Nutrition in critical care

Objective

- To provide recommendations for the assessment and management of the nutritional needs of critically ill patients.

Introduction

The Intensive Care Unit (ICU) is a specialised area of a hospital which has the facilities, equipment and staff expertise required to manage patients with life-threatening conditions. Patients in an acute hospital are classified according to their severity of illness rather than their hospital location (**Table 16.1**). Generally, the patients on the ICU will be level 2 (high dependency) or level 3 (intensive) (Faculty of Intensive Care Medicine and Intensive Care Society, 2015).

Although the ICU specialist dietitian is likely to cover all areas of critical care (including level 2), use of 'ICU,' 'critical care' and 'critically ill' throughout this section refers to level 3 patients.

Table 16.1. Classification of patients in the acute hospital setting (Department of Health, 2000).

Classification	Level of support required
Level 0	Patients whose needs can be met through normal ward care in an acute hospital.
Level 1	Patients at risk of their condition deteriorating, or those recently relocated from higher levels of care, whose needs can be met on an acute ward with additional advice and support from the critical care team.
Level 2	Patients requiring more detailed observation or intervention, including support for a single failed organ system or postoperative care and those stepping down from higher levels of care.
Level 3	Patients requiring advanced respiratory support alone or basic respiratory support together with support of at least two organ systems.

Appropriate nutrition provision in the ICU is associated with improved patient outcomes, reduced length of hospital stay, decreased duration of dependence on mechanical

ventilation and reduced infections (Villet *et al*. 2005). The best available evidence has been used to formulate these recommendations, however it is imperative that the ICU dietitian remains up to date with the current literature and changes practice accordingly. **Clinical judgement** at the bedside is warranted at all times.

Nutritional screening and assessment

Traditional screening tools for determining the risk of malnutrition, such as the 'Malnutrition Universal Screening Tool' (see **Section 1**), are not accurate in critically ill patients (Anthony, 2008). However, current international guidelines (McClave *et al*. 2016) recommend nutrition risk scoring e.g. Nutrition Risk Screening 2002 (NRS) (Kondrup *et al*. 2003), Nutrition Risk in the Critically Ill (NUTRIC) (Heyland *et al*. 2015) for all patients (based on expert consensus). Nutrition risk may distinguish between those patients who may benefit the most from nutrition support and those who may not. However, limitations exist (**Table 16.2**).

Table 16.2. Nutritional screening tools and limitations.

NRS-2002 (Kondrup *et al*. 2003):

- Detects the presence of undernutrition and risk of developing undernutrition.
- May not be specific enough for critically ill patients due to the classification of all patients with an Acute Physiology and Chronic Health Evaluation (APACHE) score. APACHE II >10 being classified as high risk.

NUTRIC score (Heyland *et al*. 2015):

- Specifically developed and validated for the critically ill patient.
- It's purpose is to help identify which critically ill patients are most likely to benefit from optimal amounts of macronutrients when considering mortality as an outcome (Rahman *et al*. 2016).
- Has been proposed as a tool to guide decisions regarding those who require more aggressive nutritional support (e.g. early parenteral nutrition), yet prospective data is currently lacking (Mclave *et al*. 2016).
- May not be practical to undertake at the bedside due to the complexity of the severity of illness scoring required.

Regardless of whether a nutrition risk score is calculated, undertaking a nutritional assessment for all patients expected to remain mechanically ventilated for more than 48 hours is desirable.

Although it is important to consider anthropometric measures (**Table 16.3**), such as body weight, they should be interpreted with caution due to the inability to accurately account for shifts in fluids status. Additional factors which are included as part of the NUTRIC score, such as projected length of stay, severity of illness, comorbidities and length of stay in hospital prior to ICU admission should also be considered.

Table 16.3. Barriers to obtaining traditional anthropometric measures.

Patients may be unable to provide a history and have no previous medical documentation of weight, height or nutritional history.
Weighing scales and equipment may not be available in the ICU; bed weighing scales additionally may not be calibrated.
Weight may fluctuate dramatically due to fluid shifts. The weight of critically ill patients can increase by 10-20% in 24hrs making readings potentially inaccurate (Lowell *et al*. 1990).
Critically ill patients are often immobile; they may not be weighed due to haemodynamic instability or unstable injuries in the context of trauma.
Anthropometric measurements (e.g. ulna, mid-upper arm circumference) are not validated tools in the ICU. Measurements should be considered as a guide only and used in conjunction with clinical judgement.
Equipment such as traction, casts and braces provide logistic difficulties and need to be accounted for in resultant measurements.
Adjusting body weight in amputees can add additional scope for errors.

Initiation of nutritional support

Enteral nutrition (EN) supports the functional and structural integrity of the gut, modulates the systemic immune response and attenuates disease severity (McClave *et al*. 2016). In the critically ill patient who is unable to maintain their own nutritional intake, it is recommended that EN be initiated within 24 to 48 hours (Kreymann *et al*. 2006; Dhaliwal *et al*. 2013; Canadian Critical Care Society and Canadian Critical Care Trials Group, 2015; McClave *et al*. 2016; Reintam *et al*. 2017).

Feeding protocols

A feeding protocol should be standard practice in the ICU to facilitate early enteral feeding (**Table 16.4**). Combined with a dedicated ICU dietitian, and a training programme to increase protocol adherence, the use of a feeding protocol has been shown to increase the overall percentage of goal energy provided (Kreymann et al. 2006; Dhaliwal *et al*. 2013; Faculty of Intensive Care Medicine and Intensive Care Society, 2015; Canadian Critical Care Society and Canadian Critical Care Trials Group, 2015; McClave *et al*. 2016).

