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Same-day single-dose *vs* large-volume split-dose regimens of polyethylene glycol for bowel preparation: A systematic review and meta-analysis

Pan H *et al.* Bowel cleansing efficacy and tolerability

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Abstract

BACKGROUND

Split-dose regimens (SpDs) of 4 L of polyethylene glycol (PEG) have been established as the “gold standard” for bowel preparation; however, its use is limited by the large volumes of fluids required and sleep disturbance associated with night doses. Meanwhile, the same-day single-dose regimens (SSDs) of PEG has been recommended as an alternative; however, its superiority compared to other regimens is a matter of debate.

AIM

To compare the efficacy and tolerability between SSDs and large-volume SpDs PEG for bowel preparation.

METHODS

We searched MEDLINE/PubMed, the Cochrane Library, RCA, EMBASE and Science Citation Index Expanded for randomized trials comparing (2 L/4 L) SSDs to large-

volume (4 L/3 L) SpDs PEG-based regimens, regardless of adjuvant laxative use. The pooled analysis of relative risk ratio and mean difference was calculated for bowel cleanliness, sleep disturbance, willingness to repeat the procedure using the same preparation and adverse effects. A random effects model or fixed-effects model was chosen based on heterogeneity analysis among studies.

RESULTS

A total of 18 studies were included. There was no statistically significant difference of adequate bowel preparation (relative risk = 0.97; 95%CI: 0.92-1.02) (14 trials), right colon Boston Bowel Preparation Scale (mean difference = 0.00; 95%CI: -0.04, 0.03) (9 trials) and right colon Ottawa Bowel Preparation Scale (mean difference = 0.04; 95%CI: -0.27, 0.34) (5 trials) between (2 L/4 L) SSDs and large-volume (4 L/3 L) SpDs, regardless of adjuvant laxative use. The pooled analysis favored the use of SSDs with less sleep disturbance (relative risk = 0.52; 95%CI: 0.40, 0.68) and lower incidence of abdominal pain (relative risk = 0.75; 95%CI: 0.62, 0.90). During subgroup analysis, patients that received low-volume (2 L) SSDs showed more willingness to repeat the procedure using the same preparation than SpDs ($P < 0.05$). No significant difference in adverse effects, including nausea, vomiting and bloating, was found between the two arms ($P > 0.05$).

CONCLUSION

Regardless of adjuvant laxative use, the (2 L/4 L) SSD PEG-based arm was considered equal or better than the large-volume (≥ 3 L) SpDs PEG regimen in terms of bowel cleanliness and tolerability. Patients that received low-volume (2 L) SSDs showed more willingness to repeat the procedure using the same preparation due to the low-volume fluid requirement and less sleep disturbance.

Key Words: Bowel preparation; Colonoscopy; Polyethylene glycol; Same-day single-dose; Split-dose; Meta-analysis

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Core Tip: Same-day single-dose polyethylene glycol-based regimens for bowel preparation seemed to be equal or better than large-volume (≥ 3 L) split-dose polyethylene glycol solution in terms of bowel cleanliness and tolerability as long as the optimal preparation-to-colonoscopy interval and diet instruction for bowel preparation were respected.

INTRODUCTION

A colonoscopy is an important tool used for colorectal cancer screening and the management of colorectal lesions. However, the success of colonoscopy is strongly dependent on the quality of bowel preparation. Prior studies have reported that poor bowel preparation can increase the risk of missed diagnosis for smaller and/or flat lesions, especially in the right colon, and prolong cecal intubation time^[1,2]. Polyethylene glycol (PEG) solutions, as efficient and safe purgative agents, offer the advantage of minimal fluid and electrolyte shifts and are reportedly the most widely used solutions for bowel preparation^[1-3].

