Australian Critical Care 32 (2019) 237–242

Contents lists available at ScienceDirect

Australian Critical Care

journal homepage: www.elsevier.com/locate/aucc

Research paper

A retrospective evaluation of nutrition support in relation to clinical outcomes in critically ill patients with an open abdomen

Rosalie Yandell, BSc (Hons), MND, PhD, APD [a, d, e, *]
Susan Wang, MBBS [b]
Peter Bautz, MBBCh, FCS(SA), MMed, FRACS [c]
Alison Shanks, BSc, PGrad Dip Nut Diet, BEd, APD [a]
Stephanie O'Connor, RN, Grad Dip Card Nsg, MNSc [b, e]
Adam Deane, MBBS, PhD, FRACP, FJFICM [b, d, e]
Kylie Lange, BSc(Ma&CompSci) (Hons) [d]
Marianne Chapman, BMBS, PhD, FFARCSI, FANZCA, FJFICM [b, d, e]

[a] *Department of Nutrition and Dietetics, Trauma Services, Royal Adelaide Hospital, Port Rd, Adelaide, 5000, Australia*
[b] *Department of Critical Care Services, Trauma Services, Royal Adelaide Hospital, Port Rd, Adelaide, 5000, Australia*
[c] *Hepatobiliary Surgery, Trauma Services, Royal Adelaide Hospital, Port Rd, Adelaide, 5000, Australia*
[d] *Centre of Clinical Research Excellence (CRE) in Translating Science to Good Health, The University of Adelaide, Frome Rd, Adelaide, 5000, Australia*
[e] *Discipline of Acute Care Medicine, The University of Adelaide, Frome Rd, Adelaide, 5000, Australia*

ARTICLE INFORMATION

Article history:
Received 21 November 2017
Received in revised form
12 April 2018
Accepted 13 April 2018

Keywords:
Nutritional support
Critical care nursing
Abdomen
Critically ill

ABSTRACT

Background: Optimising nutrition support in critically ill patients with an open abdomen is challenging.
Objectives: The aims of this study were to (i) quantify the amount and adequacy of nutrition support administered and (ii) determine any relationships that exist between mode of nutrition support delivery and clinical outcomes in critically ill patients with an open abdomen.
Methods: A retrospective review of critically ill patients mechanically ventilated for at least 48 h with an open abdomen in a mixed quaternary referral intensive care unit. Enteral and parenteral nutrition (ml) administered daily to patients was recorded for up to 21 days. Length of stay in the intensive care unit and hospital and duration of mechanical ventilation (days) were reported.
Results: Thirty patients were studied [14 male, 68 y (15–90 y), body mass index 25 kg/m^2 (11–51 kg/m^2), Acute Physiology and Chronic Health Evaluation II score 20 (7–41), energy goal 1860 kcal/d (1250–2712 kcal/d)]. Patients received 55% (0–117%) of energy goal and 56% (0–105%) protein goal from either enteral or parenteral nutrition. When enteral nutrition was delivered alone or in combination with parenteral nutrition, patients received 48% (0–146%) of their energy and 59% (19–105%) of their protein goal. Patients fed parenteral nutrition, either alone or as supplementary to enteral nutrition (n = 18), received more energy when compared with those who only received enteral nutrition (n = 9) [65 (27–117) vs 49 (15–89) % energy goal, P = 0.025]. Parenteral nutrition was associated with an increased length of stay in hospital [63 (45–156) vs 45 (17–93) d, P = 0.037].
Conclusion: Patients with an open abdomen receive about half of their nutrition requirements when fed exclusively via the enteral route. Providing combination enteral and parenteral nutrition to reach nutritional goals may not result in better clinical outcomes for patients with an open abdomen.

1. Introduction

Caring for critically ill patients with an open abdomen including how best to optimise their nutrition support is challenging.[1,2] Gut

* Corresponding author at: Department of Nutrition and Dietetics, Royal Adelaide Hospital, Port Rd, Adelaide, South Australia, 5000, Australia. Tel.: +61 8 8222 5223.
E-mail address: rosalie.yandell@sa.gov.au (R. Yandell).

https://doi.org/10.1016/j.aucc.2018.04.004

dysfunction is likely to be disordered in these patients,[3] and frequent fasting for return to surgery limits the hours of the day available to provide enteral nutrition. Limited data exist on how to feed the gut enterally when it is discontinuous, and few centres have extensive experience and confidence with the delivery of enteral nutrition distal to the site of a stoma.