Table 16.4. Features of ICU feeding protocols.

- Specify a starter feed.
- Define target feeding rate.
- Provide details of feed advancement strategies which may include a volume-based feeding approach.
- Give specific instructions on handling gastric residual volumes (GRVs).
- Detail conditions under which enteral nutrition should be adjusted, stopped or when an alternative route of delivery (such as post-pyloric feeding) should be considered.

Limitations of feeding protocols

- Whilst feeding protocols are extremely useful in the early stages of feeding, they do not account for differences between patients (such as BMI or nutritional status), feed interruptions, or changes in clinical condition.

- Although they make recommendations for alternative feeding strategies (e.g. post-pyloric), this is not enough to ensure that these are always used when appropriate.

- Use of feeding protocols alone is therefore not sufficient to prevent nutritional deficits, and therefore

individualised nutrition support from a specialist dietitian is required in those patients who remain on ICU for longer than 48 hours (Singer *et al*. 2011).

Volume-based feeding

- Volume-based feeding is a relatively new practice which is being increasingly implemented by dietitians in the critical care setting.

- Volume-based feeding protocols focus on delivering daily volumes of feed rather than a target hourly rate.

- Examples include the PEP Up protocol (Heyland *et al*. 2013; McCall *et al*. 2014) or the FEED ME protocol (Taylor *et al*. 2014), which has been shown to increase nutrition provision in the critical care patient.

- These types of protocols allow nursing staff to calculate the remaining daily feed volume to be delivered and to adjust the rate of feeding to accommodate e.g. time lost to investigations, procedures, airway management (**Table 16.5**).

Table 16.5. Frequent feeding barriers in the critical care setting.

- Fasting for procedures (e.g. surgical interventions, tracheostomy).
- Fasting for diagnostic tests.
- Feeding tube placement (e.g. tube displacement, delays in tube insertion/confirmation of position).
- High gastric residual volumes with cessation of feeding.
- Gastrointestinal (GI) intolerance (e.g. vomiting, nausea, ileus).
- Non-feed energy sources (e.g. propofol, citrate, glucose).

Route of feeding

It is practical and safe to use enteral nutrition (EN) in most critically ill patients.

Enteral Nutrition vs. Parenteral Nutrition

- The advantages of EN over parenteral nutrition (PN) include: reduced cost, maintenance of gut integrity, modulation of the immune response and a reduced risk of septic complications (Kreymann *et al*. 2006; Dhaliwal

et al. 2013; Canadian Critical Care Society and Canadian Critical Care Trials Group, 2015; McClave *et al*. 2016).

- However, the CALORIES trial found no infectious outcome differences between the administration of early EN or PN, when PN dose is equivalent to EN dose, suggesting improvements in ICU PN management practices in England (Harvey *et al*. 2014).

- A recent systematic review suggests that the advantages of EN compared to PN may be attributed to differences in caloric intake rather than the route. Therefore, if some degree of hypocaloric feeding is used, PN may be as safe as EN in the critically ill patient (Elke *et al*. 2016).

Initiation of PN

- In critically ill patients where EN is contraindicated or does not meet nutritional targets, full or supplemental PN should be considered to prevent the risks associated with underfeeding.

- The recommended timing of the initiation of PN is unclear but international guidelines suggest that exclusive PN should be withheld for the first 7 days following ICU admission in patients at low nutrition risk and commenced as soon as possible in those at high nutrition risk (Casaer *et al*. 2011; Harvey *et al*. 2014; Elke *et al*. 2016; McClave *et al*. 2016).

Supplemental PN

- A combination of PN with EN should be considered when EN fails to meet nutritional targets (Heidegger *et al*. 2013; McClave *et al*. 2016).

- Other strategies, such as prokinetics and post-pyloric feeding should be attempted first.

- Early supplemental PN is not advised in critically ill patients as it is costly and provides minimal benefits (Heyland, 2012).

Summary

- In the absence of more conclusive guidance, the need for PN should be considered on a case-by-case basis.

- The ICU dietitian is integral to this decision-making process and can reduce the inappropriate use of PN (Faculty of Intensive Care Medicine and Intensive Care Society, 2015).

- Close monitoring of critically ill patients receiving PN is required to prevent overfeeding and associated hyperglycaemia (Casaer *et al*. 2011; Casaer *et al*. 2013).

Estimation of nutritional targets in critically ill patients

Energy

- Provision of energy is a balance between too little and too much – both presenting with their own risks (Faisy *et al*. 2009; Casaer *et al*. 2011; Schetz *et al*. 2013; Faculty of Intensive Care Medicine and Intensive Care Society, 2015). Current data suggests that optimal energy provision may be 70% of measured energy expenditure (MEE) (Zusman *et al*. 2016) or 80% of estimated targets (Heyland *et al*. 2011) over the first week of ICU stay when considering mortality as an outcome.

- Indirect calorimetry (IC) is the gold standard for measuring resting energy expenditure (REE).See **Section 3**. However, due to several factors, the use of IC is not currently widespread in clinical practice (McClave *et al*. 2016).

- Weight-based predictive equations remain the primary tool for estimating energy targets (**Table 16.6** and **Table 16.7**).

