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REVIEW ARTICLE OPEN

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Intermittent vs. continuous: a comparative narrative review of enteral and parenteral nutrition support strategies in the perioperative setting

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Enteral and parenteral nutrition are two primary methods of nutritional support in clinical settings. Their administration modes—continuous or intermittent—have garnered increasing attention in recent research. Continuous enteral and parenteral nutrition provide steady metabolic support over extended periods, particularly beneficial for critically ill patients or those with high nutritional demands. Conversely, intermittent feeding, delivered at scheduled intervals, simulates natural eating patterns and may offer advantages in gastrointestinal function and metabolic regulation. Recent studies indicate notable differences between continuous and intermittent feeding in perioperative patients, especially regarding metabolic control, gastrointestinal tolerance, immune function, and postoperative complications. Continuous feeding simplifies clinical management through stable nutrient delivery but may increase the risks of metabolic overload, liver dysfunction, and gastrointestinal intolerance. In contrast, intermittent feeding promotes recovery of gastrointestinal function and potentially reduces the risk of infections and other postoperative complications. This review aims to assess the clinical outcomes of continuous versus intermittent enteral and parenteral nutrition in perioperative patients, with a primary focus on gastrointestinal surgery populations (where gut-specific mechanisms are most critical). By evaluating these feeding strategies in terms of postoperative complications, recovery, metabolic regulation, and quality of life, we seek to provide evidence-based recommendations for optimizing perioperative nutritional care and improving patient outcomes.

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INTRODUCTION

Nutritional support plays a critical role in the perioperative management of surgery patients [1]. Adequate nutrition is essential for maintaining metabolic stability, enhancing post-operative recovery, minimizing complications such as infections and anastomotic leaks, and reducing hospital stays [2]. Furthermore, proper nutritional support helps prevent and correct perioperative malnutrition, particularly in patients at risk of nutritional deficiencies, thus improving clinical outcomes and overall survival rates [3]. While Enhanced Recovery After Surgery (ERAS) protocols advocate for the resumption of oral intake within 24 h for low - risk patients to minimize the need for supplemental nutrition, this review centers on patients requiring enteral or parenteral nutrition (EN/PN). These patients include individuals at high risk of malnutrition (e.g., with weight loss >10%), those anticipating a prolonged nil - by-mouth status (>5 days), and those with gastrointestinal dysfunction or surgical complications. Thus, our analysis is highly relevant to perioperative patients not meeting ERAS criteria and needing EN/PN [4]. The method of nutritional support—whether enteral, parenteral, or a combination—depends on the patient's condition and gastrointestinal function [5, 6]. Enteral nutrition is preferred when gastrointestinal function is intact, either through oral supplements or tube feeding [7]. If the gastrointestinal tract is unable to absorb nutrients effectively, parenteral nutrition is administered intravenously [8]. Continuous feeding is widely used, yet there's limited research comparing it with intermittent feeding in perioperative patients [9, 10]. This review explores their effects on patient recovery and outcomes in the perioperative phase, focusing on gastrointestinal surgery but not excluding other types. The complex interplay between these factors is conceptually summarized in Fig. 1.

DEFINITION OF INFUSION MODALITY AND LITERATURE SEARCH STRATEGY

Enteral nutrition

Continuous enteral nutrition (CEN). Continuous enteral nutrition (CEN) involves the uninterrupted administration of nutrients via enteral feeding tubes, typically through devices such as nasogastric or jejunostomy tubes [11]. This method allows for the gradual, continuous infusion of liquid nutrients into the gastrointestinal tract, often over 24 h or longer, depending on clinical requirements. Crucially, transpyloric jejunal access necessitates continuous infusion due to the absence of pyloric reservoir function and limited jejunal distension capacity. Intermittent boluses in jejunal tubes increase aspiration and dumping syndrome risks [12].

