Nutrition Support in the Critically Ill Obese

Nobody said it was easy

Robert Cronin PgD RD, Critical Care & Colorectal Surgical Dietitian, Gloucestershire Hospitals NHS Trust, **@robbie_c44**

Kushner *et al.*[1] were not wrong when they said that the assessment and calculation of energy and protein requirements in the critically ill obese patient is *'one of the most problematic and controversial aspects of nutrition support'*.[1]

International guidelines[2, 3] and review articles[1, 4, 5] debate the right strategy for nutrition support in this group, one of hypocaloric high protein *verses* eucaloric high protein feeding. The 2016 joint Society of Critical Care Medicine and American Society of Parenteral and Enteral Nutrition guidelines for nutrition support in the critically ill recommended a hypocaloric high protein feeding (HCHP) approach in the critically ill obese, based only on expert opinion and best practice.[2] The lack of strength to this recommendation only compounds the controversy. The wider and more pressing problem of underfeeding in the critically ill obese,[6, 7] regardless of the chosen feeding strategy, is often overlooked. This article investigates the evidence behind HCHP feeding in the critically ill obese alongside the alternative calculation of energy requirements. It also highlights the degree of underfeeding in these patients and strategies critical care dietitians can implement to optimise energy and protein delivery.

The problem

When inflammation, stress and raised metabolism in critical illness encounters the baseline metabolic complications associated with obesity, such as insulin resistance, hyperlipidaemia and hypercapnia,[8] macronutrient utilisation in this cohort becomes increasing difficult.[9] To ensure optimal outcomes, the aim of nutrition support in the critically ill obese should be to prevent overfeeding and minimise metabolic complications, while maintaining lean body mass. This is a challenge for dietitians for a number of reasons. Despite indirect calorimetry (IC) being the most accurate and precise measure of resting energy expenditure (REE) in the critically ill,[2] it is expensive and has a number of methodological limitations. Even when available, the withdrawal of the gold standard indirect calorimeter from the market makes accurate and precise calculations of REE in the critically ill obese impossible.[10, 11] The lack of a validated bedside measure to determine lean body mass in the critically ill also makes accurate protein dosing difficult.[12, 13] Dietitians are therefore left having to rely on weight-based predictive equations to calculate energy and protein requirements. The disproportionate ratio of fat mass compared to fat free mass in obesity increases the risk of overfeeding energy when using weight-based predictive equations to calculate resting energy expenditure (REE).[14] Dosing of protein is also unlikely to be representative of lean body mass.[4] A HCHP feeding strategy has been recommended for the critically ill obese by the most recent 2016 Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines[2] to help dietitians achieve their aims. This recommendation is only supported by expert opinion and best practice.[2] Where is the evidence to support its use in the critically ill obese?

Hypocaloric high protein feeding in the critically ill obese

HCHP feeding is the delivery of energy that is reduced from total energy expenditure principally through the reduction in carbohydrate input, while targeting high protein and adequate delivery of other nutrients.[1] The joint

2016 ASPEN/SCCM guidelines define this in the critically ill obese as the provision of energy at 60-70% of requirements (roughly equivalent to 11-14 kcal/kg), and protein at 2-2.5 g/kg IBW/d.[2] These energy and protein recommendations are based on two randomised control trials in 16[15] and 30[16] hospitalised obese patients. They compared HCHP feeding (equivalent to 14 kcal/kg, 2g/kg IBW) to full (eucaloric) feeding (equivalent to 22-25 kcal/kg, 2g/kg IBW). Both study arms achieved similar levels of positive nitrogen balance.[15, 16] Choban *et al.*[16] also found the HCHP group required less insulin. Both studies were however underpowered to investigate important outcomes, including mortality and metabolic complications. All patients were parenterally fed and included only a small number (n13) of critically ill obese subjects.[16] No randomised control trials comparing HCHP feeding to eucaloric feeding have been performed in the critically ill obese.

Only one retrospective observational study has investigated high protein delivery (targeting 2 g/kg IBW/day) with hypocaloric (22 kcal/kg IBW) and higher energy (30 kcal/kg IBW) targets in 40 obese critically ill trauma and surgical patients.[17] HCHP feeding significantly reduced length of stay, number of antibiotic days and a trend towards a reduced number of days on the ventilator.[17] However, the nitrogen balance was negative in both groups and this study was underpowered to evaluate major end points, such as mortality and morbidity. Target protein delivery (2 g/kg IBW) was only achieved in both groups during the second week of nutrition support and the hypocaloric feeding group received the lowest average protein input (1.5 g/kg IBW). The paucity of strong evidence for a HCHP feeding approach in the critically ill obese justifies the low strength of the recommendation in the guideline.

