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OPEN

A Systematic Review and Meta-Analysis of Low-Residue Diet Versus Clear Liquid Diet

Which Is Better for Bowel Preparation Before Colonoscopy?

ABSTRACT

The goal of this systematic review was to compare the clear liquid diet and the low-residue diet to determine which is better for bowel preparation before colonoscopy. A literature search for randomized controlled trials on the effects of employing the clear liquid diet and low-residue diets before colonoscopy was conducted in major online English databases (PubMed, Web of Science, and Ovid EMBASE). After the systematic review of all 16 studies, the outcomes including quality of bowel preparation, tolerance, willingness to repeat, and adverse effects were analyzed through meta-analysis. The statistical analysis was performed by using RevMan 5.3 software. No statistically significant difference was observed between the low-residue diet and clear liquid diet groups (odds ratio [95% confidence interval] = 1.19 [0.79, 1.81]; p = .41). There was no statistically significant difference between the Boston Bowel Preparation Scale (standard mean difference [95% confidence interval] = −0.04 [−0.21, −0.14]; p = .68) Ottawa Bowel Preparation Scale (standard mean difference [95% confidence interval] = −0.04 [−0.19, 0.11]; p = .59) scores of the two groups. The quality indicators for colonoscopy of the two groups were not statistically significant. However, patient tolerance to the low-residue diet was higher (odds ratio [95% confidence interval] = 1.86 [1.47, 2.36]; p < .01). More patients in the low-residue diet group were willing to repeat the low-residue diet for bowel preparation (odds ratio [95% confidence interval] = 2.34 [1.72, 3.17]; p < .01). More patients in the clear liquid diet group experienced hunger, nausea, and vomiting. People who employed the low-residue diet before colonoscopy had the same quality of bowel preparation as those with clear liquid diet. Meanwhile, the tolerance of people with low-residue diet was better than people with clear liquid diet, and these people were more willing to repeat the colonoscopy with less adverse events.

Colorectal cancer is the second most prevalent carcinoma among males and the third most prevalent carcinoma among females in the United States (Miller et al., 2019).

Colonoscopy is an effective tool that is extensively used for the screening and surveillance of colorectal lesions to reduce the incidence and mortality of colorectal cancer (Brenner, Stock, & Hoffmeister, 2014).

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Undoubtedly, the quality of bowel preparation is important for guaranteeing the quality of the colonoscopy. Unfortunately, many patients experience inadequate bowel preparation (Kang et al., 2016; Kluge et al., 2018). Therefore, we explored methods of improving the quality of bowel preparation. In addition to the true effects of bowel preparation on bowel cleansing, patient compliance, satisfaction, and tolerability are important factors that influence the quality of bowel preparation. Therefore, the low-residue (LRD) and clear liquid diets (CLD) have become of great interest to endoscopists.

Background

Traditionally, the CLD has been used before colonoscopy to ensure the quality of bowel preparation. However, some studies have shown that using the LRD was not inferior to using the CLD for bowel preparation. Simultaneously, compared with the CLD, the LRD seems more easily accepted by patients, resulting in higher tolerance, satisfaction, and compliance (Nguyen, Jamal, Nguyen, Puli, & Bechtold, 2016). Further studies have shown that the LRD can reduce the amount of purgative intake used during the CLD to achieve similar bowel cleansing (Lee et al., 2019). Additionally, the LRD can be implemented 1 day before colonoscopy and does not require multiple days of use (Gimeno-Garcia et al., 2019). These results suggest the superiority of the LRD. Moreover, the CLD may cause blood glucose fluctuations in patients with diabetes, thus affecting patient compliance (Alvarez-Gonzalez et al., 2016). Furthermore, the potential risks of the CLD are unclear for those with gastrointestinal diseases. Nonetheless, because of the lack of randomized controlled trials (RCTs) comparing the LRD and CLD in large populations, many physicians are not convinced of the effectiveness of the LRD. Therefore, many medical institutions have not adopted the LRD.

Recently, more studies have been performed by several institutions to compare the CLD and LRD; however, the number of participants involved has been small. Therefore, the aim of this systematic review and meta-analysis was to compare the CLD with LRD before colonoscopy in terms of quality of bowel preparation, patient tolerance, willingness to repeat, and adverse effects and to determine whether the quality of bowel preparation of people with the LRD and CLD is consistent.

Methods

Eligibility Criteria

We formulated the eligibility criteria according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Liberati et al., 2009). Eligibility criteria mainly included study and report characteristics. Study characteristics were population (those able to undergo the colonoscopy were all researchable), intervention and comparator (bowel preparation with the LRD vs. the CLD), outcome (quality of bowel preparation assessed based on different scales of quality indicators for colonoscopy, tolerance to the method, willingness to repeat the method, and adverse events), and study designs of interest (only RCT that compared the LRD with the CLD for patients performing bowel preparation before colonoscopy). Report characteristics were language of the publication (only English was assessed), publication status (only full-text articles were assessed), and year of publication (only those published during or before September 2019 were assessed).

Literature Search

A comprehensive search of PubMed, Web of Science, and Ovid EMBASE databases was performed until September 2019. The terms used to perform the search were as follows: "colonoscopy" and "diet" and ("low-residue" or "low residue") and ("clear liquid" or "clear-liquid" or "clear fluid"). All search strategies are summarized in the Appendix Table (see Supplemental Digital Content, available at: http://links.lww.com/GNJ/A63). Reference lists from the reviewed articles and other relevant studies were manually searched.

Study Selection

Titles and abstracts were independently reviewed by the two investigators. When discrepancies were found at this stage, a third investigator was consulted. Full-text articles were included according to the eligibility and exclusion criteria. Then, the two investigators independently reviewed and evaluated the full-text articles. The final decision was made by the third investigator when a controversial article was encountered.