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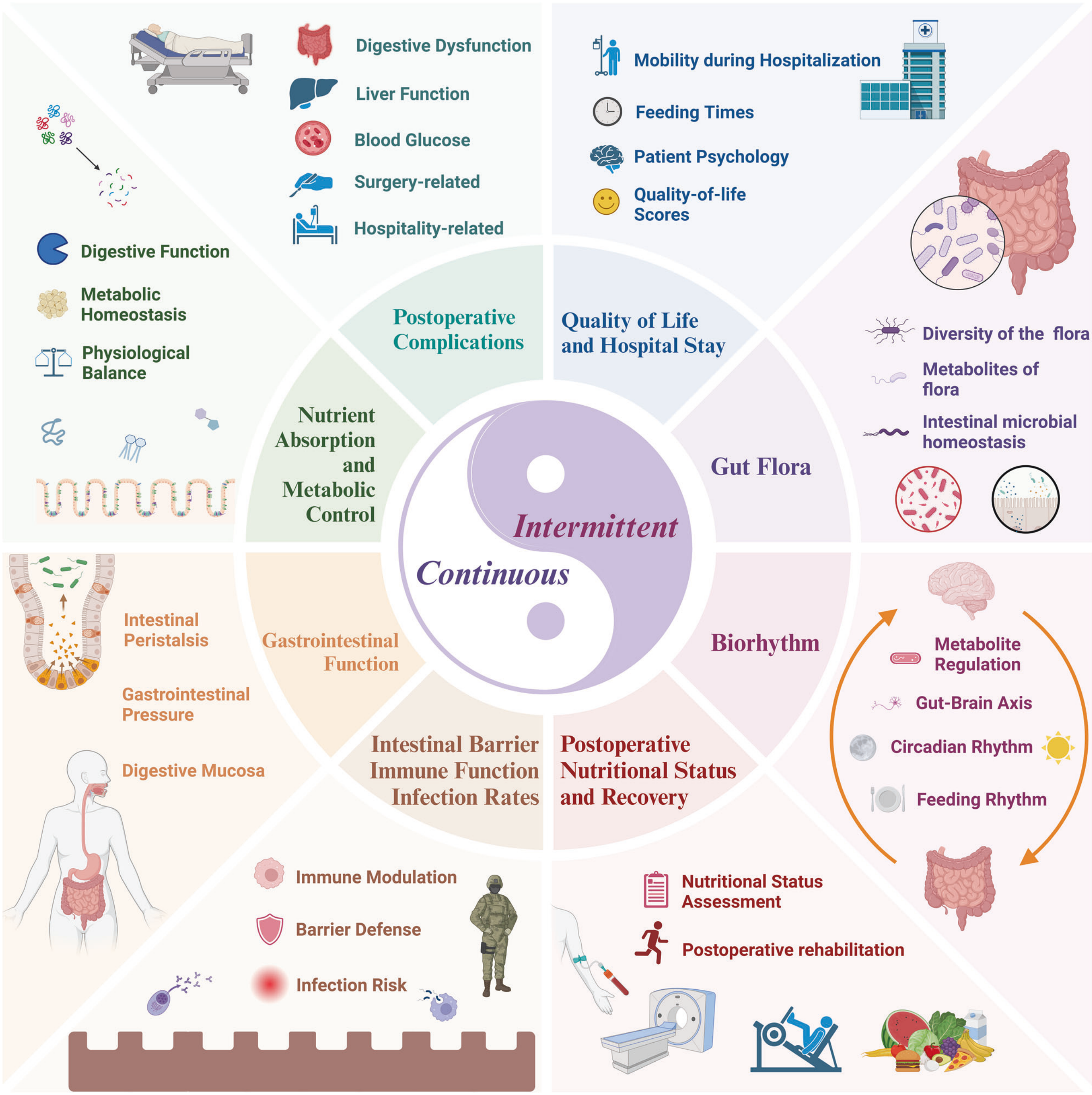

Fig. 1 This figure consists of nine sections, with a central Taiji symbol presented in purple and white tones. The Taiji symbol represents the dynamic balance between intermittent and continuous nutritional support, emphasizing the interplay of different infusion strategies in postoperative recovery. Surrounding the central symbol are various themes encompassing multiple domains, from postoperative complications to patient quality of life and physiological balance, clearly illustrating the comprehensive impact of different infusion methods on the overall health of perioperative patients. 1. Postoperative Complications: This section describes postoperative challenges, including digestive dysfunction, liver function abnormalities, blood glucose fluctuations, and complications related to surgery and hospitalization; 2. Quality of Life and Hospital Stay: Covers key aspects of patient recovery during hospitalization, including mobility, feeding times, and patient psychology, which significantly influence quality-of-life outcomes; 3. Gut Flora: Highlights the central role of the gut microbiota in postoperative recovery, focusing on microbial diversity, metabolite regulation, and the maintenance of intestinal microbial homeostasis; 4. Biorhythm: Explores the interaction between feeding rhythms, circadian rhythms, and metabolite regulation, as well as the role of the gut-brain axis. This section underscores the importance of different nutritional support strategies in regulating biorhythms and facilitating postoperative recovery; 5. Postoperative Nutritional Status and Recovery: Emphasizes the importance of nutritional assessments and rehabilitation interventions, detailing how targeted nutritional support can enhance recovery and health outcomes; 6. Intestinal Barrier, Immune Function, and Infection Rates: Focuses on the role of the intestinal barrier in regulating immune responses, providing barrier defense, and reducing infection risks, highlighting its critical importance in postoperative care; 7. Gastrointestinal Function: Illustrates dynamic changes in intestinal peristalsis, gastrointestinal pressure, and digestive mucosa, demonstrating their significance in the restoration of postoperative digestive function; 8. Digestive Function and Physiological Balance: Concentrates on metabolic homeostasis and physiological balance, detailing their impact on nutrient absorption and metabolic control, which are essential for successful recovery. This diagram provides a comprehensive visualization of the study, covering the systemic effects of intermittent and continuous nutritional support during the perioperative period. Spanning multiple dimensions, from physiological mechanisms to quality of life, it offers a robust visual reference for optimizing perioperative nutritional strategies in clinical practice. (Created in BioRender. zhou, z. (2024) https://BioRender.com/u08b403).

