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Inadequate Boston Bowel Preparation Scale Scores Predict the Risk of Missed Neoplasia on Next Colonoscopy

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Abstract

Background and Aims—The risks of missed findings after inadequate bowel preparation are not fully characterized in a diverse cohort. We aimed to evaluate the likelihood of missed polyps after an inadequate preparation as assessed using the Boston Bowel Preparation Scale (BBPS).

Methods—In this observational study of prospectively collected data within a large, national endoscopic consortium, we identified patients aged 50 to 75 who underwent average-risk screening colonoscopy (C1) followed by a second colonoscopy for any indication within 3 years

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(C2). We determined the polyp detection rates (PDR) and advanced PDR during C2 stratified by C1 BBPS scores.

Results—Among segment pairs without polyps at C1 (N=601), those with inadequate C1 BBPS segment scores had higher PDR at C2 (10%) compared with those with adequate C1 (5%, p=0.04). Among segment pairs with polyps at C1 (N=154), segments with inadequate C1 scores had higher advanced PDR at C2 (20%) compared with those with adequate C1 (4%, p=0.03). In multivariable analysis, the presence of advanced polyps at C1 (adjusted OR, 3.5; 95% CI, 1.1-10.8), but not inadequate BBPS scores at C1 (adjusted OR, 1.8; 95% CI, 0.6-5.1), was associated with a significantly increased risk of advanced polyps at C2.

Conclusions—Inadequate BBPS segment scores are generally associated with higher rates of polyps and advanced polyps at subsequent colonoscopy within a short timeframe. The presence of advanced polyps as well as inadequate BBPS segment scores can inform the risk of missed polyps and help triage which patients warrant a timely repeat colonoscopy.

Keywords

bowel preparation; missed neoplasia; colonoscopy

Introduction

Colorectal cancer (CRC) is associated with significant mortality, estimated to account for nearly 50,000 deaths in the United States in 2015 alone.[2] Although statistical trends suggest that the incidence of CRC and associated mortality is declining,[3] screening and prevention guidelines are the subject of careful scrutiny and ongoing research. At present, colonoscopy is the most effective screening tool in the reduction of colorectal cancer mortality. [4]

Variability in the adequacy of bowel preparation presents an inherent challenge during colonoscopy. Up to one quarter of all bowel preparations are deemed to be inadequate, [5] and several retrospective and prospective studies using one-time colonoscopy data have shown that inadequate bowel preparation leads to increased rates of missed lesions, including pre-cancerous adenomas.[5-10] Furthermore, over-use of colonoscopy is a problem,[11] with implications for inappropriate resource allocation,[12] and unnecessary exposure to risks.[13] More evidence is needed to refine guidelines regarding the appropriate timing of follow-up after a colonoscopy with inadequate preparation in order to reduce missed lesions and diagnostic inaccuracy whereas at the same time, alleviating unnecessary costs and risks.

The 2012 U.S. Multi-Society Task Force (USMSTF) Guidelines on CRC Screening recommend repeating an examination with “poor” bowel preparation within one year, whereas 5-year follow-up should be considered for “fair but adequate [bowel preparations] (to detect lesions >5 mm) and if small (<10 mm) tubular adenomas are detected.”[14] These guidelines are vague, challenging to apply in clinical practice, and lack a universal bowel preparation scoring system to standardize the definition of an adequate bowel preparation. More recently, the 2014 USMSTF on CRC Guidelines on Bowel Preparation recommend that when the quality of the examination is inadequate to detect polyps >5 mm, colonoscopy

should be repeated within 1 year.[15] The ability of endoscopists to translate the concept of "inadequate to detect polyps >5 mm" into clinical practice is unknown.

