0.05.			

The univariate analysis is shown in Table 3. Similarly, sex (OR:0.75; 95% CI, 0.58–0.98, P = .035), method of bowel preparation (OR:1.78; 95% CI, 1.37–2.14, P = .000), diabetes (OR:0.25; 95% CI, 0.14–0.47, P = .000), and constipation (OR: 0.19; 95% CI, 0.13–0.27, P = .000) were significantly associated with suboptimal bowel preparation.

Table 3

Univariate and multivariate logistic regression analysis for factors of suboptimal bowel preparation.

	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Age	1.00 (0.98–1.02)	0.887	1.00 (0.98–1.01)	0.532
Gender, male	0.75 (0.58–0.98)	0.035*	0.76 (0.58–1.01)	0.058
Hospital status				
Inpatient	1.30 (0.91–1.86)	0.155	1.33 (0.87–2.03)	0.189
Outpatient				
Experience of colonoscopy	1.31 (0.94–1.82)	0.110	1.35 (0.95–1.93)	0.096
Bowel preparation agents				
Polyethylene glycol (PEG)-electrolyte	0.92 (0.71–1.20)	0.557	0.78 (0.56–1.07)	0.127
Mannitol				
Family history of gastrointestinal tumors	0.83 (0.56–1.21)	0.331	0.88 (0.59–1.32)	0.538
Medical conditions				
Hypertension	0.71 (0.39–1.30)	0.264	1.02 (0.52–2.01)	0.958
Diabetes	0.25 (0.14–0.47)	< 0.001*	0.28 (0.14–0.56)	< 0.001*
Constipation	0.19 (0.13–0.27)	< 0.001*	0.20 (0.13–0.29)	< 0.001*
Use of mosapride	0.92 (0.44–1.89)	0.810	0.78 (0.37–1.67)	0.527
Ways of bowel preparation				
Split-dose	1.78 (1.37–2.14)	< 0.001*	1.69 (1.28–2.23)	< 0.001*
Same-day				
*p < 0.05. CI = Confidence Interval.				

To analyze the factors associated with suboptimal bowel preparation, a multivariate analysis adjusted to all the above factors was performed; the results are shown in Table 3. Suboptimal bowel preparation was related to split-dose bowel preparation (OR:1.69; 95% CI, 1.28–2.23, $P = .000$), diabetes (OR:0.28; 95% CI, 0.14–0.56, $P = .000$), and constipation (OR:0.20; 95% CI, 0.13–0.29, $P = .000$).

Demographic and clinical factors related to suboptimal bowel preparation in each colonic segment are shown in Table 4. Constipation was associated with suboptimal bowel preparation in all colonic segments (OR, 0.14; 95% CI, 0.067–0.280 in LC; OR, 0.21; 95% CI, 0.12–0.38 in TC; OR, 0.26; 95% CI, 0.17–0.40 in RC). Diabetes (OR, 0.19; 95% CI, 0.10–0.39) and split-dose bowel preparation (OR, 1.87; 95% CI, 1.37–2.56) were associated with suboptimal bowel preparation only in the RC.

Table 4
Factors associated with poor bowel preparation in each colon segment.

	LC		TC		RC	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Age	0.98 (0.84– 1.03)	0.412	1.01 (0.98– 1.04)	0.642	1.00 (0.98– 1.02)	0.865
Gender, male	1.05 (0.54– 2.03)	0.891	0.75 (0.46– 1.22)	0.244	0.77 (0.57– 1.06)	0.110
Hospital status						
Inpatient	0.66 (0.25– 1.76)	0.402	0.97 (0.47– 2.00)	0.930	1.48 (0.90– 2.44)	0.123
Outpatient						
Experience of colonoscopy	0.73 (0.33– 1.62)	0.442	1.54 (0.79– 2.99)	0.207	1.48 (0.98– 2.24)	0.063
Bowel preparation agents						
Polyethylene glycol (PEG)-electrolyte	1.22 (0.54– 2.78)	0.635	0.90 (0.51– 1.60)	0.718	0.83 (0.58– 1.19)	0.303
Mannitol						
Family history of gastrointestinal tumors	0.73 (0.31– 1.73)	0.471	2.51 (0.89– 7.05)	0.081	0.85 (0.55– 1.34)	0.492
Medical conditions						
Hypertension	0.47 (0.13– 1.69)	0.248	1.27 (0.37– 4.41)	0.708	1.46 (0.65– 3.30)	0.362
Diabetes	1.59 (0.19– 13.16)	0.667	0.56 (0.18– 1.75)	0.317	0.19 (0.10– 0.39)	< 0.001*
Constipation	0.14 (0.07– 0.28)	< 0.001*	0.21 (0.12– 0.38)	< 0.001*	0.26 (0.17– 0.40)	< 0.001*

LC, left side of the colon; RC, right side of the colon; TC, transverse colon. *p < 0.05. CI = Confidence Interval.