There are other important clinical considerations to be made before adopting a HCHP feeding approach in the critically ill obese. The recommended use of 11-14 kcal/kg to target 60-70% of energy expenditure is yet to undergo large scale validation in the critically ill obese.[18] The use of fixed kcal/kg equations to estimate energy requirements in the critically ill are also unable to track fluctuations in resting energy expenditure seen during critical illness.[19] Hypocaloric feeding without adequate protein input (>1.5 g/kg IBW) leads to negative nitrogen balance in the critically ill obese[17, 21] and increases mortality in the critically ill.[6] Achieving both the recommended energy and protein targets in a HCHP feeding regime[2] should, therefore, be viewed with equal importance. Also, the 2016 SCCM/ASPEN guidelines do not provide direction on the method to calculate IBW. The studies from which the protein target (2-2.5 g/kg IBW) have been derived used the Hamwi equation to calculate IBW (**Figure 1**).[15, 16, 20] When adopting this HCHP feeding approach, I feel the Hamwi equation should be used over alternative methods of calculating IBW.

Monitoring of blood urea levels in older (≥60yrs) critically ill patients is recommended,[22] alongside the avoidance of HCHP feeding in those with severe renal or hepatic dysfunction.[3] The suitability of HCHP feeding to replete muscle mass and body stores during the recovery phase of critical illness has also yet to be investigated. The use of a HPHC feeding strategy should not be universally applied to the critically ill obese, it should be adjusted and tailored based on the individual patient and their clinical condition.

Is there an alternative to hypocaloric feeding?

Predictive equations of REE in the critically ill obese do not all provide the same level of precision and accuracy.[23, 24, 25] Amongst the many published predictive equations for ventilated critically ill patients, the Penn State University 2009 (PSU 09) (<60 yrs, any BMI) and modified Penn State University 2011 (mPSU 11) (>60 yrs BMI >30 kg/m^2) provide the most accurate estimates of REE in obesity, 70% and 74% (+/- 10% of MEE) respectively.[23, 24] Accuracy rises to 80% (+/-10% of MEE) in those with a BMI >45 using the PSU 09 equation regardless of age.[26] Frequently performed estimates of REE using the PSU equations has also been shown to track the inter- and intra-individual variation in energy expenditure during critical illness, reducing the risk of over and under feeding.[19] The use of these equations for the estimation of REE in the critically ill obese has been strongly recommended in the ASPEN guidelines for hospitalised obese patients.[3]

It is important to remember that although PSU equations provide the most accurate estimates of REE, 26-30% of calculations for REE can over and under estimate to a high (> +/-10%) level.[23, 24] Close monitoring for overfeeding, which includes hyperglycaemia, high insulin requirements, hyperlipidaemia and hypercapnia, are required. A large RCT comparing eucaloric feeding, using a validated equation to measure REE, to HCHP feeding in the critically ill obese is still required.

Is the feeding strategy debate missing a more important point?

Critically ill obese patients are fed lower amounts of energy and protein compared with critically ill patients with a normal BMI. As BMI increases over 35 kg/m^2, energy delivery has been found to be 3 kcal/kg below the lower target requirements of a hypocaloric feeding strategy.[6] Protein delivery per kg actual body weight also reduces with increasing BMI.[6] An international audit of feeding practices in the critically ill found that 78% of mechanically ventilated patients with a BMI >35 kg/m^2 receive <80% of their energy and protein requirements.[7] Given that receiving ≥80% of energy targets is associated with reduced mortality, these patients are at high risk.[27] Despite the recommended higher protein requirements in the critically ill obese, this cohort also receives some of the lowest additional protein supplementation.[6] This highlights the important role of critical care dietitians to regularly monitor the delivery of energy and protein against estimated requirements, in addition to utilising tools to maximise the delivery of energy feeding targets and protein closer to requirements.

Achieving hypocaloric or eucaloric feeding targets, alongside high protein requirements, using commercially available enteral formulations in the intensive care unit is challenging.[28] The use of early enhanced enteral nutrition (**Figure 2**) in critical illness can safely increase both energy and protein delivery by 12-15%.[29, 30] The use of enteral formulas with a low energy high protein content, alongside protein supplements improves the attainment of protein targets without overfeeding energy.[28] Reducing pre-operative fasting times[31] and using 2% over 1% lipid containing sedatives (Propofol)[32] also improves enteral calorie and protein delivery.

