

Preoperative Oral Carbohydrate Loading Versus Conventional Fasting Before Elective Surgery: A Structured Narrative Review of Metabolic, Patient-Centred, and Perioperative Outcomes

Reuben Amala Chandran Manikandan

reuben7amala@gmail.com

Queens University Belfast

Research Article

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Abstract

Background

Preoperative fasting before elective surgery has been practised for decades to reduce the risk of pulmonary aspiration during anaesthesia induction. Conventional nil-per-os (NPO) protocols, however, commonly produce fasting durations that far exceed physiological requirements, contributing to glycogen depletion, peripheral insulin resistance, perioperative catabolism, dehydration, and patient discomfort, outcomes inconsistent with contemporary principles of enhanced perioperative care.

Objectives

This structured narrative review evaluates the comparative clinical evidence for preoperative oral carbohydrate loading versus conventional fasting in adult elective surgical patients, examining metabolic responses, gastric safety, patient-centred outcomes, and postoperative recovery.

Methods

A structured narrative review was conducted in accordance with the Scale for the Assessment of Narrative Review Articles (SANRA) framework. PubMed/MEDLINE, EMBASE, and the Cochrane Library were searched using predefined MeSH terms relating to preoperative carbohydrate administration, fasting, enhanced recovery, and insulin resistance. Eligible study types included randomised controlled trials (RCTs), systematic reviews, meta-analyses, and evidence-based clinical guidelines published from 1990 to December 2024.

Results

Consistent evidence demonstrates that preoperative carbohydrate loading reduces patient-reported thirst, hunger, and preoperative anxiety without increasing gastric residual volume or aspiration risk in appropriately selected patients. Metabolic evidence supports attenuation of postoperative insulin resistance and preservation of carbohydrate metabolism. Effects on postoperative complications and hospital length of stay are inconsistent across studies, with the most pronounced benefits observed when carbohydrate loading is embedded within comprehensive Enhanced Recovery After Surgery (ERAS) pathways.

Conclusions

Preoperative oral carbohydrate loading is a safe and clinically meaningful intervention for selected adult elective surgical patients, offering consistent metabolic and patient-centred benefits. Major clinical

outcome benefits remain context-dependent. Adequately powered multicentre trials evaluating carbohydrate loading across diverse surgical populations, including patients with diabetes mellitus, obesity, and advanced age, are required to establish optimised evidence-based protocols.

1. INTRODUCTION

1.1 Historical Context of Preoperative Fasting

The practice of withholding oral intake before elective surgery has its origins in 19th-century anaesthetic medicine, where concerns regarding pulmonary aspiration of gastric contents during induction of general anaesthesia provided the foundational clinical rationale. The landmark report by Mendelson in 1946 drew attention to the significant morbidity and mortality risks associated with aspiration of acidic gastric fluid, establishing a precautionary framework that remained largely unchallenged for subsequent decades. [1] The resulting convention, nil per os (NPO) after midnight, became deeply embedded in perioperative protocols internationally, often producing fasting durations of twelve to eighteen hours or beyond in clinical practice.

Contemporary perioperative research has challenged both the physiological necessity and clinical rationale of such extended fasting intervals. Prolonged fasting does not confer meaningful additional aspiration protection beyond what is achievable with evidence-based shorter intervals; instead, it induces a catabolic metabolic state that may increase perioperative risk and impair postoperative recovery. [2, 3] Modern anaesthetic societies, including the American Society of Anesthesiologists (ASA) and the European Society of Anaesthesiology (ESA), have accordingly revised their fasting guidelines to permit clear fluid intake up to two hours before anaesthesia induction in appropriately selected elective surgical patients, while permitting solid food intake up to six hours preoperatively. [4, 5]

1.2 Physiological Consequences of Prolonged Preoperative Fasting

Extended preoperative fasting precipitates a series of metabolic and physiological disturbances that may adversely influence perioperative outcomes. Hepatic glycogen stores are progressively depleted as the body transitions from a postabsorptive to a fasted metabolic state, characterised by gluconeogenesis, increased lipolysis, suppressed insulin secretion, and reduced peripheral glucose utilisation. [6] These substrate-level changes are subsequently compounded by the neuroendocrine stress response to surgical trauma, producing elevations in cortisol, catecholamines, glucagon, and pro-inflammatory cytokines, collectively amplifying peripheral insulin resistance, inducing hyperglycaemia, and accelerating protein catabolism. [7]

Postoperative insulin resistance is a well-characterised consequence of surgical stress and is broadly correlated with the magnitude and duration of the surgical insult. It has been associated with impaired glucose regulation, increased susceptibility to infective complications, delayed gastrointestinal recovery, and prolonged hospitalisation. [7, 8] Critically, the metabolic state at the time of surgical incision,

specifically the degree of hepatic glycogen repletion and circulating insulin sensitivity, appears to modulate the severity of this postoperative derangement, providing the mechanistic basis for preoperative nutritional optimisation. [9]

Beyond metabolic sequelae, prolonged fasting is associated with patient-reported symptoms including thirst, hunger, headache, dizziness, and preoperative anxiety, outcomes that reduce patient satisfaction and may impair cooperation with perioperative care preparations. [10] These patient-centred harms, though less clinically prominent than metabolic derangements, are increasingly recognised as meaningful components of perioperative quality and patient experience.