- The clinical condition of the patient (i.e. ventilated or non-ventilated) and the different phases of critical illness (catabolic vs anabolic/recovery) should be considered when choosing an appropriate predictive equation **(Table 16.6** and **Table 16.7)**.

PULL OUT SECTION
TABLE 16.6

PULL OUT SECTION
TABLE 16.7

Underfeeding

- Cumulative energy deficits are associated with poorer patient outcomes including an increased length of hospital stay, prolonged time needing mechanical ventilation and increased risk of infection (Faisy *et al*. 2009; Schetz *et al*. 2013; Faculty of Intensive Care Medicine and Intensive Care Society, 2015).

- However, these outcome measures have not been confirmed in randomised controlled trials (RCTs) when comparing either trophic feeding or permissive underfeeding to full planned feeding (Rice *et al*. 2012; Arabi *et al*. 2015).

Overfeeding

- Overfeeding can lead to the exacerbation of hypercapnia, hyperglycaemia, hypertriglyceridemia and fatty liver, uraemia and metabolic acidosis. See **Section 9**. The risk of adverse complications is likely to be highest during the initial phase of critical illness (Casaer *et al*. 2011).

- Non-feed energy sources such as the anaesthetic drug Propofol, glucose and regional citrate anticoagulation used in haemodialfiltration (see **Section 14)** should be considered when their contribution amounts to a significant volume of energy for an extended duration of time (**Table 16.5**).

Obesity

- There is a distinct lack of evidence base for the estimation of energy targets in the critically ill obese patient.

- It is likely that body composition (muscle mass vs fat mass) will have an impact on nutritional targets. However, in the absence of a bedside method to do this, clinical judgement is warranted.

- Hypocaloric high protein feeding (HCHP) is recommended (McClave *et al*. 2016). Recommendations are based on expert consensus considering two RCT's (Burge *et al*. 1994; Choban *et al*. 1997), which only included a small number of critically ill obese subjects (**Table 16.6**).

- Protein supplementation may need to be used to achieve HCHP feeding.

- Identify nutrition risk as with a non-obese patient (see **Section 2**) as a hypocaloric strategy is not applicable for all obese patients (Alberda *et al*. 2009).

- The Penn State University (PSU) equation (**Table 16.6** and Table **16.7**) has been validated in the obese patient.

Be aware of the limitations of all the predictive equations currently available (for both obese and non-obese patients)

Regular monitoring and at least weekly re-estimation of requirements by a critical care dietitian will minimise risk of over/under feeding

Protein

- Protein catabolism is increased in the critically ill patient and nutritional support cannot completely eliminate the subsequent skeletal muscle wasting (Shaw *et al*. 1987; Japur *et al*. 2010).

- The evidence base for protein targets is poor due to a lack of high quality randomised controlled trails (Ishibashi *et al*. 1998; Ferrie*et al*. 2016) and as a result makes it difficult to give clinical recommendations. Observational studies however suggest that higher protein intake is associated with improved outcomes such as hospital mortality (Hoffer and Bistrian, 2012; Weijs *et al*. 2012). One observational study suggested that achieving at least 80% prescribed protein intake may be important to survival (Nicolo *et al*. 2016).

- Critical care guidelines suggest a protein intake between 1.2-2g/kg/day (Kreymann *et al*. 2006; Singer *et al*. 2009; Dhaliwal *et al*. 2013; McClave *et al*. 2016). **Table 16.8** highlights suggested recommendations for protein targets in critically ill patients based on expert opinion in relation to clinical condition.

- Protein supplementation/high protein formulas may need to be considered if there is a need to reduce calories considerably secondary to non-feed energy sources.

Table 16.8. Recommendations for protein targets in critically ill patients.

Patient group	Protein Target (g/kg/ABW)*
General ICU (Faisy *et al*. 2009)	1.2-1.5
Trauma (Faisy *et al*. 2009)	1.3-1.5
Burns (Rousseau *et al.* 2013)	1.5-2.0
Continuous renal replacement therapy (KDIGO, 2012; McClave *et al*. 2016, Patel *et al.* 2017) (see **Section 14**)	1.5-2.5
Obese** (Choban *et al*. 2013)	2.0-2.5 (g/kg/IBW/day)***

*ABW = actual body weight; ** to be used in obese patients irrespective of clinical condition; *** IBW = Ideal body weight (see **Section 2**)

Fluid

If volume restricted EN/PN is required due to tight fluid targets during critical illness then discussions with the medical team are imperative to ensure energy, protein and micronutrient targets are still met.

Overall responsibility lies with the medical staff. Baseline requirements can be estimated using the information in **Section 3, Table 3.11**.

Micronutrients

Evidence to support a clinical benefit from the routine supplementation of vitamins and minerals in the critically ill patient is conflicting (Koekoek and Van Zanten, 2016). Consequently, there is insufficient data to make recommendations for clinical practice.

Some patient groups may have high requirements for specific micronutrients, for example, burns patients, those on continuous renal replacement therapy (Berger *et al*. 2004) or those with a deficiency (e.g. patients with high alcohol consumption or at risk of refeeding syndrome) (NICE, 2006). In these patients, supplementation should be provided in accordance with local and national guidelines.