However, the prolonged use of enteral feeding tubes (e.g., nasogastric or jejunostomy tubes) restricts patient mobility and may increase the risk of aspiration pneumonia due to impaired gastric emptying or microbial colonization of the tube [13, 14].

Intermittent enteral nutrition (IEN). Intermittent enteral nutrition (IEN) refers to the administration of nutrients at scheduled intervals throughout the day. Nutrients are infused multiple times per day, usually for durations between 30 min and 2 h, with breaks in between [15].

Parenteral nutrition

Continuous parenteral nutrition (CPN). Continuous parenteral nutrition (CPN) is administered via central or peripheral venous catheters, typically over a 24-h period to deliver nutrients at a controlled, slow rate. This solution typically contains essential components such as carbohydrates, proteins, fats, vitamins, and electrolytes, ensuring a balanced nutrient supply [16, 17]. CPN is particularly useful for patients who require long-term nutritional support but cannot rely on gastrointestinal absorption. However, its prolonged use can limit patient mobility and increase the risk of catheter-related infections, which may complicate clinical outcomes [18]. Proper catheter care and the use of antibiotic-coated catheters can help mitigate these infection risks.

Intermittent parenteral nutrition (IPN). Intermittent parenteral nutrition (IPN) involves delivering nutrients intravenously over a set period, typically 8 to 12 h daily, followed by a rest phase [19]. This method allows for faster nutrient administration at larger volumes within the patient's tolerance [17]. Typically administered over 8–12 h, which may include nighttime to align with physiological rest periods, this approach allows daytime mobility while accommodating the patient's circadian rhythm. However, the timing should be individualized based on metabolic needs and circadian biology to optimize hormonal balance.

These definitions describe technical delivery parameters only. Physiological outcomes and evidence-based comparisons are analyzed in Sections 3–5.

Literature search strategy

A systematic literature search was conducted in PubMed (2000–2024) using the following MeSH terms and keywords: ((“Enteral Nutrition”[Mesh] OR “enteral nutrition” OR “enteral feeding” OR “tube feeding” OR “nasogastric feeding” OR “jejunal feeding”) OR (“Parenteral Nutrition”[Mesh] OR “parenteral nutrition” OR “intravenous nutrition” OR “TPN” OR “hyperalimentation”)) AND ((“continuous”[tiab] OR “continuously”[tiab]) AND (“intermittent”[tiab] OR “intermittently”[tiab] OR “bolus”[tiab] OR “cyclic”[tiab])) AND ((“randomized controlled trial”[pt] OR “controlled clinical trial”[pt] OR “meta-analysis”[pt] OR “systematic review”[pt] OR “randomized”[tiab] OR “randomised”[tiab] OR “RCT”[tiab] OR “clinical trial”[tiab])). Web of Science and Cochrane Library were searched with adapted syntax. Titles/abstracts were screened for relevance, followed by full-text review. Inclusion: Clinical studies on perioperative EN/PN modes; Exclusion: Animal studies, non-English publications.

INTERMITTENT VERSUS CONTINUOUS ENTERAL NUTRITION

Metabolic control & glycemic stability

IEN VS. CEN. IEN: Mimics physiological feeding patterns, enhancing nutrient absorption and metabolic regulation. Patients achieve more stable blood glucose levels and better insulin sensitivity [14, 20], reducing hyperglycemia-related complications [21].

CEN: Provides stable support for high metabolic demands [22, 23] but increases postoperative hyperglycemia and insulin resistance risk [24].

IPN VS. CPN. IPN: Aligns with physiological rhythms but requires vigilant glucose monitoring due to rapid infusion causing blood glucose spikes [25]. Reduces overfeeding and insulin resistance risks [26].

CPN: Maintains metabolic stability [27] but causes persistent hyperglycemia and insulin resistance due to continuous glucose infusion [28].

Gastrointestinal function & tolerance

IEN VS. CEN. IEN: IEN can stimulate intestinal motility and reduce mucosal atrophy, promoting better nutrient absorption [29, 30]. Additionally, the intermittent nature of feeding reduces gastrointestinal pressure during non-feeding periods, which gives the digestive system time to rest and recover, potentially lowering the incidence of gastrointestinal intolerance, such as bloating or diarrhea [31]. However, the rapid administration of large volumes of nutrients, characteristic of IEN, may still result in discomfort, including symptoms like bloating and diarrhea, particularly in patients with compromised digestive capacity [32].

