Published in final edited form as:

J Acad Nutr Diet. 2012 July ; 112(7): 1073–1079. doi:10.1016/j.jand.2012.02.007.

Intensive Medical Nutrition Therapy: Methods to Improve Nutrition Provision in the Critical Care Setting

Patricia M. Sheean, PhD, RD, Sarah J. Peterson, MS, RD, Weihao Zhao, MS, David P. Gurka, MD, and Carol A. Braunschweig, PhD, RD

P. M. Sheean is a post-doctoral research associate, University of Illinois at Chicago Institute for Health Policy and Research, Chicago. S. J. Peterson is a clinical dietitian, Department of Food and Nutrition, and D. P. Gurka is chief and director of critical care medicine, Rush University Medical Center, Chicago, IL. W. Zhao is a research assistant, Department of Epidemiology and Biostatistics, and C. A. Braunschweig is a professor, Department of Kinesiology and Nutrition, University of Illinois at Chicago

Abstract

Patients requiring mechanical ventilation in an intensive care unit commonly fail to attain enteral nutrition (EN) infusion goals. We conducted a cohort study to quantify and compare the percentage of energy and protein received between standard care (n=24) and intensive medical nutrition therapy (MNT) (n=25) participants; to assess the percentage of energy and protein received varied by nutritional status, and to identify barriers to EN provision. Intensive MNT entailed providing energy at 150% of estimated needs, using only 2.0 kcal/cc enteral formula and 24-hour infusions. Estimated energy and protein needs were calculated using 30 kcal/kg and 1.2 g protein/kg actual or obesity-adjusted admission body weight. Subjective global assessment was completed to ascertain admission intensive care unit nutritional status. Descriptive statistics and survival analyses were conducted to examine time until attaining 100% of feeding targets. Patients had similar estimated energy and protein needs, and 51% were admitted with both respiratory failure and classified as normally nourished (n=25/49). Intensive MNT recipients achieved a greater percentage of daily estimated energy and protein needs than standard care recipients (1,198±493 vs 475±480 kcal, respectively, $P<0.0001$; and 53±25 vs 29±32 g, respectively, $P=0.007$) despite longer intensive care unit stays. Cox proportional hazards models showed that intensive MNT patients were 6.5 (95% confidence interval 2.1 to 29.0) and 3.6 (95% confidence interval 1.2 to 15.9) times more likely to achieve 100% of estimated energy and protein needs, respectively, controlling for confounders. Malnourished patients (n=13) received significantly less energy ($P=0.003$) and protein ($P=0.004$) compared with normally nourished (n=11) patients receiving standard care. Nutritional status did not affect feeding intakes in the intensive MNT group. Clinical management, lack of physician orders, and gastrointestinal issues involving ileus, gastrointestinal hemorrhage, and EN delivery were the most frequent clinical impediments to EN provision. It was concluded that intensive MNT could achieve higher volumes of EN infusion,

Copyright © 2012 by the Academy of Nutrition and Dietetics.

Address correspondence to: Patricia M. Sheean, PhD, RD, University of Illinois at Chicago Institute for Health Policy and Research, M/C 275, 1747 W Roosevelt Rd, Chicago, IL 60608. psheea1@uic.edu.

Meets Learning Need Codes 5000, 5010, 5390, and 5440. To take the Continuing Professional Education quiz for this article, log in to www.eatright.org, click the "MyProfile" link under your name at the top of the homepage, select "Journal Quiz" from the menu on your myAcademy page, click "Journal Article Quiz" on the next page, and then click the "Additional Journal CPE Articles" button to view a list of available quizzes, from which you may select the quiz for this article.

Statement of potential conflict of interest: No potential conflict of interest was reported by the authors.

For additional information on this topic, visit the Academy's Evidence Analysis Library at www.andevidencelibrary.com.

regardless of nutritional status. Future studies are needed to advance this methodology and to assess its influence on outcomes.

