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ORIGINAL ARTICLE

The value of mechanical bowel preparation prior to pediatric colorectal surgery: a systematic review and meta-analysis

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Abstract

Purpose The use of mechanical bowel preparation (MBP) before pediatric colorectal surgery remains the standard of care for many pediatric surgeons, though the value of MBP remains unclear. The aim of this study was to systematically review and analyze the effect of MBP on the incidence of postoperative complications; anastomotic leakage, intra-abdominal infection, and wound infection, following colorectal surgery in pediatric patients.

Methods Embase, MEDLINE, Web of Science, and CINAHL databases were searched to compare the effect of MBP versus no MBP prior to elective pediatric colorectal surgery on postoperative complications. After critical appraisal of included studies, meta-analyses were conducted using a random-effect model.

Results 1731 papers were retrieved; 2 randomized controlled trials and 4 retrospective cohort studies met the inclusion criteria. The overall quality of evidence was low. MBP before colorectal surgery did not significantly decrease the occurrence of anastomotic leakage, intra-abdominal infection, or wound infection compared to no MBP.

Conclusions On the basis of the existing evidence, the use of MBP before colorectal surgery in children seems not to decrease the incidence of postoperative complications compared to no MBP. To overcome confounding factors such as antibiotic prophylaxis, age and type of operation, a multicentre prospective study is suggested to validate these results.

Keywords Mechanical bowel preparation · Colorectal surgery · Postoperative complications · Pediatric surgery · Systematic review · Meta-analysis

Introduction

Historically, mechanical bowel preparation (MBP) prior to colorectal surgery is considered as one of the most important factors in decreasing the risk of postoperative complications such as anastomotic leakage and infections [1]. This risk is further decreased when MBP is combined with preoperative oral antibiotics [2].

Recent studies in adults have supported these results [3–7], yet this issue remains controversial. Various randomized clinical trials (RCTs), systematic reviews, and meta-analyses in adults indicate that MBP alone does not decrease the incidence of major postoperative complications and can therefore be safely omitted [8–10].

In children, there is a lack of evidence on the use of MBP before colorectal surgery and its usefulness has been mainly extrapolated from adult literature [11]. However, the indications for colorectal surgery and their comorbidities are vastly different between adults and children. Despite this, pediatric surgeons have commonly used MBP prior to colorectal surgery. A recent survey of the American Pediatric Surgical Association indicated that the use of only MBP before colorectal surgery remains the preferred practice for pediatric surgeons in the United States of America [12].

This study aims to review the literature regarding mechanical bowel preparation prior to pediatric colorectal surgery to evaluate whether MBP reduces the incidence of anastomotic leakage, intra-abdominal infection, or wound infection. We hypothesized that, in line with adult literature, MBP prior to pediatric colorectal surgery does not reduce

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the incidence of infectious complications compared to no MBP.

Methods

Search strategy

The Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) [13] and Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [14] were followed as a guide. This review was conducted based on a pre-specified protocol. A comprehensive electronic literature search was conducted using the Embase, MEDLINE, Web of Science, and CINAHL databases for studies published until January 10th, 2018 (Fig. 1). Articles were identified using the following (or combination of) search terms: "colorectal surgery", "bowel", "gut", "intestine", "preparation", "lavage", "cleansing" or "irrigation". In addition, a manual search of the references within retrieved articles was performed. Complete details of the search strategy are reported in Appendix 1 in Supplementary material.

Study selection criteria

Studies were included for analysis if they met the following criteria (Table 1): (1) patients aged 0–21 years that underwent elective colorectal surgery, (2) studies that compared preoperative MBP with no MBP, and (3) studies that reported at least one of the following postoperative complications: anastomotic leakage, intra-abdominal infection, or wound infection. Randomized controlled trials (RCTs), observational studies, and retrospective cohort studies in all languages were included in the search. Full text manuscripts were obtained for the articles meeting the inclusion criteria. Letters to the editor, conference abstracts, case reports, and review articles were excluded.