CEN: CEN has been associated with a potential decline in gastrointestinal function, particularly when used over extended periods. Research indicates that CEN may contribute to mucosal atrophy, as the constant nutrient supply limits the natural stimulation of the gut, which can weaken the intestinal mucosa [33]. Additionally, CEN has been linked to dysbiosis, or an imbalance in gut microbiota, which could increase the risk of gastrointestinal complications such as infections or intolerance [34]. These findings underscore the importance of carefully managing enteral feeding, particularly in critically ill patients, to prevent adverse outcomes.

Infection risk & immune response

IEN VS. CEN. IEN: IEN is associated with lower rates of postoperative infections, particularly in reducing the incidence of pneumonia and intra-abdominal infections. These outcomes may be due to the positive effects of IEN on reducing gastrointestinal pressure, which allows for improved digestion and metabolic regulation, ultimately leading to enhanced immune response [35, 36]. Moreover, the controlled feeding cycles of IEN give the gastrointestinal system time to rest, which may further support immune function and reduce infection risks [37].

CEN: It has been associated with a higher risk of postoperative infections compared to IEN. Studies have shown that patients on long-term CEN may experience higher infection rates, particularly due to the continuous use of enteral feeding tubes, which can increase the risk of pneumonia and other infections [14]. This may be due to factors such as reduced gut motility and immune response in patients receiving CEN.

IPN VS. CPN. IPN: IPN has been demonstrated to better support postoperative immune function. Studies suggest that patients receiving IPN experience lower infection rates, especially in those with compromised immune systems, when compared to those receiving continuous parenteral nutrition (CPN). This effect may be attributed to the intermittent nature of IPN, which allows for better glycemic control, a crucial factor in reducing postoperative infections [19, 38]. By maintaining more stable blood glucose levels, IPN reduces inflammatory responses, further decreasing the risk of infections [39].

CPN: While CPN provides necessary and continuous nutritional support, it has been linked to an increased risk of postoperative infections, particularly in critically ill patients. Studies have shown that infection rates are higher in patients receiving CPN, likely due to the development of persistent hyperglycemia, which is a known complication of CPN [19, 28]. Hyperglycemia contributes to immunosuppressive effects, such as impaired phagocyte function, which in turn raises the susceptibility to infections, including surgical site infections [40, 41].

Liver function & hepatotoxicity

IPN VS. CPN. IPN: Studies have shown that patients on IPN experience a lower incidence of liver dysfunction, particularly in cases requiring long-term parenteral nutrition [42]. The intermittent nature of IPN allows the liver to periodically rest, reducing metabolic stress and promoting self-regulation, which is beneficial for maintaining hepatic function [27]. This is especially important as CPN has been associated with conditions like fatty liver and cholestasis when used over extended periods.

CPN: CPN has been closely associated with liver dysfunction, with a higher risk of complications such as fatty liver and cholestasis. These liver issues are more pronounced during long-term use of CPN due to the sustained metabolic demands placed on the liver, along with the continuous infusion of nutrients, particularly lipids and carbohydrates [43]. The metabolic overload, particularly from excess lipid infusions and phytosterols, contributes to fat accumulation in the liver (steatosis), which can progress to more severe conditions like fibrosis and cirrhosis if not managed properly [44, 45].

Quality of life & mobility

IEN VS. CEN. IEN: Due to the intermittent nature of IEN, non-critically ill patients indeed enjoy greater mobility during non-feeding periods, which may contribute to a higher quality of life and improved postoperative recovery. Studies have highlighted that patients receiving IEN report improved well-being and shorter hospital stays compared to those on CEN [34, 43].

CEN: The continuous infusion required for CEN has been linked to a negative impact on patient quality of life, especially for those relying on long-term enteral feeding. One study noted that CEN patients often experience lower postoperative quality of life scores due to factors such as prolonged feeding times and restricted mobility associated with continuous feeding. Additionally, continuous feeding may lead to feelings of dependency and discomfort caused by the constant use of feeding equipment, further reducing patient autonomy and overall well-being [46].

IPN VS. CPN. IPN: The flexibility of IPN allows non-critically ill patients greater freedom of movement during non-infusion periods, which can significantly enhance their postoperative quality of life. Studies suggest that patients receiving IPN report higher quality-of-life scores during recovery, likely due to fewer restrictions on mobility compared to those on CPN [47]. Moreover, patients on IPN also experience shorter hospital stays, as the intermittent nature of the feeding supports faster recovery and better overall outcomes [48].

CPN: The continuous infusion required by CPN limits patient mobility due to the need for prolonged connection to intravenous equipment, which can significantly impact the quality of life, particularly for those on long-term parenteral nutrition. Patients receiving CPN often experience restrictions in daily activities, which contributes to a reduced quality of life [45, 49]. Furthermore, studies have shown that patients on CPN report lower quality of life scores, especially during the postoperative recovery phase, as the continuous infusion limits their physical mobility and autonomy [50]. This suggests a need for alternative strategies, such as cyclic parenteral nutrition (Cylic PN), which allows for greater mobility and improved patient outcomes.