1.3 Physiological Basis of Preoperative Carbohydrate Loading

Preoperative oral carbohydrate loading was developed in the late 1980s and 1990s as a targeted strategy to attenuate surgical metabolic stress by maintaining a metabolically fed state at the time of surgical incision. Seminal work by Ljungqvist and colleagues established that preoperative carbohydrate administration stimulates endogenous insulin secretion, promotes hepatic glycogen synthesis, and sustains peripheral insulin sensitivity before the onset of surgical stress, a physiological state fundamentally more resilient to the catabolic neuroendocrine response than the fasted state. [6, 9]

Commercial carbohydrate-loading beverages typically consist of maltodextrin-based solutions containing approximately 12–12.5% carbohydrate (approximately 50 g carbohydrate per 400 mL serving), with osmolality in the physiological range of 285–295 mOsm/kg, comparable to isotonic clear fluids. Standard protocols involve administration of an 800 mL carbohydrate drink the evening before surgery (providing approximately 100 g carbohydrate) and an additional 400 mL drink two to three hours before anaesthesia induction (50 g carbohydrate). [11]

Gastric scintigraphy and real-time ultrasonography studies have demonstrated that carbohydrate-containing clear liquids empty from the stomach within 90 minutes in healthy adult volunteers, consistent with the two-hour preoperative fluid fasting interval endorsed in contemporary guidelines. [11] This gastric behaviour has been fundamental in supporting the favourable safety profile of carbohydrate loading within evidence-based fasting recommendations.

1.4 Integration Within Enhanced Recovery After Surgery Pathways

Enhanced Recovery After Surgery (ERAS) protocols represent a paradigm shift in perioperative medicine, integrating coordinated evidence-based interventions to reduce surgical stress and accelerate functional recovery. Since their introduction in colorectal surgery by Fearon and colleagues in 2005, [14] ERAS pathways have been progressively extended to abdominal, hepatopancreatic, gynaecological, orthopaedic, thoracic, cardiac, and bariatric surgical specialties, consistently demonstrating reductions

in length of stay, postoperative complications, and readmission rates across multiple procedural settings. [15, 16, 17]

Preoperative carbohydrate loading is incorporated as a standard component of ERAS protocols endorsed by the ERAS Society and the European Society for Clinical Nutrition and Metabolism (ESPEN), alongside minimisation of preoperative fasting intervals, avoidance of routine bowel preparation, opioid-sparing multimodal analgesia, early enteral feeding, and goal-directed fluid therapy. [14, 18] Within this multimodal framework, carbohydrate loading functions as the nutritional and metabolic preparatory component, specifically targeting the perioperative insulin resistance response. However, because ERAS pathways deliver multiple simultaneous interventions, the independent contribution of carbohydrate loading to observed outcome improvements has been difficult to isolate from the aggregate effect of the overall care pathway.

1.5 Rationale and Objectives

Despite increasing adoption of carbohydrate loading in clinical perioperative practice and endorsement by major international guideline bodies, important questions remain regarding its clinical efficacy across diverse surgical populations, the independence of its metabolic effects from ERAS co-interventions, optimal formulation and timing, and appropriate use in high-risk patient subgroups including those with diabetes mellitus, obesity, and impaired gastric motility.

This structured narrative review synthesises current evidence from randomised controlled trials, systematic reviews, meta-analyses, and clinical guidelines to evaluate the clinical and physiological effects of preoperative oral carbohydrate loading compared with conventional fasting in adult elective surgical patients. The review specifically examines: (1) metabolic outcomes, postoperative insulin resistance, glycaemic regulation, and neuroendocrine stress response; (2) gastric safety, gastric emptying, residual volume, and aspiration risk; (3) patient-centred outcomes, thirst, hunger, anxiety, and satisfaction; (4) clinical recovery outcomes, length of hospital stay, gastrointestinal recovery, and time to mobilisation; and (5) postoperative complications.

2. METHODS

2.1 Review Design and Methodological Framework

This article was conducted as a structured narrative review and reported in accordance with the Scale for the Assessment of Narrative Review Articles (SANRA) framework, [19] which provides a standardised methodological guide for transparent evidence synthesis in review articles that do not employ formal systematic-review methodology. A meta-analytic approach was not pursued given the anticipated substantial clinical and methodological heterogeneity across studies in surgical populations, carbohydrate formulations, outcome definitions, fasting comparator protocols, and ERAS co-intervention delivery, heterogeneity that would preclude meaningful statistical pooling and risk producing misleading aggregate estimates.

