

Trends in preoperative carbohydrate load practice: A systematic review

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Abstract

Background: The preoperative carbohydrate load (PCL) is intended to improve surgical outcomes by reducing the catabolic state induced by overnight fasting. However, there is disagreement on the optimal PCL prescription, leaving local institutions without a standardized PCL recommendation. Results from studies that do not prescribe PCL in identical ways cannot be pooled to draw larger conclusions on outcomes affected by the PCL. The aim of this systematic review is to catalog prescribed PCL characteristics, including timing of ingestion, percentage of carbohydrate contribution, and volume, to ultimately standardize PCL practice.

Methods: A comprehensive search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Randomized controlled trials were included if they studied at least one group of patients who were prescribed a PCL and the PCL was described with respect to timing of ingestion, carbohydrate contribution, and total volume.

Results: A total of 67 studies with 6551 patients were included in this systematic review. Of the studies, 49.3% were prescribed PCL on the night before surgery and morning of surgery, whereas 47.8% were prescribed PCL on the morning of surgery alone. The mean prescribed carbohydrate concentration was 13.5% (± 3.4). The total volume prescribed was 648.2 ml (± 377).

Conclusion: Variation in PCL practices prevent meaningful data pooling and outcome analysis, highlighting the need for standardized PCL prescription. Efforts dedicated to the establishment of a gold standard PCL prescription are necessary so that studies can be pooled and analyzed with respect to meaningful clinical end points that impact surgical outcomes and patient satisfaction.

KEYWORDS

administration, critical care, diabetes, nutrition, nutrition assessment, nutrition support practice, research and diseases, surgery

INTRODUCTION

Abbreviated fasting times before surgery by ingestion of a preoperative carbohydrate load (PCL) was investigated by the first Enhanced Recovery After Surgery (ERAS) group for colorectal surgery in 2001.¹ The PCL, a carbohydrate-containing clear liquid, was included in the original ERAS protocol, among 23 other core elements.¹ The PCL has since become an instrumental part of institutional ERAS protocols for many different types of surgeries.²⁻⁵ It has been included in consensus statements and guidelines from prominent international societies.⁶⁻¹⁰

A PCL administered before surgery is intended to improve surgical outcomes by enhancing the perioperative metabolic profile, in particular by reducing insulin resistance and glycemic variability (GV).^{11,12} It is appreciated that high GV is more detrimental to patients postoperatively than hyperglycemia alone.¹³ The PCL is thought to reduce GV by providing a substrate to increase endogenous insulin production and avoid catabolism, contrary to traditional preoperative nonoral fasting guidelines.

Despite PCL recommendations in consensus statements and practice guidelines, there is no gold standard PCL prescription with respect to timing of ingestion, nutrition composition, and dosage volume. The ERAS Society stated that preoperative administration of 100 g of 12.5% oral complex carbohydrates (800 ml) on the evening before surgery and 50 g (400 ml) 2–3 h before induction of anesthesia attenuates the catabolic response induced by overnight fasting and surgery.⁹ However, the American Society of Anesthesiologists recently reaffirmed their previous recommendation that healthy adults ingest up to 400 ml of simple or complex carbohydrate-containing clear liquids until 2 h before all elective procedures requiring anesthesia to minimize hunger and thirst.¹⁰ The lack of standardized PCL prescription practices prevents pooling of data and limits the identification of potential benefits of PCL on surgical outcomes. Furthermore, some subgroups of patients, including patients with type 2 diabetes mellitus (DM), are frequently excluded from PCL prescription despite growing evidence that PCL is safe for this patient population.¹⁴

The aim of this systematic review is to catalog PCL characteristics studied in the literature with respect to timing of ingestion, percentage of carbohydrate contribution, and PCL volume to guide the standardization and optimization of PCL prescription practices. The review also catalogs the studies that do not exclude patients with well-controlled type 2 DM from receiving a PCL prescription to support future research in including these patients in PCL prescription.

MATERIALS AND METHODS

Study design and registration

The protocol for this systematic review was registered through the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42023397416). This study adheres to the applicable Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search strategy

A professional librarian was consulted to develop and implement the search strategy. Search syntax contained all synonyms for diet, carbohydrate loading, carbohydrate loading diet, ERAS, and dietary C-carbohydrates. A comprehensive search covering the time since database establishment through February 2023 was conducted in PubMed, Embase, Cochrane, and Web of Science in accordance with the PRISMA guidelines. All gray literature and references of published studies were searched through Rayyan (Rayyan Systems Inc) to ensure all relevant articles were included. Database search results were limited to the English language, humans, and adults. Any material used for a conference or for a presentation was excluded. The detailed search strategy may be found online in the Supporting Information section at the end of the article.