Data Extraction

Two unblinded reviewers independently extracted relevant data for standardized tabulation. The data used for the appendix or "Web extra" were extracted by the reviewers as well. Divergence was solved by consulting the third reviewer. We did not contact the original authors to obtain more data. The data extracted from the RCTs were article descriptors (first author, year of publication), study population (participant age range, gender ratio, inclusion and exclusion criteria), study environment (country, type of hospital), study methods (study design, randomization procedure), intervention (provider, structure, content), and results (number of participants who achieved adequate bowel preparation, results of Boston Bowel Preparation Scale [BBPS] and

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Ottawa Bowel Preparation Scale [OBPS], quality indicators for colonoscopy, tolerance of participants to bowel preparation, willingness to repeat, adverse effects).

Quality Assessment

We adopted the Cochrane Collaboration's Tool for Assessing Risk of Bias to assess the quality of the included articles. The Cochrane Collaboration's Tool incorporated six items: selection bias (random sequence generation and allocation concealment), performance bias, detection bias, attrition bias, reporting bias, and other bias. We used "low risk of bias," "unclear risk of bias," and "high risk of bias" to describe the bias of the articles. The two investigators independently assessed the quality of the study, and the third investigator made the final decision when they encountered a controversial article.

Data Synthesis and Analysis

The odds ratio (OR) was used to evaluate the pooled effect for tolerance, willingness to repeat, and adverse events, which were categorical variables. Meanwhile, the standard mean difference (SMD) with 95% confidence intervals (CIs) was used to assess quality of bowel preparation, which was a numerical variable. We used Cochrane's Q (expressed as P) qualitatively and the I^2 statistic quantitatively to evaluate the heterogeneity of the included studies (DerSimonian & Laird, 1986). If $I^2 > 50\%$ or $p < .10$, then we used the random-effects model because of the significant heterogeneity. Inversely, if $I^2 < 50\%$ or $p > .10$, then the fixed-effects model was used because of the homogeneity. If significant heterogeneity existed between studies, then a sensitivity analysis was performed by deleting the included studies one-by-one to determine the source. We performed all statistical analyses using RevMan 5.3 (Review Manager Version 5.3; Review Manager, Copenhagen, The Nordic Cochrane Centre, The Cochrane Collaboration, London, UK).

Results

Study Selection

One hundred fifty-five articles were identified through searching the database and references of the related articles. Thirty-nine articles were removed because they were duplicates. Eighty-nine articles were excluded for not meeting the eligibility criteria based on the titles and abstracts. Twenty-seven full-text articles were included according to the eligibility criteria. After reviewing these articles, we excluded five that were not RCTs and six that failed to compare CLD with LRD. Ultimately, 16 articles were included in the meta-analysis (Figure 1).

Characteristics of the Included Studies

The characteristics of the 16 included studies are described in Table 1. All are RCTs that compared the effectiveness of the LRD and CLD for bowel preparation. The studies were performed in nine different countries. Most studies had a sample size of 200, and the other three had sample sizes of only 100. Only one study was an RCT about pediatric colonoscopy. The mean age of patients in the other studies was between 51 and 65 years. The primary outcome of each study was the adequacy of bowel preparation; however, the definition of adequate bowel preparation differed in each study. The scales used to assess bowel preparation were also different (including BBPS, OBPS, Aronchick Scale, and Harefield Cleansing Scale [HCS]). All used bowel preparation solutions, but the types, times, and methods were different.

Quality Assessment

We used the Cochrane Collaboration's Tool for Assessing Risk of Bias to evaluate the included 16 RCTs. Studies by Scott, Raymond, Thompson, and Galt (2005); Stolpman, Solem, Eastlick, Adlis, and Shaw
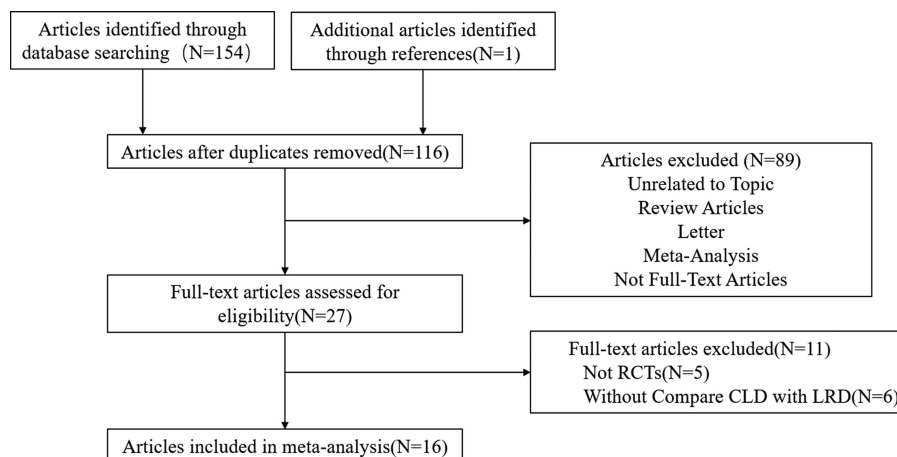

FIGURE 1. Flowchart for filtering articles.