Enteral nutrition is preferred over parenteral nutrition in critically ill patients partly because of the protective effect of trophic feeds on gastrointestinal tract immunity.[4–6] Early administration (within 24–48 h of admission) of some enteral nutrition support to critically ill patients is widely advocated owing to improvements in immune responses and reductions in oxidative stress and infection rates.[7–9] Early enteral nutrition in patients with an open abdomen may lower enterocutaneous fistulae formation and hospital costs and facilitate earlier primary fascial and skin closure,[10] although the latter is not seen in all studies. Many strategies have been suggested to facilitate the delivery of early enteral nutrition,[8] for example enteral nutrition delivery is improved by nurse-led implementation of feeding protocols.[11] Prokinetic administration and small bowel feeding may be advocated sooner and more widely when driven by the bedside nurse.

Several studies have reported delivering enteral nutrition to patients with an open abdomen.[10,12–15] The potential for intolerance of enteral nutrition is greater in patients with an open abdomen because of their preceding abdominal surgery[16] and the acute impact of enteral nutrition on the gastrointestinal tract in a pathological state. Bowel necrosis is considered more likely if enteral nutrient is administered during periods of bowel under perfusion,[15,17] and if gut motility is disordered, enteral feeding may cause bowel distention which reduces the ability to obtain fascial closure.[15,17] Consequently, enterally fed critically ill patients with an open abdomen are likely to fail in meeting recommended nutritional goals. However, the clinical impact of not meeting feeding goals is unknown.[18]

Parenteral nutrition can be administered and/or enteral nutrition can be delayed until the fascia is closed.[14] Dual feeding modalities (i.e. enteral and parenteral concurrently) may be employed to optimise the delivery of nutrients; however, this is not always supported by benefits in clinical outcomes for patients.[4,19] Indeed, early supplemental parenteral nutrition is potentially harmful in trauma patients as it confers a greater infection risk.[20] Optimising enteral nutrition support for patients with an open abdomen is therefore important.

The objectives of this study were to (i) quantify the amount and adequacy (defined by predetermined goals) of nutrition support (delivered as enteral and parenteral nutrition) administered and (ii) determine any relationships that exist between mode (enteral and parenteral) of nutrition delivery and clinical outcomes in critically ill patients with an open abdomen.

2. Methods and materials

This is a retrospective descriptive study. The medical records of patients admitted to the Royal Adelaide Hospital Intensive Care Unit (ICU), a closed mixed quaternary referral unit, were reviewed after approval by the Royal Adelaide Hospital Research Ethics Committee in 2009. The study included patients admitted to the Royal Adelaide Hospital ICU between January 2004 and December 2008 inclusive. The start date for this inclusion period coincided with the formal collection of details on a database of patients treated at our hospital with an open abdomen.

2.1. Participants

The Royal Adelaide Hospital Trauma Service database (maintained by a dedicated trauma nurse on all patients admitted to the Royal Adelaide Hospital under the trauma service) was queried to obtain a list of patients who underwent a laparotomy and were returned to the ICU with an open abdomen. An "open abdomen" was defined as the lack of skin and fascial approximation upon completion of a laparotomy. Participants were aged 18 years or older.

2.2. Data collection

A retrospective review of enteral and parenteral nutrition support for the first 21 days of their ICU admission (or until ICU discharge) was conducted. Information on demographics, hospital course, and injuries was documented. The type (enteral or parenteral) and timing (commencement in relation to ICU admission and hours per day) were noted. The medical records were evaluated to determine intolerance of enteral nutrition [defined in our unit as a gastric residual volume (GRV) of >250 ml or documented evidence of vomiting], recording administration of prokinetic drugs (metoclopramide and erythromycin) and postpyloric feeding (yes or no). The volume of enteral and parenteral nutrition (including intravenous propofol) administered daily (ml) was calculated. Bowel discontinuity at any stage during the study period was recorded (yes or no).

2.3. Feeding protocol

Patients were fed according to the feeding protocol that was used in the ICU at that time. In brief, once the medical order was documented, nursing staff commenced enteral nutrition (1 kcal/ml polymeric nutrient liquid administered at 40 ml/h for the first 24 h). GRVs were assessed 6 hourly as part of nursing care. Feed intolerance was managed by halving the rate of nutrient delivery and using prokinetics (metoclopramide 10 mg four times a day and erythromycin 200 mg twice a day) and postpyloric feeding, sequentially. Parenteral nutrition was administered if there was persistent intolerance to enteral nutrition (defined in our unit as two GRV > 250 ml in a 24-h period despite prokinetic treatment and postpyloric feeding); if the bowel was discontinuous or obstructed; or if deemed appropriate as per the clinical judgement of the treating intensivist. A dietitian calculated the feeding goal within 24 h of a patients' admission to the ICU using the Schofield equation for basal requirements multiplied by a stress factor[21,22] and collected the study data. Nursing staff increased feeding rates to goal by 20 ml/h every 6 h for feed-tolerant patients.