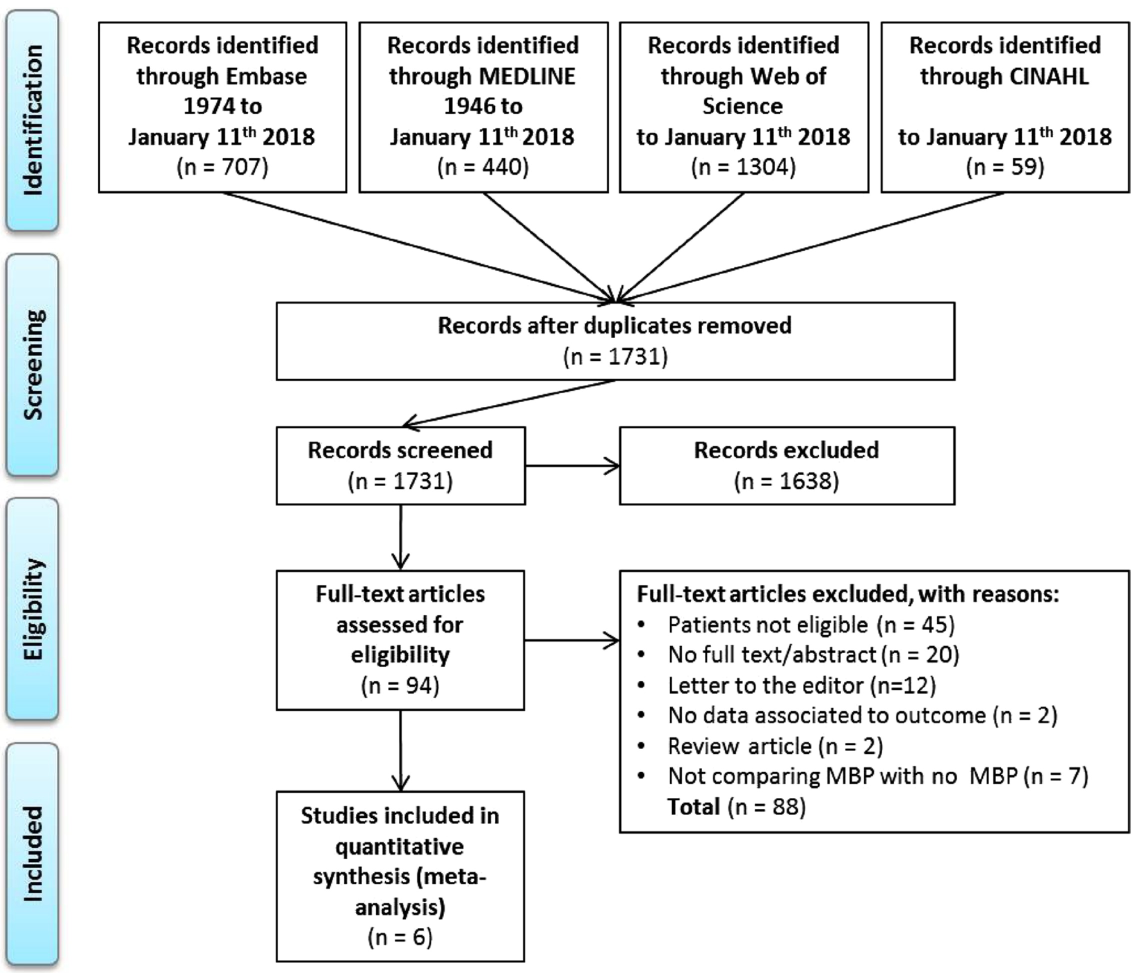

Fig. 1 PRISMA flow diagram

Table 1 Inclusion criteria

Inclusion criteria	Exclusion criteria
Pediatric patients in the age of 0–21 years	Letter to Editor, response, conference abstracts and other non-full text reports
Patients underwent elective colorectal surgery	MBP for colonoscopy in children
Patients received a form of MBP	Review articles
The study compares MBP versus no MBP	
The study reports ≥ 1 of the outcomes: anastomotic leakage, intra-abdominal infection, wound infection	
All languages	

MBP mechanical bowel preparation

Data collection process

After removing duplicates, two reviewers (MJL, JO) independently screened titles and abstracts while taking all eligibility criteria into account. All articles identified underwent an independent full text review, in which data were collected using a pre-designed and pre-specified extraction form. Information collected from each article included: first author, year of publication, country of origin, study design, sample size, gender, age of patients, details of MBP (such as type of agent), administration of oral and/or intravenous antibiotics, characteristics of no MBP management, and postoperative complications. Additionally, we contacted the authors of the studies that did not clearly report details of oral and/or intravenous antibiotic administration.

Quality assessment

Risk of bias for the included studies was evaluated using the 'Risk of Bias 2.0' tool (RoB 2.0) [15] for Randomized studies and the 'Risk of Bias In Non-Randomized Studies of Interventions' tool (ROBINS-I) [16] for the non-randomized studies. RoB 2.0 assessed the bias of studies in the following domains: randomization process, deviations from intended interventions, missing data, measurement of the outcome, and selection of the reported results. Each domain was scored as "low risk," "some concerns," or "high risk," and overall risk of bias was scored. ROBINS-I assessed the bias of studies in the following domains: confounding, selection of participants into the study, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. Each domain was scored as "low," "moderate," "serious" or "critical risk" and overall risk of bias was scored.

Additionally, we employed the 'Grading of Recommendations and Assessment, Development and Evaluation' (GRADE) assessment to evaluate the quality and certainty of the evidence [17–26]. The quality of evidence was rated as "high," "moderate," "low" or "very low" for each outcome. GRADE assessment for retrospective studies started with a baseline of low quality of evidence and randomized studies with a baseline of high quality of evidence. The quality of evidence was rated down in the presence of risk of bias, inconsistencies, indirectness, imprecision, and publication bias.

Statistical analysis

For analyzing the effect of MBP on the occurrence of postoperative complications, pooled estimates of odds ratios and their 95% confidence intervals were calculated using a random-effects model according to the Mantel–Haenszel method [27]. This was done for the individual outcomes anastomotic leakage, intra-abdominal infection, and wound infection. Review Manager 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) analysis was used. Inter-study heterogeneity was assessed using the inconsistency (I^2) score and was considered substantial if above 50% [14].

Results

Study selection

We identified 1731 unique references. No additional studies were identified from review articles or the articles' reference lists. There were no previous systematic reviews addressing our review question among the yielded search results. Of the 1731 articles, two reviewers (MJL and JO) independently selected 94 potentially relevant articles. Subsequently, these 94 full text articles were independently assessed and six articles were identified that met the eligibility criteria [28–33]. These six studies were then subjected to data extraction by MJL and JO. Discrepancies in extracted data and disagreements in quality assessment of the studies were discussed among three independent reviewers (MJL, JO, HM) and consensus was reached in all cases. For details see the PRISMA flowchart in Fig. 1.