	LC		TC		RC	
Use of mosapride	0.84 (0.54– 2.78)	0.867	0.46 (0.16– 1.39)	0.169	1.06 (0.41– 2.79)	0.902
Ways of bowel preparation						
Split-dose	1.09 (0.56– 2.12)	0.805	1.38 (0.85– 2.26)	0.196	1.87 (1.37– 2.56)	< 0.001*
Same-day						
LC,left side of the colon; RC,right side of the colon; TC,transverse colon.*p < 0.05.CI = Confidence Interval.						

Discussion

A steady increase has been observed in the incidence of CRC among young patients, worldwide. The colonoscopy surveillance guidelines emphasize the importance of optimal bowel preparation in CRC prevention. [15, 16] High-quality colonoscopy without detected polyps defers the need for a repeated procedure for at least 10 years.

The American Society of Gastrointestinal Endoscopy and American Gastroenterological Association state that the rate of optimal colonoscopy preparation should be > 98%. [17] However, studies of actual clinical practice have shown that the rate of suboptimal bowel preparation ranged from 17 to 38%. [18–22] Therefore, multiple studies have been performed to improve bowel preparations; however, only a few have studied the factors associated with preparation outcome in young patients (≤ 50 years old). In this retrospective study, we evaluated the incidence and the factors for suboptimal bowel preparation in patients ≤ 50 years old.

In this cohort, the rate of suboptimal bowel preparation was 17.8%, which is consistent with previous studies. Unexpectedly, we found that univariate and multivariate analyses showed the influence of split-dose bowel preparation, diabetes, and constipation on suboptimal bowel preparation in young patients. Particularly, split-dose bowel preparation was significantly associated with poor preparation which is consistent with previous studies. [23, 24] Specifically, the meta-analysis of Yuan-Lung Cheng et al. [25] showed that same-day regimens were a superior alternative to split-dose regimens.

Moreover, the relationship between split-dose regimen and suboptimal bowel preparation was only found in the RC. This may be attributed to the longer preparation-to-procedure time associated with split-dose regimens wherein the flow of secreted bile accumulate on the RC, presented as thick orange bilious layer of mucous in-between the folds of the RC. [26] Chang Soo Eun et al. [27] revealed that both the interval between the initiation of PEG and initiation of colonoscopy within 7 h and interval between the completion of PEG and the initiation of colonoscopy within 4 h had better quality of bowel preparation. In this cohort, the administration of PEG-electrolyte solution or mannitol regimen was finished 6 and 3 hours

ahead of colonoscopy, respectively. Therefore, a higher quality of bowel preparation was achieved which resulted in increased recognition of its importance.

A previous study established the role of diabetes as a factor in predicting suboptimal bowel preparation. [28] Similarly, we found that young patients with diabetes were at a higher risk of suboptimal bowel preparation which was consistent with the study of Dik VK et al. [29] Clinical experience indicates that diabetic patients have delayed gastrointestinal motility, which may result in impaired transit times and reduced bowel movements. [19] However, the explanation regarding the presentation of suboptimal bowel preparation in the RC among patients with diabetes remains speculative. All ingested fiber reach and exert their effect in the colon. We hypothesized that dietary patterns change have an influence on RC cleansing. Vegetables contain higher amounts of fiber which is commonly recommended for patients with diabetes. Bowel preparation instructions required decrease dietary fiber intake leading to prolongation of oral-to-anal transit time affecting motor activity and electric spike potential in the RC. A previous study found that motor and electrical spike activity in the RC were more influenced by fiber intake than the mid- or left colon in stump-tailed monkeys. [30]

Another risk factor influencing suboptimal bowel preparation in young patients is constipation, which is consistent with previous findings. According to Guo X et al 's. [31] study, patients with functional constipation had inadequate bowel cleansing. In patients with constipation, delayed colonic transit movements potentially cause less effective washout of laxatives, increasing the risk of inadequate bowel preparation. Furthermore, the current study shows that the association between constipation and suboptimal bowel preparation was found in all colonic segments, which is consistent with most studies. Zhai et al. [32] recently showed that patients with constipation had prolonged total colon transit time in all colonic segments including RC, LC, and rectosigmoid colon compare with healthy controls. Dong et al. [33] demonstrated that infrequent bowel movements (< 3/week) were significantly associated with poor bowel preparation in all segments using Ottawa Bowel Preparation Scale.