Immune modulating nutritional support

- Immune modulating enteral feeds contain added 'functional' substrates which may include; arginine, glutamine, n-3 polyunsaturated fatty acids, nucleotides and antioxidants (e.g. selenium and vitamin C).
- The use of these formulae remains controversial as the published studies differ in the combination and quantity of substrates used, the timing of their use and the type of critically ill patient studied (Marik and Zaloga, 2008; Heyland *et al*. 2013; Van Zanten *et al*. 2014). Consequently, no overall synthesis of the results is possible (Kreyman *et al*. 2006; Dhaliwal *et al*. 2013; Canadian Critical Care Society and Canadian Critical Care Trials Group, 2015; McClave *et al*. 2016) and therefore immunonutrition should not be routinely used in the critically ill patient.
- Similar issues with study heterogeneity arise with studies investigating the use of parenteral glutamine and selenium supplementation (Andrews *et al*. 2011; Bollhalder *et al*. 2013). Recent international guidelines recommend that parenteral glutamine supplementation should not be used routinely in the critical care setting (McClave *et al*. 2016).

Barriers to nutritional delivery

- Delivery of energy and protein is frequently reported to be below prescribed levels (Alberda *et al*. 2009). **Table 16.5** highlights some of the causes of feed interruptions that commonly occur in the ICU setting.
- The implementation of specific strategies (e.g. fasting guidelines, enteral feeding protocols, volume-based feeding strategies) can help to reduce the volume of missed feed and minimising avoidable causes of feed cessation should be encouraged.

Gastrointestinal intolerance

Gastrointestinal (GI) intolerance is a frequent occurrence in the critically ill patient (Nguyenn *et al*. 2007) and can manifest itself in several ways, including delayed gastric emptying, vomiting, abdominal distension, diarrhoea and constipation. The causes of GI intolerance are multifactorial (Mentec *et al*. 2001; Deane *et al*. 2007) and evidence suggests that patients who develop GI dysfunction in the ICU have worse outcomes (Mutlu and Factor, 2001; Gungabissoon *et al*. 2015).

Gastric residual volumes

- GRV measurements (usually 4-6 hourly) have been used as a surrogate measure of gastric emptying which is assumed to reflect tolerance and absorption of feed.
- Two studies (McClave *et al*. 2005; Montejo *et al*. 2010) found no increase in the incidence of aspiration or ICU acquired pneumonia when GRV cut off was increased to 400ml and 500ml respectively in comparison to a cut off value of 200ml.
- One study also found that the mean volume of enteral feed delivery was significantly greater in the increased GRV group (McClave *et al*. 2005). Because of these findings most centres now tolerate higher GRV, with some experts questioning the need for measuring GRV at all (Reignier *et al*. 2013).
- Patient population (e.g. medical vs surgical) should be considered when deciding the best GRV measurement protocol for individual ICUs.

Prokinetics

- Prokinetics are commonly used to enhance the delivery of EN in critically ill patients who have delayed gastric emptying.
- Both metoclopramide and erythromycin are used as prokinetic drugs, with combination therapy demonstrating an increased rate of successful feeding compared with monotherapy in critically ill patients (Nguyen *et al*. 2007).
- Tachyphylaxis and side-effects have been reported for both agents and consequently metoclopramide is commonly utilised as first line treatment (10mg IV 8 hourly). If large GRVs persists, erythromycin (250mg IV 6 hourly) is added (always refer to local policies for dose recommendations).
- Exact practice will vary across units, however alternate feeding routes should be considered if enteral feeding remains unsuccessful.

Post-pyloric feeding

- Post-pyloric feeding may be considered in patients with delayed gastric emptying as an alternative method for successfully delivering enteral nutrition when gastric feeding has failed.

- Jejunal feeding can be administered via post-pyloric feeding tubes or via a surgically inserted jejunostomy. Post-pyloric feeding tubes can be inserted via endoscopy or radiology, or at the bedside with the use of specialist equipment.

Enteral feed choice in ICU

- For most critically ill patients, a polymeric formula is suitable and recommended.
- High protein feeds or modular protein supplements are often used to meet the protein needs of critically ill patients whilst avoiding excessive amounts of energy.

Low sodium feeds

- Hypernatraemia is common in the critically ill patient and is often due to inadequate fluid administration, excessive sodium administration or high fluid losses (Lindner and Funk, 2013).
- Enteral nutrition is unlikely to be the cause and therefore the use of a low sodium feed (which can also be low in protein) is not routinely advised.
- It is important that the cause of hypernatraemia is identified and appropriately managed by the multidisciplinary team. This may involve the use of additional enteral water or a review of the prescribed medications to identify and potentially alter those high in sodium.

Specialist renal feeds

- A low electrolyte, low volume or specialist renal feed is not indicated for patients with acute kidney injury who are receiving continuous renal replacement therapy.
- However, these feeds may be appropriate for patients with deteriorating renal function who are not receiving renal replacement therapy or those on intermittent haemodialysis who require fluid restriction.
- As some of these feeds are also low in protein, an additional source of protein may be required.

PULL OUT SECTION
TABLE 16.9

Key points

- Estimating energy and protein requirements in critically ill patients is challenging.
- Feeding protocols should be standard practice in the ICU to facilitate early enteral feeding.
- Enteral feeding is the route of choice and the need for parenteral nutrition should be considered on a case by case basis.
- Provision of nutrition support in critically ill patients is complex and requires the skills of a specialist dietitian.

References

Alberda, C., Gramlich, I., Jones, N., Jeejeebhoy, K., Day, A.G., Dhaliwal, R. and Heyland, D.K. (2009) The relationship between nutritional intake and clinical outcomes in critically ill patients: results of an international multicentre observational study. *Intensive Care Medicine* **35(10)**,1728-1737.