Keywords

Medical nutrition therapy; Enteral nutrition; Critical care; Subjective global assessment; Intensive care unit

Patients admitted to medical intensive care units (ICUs) often receive nutrition support, primarily in the form of enteral nutrition (EN) or less often as parenteral nutrition (PN) because of the historical associations between malnutrition and increased morbidity and mortality in this population.¹ The traditional goals of nutrition support in this setting have been to preserve lean mass, to maintain immunocompetence, and to improve patient outcomes.² The specific timing of delivery (eg, early vs late), formula selection (eg, standard vs immune-enhancing) and route of administration have thus been the focus of considerable clinical attention during the past three decades. Several studies have shown that patients in ICUs receive only 50% to 60% of prescribed enteral feeding,³⁻⁶ which hinders purported benefits concerning timing, formulation, and/or delivery. Consequently, a number of North American societies have used current evidence, expert opinion, and consensus to publish specific guidelines to help unify nutrition support practices and to highlight the adjuvant or therapeutic role of nutrition provision in ICU settings.^{2,7,8}

The clinical practicalities of meeting optimal enteral infusion rates are hampered by a variety of factors, including those related to feeding tolerance (eg, nausea and vomiting), standard nursing practices (eg, feeding interruptions for medication administration and changes in body position), convention (eg, nil per os for a test or procedure) and disease acuity (eg, hemodynamically unstable). Efforts to overcome these barriers are critical to improving feeding provision in this setting to design effective nutrition trials. Therefore, the goals of our study were twofold: to test the feasibility of intensive medical nutrition therapy (MNT) tailored to deliver 100% of estimated nutrition needs, and to assess the influence of malnutrition and perceived barriers on obtaining estimated nutrition needs. It was hypothesized that patients receiving intensive MNT would achieve a greater percentage of estimated needs than patients receiving standard care, regardless of nutritional status.

Methods

Overview, Study Design, and Population

This study was conducted to quantify the nutrition provision for adult patients (aged 18 years) who required mechanical ventilation (MV) for at least 24 hours before and after the initiation of nutrition support. EN was the preferred mode of nutrition provision throughout the study, as recommended by consensus guidelines.^{2,7,8} Patients who received standard care (ie, the controls) comprised the participants in the first half of the study and were fed according to the institution's standard feeding protocol. The amount of energy and protein ordered was compared with the amount received and goals and barriers to feedings were identified. Results from this half of the study informed the intensive MNT protocol development, which was designed to meet 100% of estimated energy and protein needs for all eligible patients. To improve internal validity and help control disease acuity, patients who transferred from another ICU, were previously intubated during the same hospitalization, or who died before ICU discharge were excluded. A total of 49 patients (standard care=24 patients; intensive MNT=25 patients) were admitted to the medical ICU at an urban university medical center who met the inclusion criteria. Ethical approval for this study was granted by the medical center's Institutional Review Board.

Standard Care—Nutrition assessments were completed by a registered dietitian and nutrition support recommendations were conveyed in daily multidisciplinary patient care rounds and via the electronic medical record, specifying formula, type of feeding (eg, bolus, intermittent, or continuous), initiation rate, and goal infusion. Enteral feeding devices were placed by the medical service and EN was administered shortly after MV, at the discretion of the attending service. Per the ICU EN feeding protocol, nursing staff members held EN if gastric residual volumes exceed >250 cc during a 4-hour infusion period, vomiting occurred, or aspiration was suspected. PN was initiated when patients could not be fed via the enteral route within 72 to 96 hours of intubation, as deemed appropriate by the attending service. All efforts to transition patients from PN to EN were completed uniformly throughout the study period. The number of days of EN and PN were recorded for each patient and EN formulae without macronutrient modulars were utilized.

Intensive MNT—Patients in the intensive MNT group received all of the standard care practices described above; however, EN prescription practices were altered based on observations made during the standard care phase of the study. To improve overall energy provision the following changes were made: hourly EN infusion rates were increased to provide 150% of estimated daily needs accounting for frequent feeding interruptions, only 2.0 kcal/cc enteral formulae were used, and enteral feedings were prescribed during a 24-hour period (eliminating bolus or intermittent feeding prescriptions). To avoid the complications of prolonged overfeeding, EN volumes were reviewed on a daily basis. If patients received EN volumes >100% of estimated energy needs for 3 sequential days, EN volumes were subsequently decreased proportionally to more closely match estimated energy needs.

