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Efficacy of different bowel preparation regimen volumes for colorectal cancer screening and compliance with European Society of Gastrointestinal Endoscopy performance measures

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Abstract

Background: Various volumes of bowel preparation are used in clinical practice. There is conflicting data on the effectiveness of individual regimens. This study aims to evaluate the efficacy and compliance of currently used bowel preparations with the European Society of Gastrointestinal Endoscopy (ESGE) performance measures using data of the Dutch nationwide colorectal cancer screening (CRC) program.

Methods: In a prospective, multicenter endoscopy database, we identified all CRC screening colonoscopies performed in 15 Dutch endoscopy centers from 2016 to 2020. We excluded procedures without documented bowel preparation or the Boston Bowel Preparation Scale (BBPS) score. Bowel preparation regimens were categorized into three groups, that is, 4-L (polyethylene glycol (PEG)), 2-L (2-L PEG with ascorbic acid) and ≤1-L volumes (sodium picosulfate with magnesium citrate, 1L-PEG with sodium sulfate and ascorbic acid or oral sulfate solution). European Society of Gastrointestinal Endoscopy performance measures included adequate BBPS score (≥6) (>90%), cecal intubation rate (CIR, >90%), adenoma detection rate (ADR, >25%) and polyp detection rate (PDR, >40%). Logistic regression was performed to identify predictive factors for adequate BBPS and patient discomfort.

Results: A total of 39,042 CRC screening colonoscopies were included. Boston Bowel Preparation Scale scores, CIR, ADR and PDR for 4L, 2L and ≤1L regimens all met the minimum ESGE performance measures standards. However, an adequate

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BBPS score was more frequently seen with 2L regimens (98.0%) as compared to 4L (97.1%) and ≤1L regimens (97.0%) ($p < 0.001$), respectively. In addition, CIR was higher for ≤1L (98.4%) versus 4L (97.7%) and 2L (97.9%) regimens ($p = 0.001$), ADR higher for lower volume (≤1L (60.0%) and 2L (61.2)) versus higher volume (4L (58.6%)) regimens ($p < 0.001$), and PDR higher for ≤1L (70.0%) and 2L (70.8%) versus 4L (67.2%) regimens ($p < 0.001$). Boston Bowel Preparation Scale for ≤1L regimens was higher when combined with bisacodyl (97.3%) than without (95.6%) ($p < 0.001$). Overall, bisacodyl use was independently associated with higher patient discomfort (odds ratios = 1.47, confidence intervals = 1.26–1.72).

Conclusions: Despite variations in bowel preparation volumes, all regimens meet the minimum ESGE performance measures for bowel preparation and other quality parameters. Boston Bowel Preparation Scale can be further improved if ultra low volume regimens are combined with bisacodyl. The choice for either bowel preparation volume can therefore be based on volume-tolerance and patient preference.

KEYWORDS
bowel preparation, cancer screening, colorectal cancer, screening

INTRODUCTION

Adequate bowel preparation is an essential part of a high-quality colonoscopy. Suboptimal bowel preparation results in a lower cecal intubation rate (CIR) and lower adenoma detection rate (ADR), with a negative impact on colorectal neoplasia detection and thus colorectal cancer prevention.[1–4] Moreover, repeated colonoscopy because of inadequate bowel preparation impacts the cost-effectiveness of screening programs by significantly increasing healthcare costs.[5,6]

With the introduction of nationwide colorectal cancer screening (CRC) programs in Europe, the European Society of Gastrointestinal Endoscopy (ESGE) developed a set of performance measures for colonoscopy. One of these performance measures underlines the importance of adequate bowel cleansing.[7,8]