2.4. Study group definitions

Patients were divided into one of four groups on the basis of type of nutrition support provided during the first 21 days of their stay in the ICU: *enteral only* (E; i.e. no other source of nutrition including propofol was provided during the first 21 days of their ICU stay), both *enteral and parenteral* (B; i.e. enteral and parenteral nutrition was provided at some point in their ICU stay), *parenteral only* (P; i.e. no enteral source of nutrition was provided for the duration of their ICU stay), or *nil* nutrition (N; patients did not receive any nutrition for the duration of their ICU stay). *Any parenteral* (in the Results section and subsequently) refers to groups B and P combined.

2.5. Nutrition sources

Enteral nutrition was a macronutrient 1–2 kcal/ml of either polymeric or semi-elemental liquid formula (Abbott Nutrition, Australia). Parenteral nutrition consisted of a commercially available macronutrient (with or without lipid), multi-chamber bag

(Baxter Healthcare Pty Ltd, Australia). Separate daily trace element and multivitamin infusions were given during the provision of parenteral nutrition. Intravenous propofol which provides 1.1 kcal/ml was counted as a source of parenteral nutrition.

2.6. Data analysis

Descriptive statistics were used to report demographic variables. The groups were compared regarding the type and amount of nutrition provided, and their outcomes including length of stay (LOS) in ICU and hospital, duration of mechanical ventilation, and ICU and hospital mortality. The amount of nutrition was defined as net energy (kcal) and protein (g) delivered as a percentage of goal energy prescribed. Day 1 in the ICU was defined as the first day (after 13:00 h) of the ICU admission and was not necessarily 24 h. Data for subsequent days were recorded from 13:00 h to the following 13:00 h. Categorical data were evaluated using Chi-squared tests, and continuous data were analysed using Mann–Whitney and Kruskal–Wallis tests for unadjusted comparisons between groups and analysis of covariance adjusting for Acute Physiology and Chronic Health Evaluation (APACHE) II score and age. Post-hoc analyses were done by Bonferroni-adjusted pairwise comparisons between groups. Data are presented as median (range) unless otherwise indicated. Confounding factors considered were APACHE II score and age. Statistical analysis was carried out using SPSS V18.0 software (IBM Inc, 2010).

3. Results

3.1. Patient demographics

Forty-three patients with an open abdomen met the initial inclusion criteria with 30 patients meeting the criteria to be studied in the final cohort (Fig. 1). Patient demographics for the study cohort are detailed in Table 1.

3.2. Feeding outcomes for the entire study cohort

The median energy goal was 1860 kcal/d (1250–2712 kcal/d), and protein goal was 86 g/d (59–115 g/d). Nutrition started on Day 3 (2–8) of the patients' ICU admission, and enteral nutrition started

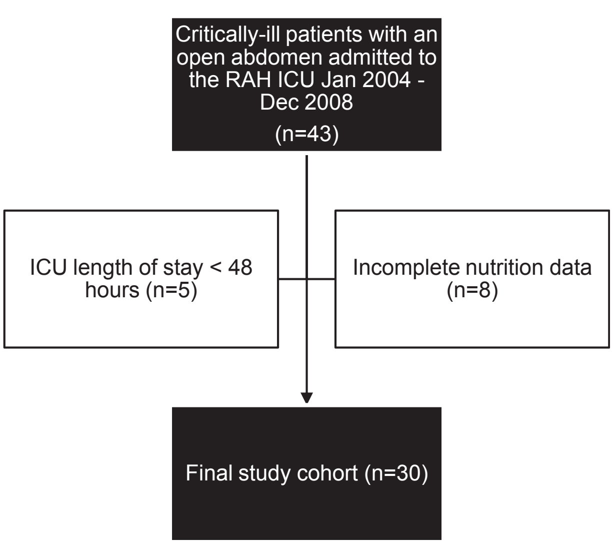

Figure 1. Study cohort for final analysis. RAH = Royal Adelaide Hospital; ICU = intensive care unit.