Data Collection—The following variables were collected for each participant: age, sex, race/ethnicity, ICU diagnosis, admission height and body weight, and admission glucose level. To assess severity of illness, Acute Physiology and Chronic Health Evaluation (APACHE) II and IV scores were calculated.^{9,10} Admission anthropometric data (height and body weight) were used to calculate body mass index (BMI). To assess the influence of malnutrition on the ability to achieve intakes at estimated energy and protein needs, Subjective Global Assessment (SGA) was utilized to capture ICU admission nutritional status. SGA was originally developed to predict outcomes in surgery patients,^{11,12} is associated with morbidity and mortality in various patient populations,¹³⁻¹⁵ and has been shown to be reliable in ICU settings.¹⁶ Patients were ranked as normally nourished, moderately or suspected of being malnourished, or severely malnourished. Tools that used objective markers to assess nutritional status (eg, weight, albumin, transferrin, and retinol binding protein) were rejected because these markers become unreliable in the face of critical illness.^{17,18} Even though the Nutrition Risk Screening tool¹⁹ includes subjective information; it was deemed less comprehensive than SGA because it relies on weight loss, food intake, and BMI only for nutritional status assessment.

Estimated Energy and Protein Needs—The use of indirect calorimetry is the gold standard for energy needs assessment; however, due to prohibitory percentages of fraction of inspired oxygen (ie, >50%) and the frequency of weaning trials for extubation, this was impractical in this patient population. To estimate nutrition needs, energy goals were calculated using 30 kcal/kg admission or obesity-adjusted ideal body weight.²⁰ The energy provision of propofol (1.1 kcal/cc) was tabulated daily and included as a component of the daily energy goals, as appropriate. Kilocalories from intravenous fluids containing dextrose were not included in the energy summations; solutions without dextrose are typically prescribed. Protein needs were estimated using 1.2 g protein/kg ideal body weight for patients without obesity and adjusted ideal body weight for patients with obesity.²¹

Participants' estimated energy and protein needs were re-examined weekly and adjusted, if appropriate. In addition, to gain an understanding of modifiable and nonmodifiable barriers to achieving estimated needs, the following data were recorded and grouped as follows: clinical management (ie, weaning trial, suctioning, test/procedure), gastrointestinal (GI) issues (ie, GI bleed, ileus, obstruction, or ischemic bowel), EN-related (ie, no access, high residual volumes, nausea/vomiting, aspiration, clogged EN tube, or diarrhea), no physician order, or other (ie, hemodynamically unstable or mental status changes).

Statistical Analyses—The percent of estimated energy and protein needs received was the primary outcome of interest. Descriptive statistics were used to compare baseline measures and differences between groups, using two-sample *t* tests for continuous variables and Pearson, χ^2 , and Fisher's exact test for categorical variables. Data are expressed as means, medians, standard deviations, and frequencies and a *P* value of 0.05 was used to denote statistical significance. For comparisons using nutritional status, patients were dichotomized as normally nourished vs malnourished, collapsing moderate and severely malnourished into one nutritionally compromised group to aid in interpretation. Kaplan-Meier plots and log-rank tests were used to compare time until event (ie, achieving 100% of estimated energy or protein needs). To estimate the odds ratios and CIs for the meeting energy and protein goals, Cox proportional hazards models were used controlling for covariates. All analyses were performed using SAS (version 9.2, 1998, SAS Institute Inc).

Results

Patient Characteristics

Demographic information is provided in Table 1, stratified by feeding and nutrition group. A typical patient was 56.0 years of age, female, overweight using national cutpoints, admitted with respiratory failure, and had an APACHE II and IV score of 24.2 and 79.8, respectively. EN was used in a majority of patients (41 out of 49 patients). Only differences in mean BMI (32.5 vs 25.7; *P*=0.004), estimated energy (2,102 vs 1,800 kcal/d; *P*=0.002), and protein needs (85 vs 71 g/day; *P* 0.001) were detected when baseline characteristics were examined by nutritional status.

Energy and Protein Delivery

Overall, the intensive MNT group achieved a greater percentage of estimated daily energy and protein needs than patients receiving standard care (1,198±493 vs 475±480 kcal, respectively; *P*<0.0001 and 53±25 vs 29±32 g, respectively; *P*=0.007) despite longer ICU stays. When examined longitudinally using median length of stay (7 days), energy and protein provision peaked on Day 5 (see the Figure). Kaplan-Meier analyses revealed intensive MNT vs standard care recipients met 100% of estimated energy needs significantly sooner (*P*<0.002), but no differences were detected between groups for meeting 100% of estimated protein needs (*P*=0.57). When controlling for age, APACHE II scores, and nutritional status, Cox proportional hazards models showed that patients in the intensive MNT group were 6.5 (95% CI 2.1 to 29.0) and 3.6 (95% CI 1.2 to 15.9) times more likely to achieve 100% of estimated energy and protein needs, respectively. Nutritional status was not a significant covariate or interaction term in either of these models.

