



Improving the quality and acceptance of colonoscopy preparation by reinforced patient education with short message service: results from a randomized, multicenter study (PERICLES-II)

Benjamin Walter, MD,¹ Peter Klare, MD,² Katharina Strehle,² Jens Aschenbeck, MD,³ Leopold Ludwig, MD,⁴ Nektarios Dikopoulos, MD,⁴ Martina Mayr, MD,⁵ Bruno Neu, MD,⁵ Alexander Hann, MD,¹ Benjamin Mayer, PhD,⁶ Alexander Meining, MD,¹ Stefan von Delius, MD⁷

Ulm, Germany

Background and Aims: Sufficient bowel preparation is crucial for successful screening and surveillance colonoscopy. However, the rates of inadequate preparation are still high. We investigated the effects of reinforcing patient education and guidance by using the short message service (SMS).

Methods: In this prospective, endoscopist-blinded, multicenter study, standard instructions pertaining to split-dose preparation were provided in a verbal and written format to all patients during the initial appointment. Patients were randomly assigned (1:1) to a group that received reinforced education starting 4 days before the colonoscopy (SMS group) or to the control group which did not receive further education. The primary outcome was the percentage of insufficient preparation results (Boston Bowel Preparation Scale [BBPS] score <6). The secondary outcomes included quality of bowel preparation according to the BBPS, polyp and adenoma detection rates, and patients' perceived discomfort in the preparation procedure.

Results: The percentage of patients with insufficient bowel preparation was significantly lower in the SMS group (9%) than in the control group (19%) ($P = .0013$). The mean BBPS score was significantly higher in the SMS group (7.4 ± 0.1) than in the control group (6.5 ± 0.1) ($P < .0001$). Each colon segment had significantly higher BBPS scores in the SMS group. The adenoma detection rate and number of detected adenomas in the right segment of the colon were higher in the SMS group. SMS messages were accompanied by a lower level of discomfort during preparation (numeric rating scale) (5.2 SMS vs 5.8 controls) ($P = .0042$).

Conclusions: Reinforced patient education by using SMS messages during the 4 days before colonoscopy increased bowel cleanliness, adenoma detection in the right segment of the colon, and reduced discomfort. (Clinical trial registration number: NCT02272036.) (Gastrointest Endosc 2019;89:506-13.)

Abbreviations: ADR, adenoma detection rate; BBPS, Boston Bowel Preparation Scale; CRC, colorectal cancer; NRS, numeric rating scale; PDR, polyp detection rate; SMS, short message service.

DISCLOSURE: B.M. Walter received funding for this study from Gesellschaft für Gastroenterologie in Bayern. All other authors disclosed no financial relationships relevant to this publication.

See CME section; p. 625.



Use your mobile device to scan this QR code and watch the author interview. Download a free QR code scanner by searching "QR Scanner" in your mobile device's app store.

Copyright © 2019 by the American Society for Gastrointestinal Endoscopy 0016-5107/\$36.00

<https://doi.org/10.1016/j.gie.2018.08.014>

Received April 9, 2018. Accepted August 9, 2018.

Current affiliations: Klinik für Innere Medizin I, Universitätsklinik Ulm, Ulm (1), II. Medizinische Klinik und Poliklinik, MRI der TU München, München (2), Gastroenterologische Praxis, Berlin (3), Gastroenterologische Schwerpunktpraxis, Dornstadt (4), Medizinische Klinik II, Krankenhaus Landshut-Achdorf, Landshut (5), Institut für Epidemiologie und Medizinische Biometrie, Universitätsklinik Ulm, Ulm (6), Medizinische Klinik II, RoMed Klinikum Rosenheim, Rosenheim, Germany (7).

Reprint requests: Benjamin M. Walter, MD, Klinik für Innere Medizin I, Universitätsklinik Ulm, Albert-Einstein-Allee 23, 89081 Ulm, Germany.

Colorectal cancer (CRC) is a leading cause of cancer morbidity and mortality in Europe and the United States.¹ The combination of a well-defined precursor lesion and a long preclinical course makes CRC an ideal candidate for cancer prevention screening.^{2,3} Unfortunately, low participation rates in CRC screening programs worldwide remain a major concern for the efficiency of fighting CRC.^{3,4} Especially with regard to the preparation for colonoscopy, even the recommended split-dose preparation these days is perceived as a major impediment to undergoing colonoscopy.^{5,6} Nevertheless, sufficient bowel preparation is the cornerstone for successful colonoscopy in terms of diagnostic accuracy, procedural safety, and cost effectiveness.^{7,8}

Although the quality of bowel preparation is influenced by various factors, it depends largely on patients' compliance regarding instructions about purgatives and diet.⁹ The main discomfort reported by the patients relates to uncertainties regarding dealing with the dietary recommendations and adverse GI symptoms owing to using the burdensome amounts of purgatives.^{6,10} Hence, it is not surprising that inadequate bowel preparation is reported in up to 25% of all patients undergoing colonoscopy.¹¹

Patient education and guidance is therefore a valuable tool that enables patients to follow the bowel preparation instructions accurately.^{9,12} Different methods and tools of better education concerning bowel preparation, with a focus on purgative intake, have been tested. However, they have had inconsistent and complex results regarding implementation in medical practice.¹³⁻²²

Globally, a rapidly increasing number of individuals use mobile phones in their daily lives. There have been efforts to apply this new technology to patient education. At present, the use of SMS still represents the most well-established and widely used data application worldwide.²³ Text messaging is inexpensive, with a low demand for resources and can be sent automatically.¹⁴

Until now, studies surrounding improving colonoscopy preparation have focused mostly on bowel purgatives alone.^{15,17} The impact of direct patient guidance via mobile phones remains unclear. The aim of this prospective multicenter study (PERICLES II; Prospective study for improvement of colonoscopy bowel preparation procedure by software supported visualization) was therefore to evaluate the impact of 4-day guidance by SMS on the rate of sufficient bowel preparation, quality of bowel preparation, patient discomfort, and polyp and adenoma detection.

MATERIALS AND METHODS

Study design

A prospective, endoscopist-blinded, randomized, multicenter study was conducted at 2 tertiary-care hospitals and 2 gastroenterology care centers in Germany between December 2015 and January 2017. Individuals aged >18

years with scheduled outpatient colonoscopy were enrolled. Cases of pregnancy, impaired mental status, severely compromised medical status, American Society of Anesthesiologists Physical Status Classification System class III and higher, inability to use a mobile phone, and individuals who declined participation were excluded from the trial.