Gut microbiota & circadian rhythm

IEN VS. CEN. IEN: The flora of the human gut has its own biological rhythms and maintains a dynamic balance of microorganisms throughout the intestinal tract. Different patterns of feeding and nutrient infusion can significantly affect the gut flora; regular feeding cycles and circadian rhythms help to maintain this dynamic balance, while conversely irregular feeding or prolonged and continuous nutrient supply may disrupt this balance, leading to metabolic syndrome or inflammatory diseases or even tumorigenesis [51].

Therefore, from the perspective of biological rhythms, intermittent nutrition is more in line with the body's natural eating rhythm, can maintain the dynamic balance of intestinal flora in perioperative patients, and can fully stimulate the intestinal tract, promote intestinal peristalsis and secretion of digestive juices, improve nutrient absorption, effectively prevent bacterial translocation, and better maintain the diversity of the composition of the intestinal flora and reduce intestinal permeability [52]. The circadian rhythm of intestinal flora can be restored to some extent under conditions of nutrient intake restriction (e.g., fasting and intermittent feeding), suggesting that we need to pay more attention to the rhythmicity of the timing of feeding when developing clinical nutrition programs [53].

CEN: Continuous enteral nutrition infusion can provide patients with stable nutritional intake. Still, it is also its continuous infusion pattern that conflicts with the body's biological rhythms (especially those of circadian and feeding rhythms), which may lead to a decrease in the diversity of the intestinal flora, disrupt endogenous rhythm regulation, increase the risk of pathogenic infections, increase the metabolic burden and induce inflammatory responses, thus posing a danger to the patient's postoperative recovery [54].

Metabolites of intestinal flora affect human circadian rhythms via the gut-brain axis, and this disruptive effect is especially pronounced in the presence of poor synchronization between feeding rhythms and endogenous biological clocks. Metabolites of intestinal flora, such as short-chain fatty acids (SCFAs), can

Table 1. This comparative analysis synthesizes key clinical outcomes for intermittent vs continuous nutrition support specifically in perioperative gastrointestinal surgery patients.

Metric	IEN	CEN	IPN	CPN
Gastrointestinal function recovery	Significant improvement	Possible delay	N/A	N/A
Glycemic control	Requires close monitoring	Short-term stability	Better control	Hyperglycemia risk↑
Infection risk	Reduced	Increased	Reduced	Increased
Hospital stay duration	Shortened	Potentially prolonged	Shortened	Potentially prolonged
Quality of life	Significantly improved	Restricted	Mobility improved	Severely restricted
Liver dysfunction	N/A	N/A	Risk reduced	Risk significantly increased
Applicable Patient population	Patients with intact gastrointestinal function	Critically ill/diabetic patients	Patients with stable metabolic conditions	Patients requiring long-term NPO status

Arrow direction indicates beneficial (↑) or adverse (↓) effects, with dot fill levels denoting evidence strength based on systematic review of cited studies.
↑ Increased risk/effect, *N/A* Not applicable, *NPO* Nil per os (nothing by mouth).

modulate the expression of appetitive and circadian genes in the hypothalamus, which can affect whole-body metabolism and behavior [55].

A comparative summary of these outcomes is presented in Table 1.

CONCLUSIONS

In conclusion, selecting the appropriate nutritional support method is crucial for optimizing the outcomes of perioperative patients undergoing surgery. While intermittent enteral or parenteral nutrition may offer clinical advantages in certain cases, continuous nutritional support remains essential for the broader population of surgery patients. The decision to employ intermittent or continuous feeding should be based on the latest evidence from clinical research and should be tailored to the patient's specific surgical procedure, nutritional needs, and individual circumstances. A comprehensive evaluation of the risks and benefits of each administration method is necessary to maximize postoperative recovery and patient outcomes.