Study characteristics

This review included six studies: two randomized controlled trials (RCT) [28, 29] and four retrospective cohort studies [30–33]. 2178 patients were included in the analyzed studies (1011 received MBP and 1167 did not). Age at enrollment varied within and across studies, from 0 to 21 years of age. Breckler et al. [31] included patients up to 18 years of age, Leys et al. [30] and Aldrink et al. [28] included patients up to 20 and 21 years, respectively, and Ares et al. [28], Serrurier et al. [32] and Shah et al. [29] included patients under 10, 14 and 15 years of age, respectively (Table 2). Five of the included studies [28–32] reported the following indications for colorectal surgery: anorectal anomalies ($n = 383$), Hirschsprung disease ($n = 262$), Crohn's disease ($n = 40$), ulcerative colitis ($n = 18$), rectal trauma ($n = 15$), necrotizing enterocolitis ($n = 14$), colon atresia ($n = 6$), and other ($n = 25$, e.g., colostomy closure for sigmoid volvulus, resection of rectal duplication cyst, reestablishment of intestinal continuity with history of NEC, colonic dysmotility/pseudo-obstruction, adenomatous polyposis, and perforated appendicitis). The remaining study [33] reported indications for surgery exclusively for children under 1 year of age ($n = 839$ out of 1581 in total) with atresia of the large intestine and anorectal malformations together ($n = 392$), Hirschsprung disease ($n = 170$), or inflammatory bowel disease ($n = 47$) (Table 2). Overall, the most common indications for colorectal surgery in these studies were anorectal malformation, Hirschsprung disease, and inflammatory bowel disease.

MBP and prophylactic antibiotics

Randomized controlled studies

The MBP agent administered in both RCTs was polyethylene glycol (PEG) [28, 29]. In both studies, intravenous antibiotics were administered in the MBP and no MBP groups. In Aldrink et al. oral antibiotics were not given in both study groups [28]. In Shah et al., this information was not available [29]. For this reason, we contacted the authors who clarified that none of the patients in either study groups received oral antibiotics (Table 2) [29].

Non-randomized studies

The MBP agent most commonly administered was PEG [31, 32]. Ares et al. [33] included patients that received PEG or magnesium citrate as MBP agent. In Leys et al. [30], the administrations of enemas, stomal irrigation, laxatives, and/or oral antibiotics (in isolation or in combination) were considered as preoperative MBP (Table 2).

In three of the retrospective studies, the 'MBP group' consisted of patients that received MBP and patients that received a combination of MBP and oral antibiotics prior to the surgery [30–32]. All patients in these studies received perioperative intravenous antibiotics [30, 32] except for Breckler et al. [31] in which 95 of 98 patients (97%) received intravenous antibiotics. Ares et al. [33] reported a separate group of patients receiving MBP combined with oral antibiotics and did not provide data regarding the use of intravenous antibiotic prophylaxis. Contacting the authors did not provide additional data regarding the use of intravenous antibiotic prophylaxis due to the retrospective nature of the study (Table 2).

Postoperative complications in randomized controlled studies

The incidence for anastomotic leakage was 4.8% (2/42) in the MBP group versus 2.9% (1/34) in the no MBP group (OR 1.32; 95% CI 0.16–11.31). The incidence for intra-abdominal infection was 7.1% (3/42) in the MBP group versus 5.9% (2/34) in the no MBP group (OR 1.08; 95% CI 0.11–10.74). The incidence of wound infection was 16.7% (7/42) in MBP group versus 14.7% (5/34) in the no MBP group (OR 1.10; 95% CI 0.22–5.48). This indicates that the incidence of postoperative complications did not significantly differ between the MBP and no MBP groups. The I^2 score showed no value > 50% for the outcomes above (Fig. 2).

Postoperative complications in non-randomized studies

The incidence for anastomotic leakage was 3.2% (28/871) in MBP group versus 4.7% (53/1125) in the no MBP group (OR 0.81; 95% CI 0.50–1.31). The incidence for intra-abdominal infection was 0.7% (2/297) in the MBP group versus 0.8% (1/118) in the no MBP group (OR 0.91; 95% CI 0.08–10.15). The incidence for wound infection was 6.6% (64/969) in MBP group versus 3.9% (44/1133) in the no MBP group wound infection (OR 1.39; 95% CI 0.67–2.90). This indicates that the incidence of postoperative complications did not significantly differ between the MBP and no MBP groups. The I^2 score showed no value > 50% for the outcomes above (Fig. 3).

Quality of the included studies

Risk of bias in randomized controlled trials (RoB 2.0)

Shah et al. [29] did not report details of the randomization process; it was not clear how mechanical bowel preparation was assigned, resulting in some concerns arising from the randomization process. Aldrink et al. [28] reported that 39% of the patients received a different dose of intravenous

Table 2 Baseline study characteristics and details of MBP and antibiotic prophylaxis

First author	Year	Country	Sample	Groups № (%)	Age	Males (%)	Indications for surgery (№)	Surgery location	Type of surgery	Primary outcomes reported	MBP policy	No MBP policy	Timing of nil by mouth	Timing of MBP	Antibiotic prophylaxis
Randomized controlled trials															
Aldrink [28]	2015	USA	44	MBP: 24 (55%) No MBP: 20 (45%)	Overall mean: 7.3 years (SD6.6 years, median 6 years)	N/A	Reported for both groups (MBP and no MBP): UC (12), CD (7), HD (7), ARM (10), other diagnoses (8)*	Colon and/or rectum	Intra-abdominal anastomosis, PT, others (CC)	Anastomotic leakage, intra-abdominal infection, wound infection	PEG per os/nasogastric tube	CLD only	From midnight before surgery	The day prior to surgery	Both MBP and no MBP groups IV: cefoxitin 1 dose pre-operatively, 1 dose post-operatively (8 h after first dosage) Oral: none
Shah [29]	2016	USA	32	MBP: 18 (56.3%) No MBP: 14 (43.7%)	Overall mean: 7.1 years ± 6.5	Total: 18 (56.3%) MBP: not specified No MBP: not specified	MBP ARM (6), UC (1), HD (4), CD (2), FAP (4), trauma (1) No MBP ARM (4), UC (5), HD (1), CD (2), FAP (0), trauma (0), duplication cyst (1), appendicitis (1)	Colon and/or rectum, ileostomy take-downs as well	MBP IC (6), CC (7), PT (3) BR (2) No MBP IC (7), CC (4), PT (1), BR (2)	Anastomotic leakage, abdominal abscess, wound infection	PEG per os/nasogastric tube	CLD from noon on day before surgery	2–6 h prior to surgery, depending on what the anesthesiologist required	From 4 pm on the day before surgery	Both MBP and no MBP groups IV: cefazoline and metronidazole preoperatively. In case of allergy, clindamycin was used alternatively Oral: none