The quality of bowel preparation is dependent on patient compliance, type of bowel preparation used and timing of administration.[9] Patients are often required to drink large volumes in a limited period, which can be cumbersome and, when taken incompletely, might result in insufficient bowel cleansing. Various volumes of bowel preparation regimens are available and used in daily clinical practice. These regimens range from 4-L polyethylene glycol (PEG) regimens to 'ultra-low' volume regimens, such as 0.3-L sodium picosulfate with magnesium citrate (SPMC) or 1-L PEG with sodium sulfate and ascorbic acid. Studies have shown that adequate patient instructions and lower volumes of bowel preparation increase patient compliance and willingness to repeat endoscopy.[10,11] However, reports on the effectiveness of ultra-low volume bowel preparations pertaining to actual performance measures have suggested that they are not as effective as high- and low volume bowel preparations regimens.[12–14]

Key summary

Summarize the established knowledge on this subject

- The quality of bowel preparation is dependent on patient compliance, type of bowel preparation used and timing of administration.
- Requiring patients to drink large volumes of bowel preparation regimen leads to less patient compliance compared to drinking smaller volumes of bowel preparation.
- Previous studies have suggested that 'ultra-low' volume bowel preparation regimens are not as effective as high- and low-volume bowel preparations regimens and do not meet European Society of Gastrointestinal Endoscopy (ESGE) minimum performance measure standards.

What are the significant and/or new findings of this study?

- Four-liter, 2-L and ≤1-L bowel preparation regimens are all effective in meeting the ESGE minimum performance measure standards, including bowel preparation, cecal intubation, adenoma detection rate (ADR) and polyp detection rate.
- Bowel preparation can be further improved if ultra-low volume regimens are combined with bisacodyl.
- The choice for either bowel preparation regimen should mainly be based on volume-tolerance and patient preference.

The aim of this study was to evaluate the efficacy of various bowel preparation regimen volumes in preparing the colorectum for colonoscopy in line with the existing ESGE performance measures by reviewing the endoscopy data generated in the Dutch nationwide CRC program.

METHODS

Database and data collection

For this study, we analyzed data from a prospective gastrointestinal (GI) endoscopy database (Trans.IT database, Rotterdam, the Netherlands). This database has been described in detail in previous publications.[15–17]

In brief, the database is a multicenter database that collected anonymized endoscopy report data from 20 Dutch hospitals (3 academic and 17 non-academic hospitals) in the period January 2012 to December 2020. Participating sites used a structured reporting tool developed by Trans.IT to create uniform endoscopy reports. The endoscopy reports were made by the endoscopist immediately following endoscopy. Afterward, it was mandatory to add the pathology results to the endoscopy report. All anonymized endoscopy reports were automatically uploaded into the database. Patient and endoscopy characteristics, and endoscopic findings are extracted from each endoscopy report and automatically stored in the database. Approximately 650,000 endoscopy reports were collected in this period, with over 150,000 reports in 2019 and 2020.

As complete data from the Dutch CRC program was recorded in the database from 2016, we decided to analyze all CRC colonoscopies performed between January 2016 and December 2020 in 15 centers. Endoscopic reports with undocumented bowel preparation medication or Boston Bowel Preparation Scale (BBPS) scores were excluded.

Outcomes and definitions

The primary outcomes included the individual ESGE performance measures, that is, adequate bowel preparation rate (ESGE minimum standard 90%), CIR (ESGE minimum standard 90%), ADR (ESGE minimum standard 25%), and polyp detection rate (PDR) (ESGE minimum standard 40%). These items are mandatory to be collected in the Dutch CRC program and thus in the endoscopy report. Mandatory items are however not required to complete an endoscopy report in the database and can be left blank. We extracted the performance measure results from all endoscopy reports. Adequate bowel preparation was defined as a BBPS score of six or higher and a score of at least two per colon segment.[18] Colon segments were scored during colonoscopy after washing and fluid aspiration. Adenoma detection rate was cross checked using separate histology reports, which were retrospectively updated in the database. We categorized bowel preparation regimens into three groups: (a) high volume: 4-L (standard-volume PEG)), (b) low volume: 2-L (2-L PEG with ascorbic acid (PEGA)) and (c) ultra-low volume: ≤1-L volume preparations (SPMC, oral sulfate solution (OSS) or 1-L PEG with sodium sulfate and ascorbic acid). Results were stratified by type of bowel preparation regimen. All patients in the Dutch CRC program received detailed instructions on the bowel preparation regimen before colonoscopy by a dedicated nurse and were asked to use a low-fiber diet 3 days prior to colonoscopy. Additional amounts of clear liquid allowed during bowel preparation depended on the type of bowel preparation regimen. For high-volume regimens no additional volume of clear liquid was recommended, but for low- and ultra-low volume regimens, at least 2–4 L of additional clear liquid were recommended. Additionally, we assessed the effect of bisacodyl use on bowel preparation quality and patient comfort. The 4 L, 2L or ≤1L regimens were prescribed with or without the addition of bisacodyl. The effect of bisacodyl was separately assessed by comparing groups with or without bisacodyl. Patient comfort was assessed using the Gloucester Comfort Scale (GCS).[19] This scale ranges from 1 to 5, with 1 meaning no discomfort and 5 meaning severe discomfort. The comfort score is registered by the nurse attending the colonoscopy at the end of each colonoscopy and is registered in the report. A score of 4 or 5 was defined as significant patient discomfort.