The study was approved by the institutional review board and ethics committee of the Technische Universität München and was registered at [ClinicalTrials.gov](https://www.clinicaltrials.gov) (NCT02272036). Written informed consent was obtained from all patients. All authors had access to study data, and they reviewed and approved the final manuscript.

Assignments and blinding

A computerized random number table was used. The scheduled study participants were randomized 5 days before the colonoscopy. Patients were allocated to 1 of the following 2 groups: the control group, which received standard education for bowel preparation, and the SMS group, which received standard education and reinforcement reminders on diet and purgative intake starting 4 days before the colonoscopy. All members of staff involved in the colonoscopy procedure were unaware of the education allocation. Patients were asked not to mention their study allocations to the endoscopists.

Bowel preparation and patient education

All patients were prescribed a standard split-dose preparation regimen based on 2 L polyethylene glycol plus ascorbic acid (Moviprep; Norgine Pharma, Harefield, Uxbridge, England). All patients were instructed to start a low-fiber diet 3 days before the colonoscopy, and they were asked to drink at least 2 L of additional clear liquids after ingestion of the purgative.

Standard instructions were given verbally to all patients during the initial preparation appointment and they were provided in a written format ([Appendix 1](#), available online at www.giejournal.org). The control group received no further education. The SMS group received reinforced education spanning a period of 4 days before the scheduled colonoscopy. The characters of the reinforced education messages were shorter and more concise than the standard instructions because of the limitation of 160 signs per SMS. In total, the patients received 15 SMS messages ([Appendix 2](#), available online at www.giejournal.org).

SMS system

A system to send repeated text-message reminders with instructions for each step of the colonoscopy preparation process was created (provided by smartpatients.eu, Munich, Germany).²⁴ The contents of the SMS instructions mainly focused on dietary restrictions and adequate timing of purgative intake ([Appendix 2](#), [Supplementary Fig. 1](#), [Appendix 1](#), available online at www.giejournal.org). The SMS messages were free of charge for the study participants. In case of postponement of the

TABLE 1. Baseline characteristics of study population

Characteristic	Control* (n = 247)	SMS† (n = 248)	P value
Age, mean (± SD), y	47.2 (14.8)	47.5 (13.6)	.7919
Sex, no. (%)			.4189
Male	116 (47%)	126 (51%)	
Female	131 (53%)	122 (49%)	
Marital status, no. (%)			.3492
Single/widowed	32 (13%)	39 (15%)	
Married/partnership	204 (85%)	213 (84%)	
No data	4 (2%)	3 (1%)	
Medical insurance, no. (%)			.8516
Statutory	234 (95%)	234 (94%)	
Private	13 (5%)	14 (5%)	
ASA class, no. (%)			.2252
I	127 (51%)	114 (46%)	
II	120 (49%)	134 (54%)	
BMI, mean (± SD), kg/m ²	25.4	25.6	.8135
Prior colonoscopy, no. (%)			.2271
No	144 (58%)	158 (64%)	
Yes	101 (41%)	87 (35%)	
No data	2 (1%)	3 (1%)	
History of abdominopelvic surgery, no. (%)	25 (10%)	28 (11%)	.6741
Chronic constipation, no. (%)	2 (0.7%)	2 (0.8%)	.9968
Diabetes, no. (%)	13 (5%)	10 (4%)	.5154
Opioid use, no. (%)	2 (0.8%)	3 (1.2%)	.6564
Colonoscopy indication, no. (%)			
CRC screening	58 (23%)	67 (27%)	
Diagnostic, surveillance	133 (54%)	116 (47%)	
IBD	19 (8%)	21 (8%)	
Other	37 (15%)	44 (18%)	
Withdrawal time, min	7.7 ± 0.07	7.8 ± 0.07	.1919
Colonoscopy time, min (scope in to scope out)	26.3 ± 1.3	25.8 ± 2.5	.6312

SMS, Short message service; SD, standard deviation; ASA, American Society of Anesthesiologists Physical Status Classification System; BMI, body mass index; CRC, colorectal cancer; IBD, inflammatory bowel disease.

*Control, standard colonoscopy preparation.

†SMS, SMS-reinforced colonoscopy preparation.

appointment, participants retained their original study assignments. For those assigned to the SMS group, messages were sent for the new appointment.

Assessments

Variables known to influence the result of the bowel preparation, such as marital status, health insurance, body mass index, prior colonoscopy, history of abdominopelvic surgery, chronic constipation, diabetes, and regular opioid use were assessed.

On the day of colonoscopy, patients returned a questionnaire in a closed envelope, providing information regarding whether the SMS messages were received or not, the subjective grade of discomfort during colonoscopy preparation, and

whether the messages were perceived as helpful (if applicable) or as a hindrance. The latter 2 responses were obtained by using the numeric rating scale (NRS). The burden of preparation was qualified on a scale of 1 (very low) to 10 (extremely high). Perception of the messages' helpfulness was qualified on a scale of 1 (not helpful) to 10 (very helpful). Perception of the messages as a hindrance was qualified on a scale of 1 (no hindrance) to 10 (big hindrance).

Colonoscopy

The Boston Bowel Preparation Scale scoring system²⁵ (BBPS) was introduced to the participating endoscopists before the initiation of the study. All colonoscopies were performed by experienced endoscopists (experience with

>1000 colonoscopies). Overall, 11 endoscopists participated in the study. Scope-in to scope-out time and withdrawal time were measured. The BBPS score was calculated directly after the colonoscopy was performed by the respective endoscopist. Each of the 3 segments of the colon (right, including the cecum and ascending colon; transverse, including the hepatic and splenic flexures; and left, including the descending colon, sigmoid colon, and rectum) was assigned a score from 0 to 3, defined as follows: 0, unprepared colon segment with mucosa barely seen because of solid stool that cannot be cleared; 1, portion of mucosa of the colon segment seen but other areas of the colon segment not seen well because of staining, residual stool, or opaque liquid; 2, minor amount of residual staining, small fragments of stool and/or opaque liquid, but mucosa of the colon segment seen well; 3, entire mucosa of the colon segment seen well with no residual staining, small fragments of stool, or opaque liquid.²⁵ An instructional video was provided online for additional training.