Table 1
Patient demographics.

Number of patients	30
Age (y)	68 (15–90)
Male	14 (47%)
Body mass index (kg/m^2)	25 (11–51)
Reason for open abdomen traumatic	13 (43%)
APACHE II score	20 (7–41)
Major reasons for admission	
Bowel perforation	4 (13%)
Duodenal ulcer perforation	4 (13%)
Sepsis	2 (7%)
Patients with multiple injuries	10 (33%)
Length of stay (days)	
Hospital (n = 21)[a]	54 (17–156)
ICU (n = 25)[a]	15 (2–41)
Mortality	
Hospital	9 (30%)
ICU	5 (17%)
Time to definitive abdomen closure	
<3 days	4 (13%)
3–7 days	19 (65%)
>7 days	7 (22%)
Definitive abdomen closure whilst in ICU	23 (77%)

ICU = intensive care unit.
Data are number (%) or median (range).
[a] Sample size adjusted as length of stay was only calculated for survivors.

on Day 5 (2–14) of the patients' ICU admission. The mean volume of daily enteral nutrition delivered was 683 ml (0–1647 ml). Patients received 55% (0–117%) of their energy goal and 59% (19–105%) of their protein goal from any feeding modality. Most patients tolerated enteral nutrition [23/30 (77%)]. When only enteral nutrition was delivered (i.e 225/418 total study days), 48% (0–146%) of daily energy goal and 41% (10–103%) of daily protein goal were achieved. About three quarters of patients who tolerated at least some enteral nutrition (16/23 (70%)) achieved 80% of their energy goal from enteral means. Three patients (10%) received no nutrition support Fig. 2.

3.3. Modes of nutrition support

Twenty-three patients were enterally fed. Of them, 17/23 (74%) received prokinetic drugs, and 4/23 (17%) were administered postpyloric feeds at some time during the study period. Four patients (13%) were fed exclusively via the parenteral route. Parenteral nutrition was used twice as frequently when the bowel was discontinuous (45% vs 21% of discontinuous bowel study days), although this was not statistically different [odds ratio = 0.33, P = 0.077, 95% confidence interval (0.1, 1.1)]. Parenteral nutrition (either alone or in combination with enteral) delivered a greater proportion of the patients' energy goal than enteral feeding [65 (27–117) vs 49 (15–89) %; P = 0.019 after adjusting for APACHE II score].

3.4. Clinical outcomes

LOS in ICU (r = 0.33, P = 0.111) and hospital (r = −0.19, P = 0.403) was not related to total energy delivery nor was ICU (P = 0.742) and hospital (P = 0.32) survival. Hospital LOS (r = −0.01, P = 0.956), ICU LOS (r = 0.32, P = 0.118), and duration of mechanical ventilation (r = 0.28, P = 0.159) were not related to protein delivery. Parenteral nutrition use was associated with prolonged hospital LOS compared to when enteral nutrition was the sole nutrition source [63 (45–156) vs 45 (17–93) d, P = 0.037]; however, this was not significant after adjusting for APACHE II score and age (P = 0.141). Patients who received prokinetics had a LOS in the ICU