REFERENCES

1. Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, et al. ESPEN practical guideline: clinical nutrition in surgery. Clin Nutr. 2021;40:4745–61. https://doi.org/10.1016/j.clnu.2021.03.031.
2. Osland E, Yunus RM, Khan S, Memon MA. Early versus traditional postoperative feeding in patients undergoing resectional gastrointestinal surgery: a meta-analysis. JPEN J Parenter Enter Nutr. 2011;35:473–87. https://doi.org/10.1177/0148607110385698.
3. Correia MI, Waitzberg DL. The impact of malnutrition on morbidity, mortality, length of hospital stay and costs evaluated through a multivariate model analysis. Clin Nutr. 2003;22:235–9. https://doi.org/10.1016/s0261-5614(02)00215-7.
4. Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, et al. ESPEN guideline: clinical nutrition in surgery. Clin Nutr. 2017;36:623–50. https://doi.org/10.1016/j.clnu.2017.02.013.
5. Serón-Arbeloa C, Puzo-Foncillas J, Garcés-Gimenez T, Escós-Orta J, Labarta-Monzón L, Lander-Azcona A. A retrospective study about the influence of early nutritional support on mortality and nosocomial infection in the critical care setting. Clin Nutr. 2011;30:346–50. https://doi.org/10.1016/j.clnu.2010.11.004.
6. Reignier J, Darmon M, Sonneville R, Borel AL, Garrouste-Orgeas M, Ruckly S, et al. Impact of early nutrition and feeding route on outcomes of mechanically ventilated patients with shock: a post hoc marginal structural model study. Intensive Care Med. 2015;41:875–86. https://doi.org/10.1007/s00134-015-3730-4.
7. Pardo E, Lescot T, Preiser JC, Massanet P, Pons A, Jaber S, et al. Association between early nutrition support and 28-day mortality in critically ill patients: the FRANS prospective nutrition cohort study. Crit Care. 2023;27:7. https://doi.org/10.1186/s13054-022-04298-1.
8. Choi YK, Kim HJ, Ahn J, Ryu JA. Impact of early nutrition and feeding route on clinical outcomes of neurocritically ill patients. PLoS One. 2023;18:e0283593. https://doi.org/10.1371/journal.pone.0283593.
9. Reese MK, Hewlings S. Enteral versus parenteral nutrition: use in adult patients undergoing hematopoietic stem cell transplantation. Clin J Oncol Nurs. 2019;23:173–9. https://doi.org/10.1188/19.CJON.173-179.
10. Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clin Nutr. 2019;38:48–79. https://doi.org/10.1016/j.clnu.2018.08.037.
11. MacLeod JB, Lefton J, Houghton D, Roland C, Doherty J, Cohn SM, et al. Prospective randomized control trial of intermittent versus continuous gastric feeds for critically ill trauma patients. J Trauma. 2007;63:57–61. https://doi.org/10.1097/01.ta.0000249294.58703.11.
12. McClave SA, Martindale RG, Vanek VW, McCarthy M, Roberts P, Taylor B, et al. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and AmericanSociety for Parenteral and Enteral Nutrition (A.S.P.E.N.) [published correction appears in JPEN. JPEN J Parenter Enter Nutr.2016;40:159–211. https://doi.org/10.1177/0148607115621863.
13. Reignier J, Mercier E, Le Gouge A, Boulain T, Desachy A, Bellec F, et al. Effect of not monitoring residual gastric volume on risk of ventilator-associated pneumonia in adults receiving mechanical ventilation and early enteral feeding: a randomized controlled trial. JAMA. 2013;309:249–56. https://doi.org/10.1001/jama.2012.196377.
14. Thong D, Halim Z, Chia J, Chua F, Wong A. Systematic review and meta-analysis of the effectiveness of continuous vs intermittent enteral nutrition in critically ill adults. JPEN J Parenter Enter Nutr. 2022;46:1243–57. https://doi.org/10.1002/jpen.2324.
15. Lee HY, Lee JK, Kim HJ, Ju DL, Lee SM, Lee J. Continuous versus intermittent enteral tube feeding for critically ill patients: a prospective, randomized controlled trial. Nutrients. 2022;14:664 https://doi.org/10.3390/nu14030664.
16. Marik PE, Zaloga GP. Early enteral nutrition in acutely ill patients: a systematic review. Crit Care Med. 2001;29:2264–70. https://doi.org/10.1097/00003246-200112000-00005.
17. Dimick JB, Swoboda S, Talamini MA, Pelz RK, Hendrix CW, Lipsett PA. Risk of colonization of central venous catheters: catheters for total parenteral nutrition vs other catheters. Am J Crit Care. 2003;12:328–35.