No significant differences were detected for average energy or protein intake in malnourished vs normally nourished patients (732±696 vs 952±493 kcal, respectively, *P*=0.21; and 34±32 vs 48±29 g, respectively, *P*=0.10) noting similar ICU length of stay. However, within the standard care group, malnourished patients (*n*=13) received significantly less energy and protein than normally nourished patients (*n*=11) (221±343 vs 774±455 kcal, respectively, *P*=0.003; and 13±21 vs 49±33g, respectively, *P*=0.004). The

differences in energy and protein delivery were not significant for the malnourished (n=11) and normally nourished (n=14) patients in the intensive MNT group ($1,336 \pm 482$ vs $1,091 \pm 492$ kcal, respectively, $P=0.23$; and 58 ± 23 vs 48 ± 26 g, respectively, $P=0.32$).

Barriers to Achieving Energy and Protein Targets

There were 178 barriers to achieving estimated energy and protein needs recorded (Table 2). GI bleeding (n=15) and ileus (n=16) occurred more often in the intensive MNT vs standard care group ($P=0.001$) and lack of physician orders occurred less often in the intensive MNT vs standard care group (15 vs 23, respectively; $P=0.02$). No significant differences for any barriers were detected when stratified by nutritional status.

Discussion

This study was designed to determine whether intensive MNT could deliver nutrition support more effectively to a patient population prone to underfeeding. We have demonstrated that the majority of critically ill patients, regardless of admission nutritional status, can attain estimated feeding needs when infusions of energy-dense formulae are increased to account for feeding interruptions. Traditionally, nutrition support in critically ill patient populations has been viewed as an adjuvant treatment, providing essential substrates to preserve lean mass and prevent malnutrition. However, the most recent guidelines set forth by the Society of Critical Care Medicine and the American Society for Parenteral and Enteral Nutrition have enhanced the role of nutrition provision in this setting as one of nutrition therapy, highlighting its potential abilities to attenuate the metabolic response to stress, to prevent oxidative cellular damage, and to provide positive immunologic modulation.^{2,8} These guidelines specifically emphasize that nutrition-based modulation of the stress response includes early EN, appropriate nutrient infusions, and tight blood glucose control. Our study provides a unique approach to improve guideline adherence and can be used in future studies to overcome the methodologic shortcomings of suboptimal nutrition delivery that is often encountered in feeding trials.

Since its advent several decades ago, EN has gained significant appreciation in critical care populations as the preferred mode of nutrient delivery. It is generally perceived to be more physiologic, have fewer complications,²² and is less costly than PN.²³ In addition to the increasing availability of enteral formulae and feeding devices, EN protocols and clinical practice guidelines have been instituted to not only raise awareness concerning the importance of nutrition provision during critical illness but to decrease the heterogeneity surrounding nutrition practices in ICUs. In a recent large prospective observational study by Cahill and colleagues,²⁴ the nutrition practices performed from 158 ICUs across five continents in 2,946 patients requiring MV were compared with the evidence-based Canadian Critical Care Nutrition Practice Guidelines. The average time to initiate EN was nearly 3 days (46.5 hours) after admission and nutritional intake averaged only 59% and 60% of energy and protein goals, respectively. This is not unexpected because failure to achieve feeding goals has long been problematic for patients in ICUs with numerous investigators reporting intakes 50% to 70% of prescribed goals.^{3,4,6,25,26} These rates are similar to those who received standard care in our study; however, the finding that malnourished patients received significantly less energy and protein than normally nourished patients receiving standard care is intriguing. Although critical illness poses a number of physiologic challenges to successful EN,²⁷ our data support the commonly perceived notion that malnourished patients are inherently more difficult to feed. Importantly, malnourished patients were able to meet estimated energy and protein needs with intensive MNT.