The threshold for determining inadequate and adequate bowel preparation was defined as ≥ 6 , based on the recommendation for performance measures for lower-GI endoscopy by the European Society of Gastrointestinal Endoscopy.²⁶ Sedation of the patients was performed by using propofol. Application of a second sedation agent, such as midazolam, was possible, if necessary. Detected polyps >5 mm were resected according to the German endoscopy guidelines by snare, with or without submucosal injection (saline solution-assisted polypectomy) by using the cut-and-coagulation technique. Polyps <5 mm were resected by using forceps or snare by using the cold-snare technique. A histopathologic analysis was performed by local pathologists on the removed polyps. In order to enhance comparability, given potential variation in bowel preparation quality by time of day, all colonoscopies were performed between 8 AM and 1 PM.

End points

The primary endpoint was the percentage of insufficient bowel preparation quality. The secondary endpoints included bowel preparation as rated by the endoscopist with the use of the BBPS and the number of detected polyps in the right and left segments of the colon. The polyp detection rate (PDR), adenoma detection rate (ADR), and advanced ADR were respectively calculated. Advanced adenomas are defined as adenomas with an endoscopic size ≥ 10 mm, high-grade dysplasia, or villous features.²⁷ The PDR for CRC screening patients was calculated, defined as the number of patients with at least 1 polyp divided by the total number of screening patients.^{27,28} ADR, defined as the number of patients with at least 1 adenoma divided by the total number of CRC screening patients, was calculated.

Patients' subjective perceived discomfort and/or burden regarding preparation and their perception of SMS messages as helpful or as a hindrance were assessed by using the NRS.

TABLE 2. Colonoscopy outcomes regarding bowel cleanliness measured with the Boston Bowel Preparation Scale

Colonoscopy outcome	Control (n = 247)	SMS (n = 248)	P value
Quality of preparation, no. of patients (%)			.0013
Sufficient ≥ 6	199 (81%)	225 (91%)	
Insufficient < 6	48 (19%)	23 (9%)	
BBPS, mean (SEM)	6.5 (0.1)	7.4 (0.1)	$< .0001$
BBPS for colon segments, mean (SEM)			
Left side of colon	2.3 (0.03)	2.5 (0.04)	.0001
Transverse colon	2.2 (0.05)	2.5 (0.04)	$< .0001$
Right side of colon	1.9 (0.1)	2.3 (0.04)	$< .0001$

SMS, Short message service; BBPS, Boston Bowel Preparation Scale; SEM, standard error of the mean.

Statistical analysis

Based on experience from internal quality control data, a BBPS score of < 6 was observed in 18% of outpatient colonoscopies with split-dose preparation. The rate of inadequate bowel preparation in patients with reinforced education by SMS messages was expected to be reduced from 18% to 9%. Thus, a sample size of 250 patients in each group was calculated for a statistical power of 80% at a 2-tailed significance level of 0.05. Statistical tests were performed by using SPSS version 24 (IBM, Armonk, NY, USA). The chi-square test, *t* test, and correlation analysis were used wherever applicable. Simple and linear regression was used to determine the characteristics associated with the BBPS. A *P* value of $< .05$ indicated statistical significance.

RESULTS

Overall, 500 eligible individuals were included in the study and were randomized 1:1 to 1 of the 2 study groups. Five patients canceled their colonoscopy appointments and did not reschedule them (Supplementary Fig. 2, available online at www.giejournal.org). Two patients were sent to the hospital ward in order to complete the bowel preparation before the outpatient colonoscopy. There were no significant differences between the 2 groups with regard to sex and age (Table 1). The age group of 18 to 49 years was represented by 201 study participants (control: *n* = 106, SMS: *n* = 95). Age group 50 to 65 years was represented by 240 study participants (control: *n* = 110, SMS: *n* = 130). Participants aged 66 to 77 were represented by 54 individuals (control: *n* = 31, SMS: *n* = 23). No significant differences were detectable between the 2 groups regarding further variables known to influence the result of bowel preparation (Table 1).

No serious adverse events or adverse events were reported during the study period. In the study, indications for

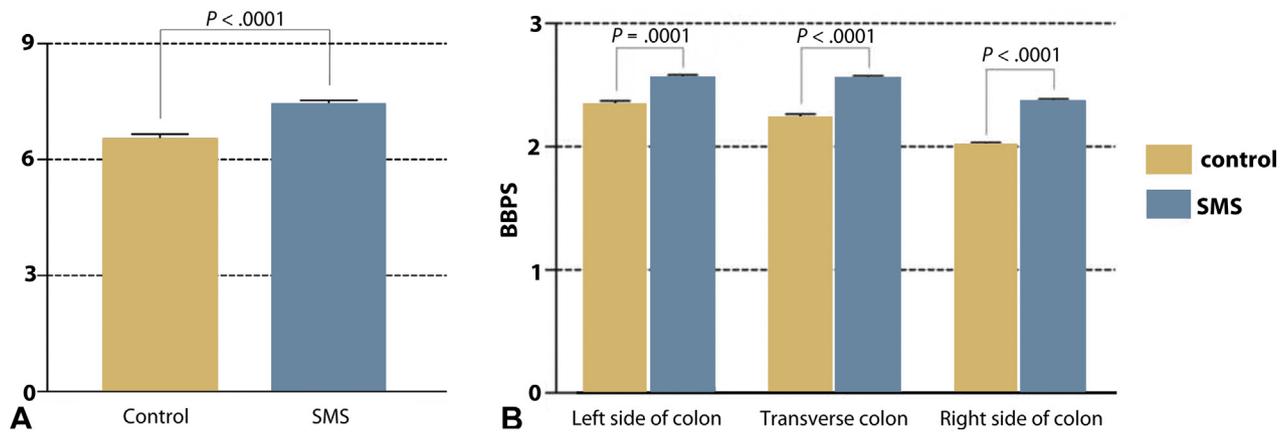


Figure 1. Bowel preparation qualities, as rated by using the Boston Bowel Preparation Scale (BBPS). **A**, Total BBPS scores. *SMS*, short message service. **B**, BBPS scores according to each segment of the colon. *BBPS*, Boston Bowel Preparation Scale; *SMS*, short message service.