TABLE 1. Characteristics of the Included Studies

Study	Country	Sample Size		Demographics		Definition of Adequate Bowel Preparation	Type of Bowel Preparation Solution
		CLD	LRD	CLD	LRD		
Scott et al., 2005	United States	92	93	Female: 59 (64.1%) Mean age: 57 years	Female: 44 (47.3%) Mean age: 57 years	Aronchick Scale Adequate bowel preparation was excellent or good	NaP, the evening before, split-dose
Rapier & Houston, 2006	United States	37	38	Female: 15 (40.5%) Mean age: 61 years	Female: 16 (42.1%) Mean age: 61 years	Aronchick Scale Adequate bowel preparation was excellent or good	Magnesium citrate and bisacodyl, the day before, oral and rectal
Park et al., 2009	Korea	106	108	Female: 47 (44.3%) Mean age: 55.2 years	Female: 47 (43.5%) Mean age: 53.1 years	Ottawa Scale Adequate preparation was not described	4L PEG, the morning of the day, split-dose
Soweid et al., 2010	Lebanon	98	102	Female: 43 (43.9%) Mean age: 55.5 years	Female: 52 (51.0%) Mean age: 56.6 years	Aronchick Scale Adequate bowel preparation was excellent or good	4L PEG-ES, the evening before
Koh et al., 2011	Korea	40	40	Female: 14 (35%) Mean age: 51.4 years	Female: 13 (32.5%) Mean age: 54.3 years	Ottawa Scale Adequate preparation was not described	4L PEG-ES, the morning before
Melicharkova et al., 2013	Canada	108	105	Female: 55 (60%) Mean age: 57.1 years	Female: 49 (53%) Mean age: 56.5 years	Ottawa and Aronchick Scales Adequate bowel preparation was excellent or good	The Pico-Salax, the evening before, traditional or split-dose
Sipe et al., 2013	United States	91	105	Female: 53 (58.2%) Mean age: 57.8 years	Female: 50 (47.6%) Mean age: 56.9 years	Boston Bowel Preparation Scale Adequate preparation was not described	OSS, the evening before, split-dose
Stolpman et al., 2014	United States	101	100	Female: 48 (47.5%) Mean age: 60.0 years	Female: 39 (39.0%) Mean age: 60.0 years	Boston Bowel Preparation Scale Adequate bowel preparation was score ≥6	SUPREP, the evening before, split-dose
Flemming et al., 2015	Canada	116	98	Female: 64 (58.7%) Mean age: 65 years	Female: 64 (61%) Mean age: 62 years	Ottawa and Aronchick Scales Adequate preparation was not described	4L PEG-ELS, the evening before, traditional or split-dose
Butt et al., 2016	Australia	111	115	Female: 53 (47.7%) Mean age: 52 years	Female: 56 (48.7%) Mean age: 53 years	Harefield Cleansing Scale Adequate preparation was defined as A or B level	2L PEG and Asc, the evening before or on the day, split-dose
Walter et al., 2017	United States	72	68	Female: 38 (52.8%) Mean age: 51 years	Female: 42 (61.8%) Mean age: 56 years	Boston Bowel Preparation Scale Adequate bowel preparation was score >5	2L PEG-ELS, the afternoon before, split-dose
Mytyk et al., 2018	Poland	96	88	Female: 43 (44.8%) Mean age: 15.1 years	Female: 41 (46.6%) Mean age: 14 years	Boston Bowel Preparation Scale Adequate preparation was not described	4L PEG-ELS, the day before, split-dose

(continues)

TABLE 1. Characteristics of the Included Studies *(Continued)*

Study	Country	Sample Size		Demographics		Definition of Adequate Bowel Preparation	Type of Bowel Preparation Solution
		CLD	LRD	CLD	LRD		
Thukral et al., 2019	United States	107	108	Female: 51 (47.7%) Mean age: 55.8 years	Female: 52 (47.7%) Mean age: 57.0 years	Boston Bowel Preparation Scale Adequate bowel preparation was excellent or good	Magnesium citrate, the day before, split-dose
Alvarez-Gonzalez et al., 2019	Spain	132	135	Female: 63 (48%) Mean age: 60.1 years	Female: 59 (44%) Mean age: 59.9 years	Boston Bowel Preparation Scale Adequate bowel preparation was score ≥2 per segment	4L PEG, the evening before, split-dose
Gee et al., 2019	Malaysia	49	48	Female: 64 (58%) Mean age: 65 years	Female: 64 (58.7%) Mean age: 65 years	Aronchick Scale Adequate bowel preparation was excellent or good	3L PEG or sodium phosphate instead, the day before
Gomez-Reyes et al., 2019	Mexico	105	100	Female: 67 (64%) Mean age: 55.2 years	Female: 66 (66%) Mean age: 55.2 years	Boston Bowel Preparation Scale Adequate bowel preparation was score ≥2 per segment	4L PEG, 16 hours before, single-dose

Note. Asc = ascorbic acid; CLD = clear liquid diet; OSS = oral sulfate solution; LRD = low-residue diet; PEG-ELS = polyethylene glycol electrolyte solution.

(2014); and Sipe et al. (2013) had low to moderate quality; however, all other studies had high quality. The study by Scott et al. had a high risk of random sequence generation (selection bias), and that by Stolpman et al. did not describe random sequence generation. All three studies with low to moderate quality did not mention allocation (selection bias). Outcome data were adequately reported in all studies. Although double-blinding was used in all studies, the authors did not specify how it was initiated or how the random sequence was generated. All researchers and estimators were blinded but the subjects were not (Figure 2).

Quality of Bowel Preparation

Of the eligible articles, 12 (n = 2205) (Alvarez-Gonzalez et al., 2019; Butt, Bunn, Paul, Gibson, & Brown, 2016; Flemming, Green, Melicharkova, Vanner, & Hookey, 2015; Gee et al., 2019; Melicharkova, Flemming, Vanner, & Hookey, 2013; Mytyk et al., 2018; Rapier & Houston, 2006; Scott et al., 2005; Soweid et al., 2010; Stolpman et al., 2014; Thukral et al., 2019; Walter et al., 2017) evaluated the number of participants who achieved excellent or good bowel preparation. These studies used the BBPS, Aronchick Scale, or HCS to determine the eligibility criteria. The overall adequate bowel preparation rates were 86.4% (950/1099) for the LRD group and 83.5% (923/1106) for the CLD group. There was no statistically significant difference between the two groups regarding the quality of bowel preparation (OR [95% CI] = 1.19 [0.79, 1.81]; p = .41) (Figure 3).

We selected the random-effects model because of the statistically significant heterogeneity (I^2 = 58%; p < .01). When conducting a sensitivity analysis, the main source of heterogeneity was observed in the study by Soweid et al. Similar results were obtained when we removed the study by Soweid et al. (OR [95% CI] = 1.04 [0.80, 1.37]; p = .76), but there was no statistically significant difference in heterogeneity (I^2 = 15%; p = .30). This result also indicated the reliability of the conclusion. In the study by Soweid et al., we found that the consumption of polyethylene glycol electrolyte solution (PEG-ES) was significantly greater for the LRD group compared with the CLD group. Furthermore, Soweid et al. acknowledged that regardless of the type of diet used, the amount of purgative intake remarkably affected the quality of bowel preparation. This may have been the reason for the statistically significant difference in the quality of bowel preparation between the LRD and CLD groups and was one of the main sources of heterogeneity between groups.