The Boston Bowel Preparation Scale (BBPS) is a well-validated scale for assessing bowel preparation cleansing after standard cleansing maneuvers have been performed. Based on a recent systematic literature review,[16] the BBPS was recommended for use in clinical practice.[10,15,17,18] Several recent prospective studies of one-time colonoscopies have demonstrated an association between higher BBPS scores and higher polyp and adenoma detection rates.[24-26] A BBPS segment score of 0 or 1 has been suggested as inadequate, necessitating early repeat colonoscopy.[9,19,20] Understanding the incidence of missed lesions based on the degree of bowel cleanliness using the BBPS on a baseline examination would provide guidance on a threshold of cleanliness needed to ensure confidence in a low miss rate of polyps, thereby informing timing of repeat colonoscopy after colonoscopy with less-than-perfect bowel cleanliness. A recent prospective study attempted to address this question[20]; however, the study was limited to male veterans at a single medical center.

We hypothesized that the BBPS could predict the likelihood of missed polyps based on initial BBPS segment scores among a large consortium of gastroenterology practices throughout the United States, thereby providing evidence to inform recommendations for repeat colonoscopy after less-than-perfect bowel preparation.

Methods

This study was approved by the Institutional Review Board with waiver of informed consent at Boston Medical Center in November 2010.

Setting

The Clinical Outcomes Research Initiative (CORI) is a consortium of gastrointestinal practices, which at the time of this study included 57 practices with 457 physicians from over 18 states. A specialized electronic health record was used by providers to generate their endoscopy reports which were then stored in a data repository containing minimal patient and provider identifiers called the National Endoscopic Database. Data for this study were prospectively generated between October 2009 and November 2014. Over this time period, there were approximately 98,000 average-risk screening colonoscopies performed within CORI. A detailed description of the CORI National Endoscopic Database has been described elsewhere.[19,21]

The Boston Bowel Preparation Scale (BPPS)

The BPPS has been described in detail previously.[10] Briefly, a numerical scoring system is applied to the right side of the colon (R), transverse colon (T), and left side of the colon (L) after all cleaning, washing, and suctioning is performed. Each segment receives a score of 0 to 3 based on the quality of bowel preparation, with 0 indicating an unprepared colon and 3 indicating a clean colon without residual stool obstructing visualization of the mucosa. The overall BBPS score is the sum of the 3 segment scores and ranges from 0 to 9. CORI includes photos of BBPS segment score definitions within the reporting software.

Study Population

We included patients aged 50 to 75 who underwent average-risk screening colonoscopy that included a BBPS score followed by a second colonoscopy for any indication that included an assessment of bowel cleanliness. Indications were categorized as screening, surveillance, therapeutic, and diagnostic (eg, anemia, abdominal pain, constipation, diarrhea, GI blood loss, and weight loss). The second examination had to occur within 3 years of the baseline colonoscopy in order to minimize the chance of de novo pathology on the second examination. Observational data regarding colorectal polyp growth-rates suggest that lesions less than 10 mm tend to remain stable over a 3-year period.[1]

Assessment of colonoscopy adequacy

The baseline average-risk screening colonoscopy had to include an assessment of bowel preparation quality using the BBPS and is denoted as “C1,” for “colonoscopy no. 1.” Colonoscopy examinations without a BBPS score were not included. Adequacy of preparation for C1 overall was defined a priori as BBPS segment scores of ≥2 for all 3 segments of the colon. Colonoscopies that were aborted before reaching the cecum due to poor bowel cleanliness were included and un-visualized segments were assigned a BBPS segment score of 0, in accordance with the BBPS definition.[10] Incomplete procedures for reasons other than inadequate bowel cleanliness (eg, patient discomfort or cardiopulmonary instability) were excluded.

A second colonoscopy was performed for any indication within 3 years of C1 and is denoted as “C2” for “colonoscopy no. 2.” Adequacy of preparation for C2 was defined by either a BBPS segment score ≥2 for all three segments or a qualitative scoring for the entire examination as “excellent,” “good,” or “adequate to exclude polyps >5 mm.” We allowed for these definitions of C2 preparation adequacy in order to achieve a sufficient sample size of C1 examinations with a corresponding C2 follow-up examination.