Figure 1: Calculation of Ideal Body Weight using Hamwi Equation

Hamwi Ideal Body Weight	in = height in inches
Men	48 + (in - 60) x 2.7
Women	45.5 + (in - 60) x 2.2

The use of total parenteral nutrition (TPN) or supplementary parenteral nutrition (SPN) to optimise energy and protein delivery in the critically ill obese is a contentious tool. The joint SCCM/ASPEN 2016 guidelines recommended that early (<day 7) initiation of TPN should only be undertaken in those at high nutrition risk, whereas SPN should be delayed to day 7-10 regardless of nutrition risk.[2] Despite this, I think early SPN is still a useful tool to bridge the energy and protein gap in critically ill patients with a high nutrition risk. The initiation of early TPN and SPN should be taken on a case by case basis, led by a dietitian who can assess nutrition risk while monitoring closely for the risk of overfeeding. Even with a high nutrition risk score, achieving energy and protein requirements using SPN or TPN can still be problematic. Fixed nitrogen calorie multi-chamber parenteral formulations can still make it difficult to achieve protein requirements without overfeeding energy. Bespoke parenteral nutrition formulations may therefore be required but access to this facility is not universally available.

To guide the assessment of nutrition risk, a conceptual model of nutrition risk specifically for the critically ill obese has been proposed by Dr Daren Heyland, *et al.* (**Figure 3**) but is as yet unpublished. The influencers within this model have either been taken from previous nutrition risk research[33] or original research[6, 34-36] in obese and non obese critically ill subjects. Many of them could, therefore, still be considered as part of a dietetic assessment of nutrition risk in the critically ill obese.

The degree of obesity (BMI >35kg/m^2),[6] number of prior co-morbidities (≥2),[34] age (>50yrs) and length of hospital stay before admission to the intensive care unit (≥1 day)[33] should be considered when assessing high nutrition risk in the critically ill obese. Assessments of low muscle mass[35] and the presence of sarcopenic obesity[36] could also be useful in the future once a bedside measurement of muscle mass has been validated.[12] Until such a time, its use remains very isolated to the research setting.

Conclusions

It is clear that we need more robust evidence to direct the right feeding strategy for critically ill obese patients. Whichever feeding strategy you choose it is important to be aware of the limitations and contraindications to its use. Critically ill obese patients remain underfed regardless of the feeding strategy and this trend must be reversed. Tools to optimise energy and protein delivery should be considered and implemented; the critical care dietitian is best placed to oversee this. The early initiation of parenteral feeding as one of these tools should be considered alongside the assessment of nutrition risk. While we wait for a validated risk tool in the obese, a more simplified assessment can be carried out at the bedside.

Figure 2: Components of Early Advanced Enteral Feeding on the Intensive Care Unit

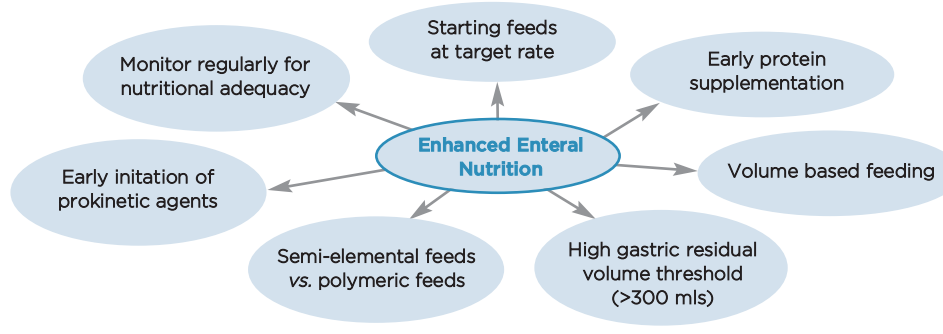
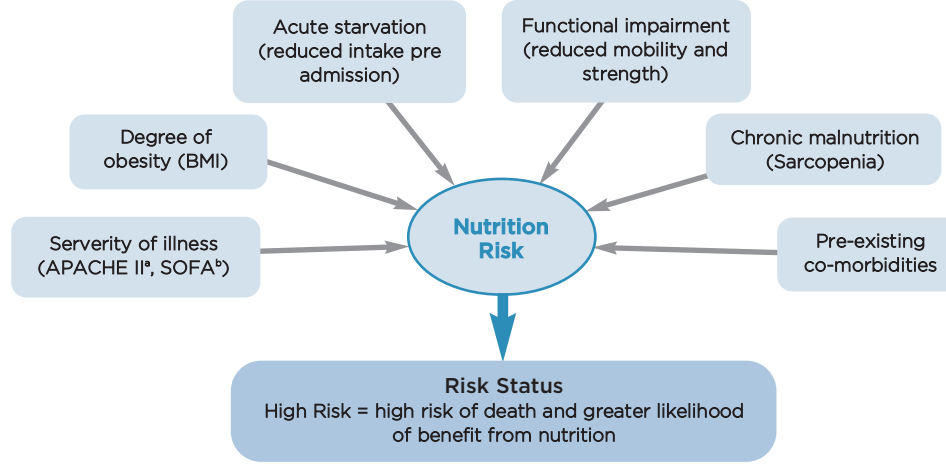