Statistical analysis

Statistical analyses were performed using IBM SPSS statistical software package version 28 (Armonk, NY). Data were exported from the Trans.IT in comma-separated files and imported in SPSS statistical software. Categorical variables were reported as frequencies (%) and non-parametric data as medians with interquartile ranges [IQR]. The Chi-square test or Fisher's Exact test were used for categorical and dichotomous variables. A 2-sided $p < 0.05$ was considered statistically significant.

Univariate logistic regression was performed to identify variables (bisacodyl use, bowel preparation volume, gender, age, split-dose preparation, GCS, American society of Anesthesiology (ASA) classification, BBPS and year of endoscopy) associated with adequate BBPS or patient discomfort during endoscopy. Variables with a p-value of <0.2 in univariate analysis were included in the multivariate logistic regression model to identify independent variables associated with an adequate BBPS or significant patient discomfort. Bisacodyl was purposefully included in the multivariate model to further assess its effects. Outcomes were reported using odds ratios (OR) and 95% confidence intervals (CI).

Ethical considerations

Collecting patient data in the Trans.IT database has been approved by the privacy officer of the Erasmus Medical Center in accordance with the Dutch Personal Data Protection Act. All patient data is

anonymously stored in a secure environment and therefore exempt from approval by the Medical Ethical Committee. All included hospitals provided written consent for participation.

RESULTS

Dataset

When this study was performed, data from 15 centers were available in the database, comprising 40,953 CRC colonoscopies performed between January 2016 and December 2020. We excluded 1911 endoscopy procedures because either the BBPS score could not be calculated (676, 1.7%) or information on the type of bowel preparation was not available (1235, 3.0%), resulting in 39,042 colonoscopy procedures included in the final analysis.

Characteristics

Patient characteristics and endoscopy details are shown in Table 1. Median age of patients at the time of colonoscopy was 65 years [IQR 59–71 years], with 42.2% of colonoscopies performed in females. The most prevalent ASA classification was ASA 2 with 66.7% of endoscopies performed in patients with an ASA classification of 2. In 5775 (14.8%) procedures, patients had received a 4L regimen as bowel preparation, whereas a 2L preparation or *a* ≤1L preparation (SPMC in 14,588 cases, OSS in 754 cases and 1L PEG with sodium sulfate and ascorbic acid in 1086 cases) were prescribed in 17,452 (44.7%) and 15,815 (40.5%) patients, respectively. In 99.1% of cases (n = 38,701), patients were instructed to drink half of the bowel preparation on the day before and the other half on the day of colonoscopy (split-dose).