Endpoints

The primary endpoint was polyp and advanced polyp detection rates among colon segments at C2 stratified by C1 BBPS scores. Because pathology data were not reliably available within CORI, we were not able to evaluate polyp histology for classification as adenomas or advanced adenomas. Instead, a size threshold of >9 mm for polyps was chosen as a surrogate marker of advanced adenomas based on a previous validation study of 13,000 screening colonoscopies within CORI, which found that size >9 mm had a specificity for advanced adenomas (defined as size >10 mm, serrated, villous, HGD) of 84%.[21]

Secondary endpoints included polyp and advanced polyp detection rates at C2 by initial findings at C1 (polyp, advanced polyp) at the patient-level and by colon segment location (right, transverse, left). We also performed a sensitivity analysis limited to pairs of colonoscopies in which C2 was performed within 1 year of C1.

Analysis

The primary analysis was performed at the level of the colon segment with each pair of C1 and C2 colonoscopy examinations contributing 3 colon segment pairs (right, transverse,

left). We compared findings during C2 examinations among patients with initial inadequate bowel preparation at C1 that was adequate at C2. Pairs of C1 and C2 examinations were excluded if C2 was inadequate.

Patients with adequate preparations at both C1 and C2 provided estimates for baseline polyp miss rate unrelated to bowel preparation, recognizing that C1 polyp detection rates (PDR) may be unusually high due to selection bias that enriched for patients with polyps.

Chi-square test and the Fisher exact test were used to evaluate categorical variables and Wilcoxon rank sum test was used for non-parametric continuous variables. A multivariate model evaluating the risk of advanced polyps at C2 controlled for several factors (ie, age, gender, BBPS segment score). A generalized linear mixed model was created to evaluate whether segment location affected the relationship between C1 BBPS segment score and C2 findings. Analyses were performed using SAS 9.3. P-values <0.05 were considered significant.

Sample size estimate

We based our sample size estimate on assumptions around the polyp detection rate (ie, miss rate) for C2 examinations among C1 examinations with BBPS segment scores of 0 and 1 versus C1 examinations with segment scores of 2 or 3. Assuming an estimated polyp detection rate of 10% among C1 segments with BBPS 0 and 1 and 2% among C1 segments with BBPS 2 and 3, we would need 138 colon segment pairs in each group to detect this difference with 80% power at the alpha=0.05 level.

Results

Between 2009 and 2014, there were approximately 98,000 average risk screening colonoscopies performed within CORI of which 11,177 (11%) included a BBPS score. Among the examinations with a BBPS score, 365 (3%) had 2 procedures within the database. These 365 average-risk screening C1 examinations were performed by 99 different CORI endoscopists from 29 different practice groups. At least 24 of the endoscopists (24%) completed the on-line BBPS Educational Program.[22] Of these 365 examinations, 335 met inclusion criteria with a C2 examination with preparation rating documented within 3 years (Figure 1). Among the 335 included C1-C2 examination pairs, 149 had an inadequate C1 total score and 186 had an adequate C1 total score. In the C1 “inadequate” group, 30 of the 149 examination pairs were excluded due to an inadequate C2 score, leaving 119 total colonoscopy pairs available for patient-level analyses. These 119 colonoscopies yielded a potential of 357 segments (119×3), of which 109 were excluded (BBPS segments scores were 2 or 3,) leaving 248 evaluable colon segment pairs in the C1 “inadequate” available for the segment analysis. In the C1 “adequate” group, 17 of the 186 examination pairs were excluded due to an inadequate C2 score, leaving 169 total colonoscopy pairs available for patient-level analysis. These 169 colonoscopies yielded 507 segments (169 × 3) for the segment analysis.

Compared with patients with adequate C1 bowel preparation (Table 1), patients with inadequate C1 bowel preparation were more likely to be male (71% vs 60%, p=0.04) and

slightly younger (59 vs 61 years old, p=0.02). Patients with inadequate C1 bowel preparation were more likely to undergo C2 for an indication of screening (55% vs 5%, p<0.0001), whereas patients with adequate C1 bowel preparation were more likely to undergo C2 for an indication of surveillance (68% vs 30%, p<0.0001). The lag time between C1 and C2 examinations was shorter in patients with inadequate C1 scores (186 days vs 374 days, p<0.0001).