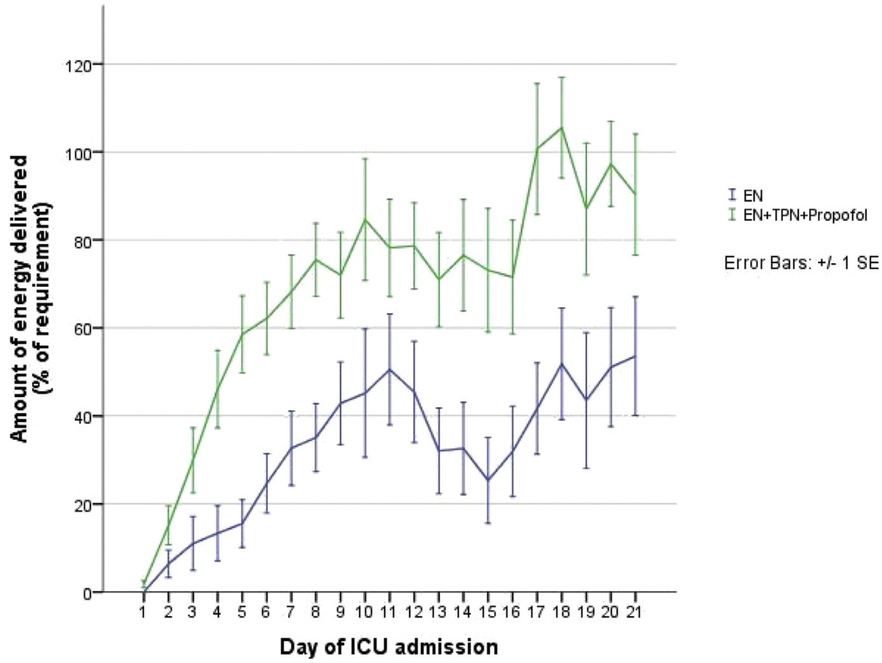

Figure 2. The amount of energy provided during the first 21 days of their ICU admission to patients with an open abdomen from enteral sources and from all artificial nutrition sources (enteral, parenteral, and propofol). ICU = intensive care unit; EN = enteral nutrition; PN = parenteral nutrition; TPN = total parenteral nutrition; SE = standard error (n = number of patients).

three times that of patients who did not receive prokinetics [22 (4–41) vs 8 (3–18) d; P < 0.001 adj]. Prokinetic use was not associated with survival in ICU (P = 0.783 adj) and hospital (P = 0.833 adj). Patients who received postpyloric feeding tended to have a longer LOS in the ICU than the patients who did not [21 (9–39) vs 14 (3–41) d];however, neither this difference (P = 0.693 adj) nor hospital LOS was statistically significant (P = 0.763 adj).

4. Discussion

Our study describes energy and protein delivery in relation to feeding goals and clinical outcomes in patients with an open abdomen. We have confirmed that enteral nutrition can be delivered to patients with an open abdomen, and in patients in whom the gastrointestinal tract is continuous, a significant proportion of their energy requirements can be delivered via the enteral route. Half of nutritional goals were delivered to the patients in this cohort. It is unclear however whether the delivery of more nutrition to this group via the use of parenteral nutrition will improve clinical outcomes.

Adequately nourishing a patient with an open abdomen is important due to the catabolic nature of the underlying disease and/or injuries and the estimated losses of an additional 2g per day nitrogen per litre abdominal fluid loss.[13] Reservation around feeding patients with an open abdomen enterally is levelled at safety concerns related to oedema, intra-abdominal hypertension, and haemodynamic instability.[23] Providing even trophic enteral nutrition to patients with an open abdomen[10,12,14,15,24] may be beneficial. Patients with an open abdomen fed enterally early were more likely, than those in whom enteral feeds were started later, to have earlier primary closure, lower fistulae formation, and an almost 30% reduction in hospital costs.[10] Early enteral feeding was associated with a reduction in rates of ventilator-associated pneumonia.[15] Most patients with an open abdomen were able to tolerate "goal" rates of tube feeds[12] when enteral nutrition was initiated within four days of the initial laparotomy. In almost 600 patients with an open abdomen, administration of enteral nutrition was associated with increased fascial closure rates, decreased complication rates, and decreased mortality.[25] Over two-thirds of our cohort was able to tolerate enteral nutrition, and over 70% of them achieved at least 80% of their estimated energy goal. In patients with an open abdomen but without a bowel injury, enteral nutrition is feasible and potentially even beneficial.

When intragastric feeding fails in critically ill patients, usually as a result of delayed gastric emptying, the sequential use of prokinetics and postpyloric feeding is recommended.[26] Patients presenting to the ICU with sepsis and multitrauma are at greater risk of slow gastric emptying when compared with a general cohort of critically ill patients.[27] Nursing-led feeding protocols can benefit the nutrition support of patients; nurses are uniquely placed to act promptly to indicators of poor gastric tolerance to feeding and make timely recommendations to commence prokinetics or feed more distally. Byrnes et al.[12] fed 75% of their open abdomen patients distal to the pylorus and showed that two-thirds of their cohort tolerated goal feeds. We used prokinetics in 17/23 (74%) of our enterally fed patients and fed almost one-fifth via nasojejunal tubes. Both strategies were without adverse effects and enabled us to achieve tolerance of enteral nutrition in most patients. Even when nutrient is delivered directly into the small intestine, the amount of nutrient absorbed is markedly reduced in patients with large GRVs when compared to those with smaller GRVs.[28] Byrnes et al.[12] started feeds slowly at a rate of 10 ml/h and gradually advanced to goal but did not indicate what parameters were monitored in order to advance to goal. It is useful for GRV to be determined while patients are being fed postpylorically (two separate tubes or a double-lumen tube are needed to facilitate this). There are data demonstrating that gastric emptying and the organisation of antro–pylorodudenal waves are disordered in critically ill patients.[29] Specifically, there are more retrograde waves present in this patient population and that there is a close correlation between gastric emptying and waves that are retrograde. While "significant" gastric output should make one cautious to trial enteral nutrition, increased gastrostomy output *alone* should not prompt cessation of enteral nutrition via jejunal access.[14] The safety and efficacy of using nasojejunal tubes studied in a prospective manner in this patient group warrants further investigation, and its implementation would be largely dependent on the confidence of the clinicians in individual ICU in question in utilising such a strategy.