2.2 Literature Search Strategy

A literature search was performed across PubMed/MEDLINE, EMBASE, and the Cochrane Library from database inception to December 2024. The following Medical Subject Headings (MeSH) terms and text-word equivalents were employed individually and in Boolean combination:

("preoperative carbohydrate loading" OR "oral carbohydrate" OR "carbohydrate drink" OR "maltodextrin" OR "preoperative nutrition") AND ("preoperative fasting" OR "nil per os" OR "NPO" OR "overnight fasting") AND ("elective surgery" OR "perioperative" OR "general anaesthesia" OR "regional anaesthesia" OR "ERAS" OR "enhanced recovery after surgery" OR "insulin resistance" OR "postoperative recovery").

The search was supplemented by manual review of reference lists of retrieved primary studies, relevant systematic reviews and meta-analyses, and published clinical practice guidelines from recognised professional societies. Grey literature, conference abstracts, and unpublished manuscripts were not systematically searched.

2.3 Eligibility Criteria

Studies were considered eligible if they evaluated preoperative oral carbohydrate loading compared with conventional fasting protocols in adult surgical patients aged 18 years or older undergoing elective surgical procedures under general or regional anaesthesia. Eligible study types included randomised controlled trials, non-randomised controlled clinical trials, systematic reviews, meta-analyses, and evidence-based clinical guidelines and consensus statements from recognised perioperative care societies.

Studies were excluded if they involved: paediatric surgical populations (age < 18 years); emergency or urgent surgical procedures; animal experimental models; non-oral or enteral tube-based carbohydrate administration; total parenteral nutrition as the primary intervention; case reports or case series; editorials, letters, and opinion articles without original clinical data; and publications in non-peer-reviewed sources. Systematic reviews without primary data were considered for contextual guideline discussion only.

2.4 Outcomes of Interest

Primary outcomes of interest were: postoperative insulin resistance (measured by hyperinsulinaemic-euglycaemic clamp, HOMA-IR, or surrogate glycaemic measures); postoperative complications; and length of hospital stay. Secondary outcomes included: gastric residual volume; aspiration events; patient-reported thirst, hunger, and preoperative anxiety; postoperative nausea and vomiting (PONV); time to gastrointestinal recovery (return of flatus or oral intake tolerance); and patient satisfaction with preoperative preparation.

2.5 Evidence Appraisal and Synthesis

Individual studies were appraised qualitatively with consideration of study design, sample size, surgical context, blinding and allocation concealment, outcome definitions, and risk of bias. As formal meta-analytic pooling was not performed, quantitative bias scoring instruments such as the Cochrane RoB 2.0 tool were not applied. However, methodological quality considerations are integrated into the narrative synthesis and reflected in the strength-of-evidence designations assigned in the evidence summary. Findings are organised according to major outcome domains and presented with critical evaluation of directional consistency, magnitude of effect, and potential sources of heterogeneity.

3. RESULTS

3.1 Overview of the Available Evidence Base

The available evidence base encompasses multiple RCTs, pooled analyses, systematic reviews, and international clinical guidelines, with studies conducted across abdominal, colorectal, gynaecological, orthopaedic, laparoscopic, and mixed elective surgical populations. Two pooled analyses form the cornerstone of the quantitative evidence base. The Cochrane systematic review by Smith and colleagues, the most comprehensive meta-analytic synthesis to date, identified 27 RCTs involving 1,976 participants and provided pooled evidence across metabolic, patient-centred, and clinical outcome domains. [20] A prior meta-analysis by Awad and colleagues, incorporating 18 RCTs (n = 1,219), specifically examined insulin resistance and comfort outcomes across multiple surgical procedures. [13] Both pooled analyses supported metabolic and patient-centred benefits but noted important limitations in the evidence quality for major clinical outcome endpoints.

Common carbohydrate formulations evaluated in included studies consisted of maltodextrin-based beverages (12–12.5% carbohydrate solution) administered as an approximately 800 mL evening drink followed by a 400 mL drink two to three hours before anaesthesia induction. Fasting comparators typically employed NPO-from-midnight protocols or water-only fasting regimens. Some studies used isotonic placebo drinks (e.g., artificially sweetened water or isotonic saline) rather than nil per os, providing a more methodologically rigorous comparator that isolates the carbohydrate effect from volume and hydration effects.

3.2 Effects on Postoperative Insulin Resistance and Metabolic Stress Response

Attenuation of postoperative insulin resistance represents the most mechanistically coherent and consistently demonstrated benefit of preoperative carbohydrate loading. The hyperinsulinaemic-euglycaemic clamp technique, the gold-standard quantitative measure of insulin sensitivity, was employed in landmark studies to formally characterise insulin resistance following surgery under different preoperative nutritional states.