Colonoscopy outcomes

The ESGE performance measures stratified by preparation regimen brand are shown in Supplementary Tables 1 and Supplementary Table 2. ASA classification is shown in Table 2. The BBPS score, CIR, ADR and PDR for 4L, 2L and ≤1L regimens all met the minimum standards of the individual ESGE performance measures. Nonetheless, differences were found between the absolute scores of the individual performance measures between the different bowel preparation regimens. In more detail, 2L regimens had a higher rate of adequate BBPS (98.0%) versus 4L (97.1%) and ≤1L regimens (97.0%) ($p < 0.001$), while CIR was higher for ≤1L (98.4%) versus 4L (97.7%) and 2L (97.9%) regimens ($p = 0.001$), ADR higher for ≤1L (60.0%) and 2L (61.2%) versus 4L (58.6%) regimens ($p < 0.001$) while PDR was also higher for ≤1L (70.0%) and 2L (70.8%) versus 4L

TABLE 1 Patient characteristics and endoscopy characteristics.

Details	N of colonoscopies = 39,042	ASA 1 N = 9636 (24.7%)	ASA 2 N = 26,029 (66.7%)	ASA 3 N = 3093 (7.9%)	ASA 4 N = 49 (0.1%)
Patient characteristics					
Gender (female), % (*n*)	42.2 (16,457)	40.9 (3944)	43.0 (11,200)	38.9 (1202)	49.0 (24)
Age in years, median [IQR]	65 [59–71]	61 [58–67]	66 [61–71]	68 [63–73]	67 [61–71.5]
Bowel preparation details					
4L bowel regimen, % (*n*)	14.8 (5775)	15.4 (1483)	13.8 (3604)	20.6 (637)	30.6 (15)
2L bowel regimen, % (*n*)	44.7 (17,452)	46.7 (4500)	44.6 (11,614)	37.8 (1169)	34.7 (17)
≤1 bowel regimen, % (*n*)	40.5 (15,815)	37.9 (3653)	41.5 (10,811)	41.6 (1287)	34.7 (17)
SPMC	35.8 (13,975)	35.1 (3386)	36.5 (9509)	33.2 (1027)	22.4 (11)
1L PEG	2.8 (1086)	1.3 (129)	2.9 (746)	6.7 (206)	10.2 (5)
OSS	1.9 (754)	1.4 (138)	2.1 (556)	1.7 (54)	2.0 (1)
Bisacodyl usage, % (*n*)	62.6 (24,441)	67.4 (6494)	61.4 (15,978)	59.7 (1846)	46.9 (23)
Split-dose preparation, % (*n*)	99.1 (38,701)	98.9 (9530)	99.3 (25,846)	98.4 (3044)	100.0 (49)
ASA classification					
ASA 1, % (*n*)	24.7 (9636)				
ASA 2, % (*n*)	66.7 (26,029)				
ASA 3, % (*n*)	7.9 (3093)				
ASA 4, % (*n*)	0.1 (49)				

Abbreviations: ASA, American society of Anesthesiology; OSS, Oral sulphate solution; PEG, polyethylene glycol; SPMC, sodium picosulfate with magnesium citrate.

TABLE 2 European Society of Gastrointestinal Endoscopy (ESGE) performance measures stratified by bowel preparation volume and American society of Anesthesiology (ASA) classification.