Table 2 (continued)

First author	Year	Country	Sample	Groups № (%)	Age	Males (%)	Indications for surgery (№)	Surgery location	Type of surgery	Primary outcomes reported	MBP policy	No MBP policy	Timing of nil by mouth	Timing of MBP	Antibiotic prophylaxis
Retrospective cohort studies															
Leys [30]	2005	USA	143	MBP: 110 (76.9%) No MBP: 33 (23.1%)	MBP mean: 4.7 years (1 months to 19 years) No MBP mean: 4.8 years (4–20 years)	Total: 100 (70%) MBP: 79 (71.8%) No MBP: 21 (63.6%)	MBP HD (55), ARM (18), CD (23), RT (4), CA (6), NEC (4), IDC (1) No MBP HD (11), ARM (11), CD (6), RT (3), rectal perforation (1), meconium ileus (1)	Ileum, colon, rectum	MBP CC (41), proctectomy with PT (47), BR (7), ileocolectomy (14) No MBP: CC (16) proctectomy with PT (11), BR (4), ileocolectomy (2)	Anastomotic leakage, intra-abdominal abscess, wound infection	Enemas, stomal irrigations, laxatives, or a combination, and some of these children received oral antibiotics only	CLD only	From the day before surgery	N/A	MBP IV: perioperative antibiotics, not specified Oral: some of these children received oral antibiotics, not specified No MBP IV: perioperative antibiotics, not specified Oral: none

Table 2 (continued)

First author	Year	Country	Sample	Groups № (%)	Age	Males (%)	Indications for surgery (№)	Surgery location	Type of surgery	Primary outcomes reported	MBP policy	No MBP policy	Timing of nil by mouth	Timing of MBP	Antibiotic prophylaxis
Breckler [31]	2010	USA	118	MBP: 98 (83.0%) No MBP: 8 (6.8%) Unknown: 12 (10.2%)	All patients mean: 12.8 months	Total: 59 (50%)	Reported for both groups (MBP and no MBP): ARM (118)	Colon	CC	Wound infection	PEG (in 98% of the patients, remaining 2% not specified)	N/A	N/A	N/A	MBP IV: 95 of 98 patients (97%) received cefoxitin or combination of ampicillin and gentamicin intravenously Oral: 56 of 98 patients (57.1%) received either neomycin only or a combination of neomycin/erythromycin No MBP IV: all eight patients received cefoxitin or combination of ampicillin and gentamicin Oral: all eight patients received neomycin only or a combination of neomycin/erythromycin patients received

Table 2 (continued)

First author	Year	Country	Sample	Groups № (%)	Age	Males (%)	Indications for surgery (№)	Surgery location	Type of surgery	Primary outcomes reported	MBP policy	No MBP policy	Timing of nil by mouth	Timing of MBP	Antibiotic prophylaxis
Serrurier [32]	2012	USA	272	MBP: 187 (68.7%) No MBP: 85 (31.3%)	MBP mean: 19.4 months (range 2–176) No MBP mean: 20.9 months (range 2-168)	Total: 157 (57.7%) MBP: 104 (55.6%) No MBP: 53 (62.4%)	MBP ARM (164), HD (9), NEC (5), trauma (4), other (5) No MBP ARM (69), HD (5), NEC (3), trauma (3), other (5)	Colon and/or rectum	CC	Anastomotic leakage, abdominal abscess, wound infection	PEG per os; not specified	CLD only for 26/85 patients, remainder received a diet for age until midnight	From midnight before surgery or from MBP, whichever comes first	N/A	MBP: IV: perioperative cefoxitin; ampicillin and gentamicin; ampicillin, gentamicin and clindamycin; ampicillin/sulbactam Oral: 52% received oral preoperative antibiotics, not specified No MBP: IV: cefoxitin; ampicillin and gentamicin; ampicillin, gentamicin and clindamycin; ampicillin/sulbactam Oral: none
Ares [33]	2017	USA	1581	MBP: 429 (27.1%) MBP + oral antibiotics: 145 (9.2%) No MBP: 1007 (63.7%)	Overall mean: 1.7 ± 2.6 years	Total: 952 (60.2%) MBP: 605 (63%) No MBP: 270 (60%) MBP + oral antibiotics: 77 (53%)	Reported for patients under a year only (*n* = 839) HD (170), ARM and CA (392), IBD (47)	Colon and/or rectum	Colonic anastomoses, of which 988 were CC	Anastomotic leakage, wound infection	PEG or magnesium citrate	N/A	N/A	The day prior to surgery	MBP: IV: N/A Oral: none MBP + oral antibiotics IV: N/A Oral: neomycin or erythromycin No MBP IV: N/A Oral: none

MBP mechanical bowel preparation, *N/A* not available, UC ulcerative colitis, *CD* crohn's disease, *HD* Hirschsprung disease, *ARM* anorectal malformation, *FAP* familial adenomatous polyposis, *RT* rectal trauma, *CA* colon atresia, *NEC* necrotizing enterocolitis, *IDC* ileal duplication cyst, *IBD* inflammatory bowel disease, *PT* pull-through, *CC* colostomy closure, *IC* ileostomy closure, *BR* bowel resection, *PEG* polyethylene glycol, *CLD* clear liquid diet, *IV* intravenous

*Colostomy closure for sigmoid volvulus (1), resection of rectal duplication cyst (1), reestablishment of intestinal continuity with history of NEC (2), stoma closure for distal ileal atresia (1), colonic dysmotility/pseudo-obstruction (3) antibiotics due to surgeons deviating from the study protocol. This was possibly affecting the incidence of postoperative infectious complications. The overall risk of bias was rated as "some concerns" for all postoperative outcomes (Table 3).