Nygren and colleagues demonstrated in a foundational RCT that patients receiving preoperative carbohydrate drinks exhibited significantly lower postoperative insulin resistance compared with

overnight-fasting controls, with insulin-mediated glucose uptake significantly preserved in the immediate postoperative period. [6] Subsequent work by Svanfeldt and colleagues extended these findings, demonstrating that carbohydrate loading attenuated postoperative reductions in whole-body protein synthesis and significantly reduced protein catabolism, findings with direct implications for postoperative muscle mass preservation and accelerated functional recovery. [12]

The meta-analysis by Awad et al. confirmed a statistically significant reduction in postoperative insulin resistance across multiple studies, with improvements reflected in HOMA-IR scores, fasting serum glucose levels, and insulin concentrations. [13] The mechanistic basis involves preoperative stimulation of insulin receptor signalling and GLUT-4 transporter expression, which maintains hepatic glycogen availability before the onset of surgical neuroendocrine stress, reducing the magnitude of the subsequent glycaemic excursion. [9]

Postoperative hyperglycaemia, an established predictor of surgical site infection, cardiac events, impaired wound healing, and prolonged recovery, was reduced or attenuated in several studies following carbohydrate loading. [7, 32] The glucose benefit was most pronounced in metabolically healthy patients without baseline impairment of insulin secretion. An additional immunological benefit was reported by Melis and colleagues, who demonstrated that preoperative carbohydrate administration prevented surgery-induced depression of lymphocyte proliferative responses, an immunological correlate consistent with the attenuation of the overall metabolic stress response. [22]

3.3 Effects on Gastric Emptying and Aspiration Safety

Gastric emptying kinetics and residual volume represent critical safety parameters for any modification to preoperative fasting protocols. Gastric scintigraphy studies by Nygren and colleagues demonstrated that carbohydrate-containing clear liquids administered 90 minutes before anaesthesia yielded gastric residual volumes equivalent to those of fasted patients in healthy adults, with complete gastric emptying well within the two-hour safety interval. [11] The isotonic osmolality of modern maltodextrin formulations facilitates rapid gastric transit without delay, distinguishing them from caloric-dense, hyperosmolar, or protein-rich solutions with potentially longer emptying times.

The Cochrane systematic review by Smith et al. found no evidence of increased aspiration events in patients receiving preoperative carbohydrate drinks across the 27 included RCTs, confirming an acceptable safety profile in appropriately selected elective surgical patients. [20] These findings are reinforced by the absence of aspiration-related events in multiple large-scale ERAS implementation studies and are consistent with the endorsement of preoperative carbohydrate loading by the ASA, ESA, ESPEN, and ERAS Society. [4, 5, 18]

However, the evidence base for gastric safety has principally been derived from studies of metabolically healthy elective surgical patients with normal gastric motility. Populations requiring heightened clinical caution include patients with gastroparesis (including diabetic gastroparesis), intestinal obstruction, symptomatic severe gastro-oesophageal reflux disease, prior gastric surgery, conditions associated with

impaired gastrointestinal motility, and emergency surgical presentations. [18] Bedside gastric ultrasonography, validated as a non-invasive real-time assessment of gastric content and volume, [25] represents an emerging tool to guide individualised fasting decisions in high-risk cases, and its routine preoperative application in complex patients warrants further prospective evaluation.

3.4 Effects on Patient Comfort and Preoperative Psychological Well-being

Among all outcome domains evaluated, improvements in patient comfort represent the most consistent finding across the published literature, irrespective of surgical procedure, patient population, or comparator fasting protocol. Prolonged preoperative fasting produces a clinically relevant spectrum of patient-reported symptoms including thirst, hunger, dry mouth, headache, dizziness, malaise, and preoperative anxiety, outcomes that collectively impair the preoperative patient experience and may reduce cooperation with perioperative preparations. [3, 10]

Hausel and colleagues conducted a double-blind, multicentre RCT demonstrating that patients receiving preoperative carbohydrate drinks reported significantly lower visual analogue scale scores for thirst, hunger, and anxiety, and greater overall preoperative comfort, compared with both placebo and fasting controls. [10] These findings have been replicated across multiple patient groups and surgical settings. The Cochrane systematic review confirmed consistent and statistically significant reductions in patient-reported thirst and hunger as robust secondary benefits of carbohydrate loading, alongside improved overall preoperative wellbeing and patient satisfaction. [20]

Preoperative anxiety reduction was reported in several studies, though psychological outcome reporting has been less standardised across the literature, with fewer studies employing validated instruments such as the Amsterdam Preoperative Anxiety and Information Scale (APAIS) or the State-Trait Anxiety Inventory (STAI). Additional prospective research employing validated psychometric tools would better characterise and quantify the psychological benefits of carbohydrate loading across diverse surgical and patient contexts.

3.5 Effects on Postoperative Nausea and Vomiting

Postoperative nausea and vomiting (PONV) is among the most prevalent and distressing postoperative complications, affecting 20–30% of unselected surgical patients and significantly impairing early recovery and patient satisfaction. Evidence regarding the effect of preoperative carbohydrate loading on PONV is mixed. Hausel and colleagues reported a significant reduction in PONV severity and antiemetic requirements following laparoscopic cholecystectomy in patients receiving preoperative carbohydrate drinks compared with fasting controls. [21] The proposed mechanism involves improved perioperative glycaemic stability and reduced catecholamine-mediated gastric stimulation.