High volume (4 L) split-dose regimens (SpDs) of PEG have been recommended as the gold-standard regimen for bowel preparation^[4]; however, the large volume of fluids or poor tolerability associated with SpDs have become a source of patient dissatisfaction. The same-day single-dose (SSD) PEG has been recommended as an alternative for patients scheduled for afternoon colonoscopy^[5,6], exhibiting equal cleansing efficacy and fewer sleep disturbances than SpDs. Meanwhile, it was reported to be in favor of reducing the preparation volume and improving patient tolerance by using PEG solution combined with adjuvant laxative agents for those at risk of bowel

preparation^[7]. A previous systematic review by Enestvedt *et al*^[8] revealed that 4 L split-dose PEG was better than other bowel preparation comparators including a regimen of 4 L single-dose PEG the night before the procedure and MiraLAX/Gatorade solutions, regardless of adjuvant laxative use. However, in order to evaluate bowel cleanliness of the SSD regimens of PEG and patient tolerance in terms of sleep disturbances and side effects for bowel preparation, we conducted a systematic review and meta-analysis to compare the efficacy and tolerability of SSD PEG-based arm *vs* large-volume (≥ 3 L) split-dose PEG solutions for bowel preparation before colonoscopy, regardless of adjuvant laxative use.

MATERIALS AND METHODS

Search strategy and study selection

Systemic searches were performed in June 2021 using MEDLINE/PubMed, EMBASE, Web of Science, Google Scholar and Cochrane Library by two independent reviewers. The search strategy used the Medical Subject Heading term along with the keywords “polyethylene glycol, (bowel preparation OR bowel preparation solution), (split dose OR split-dose) and randomized controlled.” Only full texts published in English with one arm using single-dose PEG on the day of colonoscopy, regardless of adjuvant laxative use and the other arm consisting of a split-dose regimen of PEG for bowel preparation before and on the day of the procedure, were included. References from the reviewed articles were also searched to identify relevant articles that may have been missed.

Exclusion criteria consisted of the following: (1) Participants: pediatric patients, cases of prior colorectal resection and incomplete or complete bowel obstruction cases; (2) Non-colonoscopy studies; (3) Interventions: non-PEG-based solution (*i.e.* sodium phosphate, picosulfate, sodium picosulfate with magnesium citrate agents, *etc*); and (4) Comparisons: trials comparing evening-before *vs* split-dose, twice a same-day *vs* split-dose and low-volume (≤ 2 L) split-dose. A flowchart of the literature search is shown in Figure 1.

Data extraction and methodologic quality assessment

Two authors independently conducted the screening and extracted the data from selected trials with the intention to treat numbers preferred. Results from included studies reported as percentages were converted to absolute numbers.

The methodological quality of each study was graded by two investigators using a modified Jadad scoring system utilized for single (endoscopist) blinding trials^[8]. This 5-point scale assigns a single point for each of the following: (1) The study is described as randomized; (2) The randomization method is described and appropriate; (3) The study is described as blind; (4) The blinding method is described and appropriate; and (5) There is a description of withdrawals and drop-outs. A score of 5 suggested excellent quality, and a score of 0 implied a poor-quality randomized controlled trial. Single-blinding rather than double-blinding can be executed logistically for bowel preparation studies. To ensure the adequacy of blinding, all endoscopists were blinded to the bowel preparation, and staff, nurses and patients were instructed not to discuss the bowel preparation with the endoscopist. The funnel plot was used to assess publication bias. The Grades of Recommendation, Assessment, Development and Evaluation approach was presented to rate the certainty of evidence. Points of disagreement were reconciled by a discussion with another author when required.

Outcomes

The primary outcome measure was bowel cleanliness, defined as adequate bowel preparation using validated scales [Ottawa Bowel Preparation Scale (OBPS) or Boston Bowel Preparation Scale (BBPS)]. Secondary outcomes included the willingness to repeat the procedure using the same preparation, sleep disturbance and side effects, including nausea, vomiting, bloating and abdominal pain/cramps.

The total OBPS score was based upon the sum of the right, transverse and left colonic segments (reference range of 0-4 each segment) plus an overall colonic fluid score (range 0-2)^[9]. The total score ranged from 0 to 14; the lower the score, the better

the preparation. The total BBPS score was the sum of the right colon, mid-colon and left colonic segmental scale. The total score ranged from 0 to 9 (0 = very poor, 9 = excellent)^[10].