Risk of bias in non-randomized studies (ROBINS-I)

The type of surgery conducted varied among the retrospective studies. Leys et al. [30] reported colostomy, proctectomy with pull-through, colon resection, ileocolectomy, and ileal resection. This may have affected the occurrence of anastomotic leakage and intra-abdominal infection, resulting in a serious risk of confounding bias in these two outcomes. The remaining retrospective studies reported colostomy closure only [31, 32] or colonic anastomoses with colostomy closure specifically in the vast majority of the patients [33] (Table 2). Furthermore, Leys et al. compared a single surgeon that routinely omitted MBP to multiple surgeons who always administered MBP, which also contributed to serious confounding bias for all three outcomes [30]. In addition, group size and distribution of participants were skewed and different manners of MBP administration were included in this study [30]. The remaining studies had no additional risk of bias. The overall risk of bias was rated as "serious" for all postoperative outcomes (Table 4).

Assessment of quality of evidence using GRADE

The summary of the GRADE assessment is displayed in Tables 5 and 6. Inconsistency was considered to be low to moderate as heterogeneity was below 50% [14]. Indirectness was also considered not serious. Imprecision was considered serious for all outcomes, because of small sample size for all outcomes. As this meta-analysis included six studies, we did not perform funnel plot analysis. Overall, the quality of the evidence in this systematic review was considered "low" for RCTs and "very low" for non-RCTs for all outcomes (Tables 5, 6).

Discussion

This systematic review and meta-analysis is the first of its kind by evaluating the effectiveness of MBP before colorectal surgery in children. Surgical site infections occur in 13–25% of cases in children, resulting in significant morbidity for patients and costs to the healthcare system [33]. From a historical perspective, it is believed that MBP reduces the postoperative complication rate [1, 2]. The present study indicates that MBP prior to pediatric colorectal surgery seems not to decrease the rate of anastomotic leakage, intra-abdominal infection, or wound infection compared to no MBP. However, there were serious concerns for risks of bias and the quality of evidence was scored as low in RCTs and very low in the retrospective studies (Tables 5, 6). Therefore, a prospective trial is needed to validate these initial findings.

Mechanical bowel preparation before colorectal surgery clears the large bowel from feces and in theory reduces the bacterial load in the lumen to minimize the rate of infection and anastomotic complications [34]. However, MBP is not harmless and is associated with disadvantages including admission a day before surgery, expensiveness, and occasionally abdominal pain, distension, and fatigue [35, 36]. Furthermore, water and electrolyte imbalance have been reported in many cases after MBP [35]. A recent review suggested to be cautious for electrolyte imbalance when using sodium picosulfate and the authors pointed out the poor reporting of safety and tolerability of MBP in children in general [37]. MBP is also known to liquefy the solid stools, increasing the chances of intra-operative spillage and contamination [38, 39]. Further evidence questioning the utility of MBP in elective colorectal surgery originates from urgent operations which appeared to be safe without MBP [40]. In adults, postoperative complications are responsible for extended hospitalization and increased healthcare expenses [41]. Moreover, the administration of MBP is challenging in children as drinking MBP solution, or receiving a nasogastric tube for its administration, are uncomfortable and stressful [42].

Although the majority of included studies used PEG as an agent for MBP (Table 2), it is known that MBP administration is adjusted to surgeons' preferences. Therefore, the manner of MBP and the solution used can vary greatly. In a recent systematic review, the available evidence investigating the optimum MBP agents for all indications (e.g., colonoscopy, elective colorectal surgery) in children and young persons was summarized [37]. The adequacy of bowel preparation was comparable for PEG-ELS, senna, normal saline, sodium phosphate, and sodium picosulfate/magnesium citrate. PEG appeared to be the least tolerable agent across all studies, whereas sodium picosulfate and magnesium citrate were significantly better tolerated [37].

Furthermore, the distinction between the different components of bowel preparation (nil per os, mechanical bowel preparation, and oral antibiotic preparation) is not always clear in the literature. As discussed in "Results" section, some of the included studies did not explicitly distinguish MBP with or without oral antibiotic preparation (Table 2). In the adult literature, it has been confirmed that oral antibiotics are vital in reducing complications following colorectal surgery [43–45]. Recent studies in the adult population assessing the effect of combining oral antibiotics with MBP, rather than MBP alone, showed a protective effect against infectious complications when combined [3–7, 44, 45]. On