A funnel plot is shown in the Appendix Figure (see Supplemental Digital Content, available at: http://links.lww.com/GNJ/A64). The other studies reported
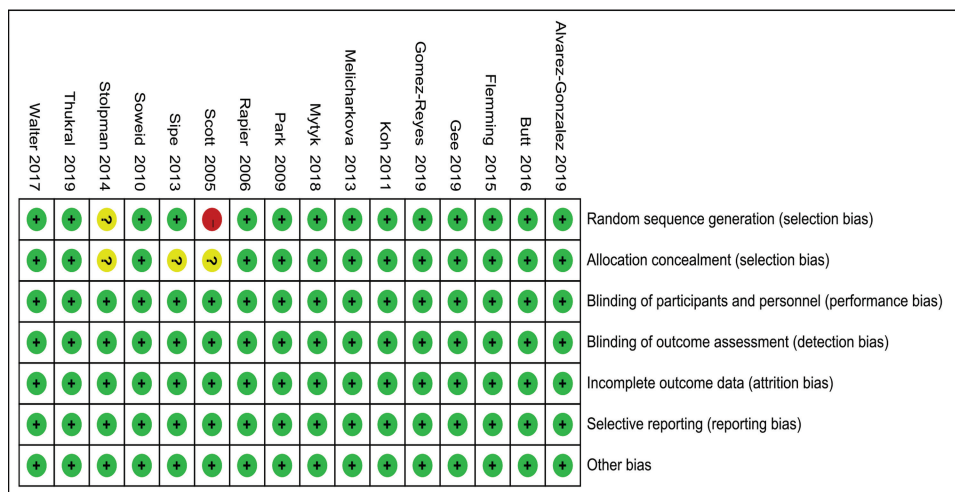
A. Risk of bias graph
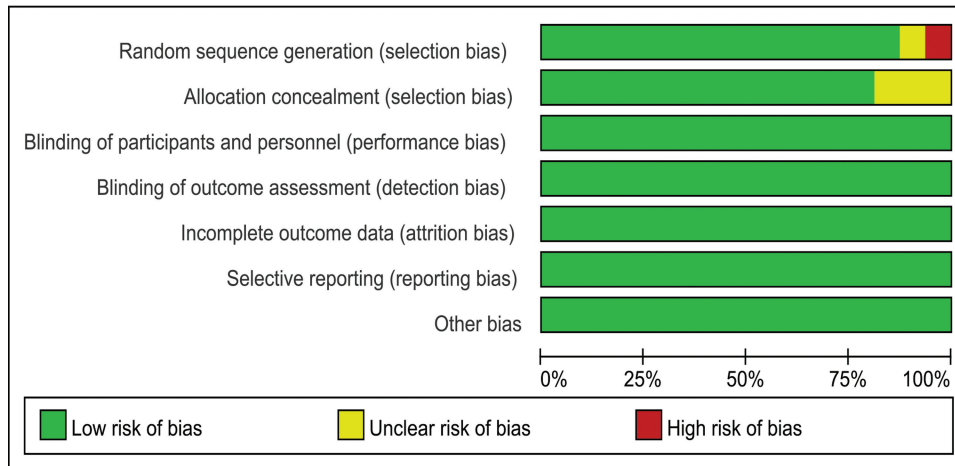
B. Risk of bias summary

FIGURE 2. Quality assessment of the studies by Cochrane Collaboration's Tool for Assessing Risk of Bias. (A) Risk of bias graph. (B) Risk of bias summary.

only BBPS or OBPS scores, but not the number of eligible participants (Gomez-Reyes et al., 2019; Koh et al., 2011; Park et al., 2009; Sipe et al., 2013). However, in each study, there was no statistically significant difference in the quality of bowel preparation between the LRD and CLD groups.

Seven studies in which 613 and 616 participants were randomly assigned to the LRD and CLD groups, respectively, adopted the BBPS or OBPS to evaluate the efficacy of colon cleansing and reported the results. Three studies (Mytyk et al., 2018; Sipe et al., 2013; Walter et al., 2017) used the BBPS to evaluate this index, and the results yielded no statistically significant differences between the two groups (SMD [95% CI] = −0.04 [−0.21, 0.14]; p = .68). Similar results were found in the other four studies (Flemming et al., 2015; Koh et al., 2011; Melicharkova et al., 2013; Park et al., 2009). When the quality of bowel preparation was evaluated with the OBPS, there was still no statistically significant difference between the two

groups (SMD [95% CI] = −0.04 [−0.19, 0.11]; p = .59). Heterogeneity among the groups was not significant (BBPS: I^2= 26% and p = .26; OBPS: I^2= 34% and p = .21).