Colon cleansing products for colonoscopy have been widely studied comparing both PEG-electrolyte solution and mannitol. However, we found no association between bowel preparation agents and the quality of bowel preparation. This was consistent with the study of Vieira et al. [34] who found similar efficacies between PEG-electrolyte solution and mannitol; however, PEG-electrolyte solution had higher tolerability, acceptability, and safety compared with mannitol. The production of combustible gases during polypectomies when using mannitol has led to its prohibition in various countries [35]; however, it remains widely used medication in China. Previous studies have demonstrated the influence of other risk factors in suboptimal bowel preparation including hypertension and hospitalization. [36, 37] However, this was inconsistent with our findings, which may be attributed to medication use that inhibits colonic peristalsis and the absence of various comorbidities in our sample.

In some studies, prokinetic agents such as mosapride have been used to improve colonic cleansing since they can stimulate gastrointestinal mobility. Tajika et al. [38] showed that patients who received 15 mg mosapride before 2L PEG solution administration had significantly more optimized bowel preparation

compared to 2 L PEG plus placebo, which was consistent with our findings. In contrast, a previous randomized controlled study showed that administration of 5 mg mosapride and PEG did not improve cleansing quality [39]; indicating that results in this field remain controversial.

This study has several limitations. First, the retrospective nature of the study led to the exclusion of other factors that may influence bowel preparation. Second, the single-center, university setting of the study may limit the generalizability of the results. Third, inter-observer bias may be possible since preparation quality assessment varies among endoscopists. To address this, the endoscopists referred to a photographic example of BBPS scores of bowel preparation quality at every examination. Fourth, bowel-cleansing agent or regimen intolerance and bowel preparation discontinuation could not be investigated, which is an important issue for bowel preparation; further studies are warranted regarding this.

To the best of our knowledge, this is the first study to analyze the risk factors associated with inadequate colonic preparations in young patients. We found that constipation, diabetes, and split-dose bowel preparation were significantly associated with suboptimal bowel preparation. This information may help clinicians to identify young patients with increased risk for suboptimal bowel preparation. However, further studies are required to improve endoscopic practices and reduce the rate of suboptimal bowel preparation for this patient population.

Declarations

Acknowledgments: The authors would like to thank the four nurses (Chao Gao, Xuefang Wang, Yixiang Guo, Xia Yang) from our Endoscopy Center and Departments of Gastroenterology for giving us assistance and nursing during the therapeutic process.

Author's contribution: Data curation: Yingzhe Lai; Formal analysis: Li Liu; Supervision: Guoxin, Huang and Pengli Ma; Original draft: Lexin Liu; Review & editing: Jingbin Wang.

Conflict of interest: The authors have no conflicts of interest to disclose.

Financial Disclosure: The authors declared that this study has received no financial support.

References

1. Bray, F. *et al.* Global Cancer Statistics 2018: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA Cancer J Clin*, **68**, 394–424 (2018).
2. Feng, R. M., Zong, Y. N., Cao, S. M. & Xu, R. H. Current Cancer Situation in China: Good Or Bad News From the 2018 Global Cancer Statistics? *Cancer Commun (Lond)*, **39**, 22 (2019).
3. Kim, S. B. *et al.* Comparison of Colonoscopy Surveillance Outcomes Between Young and Older Colorectal Cancer Patients. *J Cancer Prev*, **22**, 159–165 (2017).
4. Decruz, G. M. *et al.* Afterthoughts On Colonoscopy. Was It that Bad? *J MED SCREEN*, **28**, 63–69 (2021).