TABLE 3. Simple and multiple linear regression analyses of characteristics associated with BBPS

Characteristic	Simple linear regression			Multiple linear regression		
	Coefficient (B)	95% CI	P value	Coefficient (B)	95% CI	P value
Sex	-0.33	-0.66 to -0.01	.045	-0.3	-0.62 to 0.02	.06
Age	0.001	-0.01 to 0.01	.85			
Insurance status	0.17	-0.55 to 0.88	.65			
ASA	-0.11	-0.43 to 0.22	.52			
Diabetes	0.24	-0.53 to 1.02	.54			
Opioid use	-0.64	-2.27 to 1.0	.45			
Marital status	-0.1	-0.56 to 0.37	.68			
SMS	0.83	0.51 to 1.15	< .005	0.82	0.5 to 1.14	< .005
Prior surgery	-0.14	-0.67 to 0.39	.61			
Prior colonoscopy	-0.001	-0.34 to 0.34	1.0			

CI, Confidence interval; ASA, American Society of Anesthesiologists Physical Status Classification System; SMS, short message service.

colonoscopy for the enrolled patients were mixed (CRC screening, surveillance, inflammatory bowel disease, or others) (Table 1).

COLONOSCOPY OUTCOMES

Primary outcomes

The percentage of insufficient bowel preparation (BBPS <6) was significantly lower in the SMS group as compared with the control group (9% vs 19%; $P = .0013$) (Table 2).

The SMS group showed significantly better overall bowel preparation according to the BBPS (Table 2) (Fig. 1A). With respect to the colon segments, BBPS scores were also significantly higher in the SMS group for the left, transverse, and right segments of the colon (Fig. 1B).

In order to estimate the effect of independent variables such as age, sex, or prior colonoscopy on the dependent variable BBPS, simple linear regression was performed. Subsequent multiple linear regression demonstrated that the variable coding for the intervention (SMS) was significantly

correlated with the BBPS scores. Further, multiple linear regression analyses by using all characteristics also failed to present other significant associations, except for SMS status (Table 3).

Secondary outcomes and polyp detection analysis

Overall, 247 polyps were detected within the study. A total of 154 of the polyps were identified as adenomas, 37 as advanced adenomas, and 19 as sessile serrated adenomas. The total number of adenomas detected in both groups was not significantly different. However, more sessile serrated adenomas, and more adenomas in the right segment of the colon, were detected in the SMS group (Table 4). This effect was not statistically significant. Subgroup analysis was performed for PDRs, ADRs, and advanced ADRs (Table 5). PDRs and ADRs for CRC screening patients were significantly higher in the SMS group. For patients ≥ 50 years, significantly higher combined (screening, surveillance, and diagnostic colonoscopies) PDRs and ADRs were calculated.

TABLE 4. Number and location of polyps and adenomas detected

Polyp detection	Control	SMS	P value
No. of polyps detected (n = 247)	122	125	.0805
Adenomas (n = 154)	83	71	.5230
Advanced adenomas (n = 37)	20	17	.9824
Adenoma location			.0816
Left side of colon	58	40	
Right side of colon	25	31	
Sessile serrated adenomas (n = 19)	7	12	.1780

SMS, Short message service.

Advanced ADRs were not significantly different between the 2 groups for CRC screening and combined indications ≥50 years. The quality of bowel preparation measured with the BBPS correlated significantly with the detection of adenomas ($P < .0001$) and polyps ($P < .0001$).

Questionnaire results

Questionnaires of 485 patients were analyzed (control 241, SMS 244). Patients’ subjectively perceived burden of colonoscopy preparation is presented in Figure 2. Patients with reinforced education by SMS messages perceived the colonoscopy preparation procedure significantly less as a burden (NRS mean ± SEM; control: 5.8 ± 0.1, SMS: 5.2 ± 0.1; $P = .0042$). SMS reminders were perceived as supportive by the patients (7.9 ± 0.4) and not as a hindrance during colonoscopy preparation (1.9 ± 0.1). A majority of participants in the SMS group reported that they would use SMS guidance again for their next colonoscopy (89% vs 11%).

DISCUSSION

The present study presents a positive impact of SMS-reinforced patient guidance on the results of bowel preparation for colonoscopy. According to the data, higher ADRs for CRC screening patients were detected. We also confirmed a less-subjective perceived burden of colonoscopy preparation in patients with SMS-supported colonoscopy preparation.

Thus, the results of the present study are relevant for clinical practice for several reasons. First, because colonoscopy is the criterion standard for colon cancer screening, optimal bowel preparation is mandatory for high-quality endoscopy.⁷ It could be argued that the present, polyethylene glycol-based split-dose preparation is already excellent and accepted by the patients.²⁹ However, the high rates of insufficient results for bowel preparation must be acknowledged.¹¹ The data obtained from the present study indicate a benefit of reinforced patient guidance by using SMS as an independent variable for achieving better results for colonoscopy preparation. The higher rates of improved preparation, especially with

TABLE 5. Subgroup analysis for colonoscopy outcomes regarding polyp detection, adenoma detection and detection of advanced adenoma

Age <50, y	Control	SMS	P value
Polyps (no.)	20	17	
PDR (%)	15.9	14.2	.7082
ADR (entire colon) (%)	11.9	8.3	.3541
ADR (right side of colon) (%)	3.2	0.8	.1933
Advanced ADR (%)	3.1	0.8	.1933
Age ≥50, y			
Polyps (no.)	49	72	
PDR (%)	40.5	56.2	.0129
ADR (entire colon) (%)	28.9	41.4	.0395
ADR (right side of colon) (%)	16.5	22.6	.2242
Advanced ADR (%)	11.6	12.5	.8218
CRC-screening			
Polyps (no.)	26	50	
PDR (%)	55.2	76.1	.0007
ADR (entire colon) (%)	31.0	47.8	.0351
ADR (right side of colon) (%)	12.1	26.9	.0392
Advanced ADR (%)	8.6	14.9	.2794

SMS, Short message service; PDR, polyp detection rate; ADR, adenoma detection rate; CRC, colorectal cancer.