Study selection and data extraction

Two reviewers (L. F. R. and C. R. H.) independently screened titles and abstracts in Rayyan generated by database search. Relevant studies were selected to move onto full-text screening accomplished by using a standardized, blinded form by the same two reviewers. Any conflicts that arose in the title and abstract screening as well as the full-text screening were resolved by a third reviewer (R. J. C.).

Articles were included if they were prospective randomized controlled studies, if they studied at least one group of patients who were prescribed a PCL and the PCL was described with respect to timing of ingestion, percentage of carbohydrate contribution, and total volume. Articles were excluded if they were retrospective or nonrandomized and if the PCL timing of ingestion, percentage of carbohydrate contribution, or PCL volume were not reported. Additional exclusion criteria included systematic reviews, meta-analyses, and other studies that did not report primary data.

The following variables from each study were collected: first author, year of publication, country of publication, study design, number of participants, inclusion or exclusion of patients with type 2 DM, and PCL prescription, including timing of ingestion, percentage of carbohydrate contribution, and volume.

Risk of bias assessment and statistical analysis

A risk of bias assessment was not performed because the purpose of this systematic review was to catalog all of the published ways that a PCL has been prescribed in the literature. As such, any published study that accurately described the PCL with respect to timing, content, and volume was included. The wide variation in PCL

prescription reported in the studies included in this systematic review prohibited pooling of the data in a logical manner for a meta-analysis.

and incomplete reporting of PCL timing, carbohydrate concentration, or volume. A total of 67 studies were included in this systematic review, which included 6551 patients (Table 1).

RESULTS

A total of 3739 records were identified from databases (Figure 1). After removal of duplicate studies, 2551 records were screened and 2392 were excluded for various reasons including animal studies, not in English, abstract only, or not pertinent to the topic. A total of 159 full-text articles were retrieved and assessed for eligibility. Ninety-two articles were excluded for reasons including study design type

Timing of ingestion

All 67 of the studies reported PCL timing as either on the night before surgery only, on the day of surgery only, or both. Thirty-three studies (49.3%) prescribed PCL ingestion on the night before surgery and on the day of surgery. Thirty-two studies (47.8%) prescribed PCL ingestion on the day of surgery only. One study (1.5%) prescribed