Finally, despite efforts to increase nutrition provision, there remain a variety of clinical barriers that impede this process. Rice and colleagues²⁸ reported that the majority of feeding

interruptions in their study were secondary to bedside or operating room procedures, followed by anticipated extubation. Elpern and colleagues²⁹ observed that in addition to tests and procedures, changes in body position, unstable clinical conditions, and enteral-related complications (ie, high gastric residual volume, nausea, or vomiting) resulted in 5.23 hours/patient/day of feeding interruption. O'Meara and colleagues³⁰ also reported that EN was stopped for an average of 6 ± 0.9 hours/day/patient and prolonged interruptions were mainly associated with problems related to small bore feeding devices, elevated gastric residual volume, and weaning practices. In addition, small bore feeding tube placement and confirmation of placement were strongly associated with suboptimal nutrient delivery. McClave and colleagues³ also found that high gastric residual volumes, tube displacement, and routine nursing procedures (ie, patient baths, dressing changes, changing of bed linen, and tracheostomy management) were the three most common reasons for EN cessation in two ICUs. Although we did not quantify the hours of EN cessation or time until feeding initiation, we did report that airway management, enterally related issues, transient bowel compromise (ie, GI bleed or ileus) and lack of physician orders were the most frequent barriers to achieving higher feeding infusions. Collectively, these investigations reflect significant gaps between what is supposed to happen (ie, practice protocols) and what actually occurs (ie, bedside practice).

There are several limitations of this methodology that deserve mention. First, despite using commonly employed energy and protein calculations, these are imprecise estimates, especially when adiposity is introduced into these calculations. Objective measures of these estimates were not obtained because of the impracticalities of these measures (eg, high fraction of inspired oxygen concentrations and errors in 24-hour collections) in this population. For example, in order for indirect calorimetry measurements to be meaningful, they must be conducted under steady state conditions. In patients receiving MV, changes to the respiratory rate, tidal volume or the fraction of inspired oxygen occur throughout the day; the assumptions of indirect calorimetry are violated and the results are prone to inaccuracies. Regardless, because energy or protein were estimated similarly in both groups, it is unlikely the lack of direct measurement influenced the findings. Second, the methods used to design intensive MNT pose a risk of overfeeding, particularly for patients without frequent feeding interruptions (ie, tests and/or procedures ordered.) This occurred in one patient in the intensive MNT group and can be circumvented with daily monitoring and tailoring. Third, whereas SGA does not rely on objective markers, it lacks the sensitivity to detect acute changes (ie, <2 weeks) and to depict muscle wasting in populations with obesity where unintentional weight loss is less appreciated. Patients who were categorized as normally nourished may have been misclassified when they were, in fact, malnourished. Finally, the amount of protein delivered was knowingly modest in the intensive MNT group because of limitations posed by having access to EN products that are energy dense and protein sufficient.

Conclusions

We have demonstrated that with a few alterations to conventional EN prescription practices, intensive MNT could facilitate achieving greater volumes of EN delivery. The design of our intensive MNT regimen was based on a combination of observations made during from the standard care phase of this study and clinical intuition. For example, the decision to change from a standard polymeric 1 kcal/cc to a 2 kcal/cc EN formula was simply based on the MNT principle of volume. For patients with low volume we wanted to maximize energy provision; similar to what clinicians would initiate in patients with illness-induced anorexia (ie, making the most out of each bite.) Limited enteral formula choices are, however, a drawback of this practice. In addition, the energy and protein goals were arbitrarily calculated at 150% of estimated needs. This change was based on the catch up principle. In

other words, we observed that feeding interruptions were common; therefore, patients would need to make up for lost time and lost energy. Finally, the decision to infuse all feedings over 24 hours and eliminate bolus or intermittent feedings was largely based on simplicity. We reasoned that there would be less confusion or delays (ie, so-called feeds on hold) among the physicians and nurses if there was only one method to infuse EN feedings.