Quality Indicators for Colonoscopy

As shown in Figure 4, six studies (Alvarez-Gonzalez et al., 2019; Flemming et al., 2015; Gee et al., 2019; Gomez-Reyes et al., 2019; Stolpman et al., 2014; Walter et al., 2017) examined the polyp detection rates (PDRs), which were similar between the LRD and CLD groups (50.8% vs. 49.1%; OR [95% CI] = 1.07 [0.83, 1.38]; p = .60). Heterogeneity among the groups was not significant (I^2= 36%; p = .16). Simultaneously, there was no statistically significant difference between the LRD and CLD groups in terms of the adenoma detection rate (ADR) (47.3% vs. 43.3%; OR [95% CI] = 1.18 [0.92, 1.51]; p = .20) when we conducted a meta-analysis of five studies
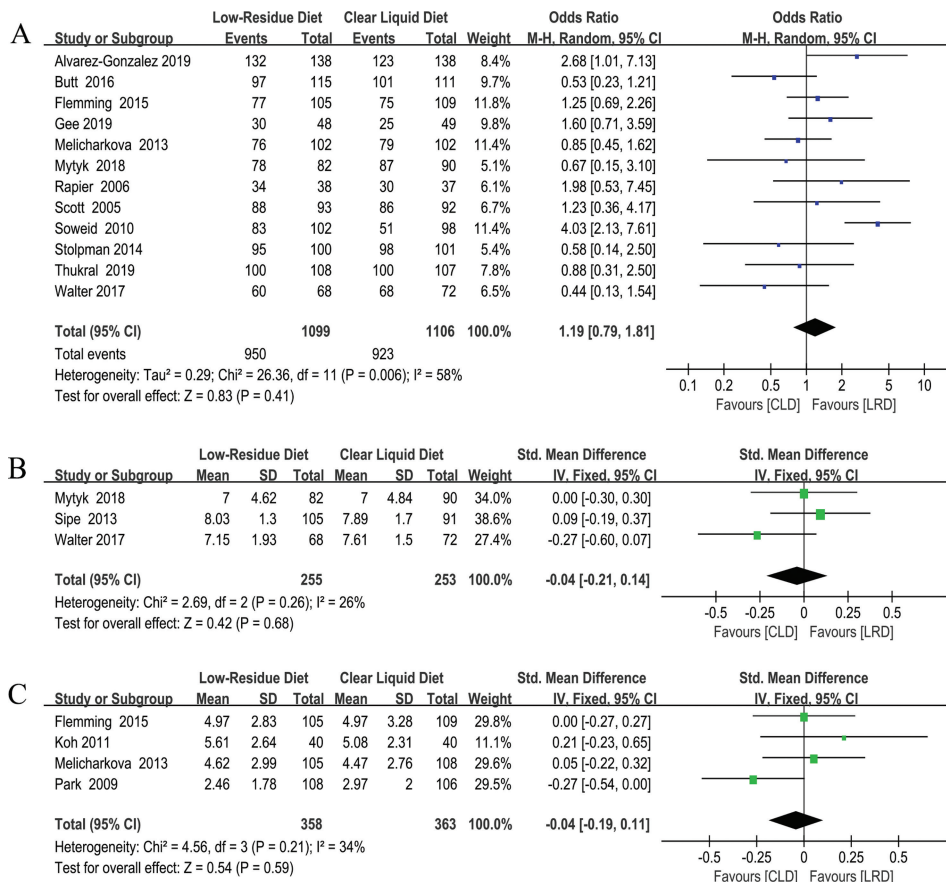
FIGURE 3. Forest plot of quality of bowel preparation between LRD and CLD groups. (A) Number of people who were qualified for the excellent or good bowel preparation. (B) Score of the BBPS. (C) Score of the OBPS.

(Alvarez-Gonzalez et al., 2019; Flemming et al., 2015; Stolpman et al., 2014; Thukral et al., 2019; Walter et al., 2017) that focused on this aspect. No significant heterogeneity was observed ($I^2 = 25\%$; $p = .25$). Four studies (Alvarez-Gonzalez et al., 2019; Flemming et al., 2015; Gomez-Reyes et al., 2019; Walter et al., 2017) documented the cecal intubation rate (CIR). These studies indicated that there was no statistically significant difference between the LRD and CLD groups in terms of the CIR (94.6% vs. 94.8%; OR [95% CI] = 0.97 [0.53, 1.77]; $p = .91$) and no significant heterogeneity among groups ($I^2 = 0\%$; $p = .49$).

Tolerance of Participants to Bowel Preparation

Eight included trials ($n = 1857$) were incorporated in the study. Of all the participants, 81.8% (780/954) could tolerate the bowel preparation before colonoscopy in the LRD group but only 71.8% (648/903) could tolerate it in the CLD group, indicating a statistically significant difference between the two groups (OR [95% CI] = 1.86 [1.47, 2.36]; $p < .01$). Heterogeneity among the groups was not significant ($I^2 = 0\%$; $p = .50$) (Figure 4).

Willingness to Repeat

Six included trials ($n = 1069$) (Koh et al., 2011; Park et al., 2009; Scott et al., 2005; Soweid et al., 2010; Stolpman et al., 2014; Thukral et al., 2019) were incorporated in the study. More participants in the LRD group (84.8%) than in the CLD group (70.9%) were willing to repeat the bowel preparation before colonoscopy, indicating a statistically significant difference between groups (OR [95% CI] = 2.34 [1.72, 3.17]; $p < .01$). Heterogeneity among groups was not significant ($I^2 = 33\%$; $p = .19$) (Figure 4).