However, the Cochrane review found insufficient pooled evidence to establish a statistically significant reduction in PONV attributable to carbohydrate loading across heterogeneous surgical populations, [20] noting that PONV incidence is strongly influenced by patient-specific risk factors, anaesthetic technique,

and concurrent antiemetic prophylaxis, confounders that were variably controlled across included studies. PONV endpoints should be included in future preoperative carbohydrate loading trials employing standardised risk stratification and prophylaxis protocols.

3.6 Effects on Postoperative Recovery and Length of Hospital Stay

Evidence regarding the effect of preoperative carbohydrate loading on length of hospital stay (LOS) and functional recovery milestones is heterogeneous, largely reflecting the methodological challenge of isolating carbohydrate loading from the multiple concurrent ERAS interventions with which it is almost invariably co-administered in clinical trials.

Several RCTs conducted within ERAS frameworks reported earlier return of gastrointestinal function, faster time to first flatus, and earlier achievement of discharge readiness criteria compared with standard fasting groups. [14, 23, 33] A systematic review and meta-analysis by Li and colleagues found a trend toward reduced LOS in abdominal and colorectal surgery in patients receiving preoperative carbohydrate loading, though heterogeneity across studies precluded a definitive quantitative conclusion. [24] The systematic review by Bilku and colleagues similarly found supportive but variable evidence for recovery-related benefits. [30]

The Cochrane review by Smith et al. found insufficient evidence of a clinically significant reduction in LOS attributable to carbohydrate loading as an isolated intervention, observing that co-interventions within ERAS pathways, including early enteral nutrition, early mobilisation, and multimodal analgesia, were likely the principal determinants of LOS reduction in ERAS-based studies. [20] Non-ERAS studies demonstrated more modest recovery benefits from carbohydrate loading alone. In procedure-specific analyses, recovery benefits appear most pronounced in major abdominal and colorectal surgery, where the magnitude of surgical stress and associated metabolic derangement is greatest.

3.7 Effects on Postoperative Complications

Evidence regarding reduction in postoperative complications attributable to preoperative carbohydrate loading remains inconclusive. While the mechanistic rationale, attenuation of insulin resistance, reduction in postoperative hyperglycaemia, immunological preservation, and reduced catabolism, would logically predict reduced infective, metabolic, and cardiopulmonary complications, this hypothesis has not been consistently supported in clinical outcome data from available trials.

Noblett and colleagues demonstrated in an RCT of colorectal surgery patients that preoperative carbohydrate loading was associated with significantly attenuated postoperative C-reactive protein elevations, suggesting reduced systemic inflammatory response; [23] however, differences in major complication rates did not reach statistical significance in this study population. Yagci and colleagues similarly reported favourable glycaemic and gastric-content outcomes in patients undergoing moderate surgery, without significant differences in complication endpoints. [32]

The Cochrane review found no statistically significant reduction in overall complication rates, readmission rates, or mortality attributable to carbohydrate loading. [20] The absence of significant complication-related findings most likely reflects insufficient statistical power in individual RCTs, which are generally sized to detect metabolic rather than complication outcomes, as well as heterogeneity in patient populations and the confounding effect of ERAS co-interventions. Adequately powered, prospective multicentre trials specifically designed to evaluate postoperative complication endpoints are required to address this critical evidence gap.

Table 1
Summary of Evidence by Perioperative Outcome Domain

Outcome Domain	Direction of Effect	Consistency	Strength of Evidence
Postoperative insulin resistance	Improved (reduced)	Consistent	Moderate–High
Postoperative glucose response	Attenuated	Moderate	Moderate
Patient-reported thirst	Reduced	Highly consistent	High
Patient-reported hunger	Reduced	Highly consistent	High
Preoperative anxiety	Reduced	Moderate	Low–Moderate
Gastric residual volume	No significant increase	Consistent	High
Aspiration events	No increased risk	Consistent	Moderate
Patient satisfaction	Improved	Consistent	Moderate
Length of hospital stay	Variable	Inconsistent	Low–Moderate
Return of GI function	Possible earlier return	Inconsistent	Low
Postoperative complications	No significant reduction demonstrated	Inconsistent	Low

4. DISCUSSION

4.1 Principal Findings and Synthesis

This structured narrative review provides a comprehensive evaluation of the comparative evidence for preoperative oral carbohydrate loading across key perioperative outcome domains. The evidence base consistently supports carbohydrate loading on metabolic and patient-centred grounds, while evidence for major clinical outcomes, complications and length of stay, remains less definitive. This pattern is

reproducible across systematic reviews and is reflected in international guideline recommendations that endorse the practice without mandating specific complication-based outcome targets. [4, 15, 18, 31]

The most robust and reproducible evidence relates to attenuation of postoperative insulin resistance and consistent improvement of patient comfort. These represent substantively meaningful clinical contributions: the former addresses a recognised mechanistic mediator of postoperative complications and delayed recovery, while the latter directly responds to the patient-experience dimension of perioperative care quality, a dimension increasingly foregrounded in patient-centred healthcare frameworks.