5. Romero, R. V. & Mahadeva, S. Factors Influencing Quality of Bowel Preparation for Colonoscopy. *World J Gastrointest Endosc*, **5**, 39–46 (2013).
6. Borg, B. B., Gupta, N. K., Zuckerman, G. R., Banerjee, B. & Gyawali, C. P. Impact of Obesity On Bowel Preparation for Colonoscopy. *Clin Gastroenterol Hepatol*, **7**, 670–675 (2009).
7. Lebwohl, B. *et al.* The Impact of Suboptimal Bowel Preparation On Adenoma Miss Rates and the Factors Associated with Early Repeat Colonoscopy. *GASTROINTEST ENDOSC*, **73**, 1207–1214 (2011).
8. Hillyer, G. C. *et al.* Split Dose and MiraLAX-based Purgatives to Enhance Bowel Preparation Quality Becoming Common Recommendations in the US. *Therap Adv Gastroenterol*, **6**, 5–14 (2013).
9. Nguyen, D. L. & Wieland, M. Risk Factors Predictive of Poor Quality Preparation During Average Risk Colonoscopy Screening: The Importance of Health Literacy. *J Gastrointest Liver Dis*, **19**, 369–372 (2010).
10. Weinberg, B. A. & Marshall, J. L. Colon Cancer in Young Adults: Trends and their Implications. *CURR ONCOL REP*, **21**, 3 (2019).
11. Clark, B. T. *et al.* Quantification of Adequate Bowel Preparation for Screening or Surveillance Colonoscopy in Men. *GASTROENTEROLOGY*, **150**, 396–405 e14-e15 (2016).
12. Lai, E. J., Calderwood, A. H., Doros, G., Fix, O. K. & Jacobson, B. C. The Boston Bowel Preparation Scale: A Valid and Reliable Instrument for Colonoscopy-Oriented Research. *GASTROINTEST ENDOSC*, **69**, 620–625 (2009).
13. Huh, C. W. *et al.* Validation of Same-Day Bowel Preparation Regimen Using 4L Polyethylene Glycol: Comparison of Morning and Afternoon Colonoscopy. *Medicine (Baltimore)*, **97**, e12431 (2018).
14. Calderwood, A. H. & Jacobson, B. C. Comprehensive Validation of the Boston Bowel Preparation Scale. *GASTROINTEST ENDOSC*, **72**, 686–692 (2010).
15. Winawer, S. J. *et al.* Guidelines for Colonoscopy Surveillance After Polypectomy: A Consensus Update by the US Multi-Society Task Force On Colorectal Cancer and the American Cancer Society. *GASTROENTEROLOGY*, **130**, 1872–1885 (2006).
16. Menees, S. B. *et al.* Patient Compliance and Suboptimal Bowel Preparation with Split-Dose Bowel Regimen in Average-Risk Screening Colonoscopy. *GASTROINTEST ENDOSC*, **79**, 811–820 (2014).
17. Rex, D. K. *et al.* Quality Indicators for Colonoscopy. *GASTROINTEST ENDOSC*, **81**, 31–53 (2015).
18. Mahmood, S., Farooqui, S. M. & Madhoun, M. F. Predictors of Inadequate Bowel Preparation for Colonoscopy: A Systematic Review and Meta-Analysis. *Eur J Gastroenterol Hepatol*, **30**, 819–826 (2018).
19. Chung, Y. W. *et al.* Patient Factors Predictive of Inadequate Bowel Preparation Using Polyethylene Glycol: A Prospective Study in Korea. *J CLIN GASTROENTEROL*, **43**, 448–452 (2009).
20. Fatima, H., Johnson, C. S. & Rex, D. K. Patients' Description of Rectal Effluent and Quality of Bowel Preparation at Colonoscopy. *GASTROINTEST ENDOSC*, **71**, 1244–1252 (2010).