Adverse Effects

Seven studies (Gee et al., 2019; Gomez-Reyes et al., 2019; Mytyk et al., 2018; Park et al., 2009; Scott et al., 2005; Soweid et al., 2010; Thukral et al., 2019) reported detailed adverse effects during bowel preparation. We conducted a meta-analysis of adverse effects such as including hunger (Gee et al., 2019; Scott et al., 2005; Soweid et al., 2010; Thukral et al., 2019), nausea (Gomez-Reyes et al., 2019; Mytyk et al., 2018; Park et al., 2009; Scott et al., 2005; Soweid et al., 2010; Thukral et al., 2019), vomiting (Gomez-Reyes et al., 2019; Mytyk et al., 2018; Park et al., 2009; Scott
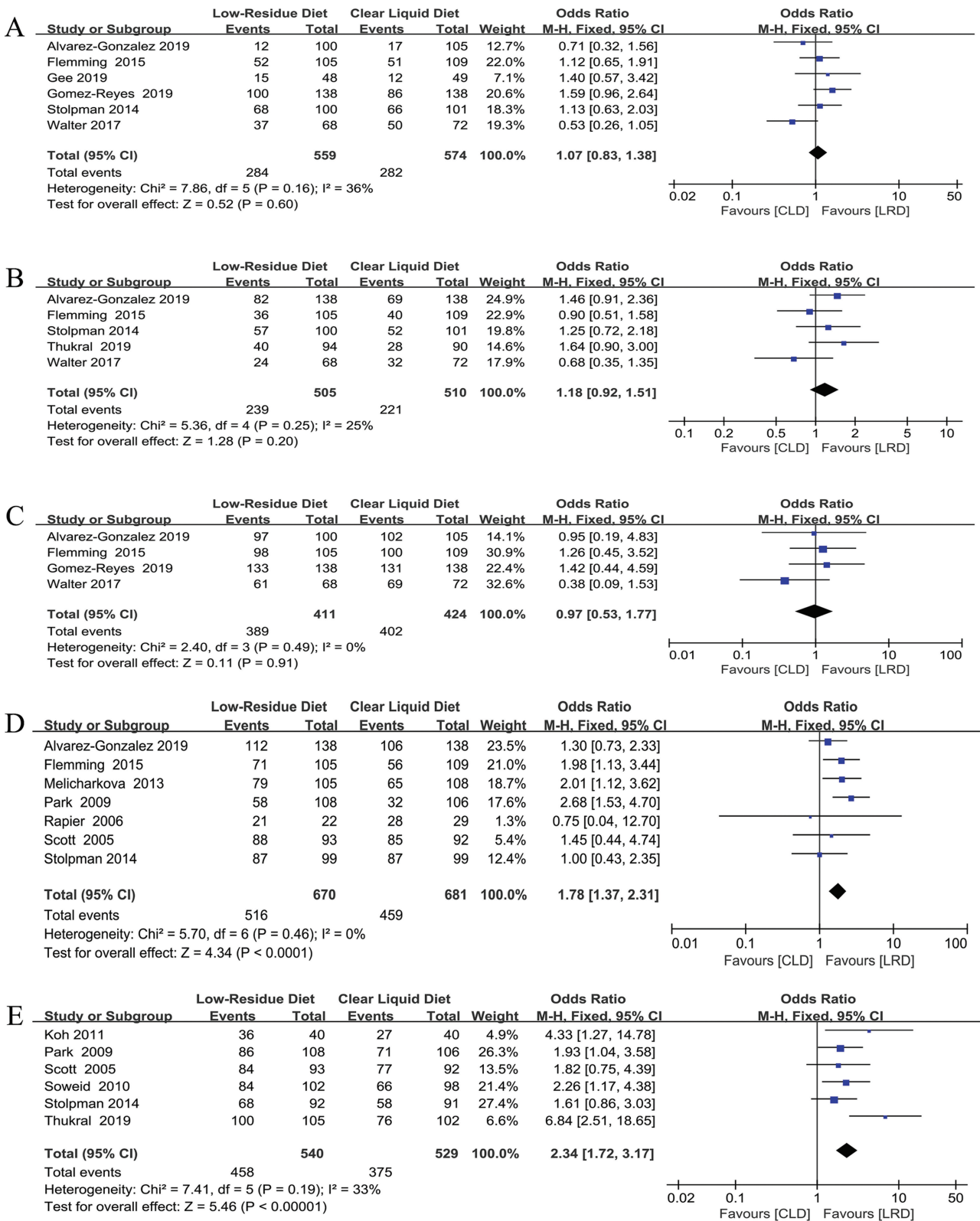
A

Study or Subgroup	Low-Residue Diet Events	Total	Clear Liquid Diet Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Alvarez-Gonzalez 2019	12	100	17	105	12.7%	0.71 [0.32, 1.56]
Flemming 2015	52	105	51	109	22.0%	1.12 [0.65, 1.91]
Gee 2019	15	48	12	49	7.1%	1.40 [0.57, 3.42]
Gomez-Reyes 2019	100	138	86	138	20.6%	1.59 [0.96, 2.64]
Stolpman 2014	68	100	66	101	18.3%	1.13 [0.63, 2.03]
Walter 2017	37	68	50	72	19.3%	0.53 [0.26, 1.05]
Total (95% CI)		**559**		**574**	**100.0%**	**1.07 [0.83, 1.38]**
Total events	284		282			

Heterogeneity: Chi² = 7.86, df = 5 (P = 0.16); I² = 36%
Test for overall effect: Z = 0.52 (P = 0.60)

B

Study or Subgroup	Low-Residue Diet Events	Total	Clear Liquid Diet Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Alvarez-Gonzalez 2019	82	138	69	138	24.9%	1.46 [0.91, 2.36]
Flemming 2015	36	105	40	109	22.9%	0.90 [0.51, 1.58]
Stolpman 2014	57	100	52	101	19.8%	1.25 [0.72, 2.18]
Thukral 2019	40	94	28	90	14.6%	1.64 [0.90, 3.00]
Walter 2017	24	68	32	72	17.9%	0.68 [0.35, 1.35]
Total (95% CI)		**505**		**510**	**100.0%**	**1.18 [0.92, 1.51]**
Total events	239		221			

Heterogeneity: Chi² = 5.36, df = 4 (P = 0.25); I² = 25%
Test for overall effect: Z = 1.28 (P = 0.20)

C

Study or Subgroup	Low-Residue Diet Events	Total	Clear Liquid Diet Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Alvarez-Gonzalez 2019	97	100	102	105	14.1%	0.95 [0.19, 4.83]
Flemming 2015	98	105	100	109	30.9%	1.26 [0.45, 3.52]
Gomez-Reyes 2019	133	138	131	138	22.4%	1.42 [0.44, 4.59]
Walter 2017	61	68	69	72	32.6%	0.38 [0.09, 1.53]
Total (95% CI)		**411**		**424**	**100.0%**	**0.97 [0.53, 1.77]**
Total events	389		402			

Heterogeneity: Chi² = 2.40, df = 3 (P = 0.49); I² = 0%
Test for overall effect: Z = 0.11 (P = 0.91)

D

Study or Subgroup	Low-Residue Diet Events	Total	Clear Liquid Diet Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Alvarez-Gonzalez 2019	112	138	106	138	23.5%	1.30 [0.73, 2.33]
Flemming 2015	71	105	56	109	21.0%	1.98 [1.13, 3.44]
Melicharkova 2013	79	105	65	108	18.7%	2.01 [1.12, 3.62]
Park 2009	58	108	32	106	17.6%	2.68 [1.53, 4.70]
Rapier 2006	21	22	28	29	1.3%	0.75 [0.04, 12.70]
Scott 2005	88	93	85	92	5.4%	1.45 [0.44, 4.74]
Stolpman 2014	87	99	87	99	12.4%	1.00 [0.43, 2.35]
Total (95% CI)		**670**		**681**	**100.0%**	**1.78 [1.37, 2.31]**
Total events	516		459			