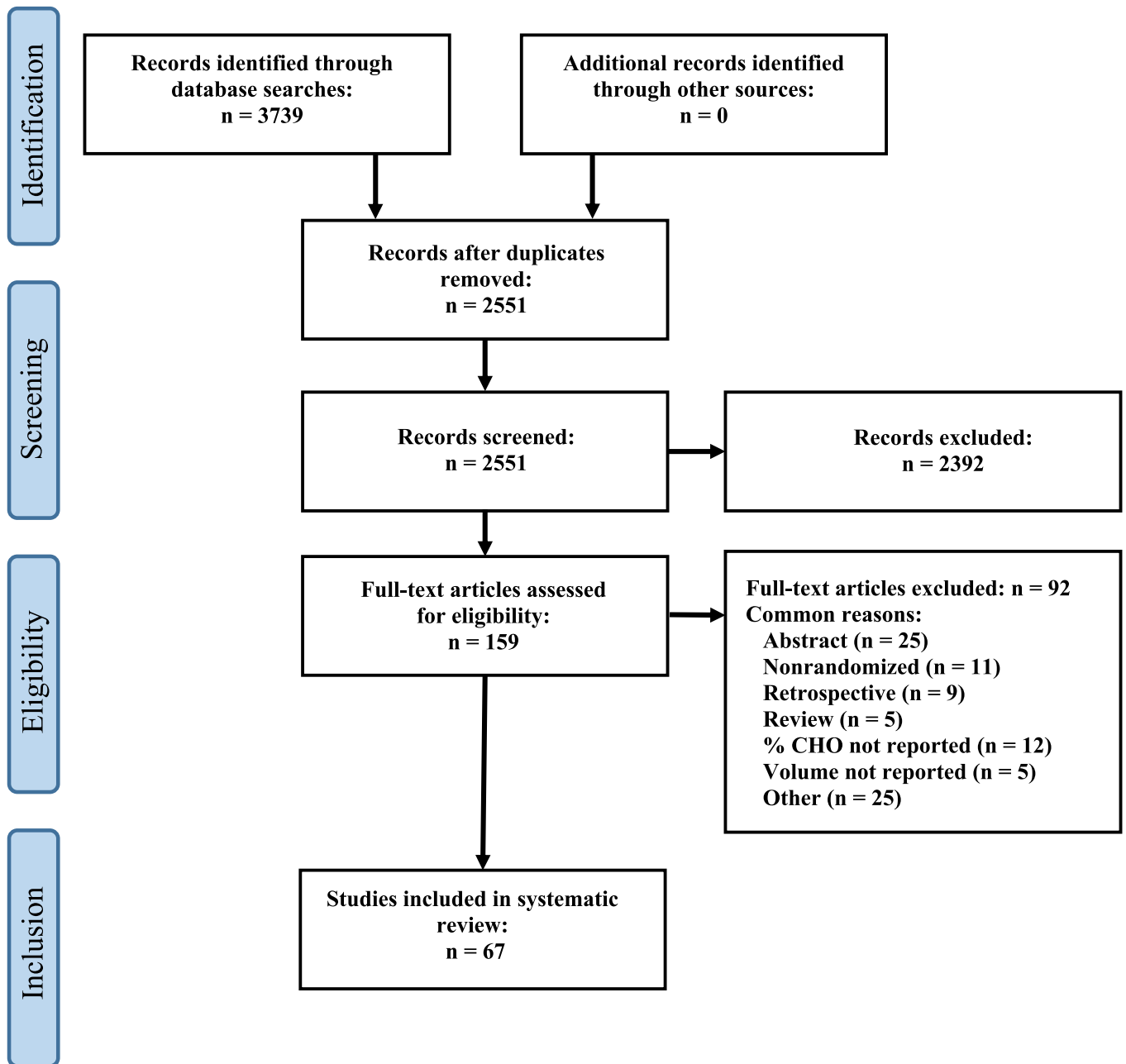


FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. CHO, carbohydrate.

TABLE 1 Characteristics of the prospective, randomized controlled studies included in this systematic review.

Author	Year	Surgical specialty	Patients (n)	Timing of ingestion ^a	Content (% CHO)	Volume (ml)	DM included ^b
Nygren et al. ¹⁹	1995	General	12	2	12.0	400	0
Nygren et al. ²⁰	1999	Colorectal and orthopedic	30	3	12.5	1200	1
Hausel et al. ²¹	2001	General	252	3	12.5	1200	0
Henriksen et al. ²²	2003	Colorectal	48	3	12.5	800	0
Hausel et al. ²³	2003	General	172	3	12.5	1200	0
Noblett et al. ²⁴	2005	Colorectal	35	3	12.5	1200	0
Yuill et al. ²⁵	2005	GI surgery	65	3	12.6	1200	0
Melis et al. ^{26,c}	2006	Orthopedic	29	2	12.6	400	0
					12.0		
Rapp-Kesek et al. ²⁷	2007	Cardiac	18	3	12.5	800	1
Yagci et al. ²⁸	2007	General	70	3	12.5	1200	0
Jarvela et al. ²⁹	2008	Cardiac	101	2	12.5	400	0
Bopp et al. ³⁰	2009	Ophthalmologic	123	2	12.5	200	1
Lauwick et al. ³¹	2009	Endocrine	208	2	12.5	400	0
Helminen et al. ³²	2009	General	210	2	12.5	400	0
Kaska et al. ³³	2010	Colorectal	221	3	13.7	800	0
Lidder et al. ³⁴	2012	Colorectal	120	2	12.6	400	0
Harsten et al. ³⁵	2012	Orthopedic	60	2	12.5	400	0
Tran et al. ³⁶	2013	Cardiac	38	3	12.5	1200	0
Yildiz et al. ³⁷	2013	General	60	1	12.5	800	0
Singh et al. ³⁸	2015	General	120	3	12.5	600	0
Azagury et al. ³⁹	2015	Bariatric	298	3	12.5	1200	1
Gava et al. ⁴⁰	2016	General	27	2	12.5	600	0
Dilmen et al. ⁴¹	2016	Spine	43	3	12.5	1200	0
Fujikuni et al. ⁴²	2016	General	80	2	17.9	875	1
Alito et al. ⁴³	2016	Orthopedic	32	2	12.0	200	1
Cakar et al. ⁴⁴	2017	General	90	3	12.5	1200	0
Lee et al. ⁴⁵	2017	Cardiac	57	3	12.8	800	0
van Stijn et al. ⁴⁶	2018	Colorectal	18	3	20.0	750	0
Hamamoto et al. ⁴⁷	2018	Colorectal	64	3	18.0	750	1
Liu et al. ⁴⁸	2018	Neurosurgery	120	2	12.5	400	0
Lee et al. ⁴⁹	2018	General	139	3	12.9	800	0
Tewari et al. ⁵⁰	2018	General	32	2	12.6	400	0
Esaki et al. ⁵¹	2018	OMFS	23	2	18.0	278	0
Gianotti et al. ⁵²	2018	General	662	3	12.6	800	0
Feguri et al. ⁵³	2019	Cardiac	57	2	12.5	200	1
Rizvanovic et al. ⁵⁴	2019	Colorectal	50	3	12.5	600	0
Sokolic et al. ⁵⁵	2019	Cardiac	80	2	12.6	200	0
Morimoto et al. ⁵⁶	2019	OMFS ^c	32	3	18.0	250	0