To establish baseline C1 polyp detection rates, the percentage of polyps, including advanced polyps, was calculated for adequate or inadequate bowel preparation cleanliness ratings. Adequate segment scores at C1 were associated with higher PDR (27% vs 6%; p<0.0001) and advanced PDR (15% vs 3%; p<0.0001) than inadequate scores at C1 (Table 2).

Baseline C1 BBPS segment scores and C1 findings were compared with C2 findings to evaluate for a possible predictive role of C1 in predicting pathology at C2 (Table 3). Segment pairs were stratified by presence and type of polyps (any vs advanced as defined by size >9 mm) given the risk imparted by baseline polyps on future polyps. Segments with inadequate BBPS scores for which no polyps were found at C1 had a higher PDR at C2 (10% vs 5%, p=0.04) but no difference in advanced PDR. Among segment pairs with polyps visualized at C1, segments with inadequate scores at C1 (20%) had higher advanced PDR at C2 than segments with adequate C1 (4%, p=0.03) but no difference in PDR. Similarly, there was a trend among segment pairs with advanced polyps visualized at C1 that segments with inadequate scores at C1 (25%) had higher advanced PDR at C2 than segments with adequate C1 (4%, p=0.07), but no difference in PDR.

Because of the association between segment location and missed neoplasia, especially in the proximal colon,[23] the association between C1 BBPS segment score and C2 findings was compared by colon segment location (ie, right, transverse, and left). No significant differences in the interval polyp findings by BBPS score by segment locations were seen.

A multivariable model predicting the risk of C2 advanced polyps was created, controlling for age, gender, advanced polyps at C1, lag time between C1 and C2 and inadequate BBPS scores at C1 (Table 4). Only C1 advanced polyps and not C1 any polyps was included in the model due to their overlap and the higher predictive value of the former. Having advanced polyps at C1 (adjusted OR, 3.5; 95% CI, 1.1-10.8) was associated with a significantly increased risk of advanced polyps at C2. Inadequate BBPS segment scores at C1 was not significantly associated with an increased risk of advanced polyps at C2 (adjusted OR, 1.8; 95% CI, 0.61-5.1). There was a slight increase in the risk of advanced polyps at C2 for every increase in year or age (adjusted OR, 1.1; 95% CI, 1.0-1.2). There was no risk of advanced polyps at C2 when adjusting for gender (adjusted OR, 0.64; 95% CI, 0.20-2.0) or lag time between C1 and C2 (adjusted OR, 1.0; 95% CI, 1.0-1.0).

In terms of findings at the patient level (ie, the presence of a polyp or advanced polyp anywhere in the colon regardless of location), we compared polyp and advanced polyp detection rates during C2 based on baseline (C1) total BBPS score stratified by baseline findings. We found that among C1 total examinations without polyps, C1 inadequate examinations had a higher rate of polyps on C2 compared with C1 adequate examinations

(18% vs 7%, p=0.05). Similarly, among C1 total examinations with advanced polyps, there was a non-statistically significant trend toward higher rate of advanced polyps at C2 among the C1 inadequate versus C1 adequate group (20% vs 9%, p=0.17). No other comparisons were statistically significant.

We evaluated findings limited to colonoscopy pairs in which C2 was performed within 1 year of C1. This included 427 colon segment pairs (C1 inadequate: N=190 and C1 adequate: N=237). Among those without baseline C1 polyps (N=337), the inadequate C1 group had a higher rate of polyps at C2 than the adequate C1 group (12% vs 6%; p=0.05). Similarly, among those with any polyp at C1 (N=90), the inadequate C1 group had a higher rate of advanced polyps at C2 compared with the adequate C1 group (18% vs 3%; p=0.02). No other comparisons were statistically significant.