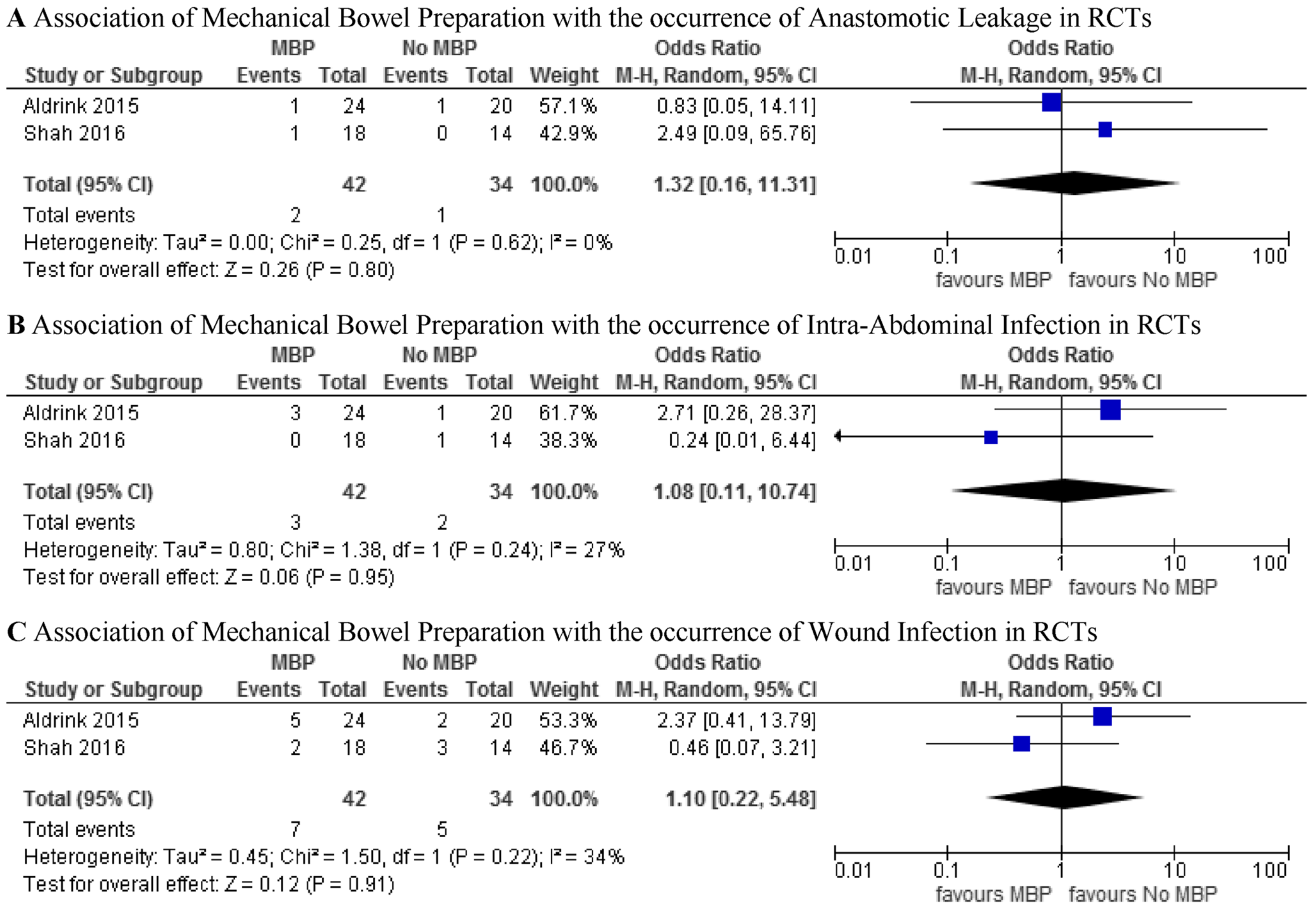

Fig. 2 Randomized Controlled Trials: Mechanical Bowel Preparation (MBP) before colorectal surgery and the occurrence of postoperative complications in children. **a** Association of Mechanical Bowel Preparation with the occurrence of Anastomotic Leakage in RCTs. **b** Association of Mechanical Bowel Preparation with the occurrence of Intra-Abdominal Infection in RCTs. **c** Association of Mechanical Bowel Preparation with the occurrence of Wound Infection in RCTs. *MBP* mechanical bowel preparation. Odds ratios with 95% confidence intervals (CIs) for each study are denoted by boxes (lines and arrows). Pooled odds ratio estimates for all studies using random effects models are represented by the diamonds (M–H = Mantel–Haenszel test). Tau-squared (Tau2) > 1, Cochran Q ($\chi 2$) $P < 0.1$, and inconsistency (I^2) ≥ 50% suggests substantial statistical heterogeneity. Z score with $P < 0.05$ indicates test for overall effect was statistically significant

the other hand, Breckler et al. [31] reported that MBP combined with oral antibiotics did not further decrease infection rate compared to MBP only in children treated with colostomy closure for imperforate anus [11]. In a similar study [33], three groups of pediatric patients were compared: MBP combined with oral antibiotics, MBP only, and no MBP. Initially, the authors found a higher incidence of postoperative complications among the patients that received both oral antibiotics and MBP compared to patients that received MBP only. However, in a random-effects model (accounting for hospital clustering), there was no difference in postoperative complications [33]. In a recent retrospective database study with adult patients, oral antibiotics alone decreased the incidence of postoperative complications, whereas oral antibiotics combined with MBP presented no superiority [46].

Patients' age varied among and within the included studies, ranging from birth to 21 years of age (Table 2). This resulted in an important source of heterogeneity as also acknowledged by Aldrink et al. [28]. Breckler et al. [31] studied an homogenous group of children of similar age undergoing one type of operation (colostomy closure after anorectal malformation repair). Other studies did not discuss variation of age as a source of heterogeneity [29, 30, 32, 33].

As presented in "Results" section, another important source of heterogeneity in retrospective studies is the variation in types of operations included. To focus on a homogenous population, colostomy takedown was the only type of operation in two studies [31, 32] and the most frequent operation in another study [33]. However, one retrospective study [30] included multiple types of operations which resulted in a serious risk of confounding bias (Table 2).