Heterogeneity: Chi² = 5.70, df = 6 (P = 0.46); I² = 0%
Test for overall effect: Z = 4.34 (P < 0.0001)

E

Study or Subgroup	Low-Residue Diet Events	Total	Clear Liquid Diet Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Koh 2011	36	40	27	40	4.9%	4.33 [1.27, 14.78]
Park 2009	86	108	71	106	26.3%	1.93 [1.04, 3.58]
Scott 2005	84	93	77	92	13.5%	1.82 [0.75, 4.39]
Soweid 2010	84	102	66	98	21.4%	2.26 [1.17, 4.38]
Stolpman 2014	68	92	58	91	27.4%	1.61 [0.86, 3.03]
Thukral 2019	100	105	76	102	6.6%	6.84 [2.51, 18.65]
Total (95% CI)		**540**		**529**	**100.0%**	**2.34 [1.72, 3.17]**
Total events	458		375			

Heterogeneity: Chi² = 7.41, df = 5 (P = 0.19); I² = 33%
Test for overall effect: Z = 5.46 (P < 0.00001)

FIGURE 4. Forest plot of quality indicators, tolerance, and willingness for colonoscopy between LRD and CLD groups. (A) Polyp detection rate (PDR). (B) Adenoma detection rate (ADR). (C) Cecal intubation rate (CIR). (D) Tolerance of participants for colonoscopy between LRD and CLD groups. (E) Willingness of participants for colonoscopy between LRD and CLD groups.

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et al., 2005; Soweid et al., 2010; Thukral et al., 2019), and abdominal pain or discomfort (Gomez-Reyes et al., 2019; Mytyk et al., 2018; Park et al., 2009; Scott et al., 2005; Soweid et al., 2010; Thukral et al., 2019). More participants in the CLD group consistently experienced hunger, nausea, and vomiting (hunger: OR, 0.34, and $p < .01$; nausea: OR, 0.73, and $p = .03$; vomiting: OR, 0.63, and $p = .04$). Heterogeneity among groups was not significant (hunger: $I^2 = 18\%$ and $p = .30$; nausea: $I^2 = 22\%$ and $p = .27$; vomiting: $I^2 = 27\%$ and $p = .23$). However, there was no statistically significant difference between groups for abdominal pain or discomfort (OR, 0.98; $p = .86$). Heterogeneity among groups was not significant ($I^2 = 0\%$; $p = .70$) (Figure 5).

Discussion

In our study, it was found that people who employed the LRD before colonoscopy had the same quality of bowel preparation as those with the CLD. Meanwhile, the tolerance, willingness to repeat, and adverse events of people with the LRD were better than those with the CLD.

The quality of bowel preparation is crucial to the quality of the colonoscopy (Kizilcik, Unver, Yildiz, Albayrak, & Fidan, 2020). Low-quality bowel preparation tends to result in lower ADR and more frequent repeat colonoscopies (Clark, Rustagi, & Laine, 2014). However, to improve the quality of bowel preparation, endoscopists prefer strict bowel preparation regimens, which may reduce patient tolerance and compliance. Poor patient tolerance and compliance are not
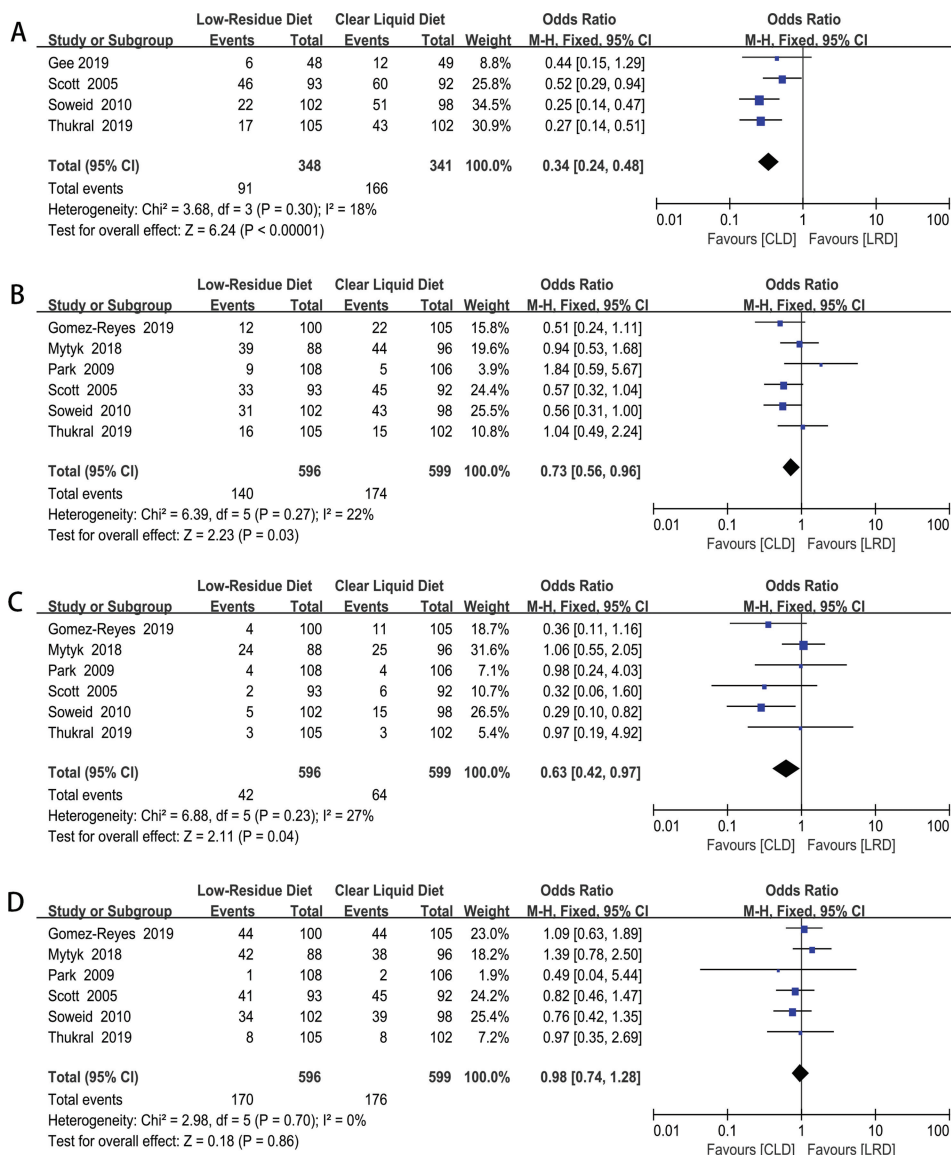