21. Borg, B. B., Gupta, N. K., Zuckerman, G. R., Banerjee, B. & Gyawali, C. P. Impact of Obesity On Bowel Preparation for Colonoscopy. *Clin Gastroenterol Hepatol*, **7**, 670–675 (2009).
22. Chan, W. K., Saravanan, A., Manikam, J., Goh, K. L. & Mahadeva, S. Appointment Waiting Times and Education Level Influence the Quality of Bowel Preparation in Adult Patients Undergoing Colonoscopy. *BMC GASTROENTEROL*, **11**, 86 (2011).
23. Seo, M., Gweon, T. G., Huh, C. W., Ji, J. S. & Choi, H. Comparison of Bowel Cleansing Efficacy, Safety, Bowel Movement Kinetics, and Patient Tolerability of Same-Day and Split-Dose Bowel Preparation Using 4 L of Polyethylene Glycol: A Prospective Randomized Study. *DIS COLON RECTUM*, **62**, 1518–1527 (2019).
24. Sriphongphankul, H., Tanpowpong, P., Lertudomphonwanit, C. & Treepongkaruna, S. Split Dose Versus Full Single-Dose Regimen of Polyethylene Glycol for Bowel Preparation in Pediatric Colonoscopy: A Pilot Study of Randomized Controlled Trial. *Eur J Gastroenterol Hepatol*, **31**, 1382–1386 (2019).
25. Cheng, Y. L. *et al.* Same-Day Versus Split-Dose Bowel Preparation Before Colonoscopy: A Meta-Analysis. *J CLIN GASTROENTEROL*, **52**, 392–400 (2018).
26. Kottapalli, V. & Wright, R. Effectiveness of Polyethylene Glycol Antegrade Gut Lavage Bowel Preparation for Colonoscopy—Timing is the Key? *GASTROINTEST ENDOSC*, **50**, 726–727 (1999).
27. Eun, C. S. *et al.* The Timing of Bowel Preparation is More Important than the Timing of Colonoscopy in Determining the Quality of Bowel Cleansing. *Dig Dis Sci*, **56**, 539–544 (2011).
28. Zad, M., Do, C. N., Heffernan, A. & Johnston, L. & Al-Ansari, M. Factors Affecting Bowel Preparation Adequacy and Procedural Time. *JGH Open*, **4**, 206–214 (2020).
29. Dik, V. K. *et al.* Predicting Inadequate Bowel Preparation for Colonoscopy in Participants Receiving Split-Dose Bowel Preparation: Development and Validation of a Prediction Score. *GASTROINTEST ENDOSC*, **81**, 665–672 (2015).
30. Brodribb, J., Condon, R. E., Cowles, V. & DeCosse, J. J. Influence of Dietary Fiber On Transit Time, Fecal Composition, and Myoelectrical Activity of the Primate Right Colon. *Dig Dis Sci*, **25**, 260–266 (1980).
31. Guo, X. *et al.* Risk Factors Associated with Inadequate Bowel Preparation in Patients with Functional Constipation. *Dig Dis Sci*, **65**, 1082–1091 (2020).
32. Zhai, C., Huang, Q., Chai, N., Zhang, W. & Linghu, E. Prediction of Inadequate Bowel Preparation Using Total and Segmental Colon Transit Time in Patients with Chronic Constipation: Some Different Outcomes. *Gastroenterol Res Pract*. 2019, 2328054 (2019).
33. Lee, D. W. *et al.* Association Between Bowel Habits and Quality of Bowel Preparation for Colonoscopy. *Medicine (Baltimore)*, **96**, e7319 (2017).
34. Vieira, M. C., Hashimoto, C. L. & Carrilho, F. J. Bowel Preparation for Performing a Colonoscopy: Prospective Randomized Comparison Study Between a Low-Volume Solution of Polyethylene Glycol and Bisacodyl Versus Bisacodyl and a Mannitol Solution. *Arq Gastroenterol*, **49**, 162–168 (2012).

35. Hong-Bin, C. *et al.* Randomized Controlled Trial of Cholestyramine and Hydrotalcite to Eliminate Bile for Capsule Endoscopy. *Saudi J Gastroenterol*, **22**, 122–126 (2016).
36. Froehlich, F., Wietlisbach, V., Gonvers, J. J., Burnand, B. & Vader, J. P. Impact of Colonic Cleansing On Quality and Diagnostic Yield of Colonoscopy: The European Panel of Appropriateness of Gastrointestinal Endoscopy European Multicenter Study. *GASTROINTEST ENDOSC*, **61**, 378–384 (2005).
37. Gu, Q., Paulose-Ram, R., Dillon, C. & Burt, V. Antihypertensive Medication Use Among US Adults with Hypertension. *CIRCULATION*, **113**, 213–221 (2006).
38. Tajika, M. *et al.* Can Mosapride Citrate Reduce the Volume of Lavage Solution for Colonoscopy Preparation? *World J Gastroenterol*, **19**, 727–735 (2013).
39. Mishima, Y. *et al.* Efficacy of Prokinetic Agents in Improving Bowel Preparation for Colonoscopy. *DIGESTION*, **77**, 166–172 (2008).

Figures

Figure 1

Study flowchart. CRC, colorectal cancer; IBD, Inflammatory bowel disease.