TABLE 1 (Continued)

Author	Year	Surgical specialty	Patients (n)	Timing of ingestion ^a	Content (% CHO)	Volume (ml)	DM included ^b
Lua et al. ⁵⁷	2019	Endoscopic	78	2	21.4	250	1
Lende et al. ⁵⁸	2019	Breast	61	3	12.0	800	0
Helminen et al. ⁵⁹	2019	General	113	2	33.5	200	0
Al-Hirmizy et al. ⁶⁰	2020	Gynecological	75	3	12.6	1200	0
Gok et al. ⁶¹	2020	General	42	3	12.5	1000	0
Kweon et al. ⁶²	2020	Orthopedic	88	3	12.8	800	0
Yi et al. ⁶³	2020	Gynecological	118	3	21.1	711	
Zhang et al. ⁶⁴	2020	Ambulatory	64	2	14.2	200	0
Clark et al. ⁶⁵	2020	Obstetric	209	3	11.8	1200	0
Zhang et al. ⁶⁶	2020	Gynecological	58	3	12.5	1200	0
Karimian et al. ⁶⁷	2020	Colorectal	29	2	12.5	400	0
Wending et al. ^{68,c}	2020	Obstetric	47	3	14.0	1065	0
					5.9		
Liu et al. ⁶⁹	2021	Obstetric	85	2	7.5	300	1
Lee et al. ⁷⁰	2021	Orthopedic	46	2	12.8	400	1
He et al. ⁷¹	2021	Obstetric	88	2	12.5	400	0
Mousavie et al. ⁷²	2021	General	78	2	12.5	200	0
Yang et al. ⁷³	2021	Obstetric	120	2	14.1	300	0
Suh et al. ⁷⁴	2021	Bariatric	134	3	16.9	592	1
Shi et al. ⁷⁵	2021	Obstetric	75	2	14.2	300	0
Chen et al. ^{76,d,e}	2021	General	136	2	10.0	500	0
				3		1000	
Cheng et al. ⁷⁷	2022	Obstetric	112	2	14.1	300	0
Wang et al. ⁷⁸	2022	Neurosurgery	151	2	12.5	250	1
Serrano et al. ⁷⁹	2022	Surgical oncology	65	3	12.5	1200	1
Tavalaee et al. ⁸⁰	2022	General	95	3	12.5	1200	0
Rajan et al. ⁸¹	2022	Endocrine	52	2	15.6	250	0
Kadado et al. ⁸²	2022	Orthopedic	153	3	12.5	1200	0
Hosseini et al. ⁸³	2022	Cardiac	210	2	10.0	250	1
Choi et al. ⁸⁴	2022	Orthopedic	56	2	12.8	400	0
Lin et al. ^{85,d}	2022	General anesthesia	78	2	14.2	100	1
						200	
						300	

Abbreviations: CHO, carbohydrate; DM, diabetes mellitus; OMFS, oromaxillofacial surgery.

^aTiming of ingestion coded as 1 = night prior to surgery, 2 = day of surgery, 3 = both night prior and day of surgery.

^bPatients with DM included in the study coded as 1 = yes, 0 = no, code not included if not specified.

^cStudies that tested >1 CHO concentration.