There are several follow-up studies that need to be conducted to advance this important practice area. First, other methods to provide intensive MNT should be explored and reported. The methods described herein provide only a template to build on. For example, Lichtenberg and colleagues³¹ reported that 20-hour infusion times for 24-hour EN volumes were successful for reducing EN energy deficit in an ICU. Other practical applications merit further investigation, such as higher infusions during the evening and night time hours when procedures are less likely to occur. Second, additional efforts are needed to advance our approaches and procedures for nutritional status classification in this patient population taking into account the current frame-work of malnutrition syndromes.^{32,33} Critical illness promotes an acute inflammatory response, resulting in rapid lean body mass depletion and acute disease or injury related malnutrition.³⁴ To date, a nutritional status classification system that recognizes the role of inflammation is essential, yet nonexistent. Further research endeavors should incorporate markers and degrees of inflammation, in conjunction with laboratory, food intake, functional status, and weight histories. In addition, systems to accurately and easily measure lean body mass changes are vital; an emerging concept demonstrated and linked to morbidity and mortality results other patient populations.^{35,36} All of these advances would afford clinicians the ability to individualize MNT, to more effectively tailor repletion or maintenance goals, to track nutritional status trajectories (ie, improvements, declines, or no changes) from admission to discharge, and to stratify outcomes. Third, clinical trials are necessary to address whether or not achieving higher energy and protein targets are indeed associated with improved critical illness outcomes. Two trials published within the past year examined mortality outcomes for critically ill patients permissively underfed compared with patients fed at goal. Both trials reported that energy intakes in the full-energy or target feeding groups were only 70% to 75% of goal^{37,38}; stressing the difficulties in feeding this population and the importance of being able to provide nutrition at levels hypothesized.

Acknowledgments

Funding/Support: Support for this study was provided by the National Institutes of Health, National Heart, Lung, and Blood Institute, grant no. R01 HL093142-02, and the National Cancer Institute, Cancer Education and Career Development Program, grant no. R25CA057699-18.

References

1. Giner M, Laviano A, Meguid MM, Gleason JR. In 1995 a correlation between malnutrition and poor outcome in critically ill patients still exists. *Nutrition*. 1996; 12(1):23–29. [PubMed: 8838832]
2. McClave SA, Martindale RG, Vanek VW, McCarthy M, Roberts P. 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.). *JPEN J Parenter Enteral Nutr*. 2009; 33(3):277–316. [PubMed: 19398613]
3. McClave SA, Sexton LK, Spain DA, et al. Enteral tube feeding in the intensive care unit: Factors impeding adequate delivery. *Crit Care Med*. 1999; 27(7):1252–1256. [PubMed: 10446815]
4. De Jonghe B, Appere-De-Vechi C, Fournier M, et al. A prospective survey of nutritional support practices in intensive care unit patients: What is prescribed? What is delivered? *Crit Care Med*. 2001; 29(1):8–12. [PubMed: 11176150]