Although the literature in adults is more extensive, our study indicates the presence of two RCTs and multiple observational studies addressing the value of MBP in

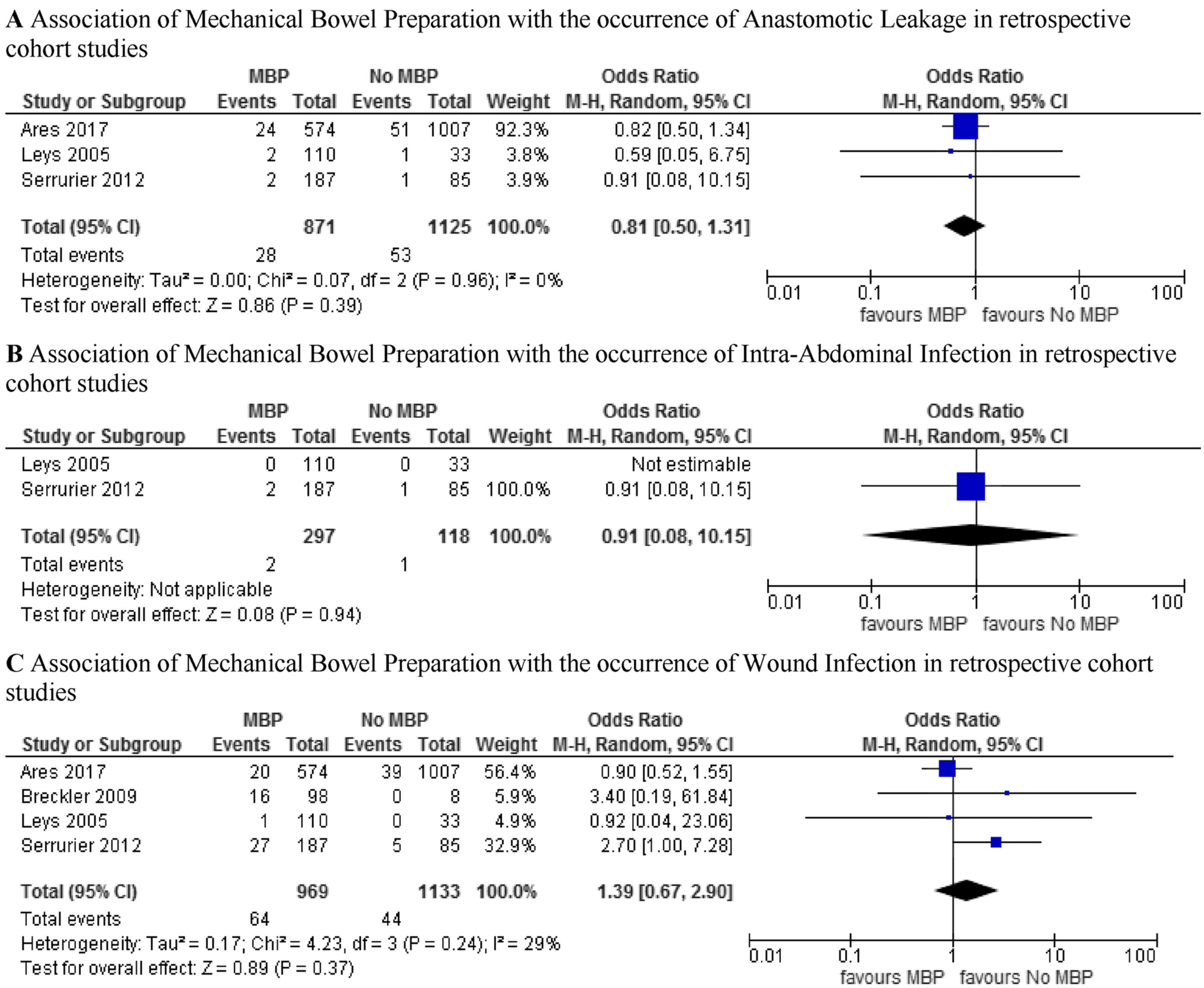

Fig. 3 Retrospective studies: Mechanical Bowel Preparation (MBP) before colorectal surgery and the occurrence of postoperative complications in children. **a** Association of Mechanical Bowel Preparation with the occurrence of Anastomotic Leakage in retrospective cohort studies. **b** Association of Mechanical Bowel Preparation with the occurrence of Intra-Abdominal Infection in retrospective cohort studies. **c** Association of Mechanical Bowel Preparation with the occurrence of Wound Infection in retrospective cohort studies. *MBP* mechanical bowel preparation. Odds ratios with 95% confidence intervals (CIs) for each study are denoted by boxes (lines and arrows). Pooled odds ratio estimates for all studies using random effects models are represented by the diamonds (M–H = Mantel–Haenszel test). Tau-squared (Tau2) > 1, Cochran Q ($\chi2$) $P < 0.1$, and inconsistency (I^2) ≥ 50% suggests substantial statistical heterogeneity. Z score with $P < 0.05$ indicates test for overall effect was statistically significant

children. Some of these studies were excluded because of comparing different methods of bowel preparation instead of comparing MBP versus no MBP [35, 47–52]. Other studies reported MBP in children but did not provide quantitative data regarding the incidence of postoperative complications [53, 54]. Our meta-analyses, which included both RCTs and retrospective cohort studies, revealed that the incidence of anastomotic leakage, intra-abdominal infection, and wound infection seems not to be decreased by MBP prior to pediatric colorectal surgery, suggesting MBP may be safely omitted.

With the lack of supporting evidence for MBP without antibiotics in both adults and children, it is interesting that a recent retrospective database study showed that the most common preparation prior to pediatric colorectal surgery was MBP alone (54.3%), followed by MBP combined with oral antibiotics (18.8%), and oral antibiotics alone (4.2%) [53]. Additionally, a survey among pediatric surgeons conducted by the American Pediatric Surgical Association indicates that the use of MBP alone remains the preferred approach for most pediatric surgeons [12]. However, an increasing number of surgeons reported omitting MBP in favor of dietary modification alone or no preparation at all [12].