Figure 3: Conceptual Nutrition Risk Assessment in the Critically Ill Obese



[a]APACHE II - Acute Physiology and Chronic Health Evaluation II.
[b]SOFA - Sequential Organ Failure Assessment score

Reproduced with kind permission of Dr Daren Heyland

References: **1.** Kushner RF, Drover J W (2011). Current strategies of critical care assessment and therapy of the obese patient (hypocaloric feeding): what are we doing and what do we need to do? Journal of Parenteral and Enteral Nutrition; 35(5): 36-43. **2.** McClave SA, et al. (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 and Enteral Nutrition; 40(2): 159-211. **3.** Choban P, et al. (2013). A.S.P.E.N. Clinical guidelines: nutrition support of hospitalized adult patients with obesity. Journal of Parenteral and Enteral Nutrition; 37(6): 714-744. **4.** Kreymann KG, et al. (2006). ESPEN Guidelines on Enteral Nutrition: Intensive care. Clinical Nutrition; 25(2): 210-223. **5.** Porta AM, Apovian C (2010). Metabolic support of the obese intensive care unit patient: a current perspective. Current Opinion in Clinical Nutrition and Metabolic Care; 13(2): 184-191. **6.** Alberda C, et al. (2009). The relationship between nutritional intake and clinical outcomes in critically ill patients: results of an international multicenter observational study. Intensive Care Medicine; 35(10): 1728-1737. **7.** Heyland DK, et al. (2015). The prevalence of iatrogenic underfeeding in the nutritionally 'at-risk' critically ill patient: Results of an international, multicenter, prospective study. Clinical Nutrition; 34(4): 659-666. **8.** Grundy SM (2000). Metabolic complications of obesity. Endocrine; 13(2): 155-165. **9.** Honiden S, McArdle JR (2009). Obesity in the intensive care unit. Clinics in Chest Medicine; 30(3): 581-599. **10.** Graf S, et al. (2015). Evaluation of three indirect calorimetry devices in mechanically ventilated patients: which device compares best with the Deltatrac II(®)? A prospective observational study. Clinical Nutrition; 34(1): 60-65. **11.** Allingstrup MJ, et al. (2016). Indirect Calorimetry in Mechanically Ventilated Patients. A Prospective, Randomized, Clinical Validation of 2 Devices Against a Gold Standard. Journal of Parenteral and Enteral Nutrition; DOI: 10.1177/0148607116662000 [Epub ahead of print]. **12.** Paris MT, et al. (2016). Validation of Bedside Ultrasound of Muscle Layer Thickness of the Quadriceps in the Critically Ill Patient (VALIDUM Study): A Prospective Multicenter Study. Journal of Parenteral and Enteral Nutrition; DOI: 10.1177/0148607116637852 [Epub ahead of print]. **13.** Moisey LL, et al. (2016). Existing equations to estimate lean body mass are not accurate in the critically ill: Results of a multicenter observational study. Clinical Nutrition; DOI: http://dx.doi.org/10.1016/j.clnu.2016.09.013 [Epub ahead of print]. **14.** Madden AM, Mulrooney HM, Shah S (2016). Estimation of energy expenditure using prediction equations in overweight and obese adults: a systematic review. Journal of Human Nutrition and Dietetics; 29(4): 458-476. **15.** Burge JC, et al. (1994). Efficacy of hypocaloric total parenteral nutrition in hospitalized obese patients: a prospective, double-blind randomized trial. Journal of Parenteral and Enteral Nutrition; 18(3): 203-207. **16.** Choban PS, et al. (1997). Hypoenergetic nutrition support in hospitalized obese patients: a simplified method for clinical application. American Journal of Clinical Nutrition; 66(3): 546-550. **17.** Dickerson RN, et al. (2002). Hypocaloric enteral tube feeding in critically ill obese patients. Nutrition; 18(3): 241-216. **18.