Discussion

In this study of a consortium of endoscopy units throughout the United States, we found that in cases without baseline polyps detected, colon segments with BBPS segments scores of 0 or 1 compared with those with scores of 2 or 3 had higher rates of polyps on subsequent examinations and similarly, in cases without baseline polyps detected, colon segments with BBPS segment scores of 0 or 1 compared with 2 or 3 had higher rates of advanced polyps on subsequent examination within 3 years. We speculate that the difference was due to missed lesions at the baseline examination.

Although we did not uniformly see this trend across all groups in the comparison, inadequate bowel preparation segment scores were generally associated with increased rates of missed polyps and advanced polyps at follow-up, a finding that was bolstered by similar outcomes when the window and thus risk for de-novo polyps at follow-up was minimized. We were surprised that in both univariate and multivariable analyses, the detection of a baseline advanced polyp and increasing age outweighed the effect of bowel preparation cleanliness in increasing the risk of advanced polyps at subsequent colonoscopy and in fact bowel preparation cleanliness was not significant.

Previous work has shown that higher BBPS scores are associated with increased polyp and adenoma detection. Most of these studies used one-time colonoscopy for analysis.[9,10,24-26] Two retrospective studies using consecutive colonoscopy information also found high adenoma miss rates with inadequate preparation, ranging from 35% to 47%; however, these studies did not use validated scoring systems in their assessment of bowel cleanliness.[7,8] Other work has shown that the BBPS, which captures differences in cleanliness among colon segments, can be used to determine follow-up recommendations.[19] A 10-year follow-up is recommended for a colonoscopy with adequate bowel preparation (all segment scores ≥2), whereas a repeat colonoscopy is recommended within 1 year of a colonoscopy with poor bowel preparation (total BBPS score of ≤2).

Clark and colleagues[20] recently conducted a prospective single center study among 438 male veterans who underwent screening or surveillance colonoscopy using the BBPS, followed by a repeat study performed by a blinded endoscopist within 60 days to evaluate polyp miss

rate. The primary endpoint in this study was the percentage of missed adenomas >5 mm. Miss-rates were significantly higher with a baseline BBPS segment score of 1 (15.9%), as compared with a score of 2 (5.2%) or 3 (5.6%). BBPS segment scores of 0 were not included in their analyses. As in our study, no differences in missed adenoma detection by bowel cleanliness were seen by segment location.

This current study in a national consortium of endoscopy units adds to the growing body of literature that colonoscopies with at least one segment that is inadequately clean (defined as BBPS segment scores of 0 or 1) necessitate early repeat evaluation. In combination with Clarks' study, this current study also helps inform clinicians with respect to anticipated risks for future polyps based on initial BBPS segment scores, which may guide shared decision making with patients. Past studies estimated risks of missed polyps due to inadequate bowel cleanliness based on colonoscopy examinations at a single time point, comparing polyp detection across different categories of bowel cleanliness,[19,25,26] rather than evaluating interval findings on repeat colonoscopy as our current study did.

The strengths of our study include the use of the large national endoscopic repository that represents routine clinical practice and includes diverse populations throughout different practice settings and providers throughout the United States. Despite these strengths, we acknowledge certain limitations. Although the CORI database offers a robust study population, only 365 (3%) of available cases used a BBPS score and could be included, thereby potentially limiting the generalizability of the data. Due to limitations in the data from the National Endoscopic Database, colonoscopy parameters including withdrawal time and pathology were unavailable. Instead, polyp size of >9 mm was used as a surrogate marker for “advanced” polyps, a size cut off previously validated among over 13,000 screening colonoscopies for which histology was available which found that 84% of polyps >9 mm were advanced adenomas by standard definitions (size >10 mm, serrated, villous histology and high-grade dysplasia).[21] Although using this size surrogate leaves the possibility of misclassifying polyps < 9 mm with high-grade dysplasia or villous features as non-advanced lesions, this should occur infrequently such as not to influence the overall results of our study.