Andrews, P.J., Avenell, A., Noble, D.W., Campbell, M.K., Croal, B.L., Simpson, W.G., Vale, L.D., Battison, C.G., Jenkinson, D.J., Cook, J.A. and the SIGNET (Scottish Intensive Care Glutamine or Selenium Evaluative Trial) Trials Group. (2011) Randomised trial of glutamine, selenium, or both, to supplement parenteral nutrition for critically ill patients. *British Medical Journal* **342**, d1542.

Anthony, P.S. (2008) Nutrition screening tools for hospitalized patients. *Nutrition in Clinical Practice* **23(4)**, 373-382.

Arabi, Y.M., Aldawood, A.S., Haddad, S.H., Al-Dorzi, H.M., Tamim, H.M., Jones, G., Mehta, S., McIntyre, L., Solaiman, O., Sakkijha, M.H., Sadat, M. and Afesh, L., for the PermiT Trial Group. (2015) Permissive underfeeding in Critically Ill Adults. *New England Journal of Medicine* **18(25)**, 2398-2408.

Berger, M.M., Shenkin, A., Revelly, J.P., Roberts, E., Cayeux, M.C., Baines, M. and Chiolero, R.L. (2004) Copper, selenium, zinc and thiamine balances during continuous venovenous hemodiafiltration in critically ill patients. *American Journal of Clinical Nutrition* **80(2)**, 410-416.

Bollhalder, L., Pfeil, A.M., Tomonaga, Y. and Schwenkglenks, M. (2013) A systematic literature review and meta-analysis of randomized clinical trials of parenteral glutamine supplementation. *Clinical Nutrition* **32(2)**, 213-223.

Burge, J.C., Goon, A., Choban, P.S. and Flancbaum, L. (1994) Efficacy of hypocaloric total parenteral nutrition in hospitalized obese patients: prospective, double blind randomized trial. *Journal of Parenteral and Enteral Nutrition* **18(3)**, 203-207.

Canadian Critical Care Society (CCCS) and Canadian Critical Care Trials Group (CCTG). (2015) *Canadian Clinical Practice Guidelines: Summary of Revisions to the Recommendations*, [Online], Available at: https://www.criticalcarenutrition.com/docs/CPGs%202015/Summary%20CPGs%202015%20vs%202013.pdf [2nd February 2018].

Cano, N., Fiaccadori, E., Tesinsky, P., Toigo, G., Druml, W., DGEM: Kuhlmann, M., Mann, H. and Horl, W.H. (2006) ESPEN guidelines on enteral nutrition: Acute renal failure. *Clinical Nutrition* **25**, 295-310.

Casaer, M.P., Mesotten, D., Hermans, G., Wouters, P.J., Schetz, M., Meyfroidt, G., Van Cromphaut, S., Ingels, C., Meersseman, P., Muller, J., Vlasselaers, D., Debaveye, Y., Desmet, L., Dubois, J., Van Assche, A, Vanderheyden, S., Wilmer, A. and Van de Berghew, G. (2011) Early versus late parenteral nutrition in critically ill patients. *New England Journal of Medicine* **365(6)**, 506-517.

Casaer, M.P., Wilmer, A. and Hermans, G. (2013) Role of Disease and Macronutrient Dose in the Randomized Controlled EpaNIC Trial: A Post Hoc Analysis. *American Journal of Respiratory and Critical Care Medicine* **187(3)**, 247-255.

Cerra, F.B., Benitez, M.R., Blackburn, G.L., Irwin R.S., Jeejeebhoy, K., Katz, D.P., Pinglewton, S.K., Pomposelli, J., Rombaeu, J.L., Shronts, E., Wolfe, R.R. and Zaloga, G.P. (1997) Applied nutrition in ICU patients' A consensus statement of the American college of chest physicians. *Chest* **111**, 769–778.

Choban, P.S., Burge, J.C., Scales, D. and Flancbaum, L. (1997) Hypoenergetic nutrition support in hospitalized obese patients; a simplified method for clinical application. *American Journal of Clinical Nutrition* **66(3)**, 546-550.

Choban, P., Dickerson, R., Malone, A., Worthington, P., Compher, C. (2013) ASPEN clinical guidelines: Nutrition Support of hospitalized adult patients with obesity. *Journal of Parenteral and Enteral Nutrition* **37**, 714-744.

Deane, A., Chapman, M.J., Fraser, R.J., Bryant, L.K., Burgstag, C and Nguyen, N.Q. (2007) Mechanisms underlying feed intolerance in the critically ill: Implications for treatment. *World Journal of Gastroenterology* **13**, 3090-3917.

Department of Health. (2000) *Comprehensive Critical Care. A review of adult critical care services*, [Online], Available at: http://webarchive.nationalarchives.gov.uk/20130107105354/http:/www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4082872.pdf [2nd February 2018].

Dhaliwal, R., Cahill, N., Lemieux, M. and Heyland, D.K. (2013) The Canadian Critical Care Nutrition Guidelines in 2013: An Update on Current Recommendations and Implementation Strategies. *Nutrition in Clinical Practice* **29(1)**, 29-43.

Elke, G., van Zanten, A.R., Lemieux, M., McCall, M., Jeejeebhoy, K.N., Kott, M., Jiang, X., Day, A.G and Heyland, D.K. (2016) Enteral versus parenteral nutrition in critically ill patients: an updated systematic review and meta-analysis of randomized controlled trials. *Critical Care* **20**,117.