ESGE performance measure (minimum standard)	BBPS ≥6 (minimum standard 90%)	Cecal intubation rate (CIR) (minimum standard 90%)	Adenoma detection rate (ADR) (minimum standard 25%)	Polyp detection rate (PDR) (minimum standard 40%)
4L bowel regimen, % (*n*)	97.1 (5606)	97.7 (5643)	58.6 (3384)	67.2 (3879)
2L bowel regimen, % (*n*)	98.0 (17,108)	97.9 (17,088)	61.2 (10,685)	70.8 (12,359)
≤1 bowel regimen, % (*n*)	97.0 (15,335)	98.4 (15,557)	60.0 (9485)	70.0 (11,066)
All procedures, % (*n*)	97 0.5 (38,049)	98.1 (38,288)	60.3 (23,554)	69.9 (27,304)
ASA classification 1 + 2 *N* = 35,665 (91.4%)				
4L bowel regimen, % (*n*)	97.5 (4962)	97.9 (4980)	57.9 (2947)	66.7 (3391)
2L bowel regimen, % (*n*)	98.3 (15,842)	98.1 (15,804)	61.4 (9887)	71,0 (11,440)
≤1 bowel regimen, % (*n*)	97.2 (14,065)	98.4 (14,234)	59.5 (8606)	69.6 (10,061)
All procedures, % (*n*)	97.8 (34,869)	98.2 (35,018)	60.1 (21,440)	69.8 (24,892)
ASA classification 3 + 4 *N* = 3142 (8.1%)				
4L bowel regimen, % (*n*)	93.3 (608)	96.3 (628)	63.5 (414)	71.2 (464)
2L bowel regimen, % (*n*)	94.8 (1124)	96.0 (1138)	58.9 (698)	68.0 (806)
≤1 bowel regimen, % (*n*)	93.9 (1224)	97.9 (1276)	65.5 (854)	74.8 (975)
All procedures, % (*n*)	94.1 (2956)	96.8 (3042)	62.6 (1966)	71.5 (2245)
Patient discomfort				
Patient with no significant discomfort, % (*n*)	97.6 (37,183)	98.5 (37,535)	60.5 (23,042)	70.1 (26,706)
Patients with significant discomfort, % (*n*)	92.3 (866)	80.3 (753)	54.6 (512)	63.8 (598)

Abbreviations: ASA, American society of Anesthesiology; BBPS, Boston bowel preparation scale.

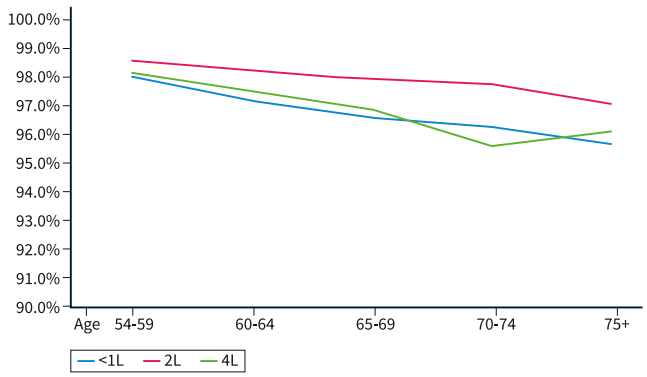

FIGURE 1 The rate of adequate bowel preparation stratified by age and bowel preparation regimen.

(67.2%) regimens ($p < 0.001$). Adequate bowel preparation rates stratified by age and bowel preparation regimen are shown in Figure 1.

Effect of bisacodyl use

The effects of the addition of bisacodyl to the bowel preparation strategy are shown in Table 3. In contrast to higher volume regimens, adequate bowel preparation rate in <1L regimens depended on whether or not bisacodyl was added (97.3% vs. 95.6%, respectively, $p \leq 0.001$).

Predictive factors for adequate bowel preparation

Univariate and multivariate logistic regression analyses were performed to identify predictive factors for adequate bowel preparation (Table 4). Bisacodyl use (OR = 1.20, CI = 1.04–1.38) and 2L regimens (OR = 1.48, CI = 1.22–1.79) were independently associated with higher odds for achieving adequate bowel preparation. In contrast, male gender (OR = 0.76, CI = 0.66–0.86), age (increment per year, OR = 0.97, CI = 0.96–0.99), significant discomfort (OR = 0.28, CI = 0.22–0.36) and ASA classification 2 (OR = 0.62, CI = 0.52–0.75), ASA classification 3 (OR = 0.28, CI = 0.22–0.35) and ASA classification 4 (OR = 0.29, CI = 0.09–0.95) were independently associated with lower odds for achieving adequate bowel preparation.