Data regarding the total number of polyps for each examination were not included, which could influence the risk for future polyps and provider recommendations for the timing for repeat examination. Nevertheless, we suspect that the finding of any polyp is likely more significant than the number of polyps during an examination with less than adequate preparation in predicting missed polyps. We acknowledge the potential for unrecognized incomplete endoscopic resection of lesions, whereby an inadequate preparation could heighten this risk. This could lead to overestimation of polyps seen at C2 as compared with adequate preparation at C1. BBPS scoring was also unavailable for all of the second colonoscopy examinations; however, we only included second examinations when the bowel preparation was assessed overall as adequate by qualitative descriptors. It is also important to note that the indication for the second colonoscopy examination varied among the study participants, especially between those with an inadequate versus adequate preparation at the time of the initial study. Patients with inadequate initial colonoscopy bowel preparation were more likely to undergo a second colonoscopy for an indication of rescreening due to poor

bowel preparation. In contrast, patients with adequate bowel preparation on initial colonoscopy were more likely to undergo a second colonoscopy for the indication of surveillance or diagnostic evaluation of a new clinical complaint, making them an inherently higher risk population. As such, this “control” group likely overestimates the baseline miss rate of colonoscopy unrelated to preparation and therefore, if anything, our study may potentially underestimate the polyp miss rate related to preparation. Last, because of the varying reasons for the repeat colonoscopy, the lag time from the first to second colonoscopy was longer in patients with adequate baseline bowel preparation. This may raise concern for the increased possibility of interval *de novo* polyp detection or growth of previously undetected polyps within the “control” group with adequate bowel cleanliness on baseline colonoscopy, which again might overestimate the baseline miss rate of colonoscopy unrelated to preparation.

In conclusion, this work further highlights the importance of an adequate bowel preparation to the detection of polyps and validates our prior observation that individuals with a BBPS segment score of 0 and 1 may be at increased risk for missed polyps, especially if advanced polyps are detected. Under these circumstances, a colonoscopy should be repeated with adequate preparation to complete the initial colonoscopy examination. Future research should evaluate the role of the BBPS in predicting miss rates of other polyp types, specifically serrated polyps.

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Abbreviations

BBPS	Boston Bowel Preparation Scale
C1	colonoscopy #1
C2	colonoscopy #2
CORI	Clinical Outcomes Research Initiative
CRC	colorectal cancer, USMSTF, US Multi-Society Task Force