Faculty of Intensive Care Medicine (FICM) and the Intensive Care Society (ICS). (2015) *Guidelines for the Provision of Intensive Care Services (GPICS)*, [Online], Available at: https://www.ficm.ac.uk/standards-and-guidelines/gpics [3rd February 2018].

Faisy, C., Lerolle, N., Dachraoui, F., Savard, J.K., Abbud, J.M. Tadie, J.M. and Fagon, J.Y. (2009) Impact of energy deficit calculated by a predictive method on outcome in medical patients requiring prolonged acute mechanical ventilation. *British Journal of Nutrition* **101**, 1079-1087.

Ferrie, S., Allman-Farinelli, M., Daley, M. and Smith, K. (2016) Protein Requirements in the Critically Ill: A Randomized Controlled Trial Using Parenteral Nutrition. *Journal of Parenteral and Enteral Nutrition* **40(6),** 795-805.

Frankenfield, D.C. and Ashcraft, C.M. (2011) Estimating Energy Needs in Nutrition Support Patients. *Journal of Parenteral and Enteral Nutrition* **35(5)**, 563-570.

Frankenfield, D.C., Ashcraft, C.M. and Galvan, D.A. (2013) Prediction of resting metabolic rate in critically ill patients at the extremes of body mass index. *Journal of Parenteral and Enteral Nutrition* **37(3)**, 361-367.

Frankenfield, D.C., Coleman, A., Alam, S. and Cooney, R.N. (2009) Analysis of estimation methods for resting metabolic rate in critically ill adults. *Journal of Parenteral and Enteral Nutrition* **33**, 27-36.

Gungabissoon, U., Hacquoil, K., Bains, C., Irizarry, M., Dukes, G., Willianson, R., Deane, A.M. and Heyland, D.K. (2015) Prevalence, risk factors, clinical consequences and treatment of enteral feed intolerance during critical illness. J*ournal of Parenteral and Enteral Nutrition* **39(4)**, 441-448.

Harris, J.A. and Benedict, F.G. (1919) *A Biometric Study of the Basal Metabolism in Man*. Washington, DC: Carnegie Institution of Washington; Publication No. 279.

Harvey, S.E., Parrott, F. Harrison, D.A. Bear, D.E., Segaran, E., Beale, R., Bellingan, G., Leonard, R., Mythen, M.G. and Rowan, K.M., for the CALORIES Trial Investigators. (2014) Trial of the Route of Early Nutritional Support in Critically Ill Adults. *New England Journal of Medicine* **371(18)**, 1673-1684.

Heidegger, C.P., Berger, M.M., Graf, S., Zingg, W., Darmon, P., Costanza, M.C., Thibault, R. and Pichard, C. (2013) Optimisation of energy provision with supplemental parenteral nutrition in critically ill patients: a randomised controlled trial. *Lancet* **381**(9864), 385-393.

Heyland, D., Muscedere, J., Wischmeyer, P.E., Cook, D., Jones, G., Albert, M., Elke, G., Berger, M.M. and Day, A.G., for the Canadian Critical Care Trials Group. (2013) A Randomized Trial of Glutamine and Antioxidants in Critically Ill Patients. *The New England Journal of Medicine* **368**, 1489-1497.

Heyland, D.K. (2012) Early supplemental parenteral nutrition in critically ill adults increased infections, ICU length of stay and cost. Evidence Based Medicine **17(3)**, 86-87.

Heyland, D.K., Cahill, N. and Day, A.G. (2011) Optimal amounts of calories for critically ill patients: depends on how you slice the cake! *Critical Care Medicine* **39(12)**, 2619-2626.

Heyland, D.K., Dhaliwal, R., Jiang, X. and Day, A.G. (2015) Identifying critically ill patients who benefit the most from nutrition therapy: the development and initial validation of a novel risk assessment tool. *Critical Care* **15(6)**, R268.

Heyland, D.K., Murch, L., Cahill, N., McCall, M., Muscedere, J., Stelfox, H.T., Vray, T., Tanguay, T., Jiang, X. and Day, A.G. (2013) Enhanced Protein-Energy Provision via the Enteral Route Feeding Protocol in Critically Ill Patients: Results of a Cluster Radomised Trial. *Critical Care Medicine* **41(12)**, 2743-2275.

Hoffer, L.J. and Bistrian, B.R. (2012) Appropriate protein provision in critical illness: a systematic and narrative review. *American Journal of Clinical Nutrition* **96(3)**, 591-600.

Ireton-Jones, C.S. and Jones, J. (2002) Improved equations for predicting energy expenditure in patients: The Ireton Jones Equations. *Nutrition in Clinical Practice* **17**, 29-31.

Ireton-Jones, C.S., Turner, W.W.Jr., Liepa. G.U. and Baxter, C.R. (1992) Equations for estimation of energy expenditure of patients with burns with special reference to ventilator status. *Journal of Burn Care and Rehabilitation* **13**, 330-333.

Ishibashi, N., Plank, L.D., Sando, K. and Hill, G.L. (1998) Optimal protein requirements during the first 2 weeks after the onset of critical illness. *Critical Care Medicine* **26(9)**, 1529-1535.