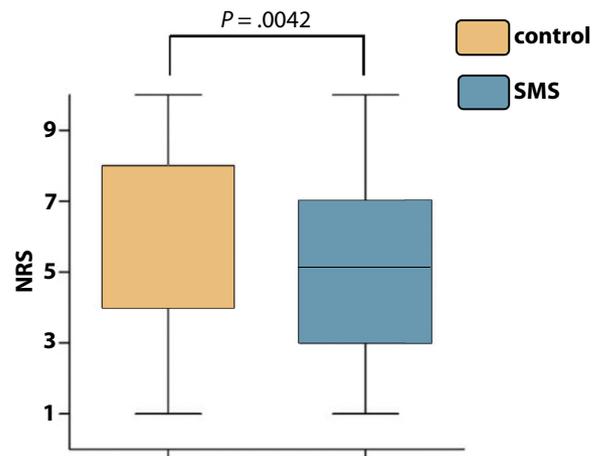


Figure 2. Comparison of patients’ subjective perceived burden of colonoscopy preparation. Numeric rating scale: 1 (no burden) to 10 (extremely high burden). SMS, Short message service; NRS, numeric rating scale.

regard to the right segment of the colon, are remarkable because this region in general remains a cause of concern for bowel preparation.^{28,30,31} These results are in accordance with a previous study conducted by Lee et al,¹⁴ who also observed a positive effect of SMS-reinforced bowel preparation in a single-center setting.

We therefore postulate that optimizing the current preparation regimen through reinforcement should be discussed before modifying a preparation regimen.

Second, the ADR is widely accepted for objective measurement of endoscopic quality in CRC screening. However, only a clean colon enables the endoscopist to visualize the full colon mucosa and increases the number of adenomas detected during colonoscopy.^{4,31,32} In this regard, we could show a higher ADR for SMS-supported bowel preparation in patients undergoing colonoscopy for CRC screening and surveillance. Additionally, a notably higher count of adenomas and sessile serrated adenomas was detected in the right segment of the colon.

Third, although it must be stated that the quality of bowel preparation can be affected by multiple factors, it is closely associated with patient compliance to purgative intake instructions and dietary recommendations.^{9,35} Thus, the acceptance of the bowel preparation procedure itself and close patient guidance are essential for optimal preparation. In this context, according to our data, SMS-supported guidance was highly effective and well-accepted. It is worth noting the main reasons for acceptance and the subjectively perceived decreased burden of preparation in the SMS group. We believe that 2 factors are relevant. First, a close 4-day guidance conveys a feeling of security and support while patients are preparing for colonoscopy. This is supported by the fact that patients perceived the SMS-based guidance, to a large extent, as helpful and not as a hindrance. Second, Chan et al³⁴ already demonstrated that the time between providing instructions to patients and the colonoscopy appointment is crucial, because instructions are forgotten over time. This forgetting underlines the importance of an easily accessible reminder system that enables patients to follow instructions more precisely and decreases the rate of misunderstanding instructions.

Regarding cost effectiveness, it could be that SMS is a tool that demands few resources and is more easily accessible to patients of all socioeconomic levels in comparison to, for example, a smart-phone application. The latter is also to be considered relevant in the context of real clinical practice.²³

The multicenter design of the study provided generalizable results; however, we acknowledge certain limitations. First, patients with indications apart from screening colonoscopy were included. This led to a relatively young mean age of patients, which could have influenced and overestimated the role of SMS guidance as the only impacting factor. Hence, the impact of SMS on first CRC screening patients alone and on elderly patients in particular must be further expanded. Second, the study presented a very high ADR for the subgroup of CRC screening patients. These findings might be classified as a partly misleading and as overestimating the effect of SMS on the ADR, because the absolute count of adenomas did not differ significantly in the study. Future studies on SMS should focus therefore on CRC screening patients to

evaluate the impact on the ADRs. Third, the adequacy rate for bowel preparation was quite low in the control group, possibly mainly based on a mixed study population. Although these data stand in line with previous studies on bowel preparation, we acknowledge that for clinical practice SMS could be a useful intervention when a very low baseline bowel preparation quality is evident.

Fourth, psychological reasons behind the decreased level of perceived burden during colonoscopy preparation with SMS support remain partly unclear, because the questionnaire did not discriminate between the abdominal side effects of the purgative and psychological aspects of discomfort. Additionally, it is not possible to discount the Hawthorne effect, because patients receiving SMS messages were more motivated to minimize symptoms they may have been experiencing. Thus, these facts must be elaborated on in further studies that use a more distinct psychological questionnaire, including, for example, an anxiety score.

As a last minor limitation, it has to be acknowledged that in this study only morning colonoscopies (until 1 PM) were included. Future studies should therefore also evaluate the effect of SMS on afternoon colonoscopies.

Conclusion

In conclusion, our study demonstrated the impact of SMS as an effective, well-accepted, and less resource-demanding tool for improving bowel preparation quality. This was associated with a higher ADR and sessile serrated adenoma detection, especially in the right segment of the colon. Hence, new media, such as SMS messages, might help close the gap of long-term patient guidance through all parts of colonoscopy preparation and might encourage more patients to participate in CRC screening.

REFERENCES

1. Brenner H, Kloor M, Pox CP. Colorectal cancer. *Lancet* 2014;383:1490-502.
2. Regula J, Rupinski M, Kraszewska E. Colonoscopy in colorectal cancer screening for detection of advanced neoplasia. *NEJM* 2006;355:1863-72.
3. Bretthauer M, Kaminski MF, Løberg M, et al. Population-based colonoscopy screening for colorectal cancer: a European randomized trial. *JAMA Intern Med* 2016;176:894-902.
4. Kaminski M, Regula J, Kraszewska E, et al. Quality indicators for colonoscopy and the risk of interval cancer. *NEJM* 2010;362:1795-803.
5. Radaelli F, Paggi S, Repici A, et al. Barriers against split-dose bowel preparation for colonoscopy. *Gut* 2017;66:1428-33.
6. McLachlan S, Clements A, Austoker J. Patient's experiences and reported barriers to colonoscopy in the screening context—a systematic review of the literature. *Patient Educ Couns* 2012;86:137-46.
7. Quintero E, Castells A, Bujanda L, et al. Colonoscopy versus fecal immunochemical testing in colorectal-cancer screening. *N Engl J Med* 2012;366:697-706.
8. Rex DK, Imperiale TF, Latinovich DR, et al. Impact of bowel preparation on efficiency and cost of colonoscopy. *Am J Gastroenterol* 2002;97:1697-700.