18. Gastmeier P, Weist K, Rüden H. Catheter-associated primary bloodstream infections: epidemiology and preventive methods. Infection. 1999;27:S1–6. https://doi.org/10.1007/BF02561609.
19. Hellerman Itzhaki M, Singer P. Advances in medical nutrition therapy: parenteral nutrition. Nutrients. 2020;12:717. https://doi.org/10.3390/nu12030717.
20. Reintam Blaser A, Starkopf L, Deane AM, Poeze M, Starkopf J. Comparison of different definitions of feeding intolerance: a retrospective observational study. Clin Nutr. 2015;34:956–61. https://doi.org/10.1016/j.clnu.2014.10.006.
21. Hu B, Sun R, Wu A, Ni Y, Liu J, Guo F, et al. Severity of acute gastrointestinal injury grade is a predictor of all-cause mortality in critically ill patients: a multicenter, prospective, observational study. Crit Care. 2017;21:188. https://doi.org/10.1186/s13054-017-1780-4.
22. Ni K, Hawkins RM, Smyth HL, Seggelke SA, Gibbs J, Lindsay MC, et al. Safety and efficacy of insulins in critically ill patients receiving continuous enteral nutrition. Endocr Pr. 2024;30:367–71. https://doi.org/10.1016/j.eprac.2024.01.009.
23. Gosmanov AR, Umpierrez GE. Management of hyperglycemia during enteral and parenteral nutrition therapy. Curr Diab Rep. 2013;13:155–62. https://doi.org/10.1007/s11892-012-0335-y.
24. Murphy PM, Moore E, Flanagan DE. Glycaemic control in insulin requiring diabetes patients receiving exclusive enteral tube feeding in an acute hospital setting. Diabetes Res Clin Pr. 2014;103:426–9. https://doi.org/10.1016/j.diabres.2013.12.007.
25. Ling PR, Mueller C, Smith RJ, Bistrian BR. Hyperglycemia induced by glucose infusion causes hepatic oxidative stress and systemic inflammation, but not STAT3 or MAP kinase activation in liver in rats. Metabolism. 2003;52:868–74. https://doi.org/10.1016/s0026-0495(03)00057-x.
26. Pasquel FJ, Spiegelman R, McCauley M, Smiley D, Umpierrez D, Johnson R, et al. Hyperglycemia during total parenteral nutrition: an important marker of poor outcome and mortality in hospitalized patients. Diabetes Care. 2010;33:739–41. https://doi.org/10.2337/dc09-1748.
27. Lucchinetti E, Lou PH, Wawrzyniak P, Wawrzyniak M, Scharl M, Holtzhauer GA, et al. Novel strategies to prevent total parenteral nutrition-induced gut and liver inflammation, and adverse metabolic outcomes. Mol Nutr Food Res. 2021;65:e1901270. https://doi.org/10.1002/mnfr.201901270.
28. Roszali MA, Zakaria AN, Mohd Tahir NA. Parenteral nutrition-associated hyperglycemia: prevalence, predictors and management. Clin Nutr ESPEN. 2021;41:275–80. https://doi.org/10.1016/j.clnesp.2020.11.023.
29. Nakayoshi T, Kawasaki N, Suzuki Y, Yasui Y, Nakada K, Ishibashi Y, et al. Epidural administration of morphine facilitates time of appearance of first gastric interdigestive migrating complex in dogs with paralytic ileus after open abdominal surgery. J Gastrointest Surg. 2007;11:648–54. https://doi.org/10.1007/s11605-006-0065-z.
30. Sun X, Spencer AU, Yang H, Haxhija EQ, Teitelbaum DH. Impact of caloric intake on parenteral nutrition-associated intestinal morphology and mucosal barrier function. JPEN J Parenter Enter Nutr. 2006;30:474–9. https://doi.org/10.1177/0148607106030006474.
31. Wobith M, Weimann A. Oral nutritional supplements and enteral nutrition in patients with gastrointestinal surgery. Nutrients. 2021;13:2655. https://doi.org/10.3390/nu13082655.
32. Tatsumi H. Enteral tolerance in critically ill patients. J Intensive Care. 2019;7:30. https://doi.org/10.1186/s40560-019-0378-0.
33. Reintam Blaser A, Bachmann KF, Deane AM. Gastrointestinal function in critically ill patients. Curr Opin Clin Nutr Metab Care. 2023;26:463–9. https://doi.org/10.1097/MCO.0000000000000955.
34. Ma Y, Cheng J, Liu L, Chen K, Fang Y, Wang G, et al. Intermittent versus continuous enteral nutrition on feeding intolerance in critically ill adults: a meta-analysis of randomized controlled trials. Int J Nurs Stud. 2021;113:103783. https://doi.org/10.1016/j.ijnurstu.2020.103783.
35. Li XK, Cong ZZ, Wu WJ, Xu Y, Zhou H, Wang GM, et al. Enteral immunonutrition versus enteral nutrition for patients undergoing esophagectomy: a randomized controlled trial. Ann Palliat Med. 2021;10:1351–61. https://doi.org/10.21037/apm-20-1399.