4.2 Mechanistic Basis for Metabolic Benefits

The metabolic rationale for preoperative carbohydrate loading is well-supported by physiological evidence from both basic science and clinical investigation. Surgical stress activates the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, resulting in glucocorticoid and catecholamine surges that drive hepatic glycogenolysis and gluconeogenesis, suppress peripheral insulin receptor signalling, and inhibit GLUT-4 transporter translocation to cellular membranes, collectively producing a state of peripheral insulin resistance. [7, 8, 9] This resistance may persist for days to weeks following major surgery, correlating with impaired wound healing, increased infective susceptibility, and accelerated protein catabolism. [8]

By stimulating preoperative insulin secretion and promoting hepatic glycogen synthesis, carbohydrate loading advances the fed metabolic state into the perioperative window. When surgical stress subsequently occurs, the insulin signalling cascade encounters a more replete metabolic substrate environment, reducing the magnitude of the glycaemic excursion and the degree of insulin resistance. [6, 9] This concept is analogous to metabolic conditioning, the preparatory optimisation of physiological reserve before an anticipated challenge, and mirrors the nutritional prehabilitation principles increasingly applied in high-risk and frail surgical populations. [29]

The immunological attenuation observed by Melis and colleagues, whereby preoperative carbohydrate administration preserved lymphocyte proliferative responses following surgical stress, introduces an additional mechanistic dimension that has not been adequately explored in subsequent research. [22] Insulin exerts well-documented anti-inflammatory effects through modulation of NF- κ B signalling and cytokine production; the immunological preservation associated with carbohydrate loading may therefore reflect both direct nutritional substrate effects and insulin-mediated immunomodulatory actions.

4.3 ERAS Integration: Context Dependency and Confounding

A central interpretive challenge throughout this review is the frequent co-administration of carbohydrate loading with multiple other ERAS interventions in clinical trial settings. ERAS pathways have demonstrated consistent reductions in LOS (mean reductions of 1–3 days in colorectal surgery),

complication rates, and readmission rates across multiple procedural specialties in systematic reviews and meta-analyses. [27, 28, 34] However, the attribution of these aggregate benefits to individual ERAS components, including carbohydrate loading, early postoperative feeding, multimodal analgesia, or goal-directed fluid therapy, requires component-level randomised evidence that is rarely available.

This context dependency is simultaneously a scientific limitation and a clinical reality: the optimal perioperative environment in which carbohydrate loading produces its greatest clinical benefit is likely one in which complementary ERAS interventions minimise fasting duration, support early enteral nutrition, reduce opioid burden, and facilitate early mobilisation. Studying carbohydrate loading in isolation from these contextual interventions, while methodologically necessary for causal inference, may systematically underestimate its synergistic clinical contribution within the ERAS ecosystem.

Future research designs should consider factorial trial designs or adaptive platform trials that permit simultaneous assessment of individual component contributions within ERAS care pathways. Stepped-wedge cluster-randomised designs may also facilitate the evaluation of specific ERAS components in settings where full-pathway implementation makes parallel group allocation impractical.

4.4 Safety Profile: Current Evidence and Remaining Uncertainties

The gastric safety of carbohydrate-containing clear liquids before elective surgery is well-established in low-risk patient populations, supported by formal gastric emptying studies, absence of aspiration events across all included RCTs in the Cochrane review, [20] and consistent endorsement by major anaesthetic and perioperative societies. [4, 5, 18] The two-hour preoperative clear fluid fasting interval, now standard in international guidelines, provides an adequate gastric emptying window for commercially available maltodextrin-based beverages.

The evidence for safety in high-risk populations, particularly patients with diabetic gastroparesis, severe obesity ($\text{BMI} > 40 \text{ kg/m}^2$), symptomatic severe gastro-oesophageal reflux disease, or known disorders of gastric motility, is substantially less robust. Formal gastric emptying assessment using bedside point-of-care ultrasonography before carbohydrate loading in high-risk individuals represents an emerging evidence-based safety practice. [25] The validated gastric ultrasound protocol assesses antral cross-sectional area as a surrogate for gastric content volume, enabling clinicians to confirm gastric emptying before proceeding with anaesthesia induction. Prospective validation of this approach in the specific context of high-risk patients receiving preoperative carbohydrate drinks is warranted.