9. Lebwahl B, Wang T, Neugut AI. Socioeconomic and other predictors of colonoscopy preparation quality. *Dig Dis Sci* 2010;2014-20.
10. Senore C, Ederle A, Fantin A. Acceptability and side-effects of colonoscopy and sigmoidoscopy in a screening setting. *Med Screen* 2011;18:128-34.
11. Lebwahl B, Kastrinos F, Glick M, et al. The impact of suboptimal bowel preparation on adenoma miss rates and the factors associated with early repeat colonoscopy. *Clin Endosc* 2011;73:1207-14.
12. Radaelli F, Paggi S, Hassan C, et al. Split-dose preparation for colonoscopy increases adenoma detection rate: a randomised controlled trial in an organised screening programme. *Gut* 2015;1-8.
13. Kang X, Zhao L, Leung F, et al. Delivery of instructions via mobile social media app increases quality of bowel preparation. *Clin Gastroenterol Hepatol* 2016;429-35.
14. Lee Y, Kim E, Choi J, et al. Impact of reinforced education by telephone and short message service on the quality of bowel preparation: a randomized controlled study. *Endoscopy* 2015;47:1018-27.
15. Liu X, Luo H, Zhang L, et al. Telephone-based re-education on the day before colonoscopy improves the quality of bowel preparation and the polyp detection rate: a prospective, colonoscopist-blinded, randomised, controlled study. *Gut* 2014;63:125-30.
16. Lorenzo-Zuniga V, Moreno de Vega V, Marin I, et al. Improving the quality of colonoscopy bowel preparation using a smart phone application: a randomized trial. *Dig Endosc* 2015;27:590-5.
17. Park J, Kim T-O, Lee N-Y, et al. The effectiveness of short message service to assure the preparation-to-colonoscopy interval before bowel preparation for colonoscopy. *Gastroenterol Res Pr* 2015;628049.
18. Prakash S, Verma S, Mc Gowan J, et al. Improving the quality of colonoscopy bowel preparation using an educational video. *Can J Gastroenterol* 2013;27:696-700.
19. Rice SC, Higginbotham T, Dean MJ, et al. Video on diet before outpatient colonoscopy does not improve quality of bowel preparation: a prospective, randomized, controlled trial. *Am J Gastroenterol* 2016;111:1564-71.
20. Shieh T, Chen M, Chang C, et al. Effect of physician-delivered patient education on the quality of bowel preparation for screening colonoscopy. *Gastroenterol Res Pract* 2013;2013:570180.
21. Spiegel B, Talley J, Shekelle P. Development and validation of a novel patient educational booklet to enhance colonoscopy preparation. *Am J Gastroenterol* 2011;106:875-83.
22. Tae JW, Lee JC, Hong SJ, et al. Impact of patient education with cartoon visual aids on the quality of bowel preparation for colonoscopy. *Clin Endosc* 2012;76:804-11.
23. Kim H-S, Hwang Y, Lee J-H, et al. Future prospects of health management systems using cellular phones. *Telemed J e-Health* 2014;20:544-51.
24. Walter BM, Klare P, Neu B, et al. Development and testing of an automated 4-day text messaging guidance as an aid for improving colonoscopy preparation. Eysenbach G, editor. *JMIR mHealth uHealth* 2016;4:e75.
25. Calderwood AH, Jacobson BC. Comprehensive validation of the Boston Bowel Preparation Scale. *Clin Endosc* 2010;72:686-92.
26. Kaminski MF, Thomas-Gibson S, Bugajski M, et al. Performance measures for lower gastrointestinal endoscopy: a European Society of Gastrointestinal Endoscopy (ESGE) quality improvement initiative. *United Eur Gastroenterol J* 2017;5:309-34.
27. Rex DK, Ponugoti PL. Calculating the adenoma detection rate in screening colonoscopies only: Is it necessary? Can it be gamed? *Endoscopy* 2017;49:1069-74.
28. Brenner H, Altenhofen L, Kretschmann J, et al. Trends in adenoma detection rates during the first 10 years of the German screening colonoscopy program. *Gastroenterology* 2017;149:356-66.e1.
29. Martel M, Barkun AN, Menard C, et al. Split-dose preparations are superior to day-before bowel cleansing regimens: a meta-analysis. *Gastroenterology* 2015;149:79-88.
30. Anderson JC, Butterly L, Robinson CM, et al. Impact of fair bowel prep on adenoma and serrated polyp detection: data from the New Hampshire Colonoscopy Registry using a standardized preparation quality rating. *Gastrointest Endosc* 2014;80:463-70.
31. Froehlich F, Wietlisbach V, Gonvers J, et al. Impact of colonic cleansing on quality and diagnostic yield of colonoscopy: the European Panel of Appropriateness of Gastrointestinal Endoscopy European multicenter study. *GIE* 2005;61:378-84.
32. Adler A, Wegscheider K, Lieberman D, et al. Factors determining the quality of screening colonoscopy: a prospective study on adenoma detection rates, from 12 134 examinations (Berlin colonoscopy project 3, BECOP-3). *Gut* 2013;62:236-41.
33. Sherer EA, Imler TD, Imperiale TF. The effect of colonoscopy preparation quality on adenoma detection rates. *Gastrointest Endosc* 2017;75:545-53.
34. Chan W-K, Saravanan A, Manikam J, et al. Appointment waiting times and education level influence the quality of bowel preparation in adult patients undergoing colonoscopy. *BMC Gastroenterol* 2011;11:86.

Endoscopedia

Endoscopedia has a new look! Check out the redesign of the official blog of *GIE* and *VideoGIE*. Use the QR code to connect to the latest updates or visit us at www.endoscopedia.com.



APPENDIX 1. TECHNICAL DATA ON THE SMS SYSTEM

SMS technical piece

Short message service (SMS) or text message reminders from a cellular phone may improve compliance in various medical situations (Park et al¹⁷). We created a system to send repeated text message reminders with instructions for each step of colonoscopy preparation. Scheduling backwards from the appointment, we devised a system to send text message reminders with instructions for the preparation, based on absolute time in terms of days prior to the colonoscopy and relative time for the day of the procedure. With the anonymized patient information, we set up a system to automate these text message reminders. For each patient, we sent 15 different messages spanning a period from 4 days to 1 hour prior to the procedure. This system keeps track of the time prior to the patient's appointment and then the messaging algorithm generates text messages with instructions and reminders for each step of the colonoscopy preparation. The system consists of 2 subsystems: a "front-end" setup interface and a "back-end" engine. The front-end setup interface consists of a patient set-up interface, a message template interface, and the text message algorithm itself. The patient set-up interface is a 2-dimensional data set with patient information, including the phone number that will receive the notification and the time and date of the procedure. The message template interface consists of a database of 15 messages. The text message algorithm requires the input of an originator, a recipient, and the message itself. The message is taken from the message template interface, and then the algorithm is able to push this to the chosen recipient by text message when requested to do so by the back-end system. The back end consists of an event-driven system. This system consists of 2 parts, the main loop and a call-back function. The main loop is set to query the front-end system every hour for the upcoming step and to specify whether a certain patient should receive notifications. When the main loop detects an event, the call-back function is initiated. The call-back function queries the text message interface for which notification to send and then alerts the text message algorithm to send the message to the patient.