There was a delay (5–14 days) in commencing enteral nutrition and thus our patients received about 50% of their energy goal when only enteral nutrition was delivered. Administering both enteral and parenteral nutrition enabled patients to receive almost 70% of their energy goal. Byrnes et al.[12] found that only 66% of their patients were able to tolerate goal feeds (despite the fact that 75% of their cohort was fed distal to the pylorus). In another study, only about 70% of patients were nourished enterally.[14] When the bowel is discontinuous, parenteral nutrition may be indicated early; a finding that we too have reported here. Nevertheless, in patients with a continuous bowel, controversy still exists as to whether to delay feeding until enteral nutrition can be commenced and established at goal or to supplement with parenteral nutrition.[4,19,30] Not providing adequate early nutrition support results in the development of an energy deficit with possible associated morbidity/mortality[30]; whereas the limitations in providing early supplementary parenteral nutrition include an increased risk of nosocomial and bloodstream infections.[20] In a multicentre observational study in the general ICU population, energy delivery from total nutrition was 31% higher in a group of patients who received early parenteral nutrition compared to patients who received late enteral nutrition.[19] Our study was not sufficiently powered to detect an effect of feeding modality on ICU or hospital survival; however, it is likely that providing early parenteral nutrition will maximise the amount of nutrition support. However, recent studies suggest that achieving nutritional goals using supplemental PN or with enteral feeding alone does not improve clinical outcomes for critically ill patients.[18,31] Functional outcome improvements are less likely too. Late rather than early provision of supplemental parenteral nutrition assists in recovery of muscle weakness in the critically ill.[32] Further, early supplemental parenteral nutrition compared with later supplemental parenteral nutrition resulted in poorer femoral muscle quality.[33] It remains to be determined whether early parenteral nutrition results in better clinical and functional outcomes for patients treated with an open abdomen.

Strength in our study design was the investigation of nutritional support beyond the first week of the ICU stay (in fact for up to the first 21 days). A recent review lends support for this methodology suggesting that while few nutritional intervention studies in critically ill patients continue for longer than a week, they ought to so as not to risk bias of shorter duration of the trial.[34] Extending the data collection for a longer duration likely captures both the acute and sub-acute phases after injury/insult. Our study was retrospective in design and therefore limited by potential bias in the data collection. Five patients had a LOS less than 48 h and were therefore not included; however, it is acknowledged that this short-stay patient cohort is generally not represented by guidelines on enteral feeding in the ICU. We were unable to retrieve complete data for a further 8 (19%) of our 43 patient cohort. Secondly, we do not have details on the medical conditions of these patients, so we cannot comment on whether their omission from our final data set has biased our results. Thirdly, there are many confounding factors that are associated with feeding outcomes in the ICU. We have analysed our data with the most relevant of these considered, including discontinuous bowel, APACHE II score, and age. We had a small sample size, limiting the generalisability of our results more broadly. Owing to small patient numbers, we have not analysed for differences in feeding outcomes between patients left with an open abdomen for traumatic and non-traumatic reasons. These two groups of patients may tolerate enteral feeds differently owing to trauma in the abdominal region impacting upon blood supply and consequently haemodynamic instability, and hence recommendations for specific strategies would be required to optimise the nutrition support for these patients. Finally, we note the age of our data. Nutrition practices are still very much of interest to clinicians, and gross practices around the provision of nutrition largely are unchanged. There is greater interest in protein provision now than before, and although the optimum amount of protein to feed is still unknown, providing more protein to critically ill patients may be associated with small improvements in anatomical and functional outcomes.[35] Arguably more patients with an open abdomen are being fed enterally as recognition for the benefits of such a practice are reported.[1] The data presented here are as relevant if not more so to current as much as historical practices around feeding critically ill patients with an open abdomen.