^dStudies that tested >1 volume.

^eStudies that tested >1 timing of ingestion.

PCL ingestion on the night before surgery only. One study (1.5%) tested two different timing regimens, comparing PCL ingestion the night before and day of surgery with the day of surgery only. It should be noted that 66 of the 67 studies included a PCL on the morning of surgery. All of those 66 studies prescribed the morning of surgery PCL within 2–4 h of surgery.

Percentage of carbohydrate contribution

All of the included 67 studies reported a percentage of carbohydrate contribution as a percentage per 100 ml. Two studies tested >1 carbohydrate contribution percentage. The carbohydrate contribution percentage for each study was plotted in chronological order of publication date (Figure 2). For the two studies that evaluated >1 carbohydrate percentage, the second percentage was depicted according to the figure legend. The carbohydrate contribution percentage ranged from 5.8% to 33.5%. The mean carbohydrate contribution percentage was 13.5% ($\pm 3.4\%$).

Forty-one of the 67 studies included in the systematic review prescribed a PCL that was reported to have a carbohydrate contribution percentage between 12% and 12.6%. Most of those studies were published earlier chronologically, whereas more recent studies reported a wider range of carbohydrate contribution percentages.

PCL volume

Of the 67 studies included in the final cohort, all 67 reported a total PCL volume prescribed. Two studies tested >1 PCL volume. The total PCL volume for each study was plotted in chronological order of the publication date (Figure 3). For the two studies that evaluated >1 PCL volume, subsequent volumes were depicted according to the figure legend. The total prescribed PCL volume ranged widely from 100 to 1200 ml, which correlated to PCL prescription study design. The overall mean PCL volume was 648.2 ml (± 377 ml). The mean PCL volume of the 34 studies that prescribed PCL on the night before surgery and on the morning of surgery was 896 ml (± 301 ml), whereas the mean PCL volume of the 33 studies that prescribed PCL on the morning of surgery only was 379 ml (± 204 ml).

DM

Of the 67 studies included in this systematic review, 16 included patients with well-controlled type 2 DM. Of note, a PCL is not recommended for patients with insulin deficiency, such as type 1 DM because the PCL aims to reduce GV by increasing endogenous insulin secretion.¹⁵