SUPPLEMENT 1. STANDARD INSTRUCTIONS FOR COLONOSCOPY PREPARATION

Four days before colonoscopy:

Please organize a pick-up for the colonoscopy appointment. You are not allowed to drive a car for 24 hours after anesthetic use.

Do not schedule any relevant appointments the day of your colonoscopy.

If you cannot keep the colonoscopy appointment, please let us know immediately.

Please do not hesitate to contact us in case of uncertainties about your medication.

Three days before colonoscopy:

Please avoid foods with seeds and fibers from now onward. (eg, grains, oatmeal, wheat bread, nuts, whole kernel corn, kiwi, melon, tomato, salad, beans).

Two days before colonoscopy:

Still avoid foods with seeds or fibers.

Please avoid high-fiber and fatty food from tomorrow.

One day before colonoscopy:

Please avoid dyed liquids like coffee, black tea, milk, red wine or colas because these interfere with bowel preparation.

Please avoid a high-fiber diet or fatty food. We recommend to avoid alcoholic beverages.

Have only a light lunch (eg, vegetable broth, chicken). You can drink clear liquids as much as you please.

Laxative intake (Moviprep) starts at 5 PM. Please follow the instructions provided.

You are asked to drink additional clear liquids, at least 2 liters.

The solution will cause frequent bowel movements (diarrhea). That does not need to worry you. This is necessary to clean the colon and remove all fecal matter. Stay near to a toilet. Get yourself comfortable, wear comfortable clothing. If you like, take something to read to the toilet.

On the day of colonoscopy:

Continue laxative intake 3 hours before your scheduled colonoscopy appointment.

You are asked to drink additional clear liquids, at least 2 liters.

The bowel movements should turn clear or yellow, without solid matter.

This indicates that your colon is likely to be ready for colonoscopy.

Stop drinking liquids at least 1 hour before the appointment.

In case of problems with laxatives or remaining fecal matter, please inform us immediately on arrival at the endoscopy unit.

After colonoscopy:

For safety reasons you will stay in the endoscopy unit until you are awake. This will take at least 2 hours.

You are not allowed to drive a car for 24 hours after anesthetic use.

Relax and avoid physically demanding activities for next 12 hours.

You are allowed to start to eat and drink after the colonoscopy. We recommend to start with a light diet.

Avoid alcoholic beverages for next 12 to 24 hours.

Your stools will normalize within the next few days.

APPENDIX 2. SMS CONTENTS FOR REINFORCED COLONOSCOPY PREPARATION. SMS INSTRUCTIONS FOR REINFORCED BOWEL PREPARATION FOR COLONOSCOPY

Four days before colonoscopy:

12:00 AM, SMS 1: Dear patient, your colonoscopy appointment is in 4 days. For optimal preparation you will get SMS as a reminder for the most important steps. This includes recommendations for diet and handling of the laxative (Moviprep).

12:01 AM, SMS 2: Checklist: Did you read your instructions already? If you prefer a sedative medication for colonoscopy, you are not allowed to drive a car afterward. Therefore please organize a pick-up service.

6:00 PM, SMS 3: If you are not able to keep the appointment or in case of any questions please don't hesitate to contact us.

Three days before colonoscopy:

7:30 AM, SMS 4: Good morning! Please avoid these foods starting now: food with seeds and fiber (eg, whole grains, kiwi, berries, tomatoes, zucchini).

Two days before colonoscopy:

7:30 AM, SMS 5: Good morning! Your appointment is in 2 days. Please continue to avoid food with seeds and fibers.

12:00 AM, SMS 6: In case of any problems with the preparation or if you can't keep your appointment, please contact us directly for a new appointment time.

4:00 PM, SMS 7: Starting tomorrow: Please avoid high fiber foods and fatty meals. Please drink only clear liquids.

One day before colonoscopy:

7:00 AM, SMS 8: Good morning! Please avoid high fiber or fatty food. You are allowed to drink water or light apple juice.

7:01 AM, SMS 9: For lunch you can have clear chicken or vegetable broth.

2:00 PM, SMS 10: At 5 PM you should start to drink the laxative Moviprep. Please follow the instructions provided.

5:05 PM, SMS 11: You have started your first liter of Moviprep. Starting now: No solid food, but lots of clear liquids—minimum 2 liters!