Patient discomfort

The occurrence of patient discomfort (GCS score 4 or 5) with the addition of bisacodyl to the bowel preparation strategy is shown in Table 3. When comparing patient discomfort with different bowel

TABLE 3 Rates of adequate bowel preparation and rates of significant patient discomfort with or without bisacodyl use per bowel preparation volume

Bowel preparation volume	Without bisacodyl use *N* = 14,601	With bisacodyl use *N* = 24,441
	Adequate bowel preparation	Adequate bowel preparation
4L bowel regimen, % (*n*)	96.8 (1819)	97.2 (3787)
2L bowel regimen, % (*n*)	98.0 (9660)	98.1 (7448)
≤1 bowel regimen, % (*n*)	95.6 (2738)	97.3 (12,597)
All procedures, % (*n*)	97.4 (14,217)	97.5 (23,832)
	Significant patient discomfort	Significant patient discomfort
4L bowel regimen, % (*n*)	2.4 (45)	4.7 (185)
2L bowel regimen, % (*n*)	1.7 (163)	2.4 (180)
≤1 bowel regimen, % (*n*)	2.1 (60)	2.4 (305)
All procedures, % (*n*)	1.8 (268)	2.7 (670)

preparation regimens, patient discomfort was 4.7% with 4L regimens combined with bisacodyl versus 2.4% with 4L regimens without bisacodyl ($p < 0.001$). For 2 L regimens, discomfort was rated as 2.4% with the addition of bisacodyl compared to 1.7% without the addition of bisacodyl ($p < 0.001$). No significant differences in patient discomfort were found between ≤1L regimens with or without bisacodyl (2.4% vs. 2.1%, respectively).

Predictive factors for patient discomfort

Univariate and multivariate logistic regression analyses were also performed to identify predictive factors for patient discomfort (Table 4). Bisacodyl use (OR = 1.47, CI = 1.26–1.72) was independently associated with higher odds for significant patient discomfort. On the other hand, male gender (OR = 0.48, CI = 0.42–0.55), adequate bowel preparation (OR = 0.29, CI = 0.22–0.37), and 2L bowel regimens and 1L bowel regimens compared with 4L bowel regimens (OR = 0.55, CI = 0.46–0.65 and OR = 0.54, CI = 0.45–0.64, respectively), were independently associated with lower odds for significant patient discomfort.

DISCUSSION

In this nationwide Dutch prospective endoscopy database study, we evaluated the efficacy and compliance to ESGE performance measures of different volumes of bowel preparation strategies, with or without bisacodyl use, in CRC colonoscopies. Irrespective of the volume, bowel preparation was adequate in over 97% of patients. All bowel preparation regimens therefore met the minimum ESGE performance measures standards, including bowel preparation, CIR, ADR and PDR. The small but statistically significant differences between different bowel preparation regimens for some of the performance measures should therefore be considered as negligible regarding clinical relevance. An interesting finding was that the addition of bisacodyl to the bowel preparation strategy only improved bowel cleansing results when it was added to ultra-low volume regimens. Ultra-low volume regimens combined with bisacodyl performed as well as high- and low-volume regimens without bisacodyl. On the other hand, the addition of bisacodyl was independently associated with a higher risk of patient discomfort during colonoscopy.

In contrast to a recent meta-analysis, we showed that the ESGE quality standard requirement for adequate bowel preparation was also met with an ultra-low volume regimen.[14] The efficacy of ultra-low volume bowel preparation regimens in this meta-analysis was evaluated in 13,222 patients. Bowel preparation with SPMC and 1L-PEGA was found to be adequate in only 75.2% and 82.9% of patients, respectively. The meta-analysis was based on 43 studies with smaller sample sizes compared to our study and originated from various Asian and European countries. Furthermore, the included studies had variable bowel preparation outcomes. As recognized by the authors, the heterogeneity in this meta-analysis may have negatively impacted the assessment of bowel preparation quality. Our study comprises a large uniformly documented dataset, which allows a more reliable assessment. Another possible explanation for the difference in bowel preparation outcomes between the meta-analysis and our study could be the organized setting of the Dutch national screening program. If patients in the Dutch screening program are invited for colonoscopy after a positive fecal immunochemical test (FIT), they receive detailed instructions on the importance of an adequate bowel preparation by a dedicated nurse. These consultations are likely a positive contributor to increased patient compliance leading to an adequate bowel preparation.