Statistical analysis

Statistical analysis was conducted with Review Manager (Version 5.4, Cochrane Collaboration, Oxford, GB). The categorical outcomes were analyzed using relative risk ratio (RR) and its corresponding 95% confidence interval (CI). Continuous data were analyzed using mean differences (MD) and corresponding 95%CI. Statistical heterogeneity was measured by graphic examination of forest plots and statistically through a homogeneity test based on the χ^2 test ($I^2 \geq 50\%$ suggests heterogeneity) in which $P < 0.10$ was considered significant for heterogeneity. A fixed-effects model was used unless there was significant heterogeneity, in which case a random-effects model was applied. Weighted MDs were used for outcomes measured on different scales. A $RR > 1$ favored the SSD arm, while a $RR < 1$ favored the SpDs arm for the favorable outcomes (adequate preparation and willingness to repeat) and the adverse outcomes (sleep disturbance and adverse effects). The MD represented the difference in means between SSD and SpDs ($SSD - SpDs = MD$); an $MD > 0$ favored the SSD arm, while an $MD < 0$ favored the SpDs arm. A higher mean BBPS score indicated better quality of bowel preparation, which was the opposite for OBPS scores. Subgroup analysis was performed to characterize heterogeneity and sensitivity.

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RESULTS

Search results

The initial search identified 490 potentially relevant articles. A total of 422 articles were excluded based on titles and abstracts because they included patients < 18 years of age, non-colonoscopy studies, reviews, retrospective studies or duplications. Sixty-eight articles were reviewed by full text. Overall, 18 articles^[11-28] comparing bowel preparation with SSDs *vs* SpDs PEG were included in this analysis. Figure 1 shows a

flowchart of studies from initial results of publication searches to final inclusion or exclusion.

Table 1 summarizes the characteristics of the 18 included studies ($n = 5464$), which consisted of 2793 patients who received SSDs and 2671 patients who received the SpDs regimen. Nine trials evaluated low-volume (2 L) SSD PEG with adjuvant laxative use *vs* large-volume (≥ 3 L) SpDs PEG^[11,12, 22-28], four trials compared 4 L SSD PEG *vs* 4 L SpDs PEG^[13,14,19,20], and six trials compared 2 L SSD PEG *vs* (≥ 3 L) SpDs PEG^[11,15-18,21]. Interestingly, in a study by Zhang *et al*^[11], patients were assigned to three groups: 2 L SSD PEG, 2 L SSD PEG with adjuvant laxative (linaclotide) and 4 L SpDs PEG.

Bowel cleanliness was evaluated either with BBPS^[11,12,14,15,18,23-27] or OBPS^[13,16,17,19-22,28]. An adequate bowel preparation was defined as a total BBPS score ≥ 6 with all colon segments scores ≥ 2 , or a total OBPS score < 5 (including score < 7 by De Leone, score ≤ 3 by Cesaro) or all colon segment OBPS score < 2 . Diet restriction was mentioned in 16 trials and consisted of low residual diet/low-fiber foods^[11,14-16,20-25,27-28] or clear liquid diet^[13,15,17,19,26,28] before colonoscopy. Colonoscopy was performed with optimal preparation-to-colonoscopy (PC) interval time in only 6 trials^[11,12,15,16,21,24], while 9 trials did not mention the PC interval^[13,14,20,22,23,25-28].

Quality of bowel cleanliness

Fourteen studies provided dichotomous information on adequate bowel preparation between the SSDs and SpDs groups, regardless of adjuvant laxative use, and significant heterogeneity was observed ($P < 0.00001$, $I^2 = 76\%$) in the pooled estimate. Using a random-effects model, no statistically significant difference was found between the two groups (RR = 0.97; 95%CI: 0.92-1.02) ($P = 0.19$) as shown in Figure 2.