36. Hogan S, Solomon M, Rangan A, Ferrie S, Carey S. The impact of preoperative immunonutrition and standard polymeric supplements on patient outcomes after pelvic exenteration surgery, taking compliance into consideration: a randomized controlled trial. JPEN J Parenter Enter Nutr. 2020;44:806–14. https://doi.org/10.1002/jpen.1709.
37. Wierdak M, Surmiak M, Milian-Ciesielska K, Rubinkiewicz M, Rzepa A, Wysocki M, et al. Immunonutrition changes inflammatory response in colorectal cancer: results from a pilot randomized clinical trial. Cancers. 2021;13:1444. https://doi.org/10.3390/cancers13061444.
38. Gao X, Liu Y, Zhang L, Zhou D, Tian F, Gao T, et al. Effect of early vs late supplemental parenteral nutrition in patients undergoing abdominal surgery: a randomized clinical trial. JAMA Surg. 2022;157:384–93. https://doi.org/10.1001/jamasurg.2022.0269.
39. Polavarapu P, Pachigolla S, Drincic A. Glycemic management of hospitalized patients receiving nutrition support. Diabetes Spectr. 2022;35:427–39. https://doi.org/10.2337/dsi22-0010.
40. Cheung NW, Napier B, Zaccaria C, Fletcher JP. Hyperglycemia is associated with adverse outcomes in patients receiving total parenteral nutrition. Diabetes Care. 2005;28:2367–71. https://doi.org/10.2337/diacare.28.10.2367.
41. Barbosa J, Valentim M, Almeida M, Vasconcelos L. The impact of fluid therapy on glycemic variation in non-diabetic patients undergoing laparoscopy. Cureus. 2023;15:e49240. https://doi.org/10.7759/cureus.49240.
42. Melendez M, Mitchell R, Heredia H, Lloyd J, Taliaferro J, Beveridge EK, et al. Lipid emulsion type and liver function in parenteral nutrition patients: a retrospective study of patients and prescribing practices. Nutrients. 2024;16:2590. https://doi.org/10.3390/nu16162590.
43. Heffernan AJ, Talekar C, Henain M, Purcell L, Palmer M, White H. Comparison of continuous versus intermittent enteral feeding in critically ill patients: a systematic review and meta-analysis. Crit Care. 2022;26:325. https://doi.org/10.1186/s13054-022-04140-8.
44. Lazarus JV, Palayew A, Carrieri P, Ekstedt M, Marchesini G, Novak K, et al. European 'NAFLD Preparedness Index' - Is Europe ready to meet the challenge of fatty liver disease? JHEP Rep. 2021;3:100234. https://doi.org/10.1016/j.jhepr.2021.100234.
45. Arenas Villafranca JJ, Nieto Guindo M, Álvaro Sanz E, Moreno Santamaria M, Garrido Siles M, Abilés J. Effects of cyclic parenteral nutrition on parenteral-associated liver dysfunction parameters. Nutr J. 2017;16:66. https://doi.org/10.1186/s12937-017-0289-7.
46. Ojo O, Keaveney E, Wang XH, Feng P. The effect of enteral tube feeding on patients' health-related quality of life: a systematic review. Nutrients. 2019;11:1046. https://doi.org/10.3390/nu11051046.
47. Martínez-Ortega AJ, Piñar-Gutiérrez A, Serrano-Aguayo P, González-Navarro I, Remón-Ruíz PJ, Pereira-Cunill JL, et al. Perioperative nutritional support: a review of current literature. Nutrients. 2022;14:1601. https://doi.org/10.3390/nu14081601.
48. Berbée C, Marx JP, Voelker MT, Schotte D, Bercker S. Parenteral nutrition in palliative care: single-centre observational study. BMJ Support Palliat Care. 2022:bmjspcare-2022-003581. https://doi.org/10.1136/bmjspcare-2022-003581
49. Avitzur Y, Miserachs M. Quality of life on long-term parenteral nutrition: can it be an indication for intestinal transplantation?. Curr Opin Organ Transpl. 2018;23:199–206. https://doi.org/10.1097/MOT.0000000000000503.
50. Stout SM, Cober MP. Metabolic effects of cyclic parenteral nutrition infusion in adults and children. Nutr Clin Pr. 2010;25:277–81. https://doi.org/10.1177/0884533610368701.
51. Dabke K, Hendrick G, Devkota S. The gut microbiome and metabolic syndrome. J Clin Invest. 2019;129:4050–7. https://doi.org/10.1172/JCI129194.
52. Liu Z, Li N, Dang Q, Liu L, Wang L, Li H, et al. Exploring the roles of intestinal flora in enhanced recovery after surgery. iScience. 2023;26:105959. https://doi.org/10.1016/j.isci.2023.105959.
53. Longo VD, Panda S. Fasting, circadian rhythms, and time-restricted feeding in healthy lifespan. Cell Metab. 2016;23:1048–59. https://doi.org/10.1016/j.cmet.2016.06.001.
54. Bishehsari F, Voigt RM, Keshavarzian A. Circadian rhythms and the gut microbiota: from the metabolic syndrome to cancer. Nat Rev Endocrinol. 2020;16:731–9. https://doi.org/10.1038/s41574-020-00427-4.
55. Tian Y, Yang W, Chen G, Men C, Gu Y, Song X, et al. An important link between the gut microbiota and the circadian rhythm: imply for treatments of circadian rhythm sleep disorder. Food Sci Biotechnol. 2022;31:155–64. https://doi.org/10.1007/s10068-021-01015-6.

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COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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