A study assessing the impact of an ultra-low volume regimen with SPMC versus a high volume regimen on participation rates and bowel preparation quality in the Polish national screening program found a lower bowel preparation quality when ultra-low volume bowel preparations were used.[12] However, of the 13,621 individuals

TABLE 4 Results of univariate and multivariate analysis to identify predictive factors for adequate bowel preparation and for significant patient discomfort

	Univariate		Multivariate		
Adequate bowel preparation	**OR**	**CI**	**OR**	**CI**	***P* value**
Bisacodyl	1.06	0.93–1.20	1.20	1.04–1.38	0.01
Bowel preparation type (4L bowel regimen = 1)					
2L bowel regimen	1.50	1.24–1.81	1.48	1.22–1.79	<0.001
1L bowel regimen	0.96	0.81–1.15	0.89	0.74–1.06	0.19
Male	0.78	0.68–0.88	0.76	0.66–0.86	<0.001
Age (increment per year)	0.96	0.95–0.97	0.97	0.96–0.99	<0.001
Split-dose	1.67	0.97–2.85			
GCS ≥4	0.30	0.23–0.38	0.28	0.22–0.37	<0.001
ASA classification (ASA 1 = 1)					
ASA 2	0.56	0.47–0.67	0.62	0.52–0.75	<0.001
ASA 3–4	0.23	0.19–0.29	0.28	0.22–0.35	<0.001
Year of endoscopy	0.98	0.93–1.03			
Significant patient discomfort					
Bisacodyl	1.51	1.31–1.74	1.47	1.26–1.71	<0.001
Bowel preparation type (4L bowel regimen = 1)					
2L bowel regimen	0.48	0.41–0.57	0.55	0.46–0.65	<0.001
1L bowel regimen	0.57	0.48–0.67	0.54	0.45–0.64	<0.001
Male	0.48	0.42–0.55	0.48	0.42–0.55	<0.001
Age (increment per year)	1.00	0.99–1.01			
Split-dose	1.02	0.50–2.05			
BBPS ≥6	0.30	0.23–0.38	0.29	0.22–0.37	<0.001
ASA classification (ASA 1 = 1)					
ASA 2	1.04	0.89–1.2			
ASA 3–4	1.16	0.90–1.50			
Year of endoscopy	0.96	0.91–1.01			

Abbreviations: ASA, American society of anesthesiology; BBPS, Boston bowel preparation scale; CI, confidence interval; GCS, Gloucester comfort score; OR, odds ratio.

included, bowel preparation quality was assessed in only 2456 individuals. The proportion of adequate bowel preparation was found to be 79.0% in ultra-low volume users versus 86.4% in high-volume bowel preparation users. Interestingly, another study assessing ESGE performance measures in the Polish national screening program in 43,277 individuals used data from the same period and found a higher overall adequate bowel preparation rate of 91.3% (including ultra-low volume and high volume bowel preparation regimens).[20] These conflicting results likely suggest that for adequate assessment of bowel preparation quality, a higher number of individuals need to be included. The CIR of 97.4% in Poland is on par with our study, while the ADR of 29.8% was lower in the Polish national screening program. Nonetheless, the latter finding can likely be explained by the fact that patients in the Dutch screening program are selected for colonoscopy after a positive preceding FIT, while the Polish national screening program is based on a colonoscopy without a preceding FIT.

In our study, we noticed that bisacodyl improves the preparation results of ultra-low volume regimens. Bisacodyl use was also independently associated with a higher likelihood of adequate bowel preparation. However, we found the effect of adding bisacodyl to high- and low-volume regimens to be limited with regard to improving bowel preparation quality. Several studies comparing 4L PEG with 2L PEG plus bisacodyl also found no significant differences in bowel cleansing efficacy but concluded that patient tolerability was better with a 2L regimen with bisacodyl than with a 4L

regimen.[21–23] A study comparing the 2L PEG with 2L PEG plus bisacodyl found similar cleansing effects, but in this study, patient tolerability was not different.[24] There are only limited data on the efficacy and patient impact of 'ultra-low' volume regimens with or without bisacodyl. Two studies comparing 1L-PEG plus ascorbic acid with bisacodyl and 2L-PEG plus ascorbic acid alone found no significant differences in adequate bowel preparation and tolerability, but no comparison was made between 1L-PEG with or without bisacodyl.[25,26] Based on our findings, we recommend adding bisacodyl only to ultra-low volume bowel regimens to improve overall bowel preparation quality in clinical practice.