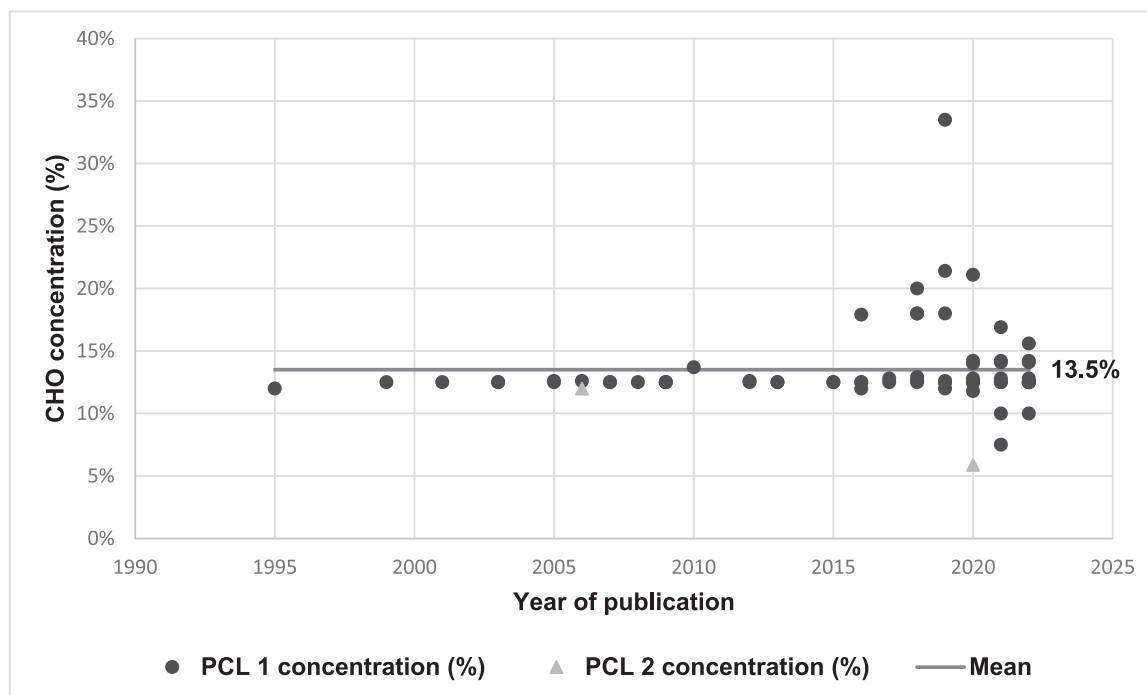


FIGURE 2 PCL carbohydrate concentration plotted against a mean of 13.5% and displayed with respect to year of publication. For the two studies that evaluated >1 carbohydrate percentage, the second percentage is depicted according to the legend. CHO, carbohydrate; PCL, preoperative carbohydrate load.

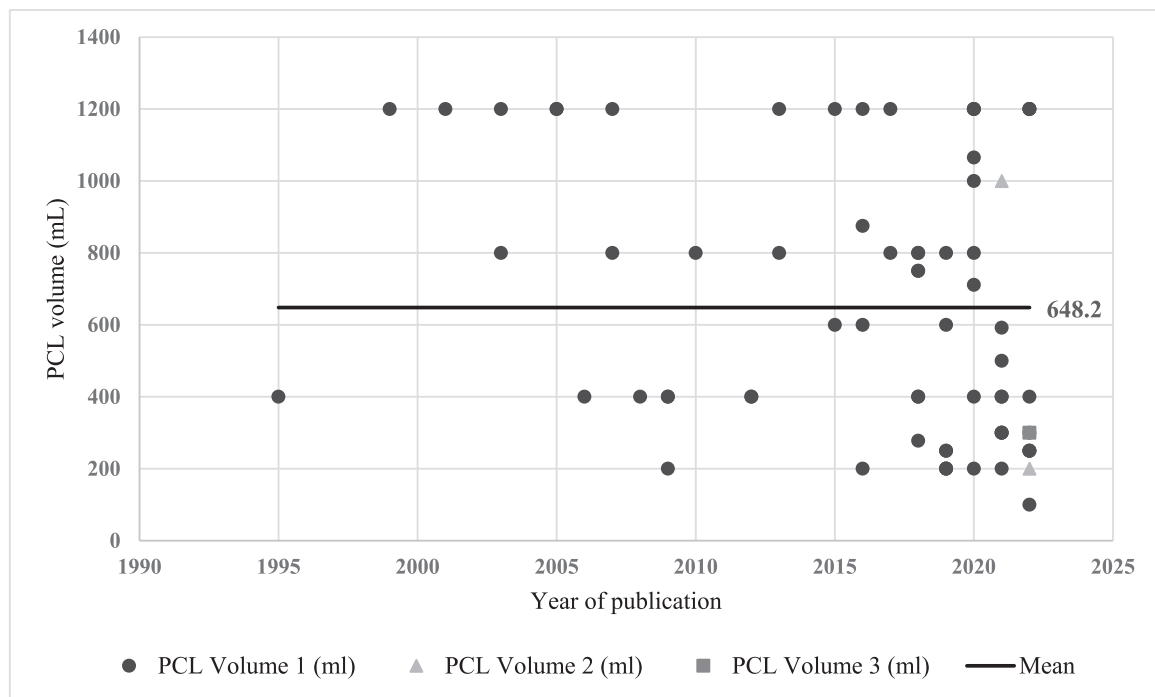


FIGURE 3 Preoperative carbohydrate load (PCL) total volume plotted against a mean volume of 648.2 ml and displayed with respect to year of publication. For the two studies that evaluated >1 PCL volume, subsequent volumes were depicted according to the legend.

DISCUSSION

This systematic review cataloged the published methods of PCL administration with respect to timing of ingestion, percentage of carbohydrate contribution, and PCL volume. The results of this systematic review depict wide variation in PCL practices, highlighting the need for standardized PCL prescription. The lack of standardization limits the ability to pool research and make evidence-based clinical recommendations that impact surgical outcomes and patient satisfaction.