An open abdomen is not a contraindication to enteral feeding. The majority of patients with an open abdomen tolerate a substantial proportion of their nutrition requirements via the enteral route. In patients who tolerate at least some enteral nutrition, prokinetic administration and postpyloric delivery of nutrition can be utilised. It may be possible to avoid delays in optimising enteral feeding by delivering nutrients directly into the small bowel in the first instance rather than attempts at intragastric feeding. Whether this strategy would benefit patients with an open abdomen should be addressed by prospective studies.

Funding

This work was supported in part by a grant from the Centre of Research Excellence Nutritional Physiology, University of Adelaide and a travel grant from the Australasian Society for Parenteral and Enteral Nutrition (AuSPEN). This work was awarded an Australasian Society of Parenteral and Enteral Nutrition Young Investigators Award.

Author contribution

Rosalie Yandell contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content, and final approval of the version to be submitted. Susan Wang contributed to the acquisition of data. Peter Bautz contributed to drafting the article and revising it critically for important intellectual content. Alison Shanks contributed to the design of the study and drafting the article and revising it critically for important intellectual content. Stephanie O'Connor contributed to the conception and design of the study and acquisition of data, analysis and interpretation of data, and drafting the article and revising it critically for important intellectual content. Adam Deane contributed to drafting the article or revising it critically for important intellectual content. Kylie Lange contributed to the design of the study, acquisition of data, analysis and interpretation of data, and drafting the article and revising it critically for important intellectual content. Marianne Chapman contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content, and final approval of the version to be submitted.

Acknowledgements

The authors would also like to thank Dr Finnis for his advice.