Interestingly, we found that bisacodyl use was associated with a higher likelihood of patient discomfort during colonoscopy. This was an unexpected finding. Normally, per procedural patient comfort is related to the level of sedation and difficulty of colonoscopy.[27] A deeper level of sedation should provide more pain control and anxiolysis. A possible explanation for our observation could be that this is due to selection bias. The group of patients that received bisacodyl may well have received this for a reason, such as a history of abdominal surgery, obstipation, prior difficulties with bowel preparation, or another reason, which are well-known reasons for discomfort during colonoscopy. Unfortunately, this information was not available in our study.

In 99.1% of colonoscopies, a split-dose bowel preparation regimen was prescribed. It has been shown that split-dose regimens provide superior bowel cleansing compared to day-before bowel cleansing regimens, regardless of the type of medication used.[28–30] The ESGE also recommends split-dose bowel preparation for elective colonoscopies.[8] Although we presume that the high rate of split-dose regimens in this study likely contributes to the high quality of bowel cleansing, we were not able to perform a formal comparison between day-before and split-dose preparations due to the low case number with the former strategy.

A strength of this study is that it is based on a large, unselected dataset using daily clinical practice data of 15 hospitals. Second, due to the mandatory registration of colorectal screening colonoscopies, the overall quality of the data is high with only a small percentage of incomplete reports (less than 5% incomplete). However, some limitations need to be mentioned as well. First, there was no information available regarding patient comfort during bowel preparation, the willingness to repeat endoscopy or patient compliance with the bowel preparation regimen. Second, as patients took bowel preparation at home, there was no information on whether complete intake of the bowel preparation solution was achieved, and incomplete intake could have affected bowel preparation results. Third, data on patient characteristics were limited. Due to restrictions by the Dutch General Data Protection Regulation law, data on patient ethnicity and socioeconomic status, among others, could not be collected. Also, information on whether patients were admitted or were treated as outpatients was not available. Fourth, not all types of bowel preparation medications that are currently available could be evaluated as they are not all available in the Netherlands. Other types of bowel preparation regimens could have resulted in different outcomes. Moreover, the group of 1L-PEG consisted of only 1086 patients and the group of OSS consisted of only 754 patients. More studies are needed to truly assess the efficacy of bowel preparation in this group.

In addition to comparing different bowel preparation regimes, it is important to consider the role of patient education and compliance in achieving adequate bowel preparation. Patient education and compliance are crucial for successful bowel preparation as they ensure that patients understand the instructions for their specific bowel preparation and follow them correctly. In our study, efforts were made to ensure patient understanding and compliance by providing detailed instructions for the specific preparation regimen assigned to each patient. These efforts are likely to be a large contributor to our positive results. However, we acknowledge that in daily clinical practice, patient education and compliance may not be consistent, and the level of patient guidance is hard to monitor. The true influence of patient guidance on our results is therefore hard to determine, but it is important for clinicians to consider the role of patient education and compliance when implementing bowel preparation protocols in their practice. Future studies should consider incorporating measures of patient education and compliance in daily clinical practice to provide a more comprehensive understanding of the factors that contribute to successful bowel preparation.

In conclusion, 4L, 2L and ≤1L bowel preparation regimens are all effective in meeting the ESGE minimum performance measure standards. The choice for either bowel preparation volume could therefore be based on volume-tolerance and preference of patients. The addition of bisacodyl should only be considered when an ultra-low volume regimen is used or is dependent on specific patient factors.

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CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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