Table 3 Risk of bias assessment in randomized controlled studies using RoB 2.0

Domain	Aldrink et al.			Shah et al.		
	O1	O2	O3	O1	O2	O3
Bias arising from the randomization process	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Bias due to deviations from intended interventions	Some concerns			Low risk		
Bias due to missing outcome data	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bias in measurement of the outcome	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bias in selection of the reported result	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Overall	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns

The risk of bias is scored as "low," "some concerns," or "high"

O1 outcome 1 (anastomotic leakage), *O2* outcome 2 (intra-abdominal infection), *O3* outcome 3 (wound infection)

Table 4 Risk of bias assessment in retrospective cohort studies using ROBINS-I

Domain	Leys et al.			Breckler et al.	Serrurier et al.			Ares et al.	
	O1	O2	O3	O3	O1	O2	O3	O1	O3
Bias due to confounding	Serious	Serious	Serious	Low	Low	Low	Low	Low	Low
Bias in selection of participants into the study	Low			Low	Low			Low	
Bias in classification of interventions	Low			Low	Low			Low	
Bias due to deviations from intended interventions	Low			Low	Low			Low	
Bias due to missing data	Low	Low	Low	Low	Low	Low	Low	Low	Low
Bias in measurement of outcomes	Low	Low	Low	Low	Low	Low	Low	Low	Low
Bias in selection of the reported result	Low	Low	Low	Low	Low	Low	Low	Low	Low
Overall	Serious	Serious	Serious	Low	Low	Low	Low	Low	Low

The risk of bias is scored as "low," "moderate," "serious," or "high"

O1 outcome 1 (anastomotic leakage), *O2* outcome 2 (intra-abdominal infection), *O3* outcome 3 (wound infection)

As outlined above, it is essential to report the use of perioperative antibiotic administration as this can influence the postoperative complication rate. A lack of reporting can create potential for a significant confounding factor [46]. In both adults and children, very little evidence supports the administration of MBP alone compared to MBP with oral antibiotics to prevent postoperative complications. It remains unknown what the role of MBP is, with or without oral antibiotics, in preventing postoperative complications following colorectal surgery in children. Therefore, a prospective study is needed clearly reporting the details of MBP and antibiotic prophylaxis. In our Institution, we will evaluate prospectively a novel protocol on MBP before colorectal surgery.

Limitations

This study reveals limitations in the current evidence. The risk of bias in RCTs for all outcomes was mainly caused by unclear randomization processes and due to deviations from intended interventions. In the retrospective studies, there was a serious risk of confounding bias for all outcomes caused by including multiple types of colorectal surgery (Table 2) and the comparison of one surgeon that routinely omitted MBP versus multiple surgeons that always administered MBP in one study [30]. In addition oral and intravenous antibiotic prophylaxis, which varied across the retrospective studies, complicated a reliable comparison [30, 32]. Finally, age at enrollment varied across the included studies, possibly confounding the results. This may have influenced the rate of postoperative complications and potentially confounded a reliable comparison.

Conclusions

Our study indicates that the quality of evidence for the use of MBP before pediatric colorectal surgery is low. On the basis of the existing evidence, MBP seems not to decrease the incidence of anastomotic leakage, intra-abdominal infection, or wound infection compared to no MBP and may therefore be safely omitted prior to colorectal surgery in children. To overcome confounding factors such as treatment allocation

Table 5 Evidence profile of postoperative complications using GRADE assessment in Randomized Controlled Trials

Certainty assessment							No of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	MBP	No MBP	Relative (95% CI)	Absolute (95% CI)		
Anastomotic leakage in randomized controlled trials												
2	RCT	Serious[a]	Not serious	Not serious	Serious[b]	None	2/42 (4.8%)	1/34 (2.9%)	OR 1.32 (0.16–11.31)	9 more per 1000 (from 25 fewer to 226 more)	⊕⊕◯◯ LOW	
Intra-abdominal infection in randomized controlled trials												
2	RCT	Serious[a]	Not serious	Not serious	Serious[b]	None	3/42 (7.1%)	2/34 (5.9%)	OR 1.08 (0.11–10.74)	4 more per 1000 (from 52 fewer to 343 more)	⊕⊕◯◯ LOW	
Wound infection in randomized controlled trials												
2	RCT	Serious[a]	Not serious	Not serious	Serious[b]	None	7/42 (16.7%)	5/34 (14.7%)	OR 1.10 (0.22–5.48)	12 more per 1000 (from 111 fewer to 339 more)	⊕⊕◯◯ LOW	

RCT randomized controlled trial, *CI* Confidence interval, *OR* Odds ratio, *MBP* mechanical bowel preparation

[a]Bias arising from the randomization process and due to deviations from intended interventions

[b]OIS was not met

Table 6 Evidence profile of postoperative complications using GRADE assessment in retrospective cohort studies

Certainty assessment							No of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	MBP	No MBP	Relative (95% CI)	Absolute (95% CI)		
Anastomotic leakage in retrospective cohort studies												
3	Observational studies	Serious[b]	Not serious	Not serious	Serious[a]	None	28/871 (3.2%)	53/1125 (4.7%)	OR 0.81 (0.50–1.31)	9 fewer per 1000 (from 14 more to 23 fewer)	⨁◯◯◯ VERY LOW	
Intra-abdominal infection in retrospective cohort studies												
2	Observational studies	Serious[b]	Not serious	Not serious	Serious[a]	None	2/297 (0.7%)	1/118 (0.8%)	OR 0.91 (0.08–10.15)	1 fewer per 1000 (from 8 fewer to 71 more)	⨁◯◯◯ VERY LOW	
Wound infection in retrospective cohort studies												
4	Observational studies	Serious[b]	Serious[c]	Not serious	Serious[a]	None	64/969 (6.6%)	44/1133 (3.9%)	OR 1.39 (0.67–2.90)	14 more per 1000 (from 12 fewer to 66 more)	⨁◯◯◯ VERY LOW	

CI Confidence interval; *OR* Odds ratio, *MBP* mechanical bowel preparation

a. OIS was not met

b. Bias due to confounding

c. Due to moderate inconsistency

in RCTs, and other factors in retrospective studies such as variation in type of surgery, administration of oral and intravenous antibiotics, and comparison of individual surgeon's practices, a large prospective randomized study is needed to validate these results.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to disclose.

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