Japur, C.C., Monteiro, J.P., Marchini, J.S., Garcia, R.W. and Basile-Filho, A. (2010) Can an adequate energy intake be able to reverse the negative nitrogen balance in mechanically ventilated critically ill patients? *Journal of Critical Care* **25(3)**, 445-450.

Kidney Disease: Improving Global outcomes. (KDIGO 2012) *Clinical practice guidelines for acute kidney injury,* [Online], Available at: http://www.kdigo.org/clinical_practice_guidelines/pdf/KDIGO%20AKI%20Guideline.pdf [3rd February 2018].

Koekkoek, W.A. and Van Zanten, A.R. (2016) Antioxidant Vitamins and Trace Elements in Critical Illness. *Nutrition in Clinical Practice* **31(4)**, 457-474.

Kondrup, J., Rasmussen, H.H., Hamberg, O. and Stanga, Z. ad hoc ESPEN working Group. (2003) Nutritional Risk Screening (NRS 2002): a new method based on an analysis of controlled clinical trials. *Clinical Nutrition* **22**, 321-336.

Kreymann, K.G., Berger, M.M., Deutz, N.E.P., Hiesmayr, M., Jolliet, P., Kazandjiev, G., Nitenberg, G., van den Berghe, G., Wernerman, J., DGEM: Ebner, C., Hartl, W., Heymann, C. and Spies, C. (2006) ESPEN (European Society for Parenteral and Enteral Nutrition) Guidelines on Enteral Nutrition: Intensive Care. *Clinical Nutrition* **25(2)**, 210-223.

Lindner, G. and Funk, G.C. (2013) Hypernatremia in critically ill patients. *Journal of Critical Care* **28(216)**, 11-20.

Lowell, J.A., Schifferdecker, C., Driscoll, D.F., Benotti, P.N. and Bistrian, B.R. (1990) Postoperative fluid overload: not a benign problem. *Critical Care Medicine* **18**, 728–733.

Marik, P.E. and Zaloga, G.P. (2008) Immunonutrition in critically ill patients: a systematic review and analysis of the literature. *Intensive Care Medicine* **34(11)**, 1980-1990.

McCall, M., Cahill, N., Murch, L., Sinuff, T., Bray, T., Tanguay, T. and Heyland, D.K. (2014) Lessons learned from implementing a novel feeding protocol: results of a multicenter evaluation of educational strategies. *Nutrition in Clinical Practice* **29(4)**, 510-517.

McClave, S.A., Lukan, J.K., Stefater, J.A., Lowen, C.C., Looney, S.W., Matheson, P.J., Glesson, K. and Spain, D.A. (2005) Poor validity of residual volumes as a marker for risk of aspiration in critically ill patients. *Critical Care Medicine* **33(2)**, 324-330.

McClave, S.A., Taylor, B.E., Martindale, R.G., Warren, M.M., Johnson, D.R., Braunschweig, C., McCarthy, M.S., Davanos, E., Rice, T.W., Cresci, G.A., Gervasio, J.M., Sacks, G.S., Roberts, P.R. and Compher, C. (2016) Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). *Journal of Parenteral Enteral Nutrition* **40(2)**, 159-211.

Mentec, H., Dupomt, H., Bocchetti, M., Cani, P., Ponche, F. and Bleichner, G. (2001) Upper digestive intolerance during enteral nutrition in critically ill patients. Frequency, risk factors, and complications. *Critical Care Medicine* **29(10)**, 1955-1961.

Mifflin, M.D., St Jeor, S.T., Hill, L.A., Scott, B.J., Daugherty, S.A. and Koh, Y.O. (1990) A new predictive equation for resting energy expenditure in healthy individuals. *American Journal of Clinical Nutrition* **51**, 241-247.

Montejo, J.C., Minambres, E., Bordeje L., Mesejo, A., Acosta, J., Heras, A., Ferre, M., Fernandez-Ortega, F., Vaquerizo, C.I. and Manzanedo, R. (2010) Gastric residual volume during enteral nutrition in ICU patients: the REGANE study. *Intensive Care Medicine* **36(8)**,1386-1393.

Mutlu, E.A. and Factor, P. (2001) GI complications in patients receiving mechanical ventilation. *Chest* **119**, 1222-1241.

National Institute for Health and Care Excellence. (NICE 2006) *Nutrition support in adults: oral nutrition support, enteral tube feeding and parenteral nutrition. Clinical Guideline 32*, [Online], Available at: https://www.nice.org.uk/guidance/cg32/resources/nutrition-support-for-adults-oral-nutrition-support-enteral-tube-feeding-and-parenteral-nutrition-pdf-975383198917
[26th March 2018].

Nguyen, N.Q., Chapman, M., Fraser, R.J., Bryant, L.K., Burgstad, C. and Holloway, R.H. (2007). Prokinetic therapy for feed intolerance in critically illness: one drug or two? *Critical Care Medicine* **35**, 2561-2567.

Nguyen, N.Q., Chapman, M.J., Fraser, R.J., Bryant, L.K. and Holloway, R.H. (2007) Erythromycin is more effective than metoclopramide in the treatment of feed intolerance in critical illness. *Critical Care Medicine* **35**, 483-489.

Nicolo, M., Heyland, D.K., Chittams, J., Sammarco, T. and Compher, C. (2016) Clinical Outcomes Related to Protein Delivery in a Critically Ill Population: A Multicenter, Multinational Observation Study. *Journal Parenteral Enteral Nutrition* **40(1)**, 45-51.