Continuous data on right colon BBPS was available in 9 trials (Figure 3). No significant heterogeneity was observed ($P = 0.22$, $I^2 = 25\%$). Using a fixed-effects model, we found that there was no significant difference between the two arms (MD = 0.00; 95%CI: -0.04, 0.03).

Five studies provided continuous data on right colon OBPS (Figure 4), and significant heterogeneity was observed ($P = 0.001$, $I^2 = 78\%$). Using a random-effects model, no significant difference was found between the two arms (MD = 0.04; 95%CI: -0.27, 0.34) ($P = 0.82$).

Subgroup analysis

2 L SSD with adjuvant vs SpDs: Seven trials provided dichotomous information on adequate bowel preparation comparing the 2 L SSDs with adjuvant laxative use to the (≥ 3 L) SpDs regimen. The pooled estimates showed significant heterogeneity within the included studies ($P = 0.05$, $I^2 = 51\%$). Using a random-effects model, no statistically significant difference was found between the two groups (RR = 1.00; 95%CI: 0.95, 1.05) ($P = 0.99$). Continuous data on the right colon BBPS was provided in 7 studies. Pooled estimate results showed no significant heterogeneity ($P = 0.12$, $I^2 = 41\%$). Using a fixed-effects model, we found that there was no significant difference between the two groups. (MD = 0.00; 95%CI: -0.05, 0.05) ($P = 0.93$). Only 1 study reported data on right colon OBPS (Table 2).

2 L SSD without adjuvant vs SpDs: Five trials compared 2 L SSDs without adjuvant to ≥ 3 L SpDs regimens and provided categorical data on the adequacy of bowel preparation. The pooled estimate results showed significant heterogeneity within the included studies ($P < 0.00001$, $I^2 = 90\%$). Using a random-effects model, no statistical difference was reported between the two groups (RR = 0.86; 95%CI: 0.72, 1.02) ($P = 0.07$).

Two trials provided continuous data on right colon BBPS. The pooled estimates showed no significant heterogeneity between both studies ($P = 1.00$, $I^2 = 0\%$). Using a fixed-effects model, no significant difference was found between the two groups. (MD = 0.00; 95%CI: -0.07, 0.07) ($P = 1.00$). Two studies provided continuous data on right colon OBPS. The pooled estimates showed significant heterogeneity ($P = 0.003$, $I^2 = 89\%$).

Using a random-effects model, ¹no significant difference was found between the two groups. (MD = 0.26; 95% CI: -0.20, 0.72) ($P = 0.26$) (Table 2).

4 L SSD without adjuvant vs SpDs: Three trials compared the adequacy of bowel preparation between 4 L SSDs without adjuvant and 4 L SpDs regimens. The pooled estimates showed that no significant heterogeneity was present within these studies ($P = 0.66$, $I^2 = 0\%$). Using a fixed-effects model, we found that there was no significant difference between the two groups (RR = 0.99; 95% CI: 0.94, 1.05) ($P = 0.82$). Only 1 study reported data on the right colon BBPS.

The right colon OBPS scores were provided in 2 studies. The pooled estimates showed ⁷no significant heterogeneity between both studies ($P = 0.71$, $I^2 = 0\%$). Using a fixed-effects model, ¹no significant difference was found between the two groups. (MD = -0.06; 95% CI: -0.30, 0.18) ($P = 0.62$) (Table 2).

Secondary outcomes

Fifteen studies provided dichotomous information on sleep disturbance between the SSD and SpDs PEG groups (Table 3). During the pooled estimates, significant heterogeneity was observed ($P < 0.00001$, $I^2 = 74\%$). Using a random-effects model, ¹²a significant difference was found between the two groups (RR = 0.52; 95% CI: 0.40, 0.68) ($P < 0.00001$). During subgroup analysis, 7 trials comparing 2 L SSD with adjuvant vs SpDs ¹³showed no significant difference in sleep disturbance between the two groups (RR = 0.69; 95% CI: 0.43, 1.10) ($P = 0.12$).