** Mogensen KM, et al. (2016). Validation of the Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition Recommendations for Caloric Provision to Critically Ill Obese Patients: A Pilot Study. Journal of Parenteral and Enteral Nutrition; 40(5): 213-721. **19.** Frankenfield DC, Ashcraft CM, Galvan DA (2012). Longitudinal prediction of metabolic rate in critically ill patients. Journal of Parenteral and Enteral Nutrition; 36(6): 700-712. **20.** Hamwi GJ (1964). Therapy: changing dietary concepts. In Diabetes Millitus: Diagnosis and Treatment. Vol 1; Danowski TS. Ed: American Diabetes Association. New York; 73-78. **21.** McCowen KC, et al. (2000). Hypocaloric total parenteral nutrition: effectiveness in prevention of hyperglycemia and infectious complications--a randomized clinical trial. Critical Care Medicine; 28(11): 3606-3611. **22.** Dickerson RN, et al. (2013). Hypocaloric, high-protein nutrition therapy in older vs younger critically ill patients with obesity. Journal of Parenteral and Enteral Nutrition; 37(3): 342-351. **23.** Frankenfield DC, et al. (2009). Analysis of estimation methods for resting metabolic rate in critically ill adults. Journal of Parenteral and Enteral Nutrition; 33(1): 27-36. **24.** Frankenfield DC (2011). Validation of an equation for resting metabolic rate in older obese, critically ill patients. Journal of Parenteral and Enteral Nutrition; 35(2): 264-269. **25.** Anderegg BA, et al. (2009). Comparison of resting energy expenditure prediction methods with measured resting energy expenditure in obese, hospitalized adults. Journal of Parenteral and Enteral Nutrition; 33(2): 168-175. **26.** Frankenfield DC, Ashcraft CM, Galvan DA (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. **27.** Heyland DK, Cahill N, Day AG (2011). Optimal amount of calories for critically ill patients: depends on how you slice the cake! Critical Care Medicine; 39(12): 2619-2926. **28.** Taylor SJ, et al. (2016). Critical care: Meeting protein requirements without overfeeding energy. Clinical Nutrition ESPEN; 11: 55-62. **29.** Heyland DK, et al. (2013). Enhanced protein-energy provision via the enteral route feeding protocol in critically ill patients: results of a cluster randomized trial. Critical Care Medicine; 41(12): 2743-2753. **30.** Taylor SJ, et al. (1999). Prospective, randomized, controlled trial to determine the effect of early enhanced enteral nutrition on clinical outcome in mechanically ventilated patients suffering head injury. Critical Care Medicine; 27(11): 2525-2531. **31.** Segaran E, Barker I, Hartle A (2015). Optimising enteral nutrition in critically ill patients by reducing fasting times. Journal of the Intensive Care Society; 17(1): 38-43. **32.** Taylor SJ, Bowles J, Jewkes C (2005). Propofol use precludes prescription of estimated nitrogen requirements. Journal of Intensive Care Medicine; 20(2): 111-117. **33.** Heyland DK, et al. (2011). Identifying critically ill patients who benefit the most from nutrition therapy: the development and initial validation of a novel risk assessment tool. Clinical Nutrition; 15(6): R268. **34.** Rahman A, Stapleton RD, Heyland DK (2012). Not all critically ill obese patients are the same: the influence of prior comorbidities. International Scholarly Research Network Obesity; 2012: 743978. **35.** Weijs PJ, et al. (2014). Low skeletal muscle area is a risk factor for mortality in mechanically ventilated critically ill patients. Critical Care; 18(2): R12. **36.** Moisey LL, et al. (2013). Skeletal muscle predicts ventilator-free days, ICU-free days, and mortality in elderly ICU patients. Critical Care; 17(5): R206.

Acknowledgement: I would like to thank Ella Segaran for guidance with writing this article.