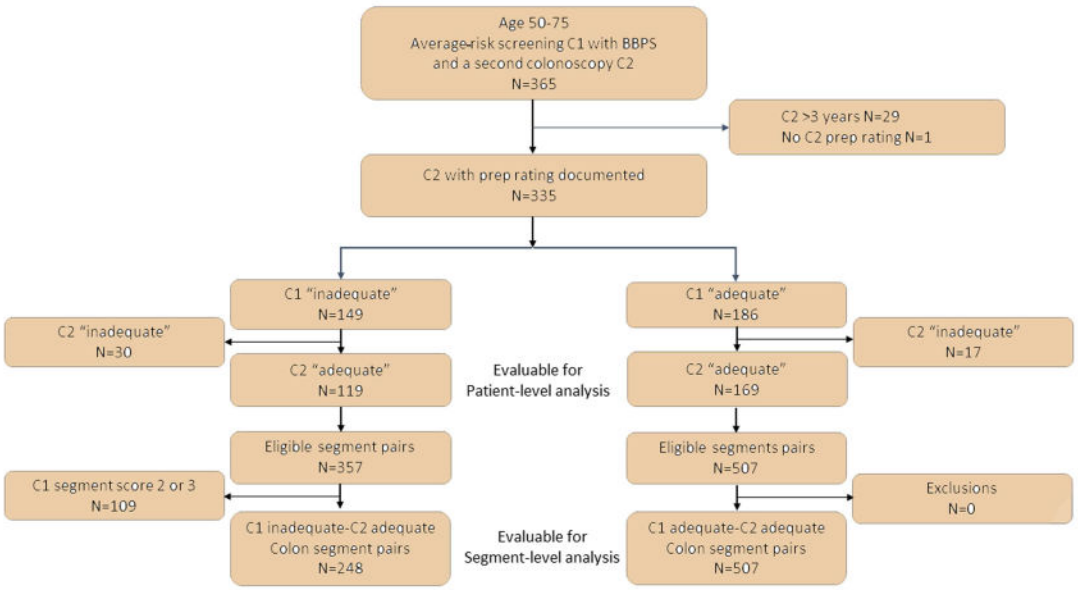

Figure 1.
Flow diagram indicating patient colonoscopy examination segments included for analysis.

Table 1

Demographics of the study sample presented for the group with inadequate and adequate bowel cleanliness at baseline colonoscopy (C1).

Variable	C1 Bowel Preparation Cleanliness		P value
	Inadequate N=119	Adequate N=169	
Gender			
Male	85 (71%)	101 (60%)	0.04
Female	34 (29%)	68 (40%)	
Median age (IQR), years	59 (53-65)	61 (55-66)	0.02
Median lag time C1-C2 (IQR), days	186 (70-381)	374 (188-525)	<0.0001
C1 Polyp detection			
Any polyp	58 (49%)	139 (82%)	<0.0001
Advanced polyp	24 (20%)	82 (49%)	<0.0001
C2 Indication			<0.0001
Screening	66 (55%)	9 (5%)	
Surveillance	36 (30%)	115 (68%)	
Therapeutic/Follow-up	5 (4%)	13 (8%)	
Diagnostic	12 (10%)	32 (19%)	

C1, colonoscopy #1 (baseline colonoscopy); C2, colonoscopy #2; IQR, interquartile range

Table 2

Baseline polyp and advanced polyp detection rates among colonoscopy segments with inadequate and adequate bowel preparations.

C1 Polyp Detection	C1 Bowel Preparation Cleanliness		P value
	Inadequate N=248	Adequate N=507	
Any polyp	6% (15)	27% (139)	<0.0001
Advanced polyp	3% (8)	15% (76)	<0.0001

C1, colonoscopy #1 (baseline colonoscopy); C2, colonoscopy #2

Table 3

Polyp and advanced polyp detection rates during colonoscopy #2 (C2) based on baseline (C1) BBPS segment scores and baseline findings.

C1 Findings	C1 BBPS segment score	C2 Findings, % (N)			
		Polyps		Advanced Polyps	
No polyp	0-1	10% (23/233)	P = 0.04	2% (4/233)	P = 0.94
	2-3	5% (20/368)		2% (6/368)	
Polyps	0-1	33% (5/15)	P = 0.54	20% (3/15)	P = 0.03
	2-3	26% (36/139)		4% (5/139)	
Advanced polyps	0-1	38% (3/8)	P = 0.67	25% (2/8)	P = 0.07
	2-3	30% (23/76)		4% (3/76)	

BBPS, Boston Bowel Preparation Scale; C1, colonoscopy #1 (baseline); C2, colonoscopy #2

Table 4

Multivariate model predicting the risk of advanced polyps for colon segments.

Variable	Risk of advanced polyps at C2			
	Unadjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P value
Gender (Female vs. male)	0.50 [0.16-1.5]	0.22	0.64 [0.20-2.0]	0.44
Age	1.1 [1.0-1.2]	0.01	1.1 [1.0-1.2]	0.01
Lag time C1-C2	1.0 [1.0-1.0]	0.64	1.0 [1.0-1.0]	0.92
C1 Advanced polyp	3.2 [1.1-9.2]	0.03	3.5 [1.1-10.8]	0.03
C1 Inadequate BBPS segment score	1.3 [0.50-3.4]	0.58	1.8 [0.61-5.1]	0.30

BBPS, Boston Bowel Preparation Scale; C1, colonoscopy #1 (baseline); C2, colonoscopy #2; CI, confidence interval; OR, odds ratio