Ten trials provided dichotomous information on patient ⁹willingness to repeat the procedure using the same preparation between the SSD and SpDs PEG groups (Table 3). During the pooled estimates, significant heterogeneity was observed ($P < 0.00001$, $I^2 = 90\%$). Using a random-effects model, a ²significant difference was found between the two groups (RR=1.15; 95% CI: 1.03, 1.29) ($P = 0.01$). Two trials in subgroup analysis of 4 L SSD without adjuvant vs SpDs found ²no significant difference between the two groups (RR = 0.89; 95% CI: 0.71, 1.13) ($P = 0.34$).

The incidence of adverse effects, including nausea, vomiting, abdominal pain and bloating, was reported in 17, 16, 17 and 15 trials, respectively (Table 3). No significant difference in nausea (RR = 0.95; 95%CI: 0.78, 1.16), vomiting (RR = 0.96; 95%CI: 0.66, 1.38) and bloating (RR = 0.80; 95%CI: 0.63, 1.01) was found between the two groups. However, there was a significant difference in abdominal pain between the two arms, favoring the SSD group (RR = 0.75; 95%CI: 0.62, 0.90).

Publication bias

For the publication bias, in our meta-analysis a better symmetry was present with the use of funnel plots (Figure 5). The Grades of Recommendation, Assessment, Development and Evaluation as one systematic approach rated the certainty of evidence for moderate level in this systematic review and meta-analysis (Table 4).

DISCUSSION

This updated meta-analysis reviewed 18 trials comparing the efficacy and tolerability of bowel preparation between SSD PEG-based and large-volume SpDs PEG regimens. In recent years, the split dose of 4 L PEG has been adopted as a standard regimen for bowel preparation. However, patients often complain of the large-volume regimen and sleep disturbance due to frequent bowel movements and abdominal discomfort. To enhance patient compliance with the preparation, several studies have suggested adding other laxatives, such as bisacodyl, linaclotide or prucalopride, to a low-volume PEG bowel preparation to reduce the solution volume^[11,12,25]. In the present study, according to the volume of PEG ingested and combination with adjuvant laxative, SSD PEG-based regimens were separated into three subgroups: low-volume (2 L) SSD PEG combined with an adjuvant agent, low-volume (2 L) SSD PEG without adjuvant laxative and large-volume (4 L) SSD PEG without adjuvant laxative. In a pooled analysis, we have shown that SSD PEG was as effective as SpDs PEG-based regimens in terms of bowel cleanliness, regardless of adjuvant laxative use and dosage.

Previous meta-analyses by Cheng *et al*^[29] and Avalos *et al*^[30] showed a trend to the equivalent efficacy for bowel preparation in terms of bowel cleanliness and adenoma detection rate when compared to same-day (one or two doses) with split-dose bowel preparation regimens regardless of purgative type. Patients with a history of pelvic surgery and colorectal surgery as high-risks of poor bowel preparation were not excluded by the forementioned studies^[29,30]. Other identified patient-related risk factors for inadequate bowel preparation include diabetes and constipation^[31]. In the present study, patients with a history of constipation and diabetes mellitus were included, and analysis results obtained were consistent with previous studies. We considered that the SSD PEG-based arm had the same efficacy in bowel cleanliness as the SpDs arm for patients at high-risk of poor bowel preparation by complying with the optimal PC interval and diet instruction before colonoscopy.

In a study by Seo *et al*^[3], multivariate analysis showed that the PC interval, the amount of PEG ingested and compliance with diet instructions were significant contributors to satisfactory bowel preparation, regardless of when the procedure was performed during the day. Colonoscopies performed with a PC interval of 3 to 5 h had the best bowel-cleansing quality throughout the colon, while a PC interval of 3 to 7 h was an acceptable scale for bowel preparation. It has been reported that after the optimal time window, small-bowel contents of bubbles and viscous bile-stained mucous are evacuated into the colon and restrict the visibility of the colonic mucosa, especially in the right colon. Small flat lesions that are difficult to identify in the right colon can easily be missed by the endoscopist if concealed by opaque small bowel effluent. Accordingly, same-day preparation with split-doses and full-doses improves bowel cleansing and increases the detection rate of small adenomas^[28].