The development of specific guidelines for PCL prescription practice may be compared to those for the prevention of post-operative nausea and vomiting (PONV). The initial approach to PONV prevention was to use anticholinergic and antihistamine medications. In 1992, a standardized dose for ondansetron was established.¹⁶ This allowed for subsequent research towards the current multimodal approach to PONV prevention: to combine medications from different classes to target multiple emetogenic pathways.¹⁷ The combination of original research and iterative systematic reviews led to the present day, standardized practice guidelines for PONV.¹⁸ Analogously, the first step of standardizing optimal PCL prescriptions would be akin to the standardization of the ondansetron dosage. The establishment of a standard PCL prescription with respect to timing of ingestion, percentage of carbohydrate contribution, and volume to reduce GV and improve surgical outcomes would open the door for subsequent research including the larger studies and data pooling needed for higher class recommendations. It may take several years to develop

gold standard PCL prescription practices that are part of a multimodal approach to reduce GV and improve surgical outcomes.

The methodological approach used in this systematic review was designed to create a comprehensive data set of the PCL prescription practices reported in the literature. This systematic review aimed to document any and all PCL practice that included quantitative prescriptions with respect to amount, timing, and content regardless of type of surgery, outcome measures etc so that it may serve as the first step to standardizing PCL prescription practice. Furthermore, the inclusion of studies that did not exclude patients with type 2 DM ensured that this systematic review cataloged current evidence-based practice so that societal guidelines can adapt to include all patients for whom PCL can be beneficial.

In this systematic review, reported data suggest that the percentage of carbohydrate contribution to the prescribed PCL was largely dependent on which commercially manufactured drinks, designed specifically for preoperative use, were available in the geographic region. For example, Nutricia Preop, manufactured in the Netherlands, has a carbohydrate composition reported between 12.0% and 12.6% and was used in many European studies, including most of the earliest studies published on the topic. The original ERAS group formed in 2001 comprised sites in the United Kingdom, Sweden, Denmark, Norway, and the Netherlands. As ERAS protocols were adopted by groups outside of Europe and by additional surgical subspecialties besides colorectal surgery, it is likely that local substitutes for Nutricia Preop were chosen for investigation. For

example, Arginaid packets made by Nestlé in Japan contain 5 g carbohydrate per packet and are to be mixed with water. Clearfast drink CF(Preop) is made in the United States and contains 14.1% carbohydrate (50 g in 12 ounces), and ProvideXtra manufactured by Fresenius Kabi in Germany contains 33.5% carbohydrate. Some studies used carbohydrate supplements or easily accessible drinks, such as Gatorade (5.8% carbohydrate), that may cost significantly less than drinks specifically marketed for use before surgery.

There are limitations to this systematic review to discuss. As a consequence of the resultant wide variation in PCL practice included in this systematic review, a meta-analysis was not performed on the data, which could not be pooled in a logical manner, and no report on clinical outcomes was included. Next, final analysis included only prospective, randomized studies to maintain a uniform study design for this systematic review thereby excluding the nine retrospective and 11 prospective, nonrandomized studies. Additionally, any study that did not include the quantitative percentage of carbohydrate contribution to the PCL was excluded. This may have excluded studies that otherwise offered useful clinical or statistical insights. In particular, this exclusion resulted in a lack of studies that used fruit juice (ie, apple juice or grain-free sour cherry juice), thus introducing a bias against parts of the world that may not have access to the products manufactured specifically for use as a PCL. Finally, this systematic review reported the prescribed PCL guidelines for each study only rather than adherence to the prescribed PCL guidelines. Poor adherence to a study protocol could potentially skew study outcomes and should be considered when investigating outcomes data.

CONCLUSION

The current PCL prescription practices vary widely with respect to timing of ingestion, percentage carbohydrate contribution, and volume of administration despite published recommendations on preoperative carbohydrate requirements to reduce the catabolic state induced by overnight fasting and surgery. Future studies are needed to determine if there is an optimum PCL prescription to reduce surgical complications and improve surgical outcomes. Efforts dedicated to the establishment of a gold standard PCL prescription are necessary so that PCL studies can be pooled and analyzed with respect to meaningful clinical end point that impact surgical outcomes and patient satisfaction.

AUTHOR CONTRIBUTIONS

Robert Canelli: Writing—original draft; writing—review and editing; methodology; conceptualization; investigation; formal analysis; project administration; data curation; resources. **Joseph Louca:** Conceptualization; investigation; writing—review and editing; resources; data curation. **Rafael M. Gonzalez:** Conceptualization; investigation; writing—review and editing; software; data curation; supervision; resources; formal analysis; visualization. **Luis F. Rendon and Ciana R. Hartman:** Conceptualization; investigation; data curation; software; methodology. **Federico Bilotta:**

Conceptualization; writing—review and editing; supervision; data curation; methodology. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

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

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