FIGURE 5. Forest plot of adverse effects between LRD and CLD groups: (A) hunger, (B) nausea, (C) vomiting, and (D) abdominal pain or discomfort.

conducive to the completion of the colonoscopy, and strict bowel preparation regimens may cause patients to avoid undergoing colonoscopies (Laiyemo et al., 2019; Radaelli et al., 2017; Stolpman et al., 2014). Therefore, an optimal bowel preparation regimen should consider bowel cleansing and the preferences of patients.

Our meta-analysis indicated that there was no significant statistical difference between LRD and CLD regarding the quality of bowel preparation. Although the overall heterogeneity was large, the categorical data analysis indicated that heterogeneity was small only after the removal of the study by Soweid et al., thus indicating that the study by Soweid et al. may have been the main source of heterogeneity. The conclusion was consistent regardless of whether the study by Soweid et al. was included. This conclusion was proven not only by categorical data but also by numerical data. Therefore, these two points illustrated the reliability of the conclusion.

The quality indicators for colonoscopy (PDR, ADR, and CIR) were not statistically significant. Therefore, the LRD is not worse than the CLD for bowel preparation in terms of bowel cleansing and colonoscopy quality. However, the LRD seems to have more advantages than the CLD in terms of patient preference. The tolerance of patients to bowel preparation with the LRD was better than the tolerance of patients to bowel preparation with the CLD. More patients who have used the LRD were willing to repeat the LRD. Simultaneously, fewer participants in the LRD group experienced adverse effects such as hunger, nausea, and vomiting. Because the LRD is not inferior to the CLD in terms of bowel cleansing and quality of colonoscopy, and because it can improve the willingness of patients to undergo colonoscopy, we believe that the LRD is better for bowel preparation than the CLD, especially for patients with diabetes or other diseases who cannot tolerate the CLD.

Compared to Other Studies

Three previous meta-analyses explored and compared the effectiveness of the LRD and CLD, and their results were similar to ours (Avalos, Sussman, Lara, Sarkis, & Castro, 2017; Nguyen et al., 2016; Song et al., 2016). In terms of eligibility criteria, our study included the most recent RCT from 2015 to September 2019. We also excluded studies that did not compare different diets individually but did compare the bowel preparation pattern for a particular type of diet combined with a particular laxative (Delegge & Kaplan, 2005). We only assessed full-text articles, which facilitated the evaluation of the quality of the included studies and allowed us to obtain complete data; however, this also may have resulted in a deficiency of the quantity of included studies.

We used both categorical and numerical data to demonstrate the similarities in the quality of bowel preparation with the two diets. Our conclusion is consistent with that of two previous studies, thus indicating the reliability of our conclusion. We considered the quality of bowel preparation and the quality indicators for colonoscopy, which comprehensively showed that the LRD was not inferior to the CLD. Previous studies concluded that there was no statistical difference in the overall adverse events of the two groups. However, when we analyzed some common adverse events separately, we found that hunger, nausea, and vomiting were less common in the LRD group, but there was no statistically significant difference in abdominal pain or discomfort between the two groups, thus illustrating the safety of the LRD.

Strengths and Limitations

Any meta-analysis inevitably has many obvious strengths and limitations. The strengths of this meta-analysis were equally apparent. First, all included studies were RCTs, resulting in improved study quality and increased reliability of the conclusions. Second, participants in the studies included in the meta-analysis were from different regions, in different age groups, and had different genders, and the types of bowel preparation solutions were not identical among the studies, which suggested that the LRD could be used by different populations for bowel preparation. Third, the study included 16 studies that met the eligibility criteria of the past decade, resulting in a meta-analysis of data of 2,912 patients and reliable conclusions.

Our study also had limitations. First, only RCTs published in English were included, which resulted in an English language bias and made it easier to yield the expected conclusion. However, none of the 16 included studies or other related literature (Tariq et al., 2019) reported that the quality of bowel preparation with the CLD was superior to that with the LRD, suggesting that we should not strongly consider the effects of this bias. Second, different studies adopted different schemes so that patients could use the LRD. Some of them used a prepackaged LRD; however, in most cases, they let the patients follow a specialized diet. The number of meals allowed were different in the included studies. Some patients were asked to replace three meals with the LRD, whereas others were asked to replace breakfast and lunch or even just breakfast with the LRD before the colonoscopy. Furthermore, the types (PEG, NaP, magnesium citrate and bisacodyl, and oral sulfate solution), times (the morning, afternoon, or evening before the colonoscopy), and methods (split-dose or not) of the bowel preparation

solution were different. These differences might have been sources of bias. Third, the included studies adopted different scales to assess the bowel preparation and define its adequacy, including the OBPS, BBPS, Aronchick Scale, and HCS. Finally, we included only full-text articles. Studies that were not available via full-text but which may have otherwise met our inclusion and exclusion criteria were not assessed.

Conclusion

The LRD is not inferior to the CLD for bowel preparation before colonoscopy. People who employed the LRD before colonoscopy had the same quality of bowel preparation as those with the CLD. Meanwhile, the tolerance of people with LRD was better than people with CLD, and these people were more willing to repeat the colonoscopy with less adverse events. ✪

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