Compliance with dietary instructions has been documented as another factor affecting the quality of bowel preparation. A meta-analysis by Chen *et al*^[32] that analyzed factors of inadequate bowel preparation found no significant difference between a low residual diet and a clear liquid diet the day before colonoscopy. In our meta-analysis, in all included trials, patients in both arms followed a low residual diet

or clear liquid diet, and no heterogeneity was found for dietary restriction before colonoscopy.

Consistent with a study by Avalos *et al*^[30] we found that significantly less sleep disturbance was associated with the SSD PEG-based regimens without adjuvant laxatives than the SpDs PEG. However, the incidence of sleep disturbance in combination regimens of low-volume (2 L) SSD with an adjuvant laxative (bisacodyl, linaclotide or prucalopride) was comparable with SpDs regimens. It was noted that bowel movements induced by bisacodyl taken on the night before colonoscopy occurred after waking up. De Leone *et al*^[28] suggested that sleeping difficulties were more likely to be attributed to the anxiety for the day-after procedure rather than nocturnal awakenings for defecation or abdominal pain in patients who took the combination regimen consisting of low-volume PEG with bisacodyl. Based on these findings, we conclude that the split-dose regimen taken the night before colonoscopy and anxiety for the procedure play an important role in the sleep quality of patients.

Patient tolerance of bowel preparation regimens mainly depends on sleep disruptions²¹ and adverse effects such as nausea, vomiting, abdominal pain/cramping and bloating. Significantly less nocturnal awakenings for defecation were reported in the SSD PEG-based arm than other SpDs PEG regimens, and no significant difference in other adverse effects was found. Given the low incidence of sleep disturbance and abdominal pain, patients were more tolerant to the SSD PEG-based arm for bowel preparation.

⁹ Moreover, patients who received the low-volume (2 L) SSD PEG regimens exhibited increased willingness to repeat the procedure using the same preparation. However, the large-volume (4 L) SSD PEG arm was not superior to the SpDs regimens in terms of willingness to repeat the procedure using the same preparation. This finding suggested that patient intolerance to ingestion of large volumes over a short period was a significant factor contributing to non-compliance and decreased willingness to repeat the procedure with the same regimen.

There are several advantages to this meta-analysis. We performed the extensive retrieval strategy and included only randomized controlled trials. Other advantages were related to the quality of the included studies and to the publication bias. The methodological quality assessment of the included studies was moderate to high according to the Cochrane risk of bias tool and modified Jadad score. For the publication bias, in our meta-analysis a rough symmetry was present with the use of funnel plots and the Grades of Recommendation, Assessment, Development and Evaluation approach.

This meta-analysis has several limitations. First, we enrolled only adult patients and excluded those who had undergone colorectal surgery and/or bowel obstruction; accordingly, the findings of our meta-analysis cannot be generalized for all patients that undergo colonoscopy. Moreover, it is widely acknowledged that constipation is a high-risk factor for poor preparation; however, there was a certain level of inconsistency on the proportion and severity of constipation within the included studies. Furthermore, adenoma detection rate was not evaluated as a secondary outcome. Indeed, adenoma detection rate is a quality indicator for colonoscopy and can be influenced by the endoscopist's level of expertise and the quality of the bowel preparation^[33].

CONCLUSION

We found that the SSD regimens of PEG were non-inferior to large-volume (≥ 3 L) SpDs PEG in terms of bowel cleanliness. Better tolerance to SSD PEG was accounted for by less sleep disturbance and abdominal pain than with the SpDs regimens. Given its efficacy and tolerability, the low-volume (2 L) SSD PEG regimen has huge prospects as a superior alternative to SpDs regimens as long as the optimal PC interval and dietary instructions for bowel preparation are respected.

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