Furthermore, the glycaemic response to carbohydrate loading in patients with diabetes or significant insulin resistance warrants specific clinical consideration. Gustafsson and colleagues demonstrated that preoperative carbohydrate loading may be safely employed in well-controlled type 2 diabetic patients without known gastroparesis, with appropriate perioperative glucose monitoring. [26] However, patients with poorly controlled diabetes ($\text{HbA1c} > 8.5\%$), significant insulin deficiency, or confirmed gastroparesis

should be individually assessed, and tailored low-carbohydrate formulations or dose-adjusted protocols for this population require formal investigation.

4.5 Patient-Centred Outcomes: A Paradigm Shift in Perioperative Value

Patient-centred outcome measurement has gained substantial prominence in surgical quality assessment, reflecting the recognition that patient experience, comfort, dignity, and wellbeing are legitimate and important healthcare outcomes alongside mortality and complication rates. The consistent improvements in thirst, hunger, anxiety, and satisfaction associated with carbohydrate loading align with patient-centred perioperative care frameworks and ERAS programme principles emphasising the quality of the entire surgical experience. [3, 10, 34]

These patient-centred benefits are particularly relevant in same-day surgical settings and ambulatory surgical centres, where preoperative experience quality directly influences patient confidence, cooperation with recovery instructions, and satisfaction with care. Prospective implementation of standardised patient-reported outcome measures (PROMs), including visual analogue scales for comfort, validated anxiety instruments, and postoperative quality of recovery scores such as the QoR-15, would substantially strengthen the evidence base for this outcome domain in future trials.

4.6 Special Populations and Evidence Gaps

The current evidence base is disproportionately derived from elective abdominal and colorectal surgery in metabolically healthy adult populations, leaving several clinically important patient subgroups incompletely characterised.

Patients with diabetes mellitus represent a particularly critical and underrepresented group, given the high prevalence of diabetes in surgical populations and their elevated risk of exaggerated perioperative metabolic stress response, hypoglycaemic episodes, and surgical site complications. [26] While limited available data suggest that carbohydrate loading may be safely used in well-controlled type 2 diabetes without gastroparesis with appropriate glucose monitoring, dedicated RCTs specifically designed for diabetic surgical populations are urgently needed.

Elderly patients (age ≥ 70 years) represent another high-priority subgroup, given age-related changes in insulin sensitivity, gastric motility, hepatic glycogen capacity, and metabolic reserve. The potential metabolic benefits, and risks, of carbohydrate loading in elderly patients with frailty, polypharmacy, or reduced functional reserve require dedicated prospective investigation with appropriate frailty stratification instruments such as the Clinical Frailty Scale (CFS).

Patients with obesity (BMI > 35 kg/m²) pose specific challenges related to baseline insulin resistance, potentially delayed gastric emptying, and elevated aspiration risk, a clinical profile that may alter both the benefit and safety profile of carbohydrate loading. Patients undergoing bariatric surgery represent a distinct perioperative population in whom existing ERAS society guidance provides limited specific

direction on carbohydrate loading; [16] dedicated trials in this context are indicated. Analogous evidence gaps exist for cardiothoracic, hepatopancreatic, and urological surgical populations.

4.7 Comparison With International Guideline Recommendations

The evidence reviewed is broadly concordant with the recommendations of major international perioperative care bodies. The ASA 2017 Practice Guidelines permit clear liquid intake up to two hours before elective procedures in healthy adults, with commercially available carbohydrate drinks encompassed within this recommendation. [4] The ESPEN 2017 Clinical Nutrition Guidelines for Surgery, updated in 2021 [31], recommend preoperative oral carbohydrate loading the evening before and two to three hours before surgery in elective non-diabetic adult patients, citing strong evidence for metabolic benefit and patient comfort. [18] The ERAS Society guidelines across multiple surgical specialties incorporate carbohydrate loading as a standard, evidence-endorsed preoperative component. [15, 16, 17, 33]

The convergence of international guideline support, despite the acknowledged inconsistency of evidence for major clinical endpoints, reflects the integration of mechanistic rationale, patient-centred benefits, strong gastric safety data, and the pragmatic clinical principle that any intervention reducing unnecessary fasting-related harm without increasing risk represents meaningful perioperative value.

4.8 Limitations of the Current Evidence Base

Several important methodological limitations constrain the interpretation and generalisability of current evidence. First, substantial clinical and statistical heterogeneity exists across studies in surgical procedure type, patient demographics, carbohydrate formulation and dose, administration timing, fasting comparator protocols, and anaesthetic technique, collectively precluding meaningful quantitative pooling outside of the identified systematic reviews and meta-analyses.

Second, outcome reporting heterogeneity, with varying definitions, measurement instruments, and follow-up periods across studies, limits inter-study comparability. The absence of a standardised core outcome set (COS) for preoperative carbohydrate loading research represents an important methodological gap that impedes cumulative evidence synthesis.

Third, most individual RCTs are single-centre studies with modest sample sizes (typically 30–100 participants per arm), lacking the statistical power required to detect clinically meaningful differences in relatively infrequent complication endpoints. Underpowering for clinical outcome endpoints may contribute to false-negative findings.