References

[1] Moore SM, Burlew CC. Nutrition support in the open abdomen. Nutr Clin Prac 2016;31:9–13.
[2] Powell NJ, Collier B. Nutrition and the open abdomen. Nutr Clin Prac 2012;27:499–506.
[3] Chapman MJ, Nguyen NQ, Deane AM. Gastrointestinal dysmotility: clinical consequences and management of the critically ill patient. Gastroenterol Clin North Am 2011;40:725–39.
[4] Gramlich L, Kichian K, Pinilla J, Rodych NJ, Dhaliwal R, Heyland DK. Does enteral nutrition compared to parenteral nutrition result in better outcomes in critically ill adult patients? A systematic review of the literature. Nutrition 2004;20:843–8.
[5] Kudsk KA, Croce MA, Fabian TC, Minard G, Tolley EA, Poret HA, et al. Enteral versus parenteral feeding. Effects on septic morbidity after blunt and penetrating abdominal trauma. Ann Surg 1992;215:503–11. discussion 11–13.
[6] Moore FA, Moore EE, Jones TN, McCroskey BL, Peterson VM. TEN versus TPN following major abdominal trauma–reduced septic morbidity. J Trauma 1989;29:916–22. discussion 22–23.
[7] McClave SA, Martindale RG, Rice TW, Heyland DK. Feeding the critically ill patient. Crit Care Med 2014;42:2600–10.
[8] McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, et al. Guidelines for the provision and Assessment of nutrition support Therapy in the adult critically ill patient. JPEN 2016;40:159–211.
[9] Preiser JC, van Zanten AR, Berger MM, Biolo G, Casaer MP, Doig GS, et al. Metabolic and nutritional support of critically ill patients: consensus and controversies. Crit Care 2015;19:35.
[10] Collier B, Guillamondegui O, Cotton B, Donahue R, Conrad A, Groh K, et al. Feeding the open abdomen. JPEN 2007;31:410–5.
[11] Friesecke S, Schwabe A, Stecher SS, Abel P. Improvement of enteral nutrition in intensive care unit patients by a nurse-driven feeding protocol. Nurs Crit Care 2014;19:204–10.
[12] Byrnes MC, Reicks P, Irwin E. Early enteral nutrition can be successfully implemented in trauma patients with an "open abdomen". Am J Surg 2010;199:359–62.
[13] Cheatham ML, Safcsak K, Brzezinski SJ, Lube MW. Nitrogen balance, protein loss, and the open abdomen. Crit Care Med 2007;35:127–31.
[14] Cothren CC, Moore EE, Ciesla DJ, Johnson JL, Moore JB, Haenel JB, et al. Post-injury abdominal compartment syndrome does not preclude early enteral feeding after definitive closure. Am J Surg 2004;188:653–8.
[15] Dissanaike S, Pham T, Shalhub S, Warner K, Hennessy L, Moore EE, et al. Effect of immediate enteral feeding on trauma patients with an open abdomen: protection from nosocomial infections. J Am Coll Surg. 2008;207:690–7.
[16] Guillaume A, Seres DS. Safety of enteral feeding in patients with open abdomen, upper gastrointestinal bleed, and perforation peritonitis. Nutr Clin Prac 2012;27:513–20.
[17] Munshi IA, Steingrub JS, Wolpert L. Small bowel necrosis associated with early postoperative jejunal tube feeding in a trauma patient. J Trauma 2000;49:163–5.
[18] Rice TW, Mogan S, Hays MA, Bernard GR, Jensen GL, Wheeler AP. Randomized trial of initial trophic versus full-energy enteral nutrition in mechanically ventilated patients with acute respiratory failure. Crit Care Med 2011;39:967–74.
[19] Cahill NE, Murch L, Jeejeebhoy K, McClave SA, Day AG, Wang M, et al. When early enteral feeding is not possible in critically ill patients: results of a multicenter observational study. JPEN 2011;35:160–8.
[20] Sena MJ, Utter GH, Cuschieri J, Maier RV, Tompkins RG, Harbrecht BG, et al. Early supplemental parenteral nutrition is associated with increased infectious complications in critically ill trauma patients. J Am Coll Surg 2008;207:459–67.
[21] Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr 1985;39(Suppl 1):5–41.
[22] Schofield WN, Schofield C, James WPT. Basal metabolic rate - review and prediction. Hum Nutr 1985;39(Suppl 1):5–96.
[23] Vargo D, Richardson D, Campbell A, Chang M, Fabian T, Franz M, et al. Management of the open abdomen: from initial operation to definitive closure. Am Surg 2009;75(Suppl):S1–22.
[24] McKibbin B, Cresci G, Hawkins M. Nutrition support for the patient with an open abdomen after major abdominal trauma. Nutrition 2003;19:563–6.
[25] Burlew CC, Moore EE, Cuschieri J, Jurkovich GJ, Codner P, Nirula R, et al. Who should we feed? Western Trauma Association multi-institutional study of enteral nutrition in the open abdomen after injury. J Trauma Surg 2012;73:1380–7. discussion 7–8.
[26] Deane A, Chapman MJ, Fraser RJ, Bryant LK, Burgstad C, Nguyen NQ. Mechanisms underlying feed intolerance in the critically ill: implications for treatment. World J Gastroenterol 2007;13:3909–17.
[27] Nguyen NQ, Ng MP, Chapman M, Fraser RJ, Holloway RH. The impact of admission diagnosis on gastric emptying in critically ill patients. Crit Care 2007;11:R16.
[28] Deane AM, Summers MJ, Zaknic AV, Chapman MJ, Di Bartolomeo AE, Bellon M, et al. Glucose absorption and small intestinal transit in critical illness. Crit Care Med 2011;39:1282–8.
[29] Chapman MJ, Fraser RJ, Bryant LK, Vozzo R, Nguyen NQ, Tam W, et al. Gastric emptying and the organization of antro-duodenal pressures in the critically ill. Neurogastroenterol Motil 2008;20:27–35.
[30] Singer P, Pichard C, Heidegger CP, Wernerman J. Considering energy deficit in the intensive care unit. Curr Op Nutr Met Care 2010;13:170–6.
[31] Doig GS, Simpson F, Sweetman EA, Finfer SR, Cooper DJ, Heighes PT, et al. Early parenteral nutrition in critically ill patients with short-term relative contraindications to early enteral nutrition: a randomized controlled trial. JAMA 2013;309:2130–8.
[32] Hermans G, Casaer MP, Clerckx B, Guiza F, Vanhullebusch T, Derde S, et al. Effect of tolerating macronutrient deficit on the development of intensive-care unit acquired weakness: a subanalysis of the EPaNIC trial. Lancet Respir Med 2013;1:621–9.
[33] Casaer MP, Langouche L, Coudyzer W, Vanbeckevoort D, De Dobbelaer B, Guiza FG, et al. Impact of early parenteral nutrition on muscle and adipose tissue compartments during critical illness. Criti Care Med 2013;41:2298–309.
[34] Bear DE, Wandrag L, Merriweather JL, Connolly B, Hart N, Grocott MPW, et al. The role of nutritional support in the physical and functional recovery of critically ill patients: a narrative review. Crit Care 2017;21:226.
[35] Ferrie S, Allman-Farinelli M, Daley M, Smith K. Protein requirements in the critically ill: a randomized controlled trial using parenteral nutrition. JPEN 2016;40:795–805.