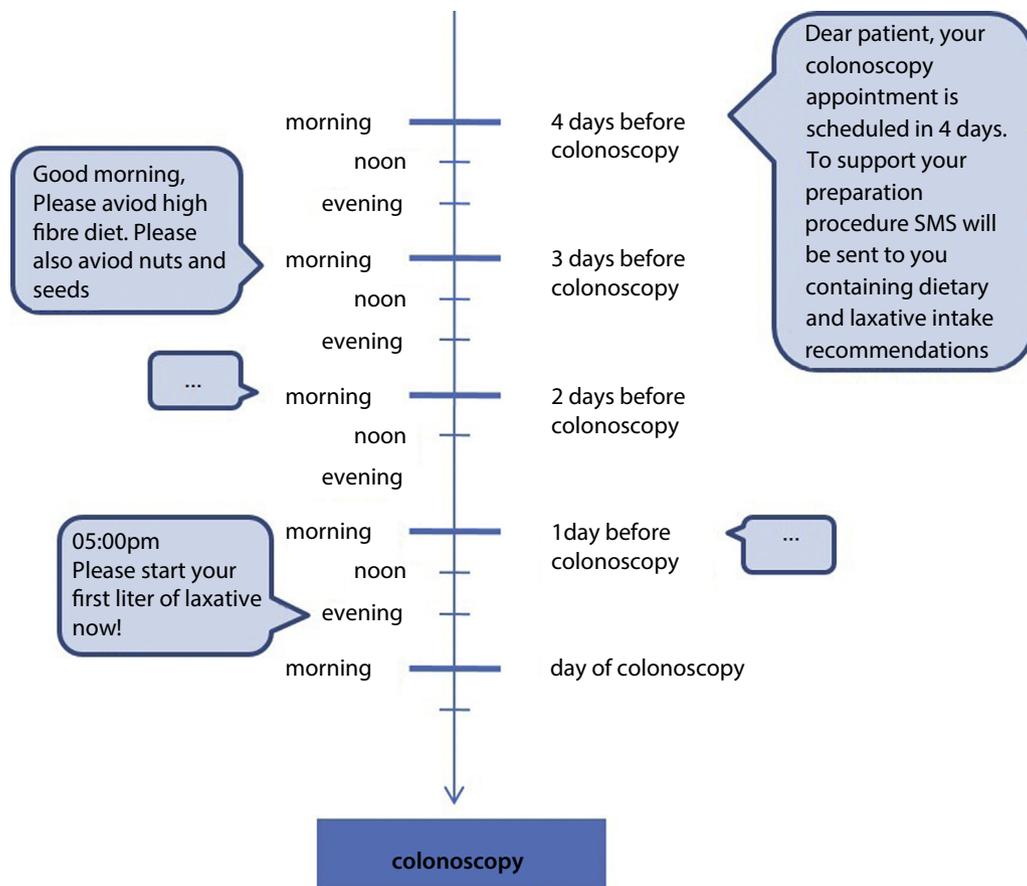
5:06 PM, SMS 12: Please stay close to the toilet! The laxative will cause liquid stools.

8:00 PM, SMS 13: Did you drink the whole liter of Moviprep? Well done! Please drink the additional 2 liters of clear fluids, if not done yet. Start with the second liter of Moviprep 3 hours before your colonoscopy appointment!

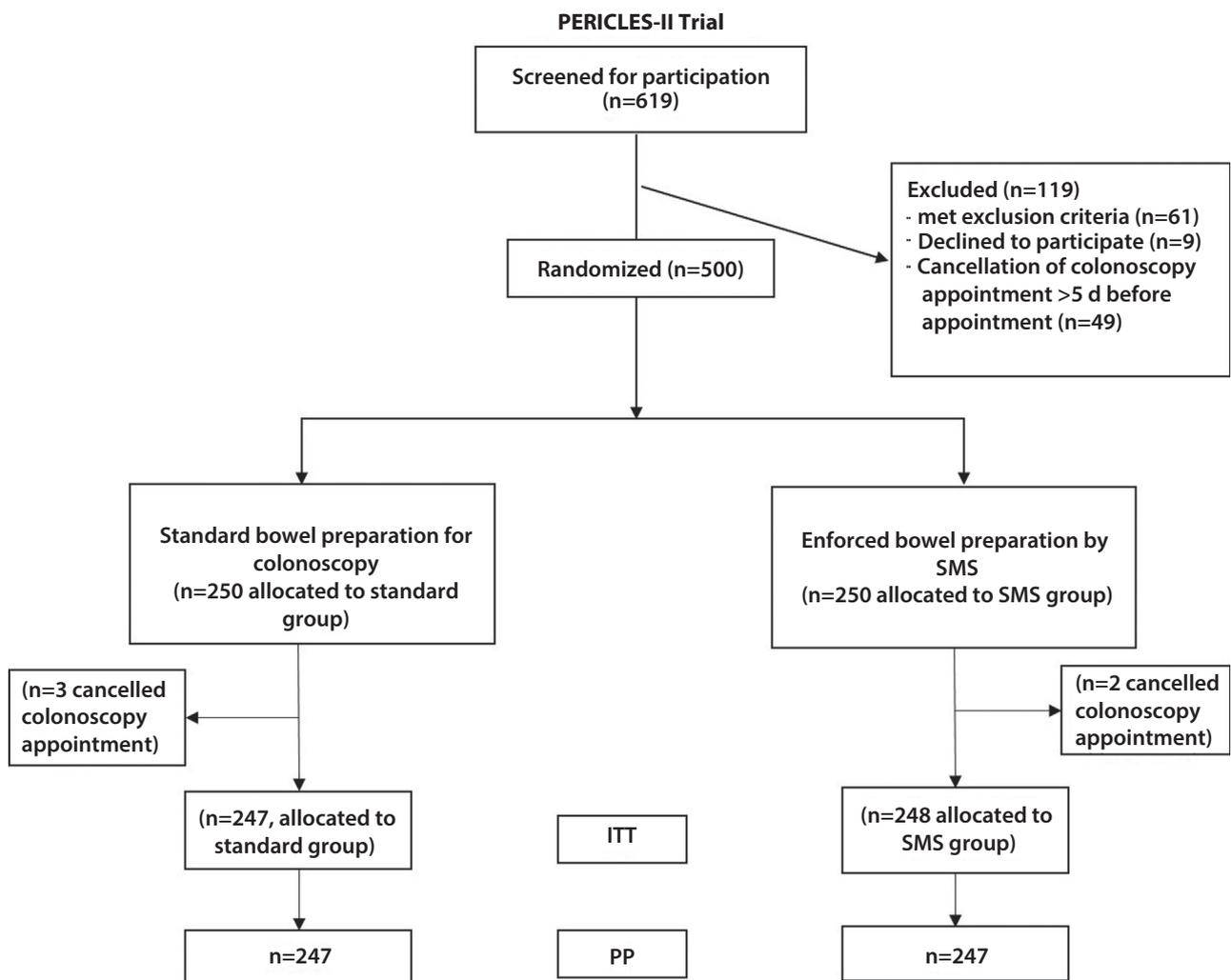
Day of colonoscopy:

3 hours before colonoscopy, SMS 14: Good morning! Did you start the second liter? Don't forget to drink an additional 2 liters of clear liquids!

1 hour before colonoscopy, SMS 15: Your colonoscopy will start in 1 hour. Starting now: Please don't drink anything else! The total time you will spend at the doctor appointment is about 2 to 3 hours.



Supplementary Fig. 1. Short message service workflow. *SMS*, Short message service.



Supplementary Fig. 2. Consort flow chart. *SMS*, Short message service; *ITT*, intention to treat analysis; *PP*, per protocol analysis.