Fourth, the confounding contribution of ERAS co-interventions renders causal attribution to carbohydrate loading alone difficult in the majority of published studies. Fifth, the risk of publication bias cannot be excluded, as positive metabolic findings may be disproportionately represented in the published literature, potentially overstating overall benefit.

4.9 Research Gaps and Future Directions

Based on the evidence reviewed, priority research questions and directions include:

- (1) Adequately powered, multicentre RCTs evaluating preoperative carbohydrate loading as an isolated intervention, independent of concurrent ERAS components, with pre-specified primary endpoints of major postoperative complications and length of hospital stay. Such trials should be stratified by surgical procedure type and patient metabolic status.
- (2) Dedicated RCTs in patients with type 1 and type 2 diabetes mellitus, examining both metabolic safety, including postprandial hyperglycaemia and hypoglycaemia risk, and clinical benefits, with formal gastric emptying assessment in gastroparesis subgroups.
- (3) Prospective trials in elderly (≥ 70 years) and frail surgical populations, incorporating validated frailty instruments, comprehensive functional outcome measures, and extended follow-up periods.
- (4) Studies evaluating optimal carbohydrate formulation (maltodextrin versus complex carbohydrate mixtures), dose–response relationships, timing and frequency of administration (evening-only, morning-only, or both), and the additive or synergistic effects of protein co-supplementation on metabolic outcomes.
- (5) Development and formal validation of a core outcome set (COS) for preoperative carbohydrate loading research through Delphi consensus methodology, incorporating patient, clinician, and methodologist perspectives to standardise future trial endpoints.
- (6) Prospective studies evaluating bedside gastric ultrasound-guided individualised fasting protocols in high-risk patients, to delineate safe implementation criteria beyond the current guideline frameworks.
- (7) Health economic evaluations and implementation fidelity analyses across healthcare systems with differing perioperative care resources, to guide equitable and cost-effective policy adoption.

4.10 Clinical Implications for Anaesthetic and Perioperative Practice

For clinicians in anaesthesia, surgery, and perioperative medicine, the evidence reviewed supports several practical clinical recommendations. Preoperative oral carbohydrate loading is appropriate and safe for adult patients undergoing elective surgery who are free of significant gastroparesis, gastrointestinal obstruction, or high aspiration risk. A standard evidence-based protocol, 800 mL carbohydrate drink the evening before surgery and 400 mL two hours before anaesthesia induction, is supported by current evidence and endorsed by multiple international societies.

Carbohydrate loading is most effectively and clinically beneficially implemented as an integrated component of comprehensive ERAS pathways that include minimised fasting intervals, early

postoperative nutrition, opioid-sparing analgesia, and early mobilisation. Isolated carbohydrate loading without accompanying ERAS infrastructure is unlikely to yield maximal clinical outcome benefits.

Patient assessment before carbohydrate loading should specifically address gastroparesis risk, gastro-oesophageal reflux severity, gastrointestinal motility disorders, and glycaemic control in diabetic patients. Institutional carbohydrate loading protocols should include clear criteria for withholding or modifying the intervention in high-risk cases, with provision for gastric ultrasound assessment where clinically indicated.

5. CONCLUSIONS

Preoperative oral carbohydrate loading represents a physiologically rational, patient-centred, and clinically well-tolerated evolution from the historically entrenched practice of prolonged preoperative fasting in adult elective surgical patients. The strongest and most consistent evidence supports attenuation of postoperative insulin resistance and meaningful, reproducible improvements in patient comfort, outcomes that address both the metabolic consequences of surgical stress and the experiential quality of perioperative care.

The effect of carbohydrate loading on major clinical endpoints, postoperative complications and length of hospital stay, is context-dependent and most apparent when carbohydrate loading is embedded within comprehensive ERAS care pathways. The evidence for independent major outcome benefit is currently inconclusive, reflecting methodological limitations of available trials rather than the absence of a plausible physiological mechanism.

The gastric safety of appropriately administered carbohydrate drinks in selected patients is well-supported by current evidence. Patient selection and clinical assessment for aspiration risk remain essential, particularly in high-risk subgroups including those with diabetes mellitus, obesity, and gastric motility disorders, where the current evidence base is insufficient to permit generalised protocol application.

Future research priorities include: adequately powered multicentre RCTs with standardised complication endpoints; dedicated investigation in patients with diabetes, advanced age, and obesity; development of a core outcome set to facilitate cumulative evidence synthesis; and ultrasound-guided approaches to individualised fasting protocol development. For the present, clinicians should incorporate preoperative carbohydrate loading as a standard component of ERAS-based perioperative care, applying evidence-based patient selection criteria and consistent adherence to established fasting interval recommendations.

Declarations

Competing interest:

All authors declare no conflicts of interest.

Ethics approval and consent to participate:

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Consent for publication:

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Author Contribution

R.A.C.M conceptualised, wrote initial and final drafts, reviewed and validated it.

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