Patel, J.J., McClain, C.J., Sarav, M., Hamilton-Reeves, J. and Hurt, R.T. (2017) Protein requirements for critically ill patients with renal and liver failure. *Nutrition in Clinical Practice* **32 (1supp)**, 101S-111S.

Rahman, A., Hasan, R.M., Agarwala, R., Martin, C., Day, A.G. and Heyland, D.K. (2016) Identifying critically-ill patients who will benefit most from nutritional therapy: Further validation of the "modified NUTRIC2 nutritional risk assessment tool. *Clinical Nutrition* **35(1)**, 158-162.

Reignier, J., Mercier, E., Le Gouge, A., Boulain, T., Desachy, A., Beliec, F., Clavel, M., Frat, J.P., Plantefeve, G., Quenot, J.P. and Lascarrou, J.B. Clinical Research in Intensive Care and Sepsis (CRICS) Group. (2013) 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. *Journal of the American Medical Association* **309(3)**, 249-256.

Reintam Blaser, A., Starkopf, J., Alhazzani, W., Berger, M.M., Casaer, M.P., Deane, A.M., Fruhwald, S., Hiesmayr, M., Ichai, C., Jakob, S.M., Loudet, C.I., Malbrain, M.L., Montejo González, J.C., Paugam-Burtz, C., Poeze, M., Preiser, J.C., Singer, P., van Zanten, A.R., De Waele, J., Wendon, J., Wernerman, J., Whitehouse, T., Wilmer, A. and Oudemans-van Straaten, H.M. ESICM Working Group on Gastrointestinal Function. (2017) Early enteral nutrition in critically ill patients: ESICM clinical practice guidelines. *Intensive Care Medicine* **43(3)**, 380-398.

Rice, T.W., Wheeler, A.P., Thompson, B.T., Steingrub, J., Hite, R.D., Moss, M., Morris, A., Dong, N. and Rock, P. (2012) Initial Trophic vs Full Enteral Feeding in Patients with Acute Lung Injury: The EDEN Randomized Trial. *Journal of the American Medical Association* **307(8)**, 795-803.

Rousseau, A.F., Losser, M.R., Ichai, C. and Berger, M.M. (2013) ESPEN endorsed recommendations: Nutritional therapy in major burns. *Clinical Nutrition* **32**, 497-502.

Schetz, M., Casaer, M.P. and Van den Berghe, G. (2013) Does artificial nutrition improve outcome of critical illness? *Critical Care* **17**, 302.

Segaran, E. (2014) Trauma and critical care, Chapter 7.12. In: Manual of Dietetic Practice. (J. Gandy, ed.), 5th edn. Wiley Blackwell, Oxford.

Shaw, J.H., Wildbore, M. and Wolfe, R.R. (1987) Whole body protein kinetics in severely septic patients. The response to glucose infusion and total parenteral nutrition. *Annals of Surgery* **205**, 288-294.

Singer, P., Anbar, R., Cohen, J., Shapiro, H., Shalita-Chesner, M., Lev, S., Grozovski, E., Theilla, M., Drishman, S. and Madar, Z. (2011) The tight calorie control study (TICACOS): a prospective, randomized, controlled pilot study of nutritional support in critically ill patients. *Intensive Care Medicine* **37(4)**, 601-609.

Singer, P., Berger, M.M., Van den Berghe, G., Biolo, G., Calder, P., Forbes, A., Griffiths, R., Kreyman, G., Leverve, X. and Pichard, C. (2009) ESPEN Guidelines on parenteral nutrition: Intensive Care. *Clinical Nutrition* **28**, 387- 400.

Taylor, B., Brody, R. and Denmark, R. (2014) Improving enteral delivery through the adoption of the "Feed Early Enteral Diet adequately for Maximum Effect (FEED ME)" protocol in a surgical trauma ICU: a quality improvement review. *Nutrition in Clinical Practice* **29(5)**, 639-648.

Van Zanten, A.R., Sztark, F., Kaisers, U.X., Zielmann, S., Felbinger, T.W., Sablotzki, A.R., De Waele, J.J., Timsit, J.F., Honing, M.L., Keh, D., Vincent, J.L., Zazzo, J.F., Fijn, H.B., Petit, L., Preiser, J.C., van Horssen, P.J. and Hofman, Z. (2014) High-protein enteral nutrition enriched with immune-modulating nutrients vs standard high-protein enteral nutrition and nosocomial infections in the ICU: a randomized clinical trial. *Journal of the American Medical Association* **312(5)**, 514-524.

Villet, S.P., Chiolero, R.L., Bollmann, M.D., Revelly, J.P., Cayeux, R.N., Delarnue, J. and Berger, M.M. (2005) Negative impact of hypocaloric feeding and energy balance in clinical outcome in ICU patients. *Clinical Nutrition* **24(4)**, 502-509.

Weijs, P.J., Stapel, S.N., de Groot, S.D., Driessen, R.H., de Jong, E., Girbes, A.R., Strack van Schijndel, R.J. and Beishuizen, A. (2012) Optimal Protein and Energy Nutrition decreases Mortality in Mechanically Ventilated Critically Ill Patients: A prospective observational cohort study. *Journal of Parenteral and Enteral Nutrition* **36**, 60-68.

Zusman, O., Theilla, M., Cohen, J., Kagan, I., Bendavid, I. and Singer, P. (2016) Resting energy expenditure, calorie and protein consumption in critically ill patients: a retrospective cohort study. *Critical Care* **20(1)**, 367.

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