5. Spain DA, McClave SA, Sexton LK, et al. Infusion protocol improves delivery of enteral tube feeding in the critical care unit. *JPEN J Parenter Enteral Nutr.* 1999; 23(5):288–292. [PubMed: 10485441]
6. Krishnan JA, Parce PB, Martinez A, Diette GB, Brower RG. Caloric intake in medical ICU patients: Consistency of care with guidelines and relationship to clinical outcomes. *Chest.* 2003; 124(1):297–305. [PubMed: 12853537]
7. Heyland DK, Dhaliwal R, Drover JW, Gramlich L, Dodek P. Canadian clinical practice guidelines for nutrition support in mechanically ventilated, critically ill adult patients. *JPEN J Parenter Enteral Nutr.* 2003; 27(5):355–373. [PubMed: 12971736]
8. Martindale RG, McClave SA, Vanek VW, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition: Executive Summary. *Crit Care Med.* 2009; 37(5):1757–1761. [PubMed: 19373044]
9. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: A severity of disease classification system. *Crit Care Med.* 1985; 13(10):818–829. [PubMed: 3928249]
10. Zimmerman JE, Kramer AA, McNair DS, Malila FM. Acute Physiology and Chronic Health Evaluation (APACHE) IV: Hospital mortality assessment for today's critically ill patients. *Crit Care Med.* 2006; 34(5):1297–1310. [PubMed: 16540951]
11. Baker JP, Detsky AS, Whitwell J, Langer B, Jeejeebhoy KN. A comparison of the predictive value of nutritional assessment techniques. *Hum Nutr Clin Nutr.* 1982; 36(3):233–241. [PubMed: 7118579]
12. Detsky AS, Baker JP, O'Rourke K, et al. Predicting nutrition-associated complications for patients undergoing gastrointestinal surgery. *JPEN J Parenter Enteral Nutr.* 1987; 11(5):440–446. [PubMed: 3656631]
13. Detsky AS, McLaughlin JR, Baker JP, et al. What is subjective global assessment of nutritional status? *JPEN J Parenter Enteral Nutr.* 1987; 11(1):8–13. [PubMed: 3820522]
14. Martineau J, Bauer JD, Isenring E, Cohen S. Malnutrition determined by the patient-generated subjective global assessment is associated with poor outcomes in acute stroke patients. *Clin Nutr.* 2005; 24(6):1073–1077. [PubMed: 16213064]
15. Sungurtekin H, Sungurtekin U, Balci C, Zencir M, Erdem E. The influence of nutritional status on complications after major intraabdominal surgery. *J Am Coll Nutr.* 2004; 23(3):227–232. [PubMed: 15190047]
16. Sheean PM, Peterson SJ, Gurka DP, Braunschweig CA. Nutrition assessment: The reproducibility of subjective global assessment in patients requiring mechanical ventilation. *Eur J Clin Nutr.* 2010; 64(11):1358–1364. [PubMed: 20700137]
17. Fuhrman MP, Charney P, Mueller CM. Hepatic proteins and nutrition assessment. *J Am Diet Assoc.* 2004; 104(8):1258–1264. [PubMed: 15281044]
18. Gabay C, Kushner I. Acute-phase proteins and other systemic responses to inflammation. *N Engl J Med.* 1999; 340(6):448–454. [PubMed: 9971870]
19. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z. Nutritional risk screening (NRS 2002): A new method based on an analysis of controlled clinical trials. *Clin Nutr.* 2003; 22(3):321–336. [PubMed: 12765673]
20. Krenitsky J. Adjusted body weight, pro: Evidence to support the use of adjusted body weight in calculating calorie requirements. *Nutr Clin Pract.* 2005; 20(4):468–473. [PubMed: 16207686]
21. Gottschlich, M., editor. The ASPEN Nutrition Support Core Curriculum. 3. Silver Spring, MD: American Society of Parenteral and Enteral Nutrition; 2007.
22. Koretz RL. Do data support nutrition support? Part II. Enteral artificial nutrition. *J Am Diet Assoc.* 2007; 107(8):1374–1380. [PubMed: 17659905]
23. Peterson SJ, Chen Y, Sullivan CA, et al. Assessing the influence of registered dietitian order-writing privileges on parenteral nutrition use. *J Am Diet Assoc.* 2010; 110(11):1703–1711. [PubMed: 21034884]
24. Cahill NE, Dhaliwal R, Day AG, Jiang X, Heyland DK. Nutrition therapy in the critical care setting: What is “best achievable” practice? An international multicenter observational study. *Crit Care Med.* 2010; 38(2):395–401. [PubMed: 19851094]

25. Barr J, Hecht M, Flavin KE, Khorana A, Gould MK. Outcomes in critically ill patients before and after the implementation of an evidence-based nutritional management protocol. *Chest*. 2004; 125(4):1446–1457. [PubMed: 15078758]
26. Binnekade JM, Tepaske R, Bruynzeel P, Mathus-Vliegen EM, de Hann RJ. Daily enteral feeding practice on the ICU: Attainment of goals and interfering factors. *Crit Care*. 2005; 9(3):R218–R225. [PubMed: 15987393]
27. 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(29):3909–3917. [PubMed: 17663503]
28. Rice TW, Swope T, Bozeman S, Wheeler AP. Variation in enteral nutrition delivery in mechanically ventilated patients. *Nutrition*. 2005; 21(7-8):786–792. [PubMed: 15975485]
29. Elpern EH, Stutz L, Peterson S, Gurka DP, Skipper A. Outcomes associated with enteral tube feedings in a medical intensive care unit. *Am J Crit Care*. 2004; 13(3):221–227. [PubMed: 15149056]
30. O'Meara D, Mireles-Cabodevila E, Frame F, et al. Evaluation of delivery of enteral nutrition in critically ill patients receiving mechanical ventilation. *Am J Crit Care*. 2008; 17(1):53–61. [PubMed: 18158390]
31. Lichtenberg K, Guay-Berry P, Pipitone A, Bondy A, Rotello L. Compensatory increased enteral feeding goal rates: A way to achieve optimal nutrition. *Nutr Clin Pract*. 2010; 25(6):653–657. [PubMed: 21139131]
32. Soeters PB, Schols AM. Advances in understanding and assessing malnutrition. *Curr Opin Clin Nutr Metab Care*. 2009; 12(5):487–494. [PubMed: 19512916]
33. Jensen GL, Bistrian B, Roubenoff R, Heimbarger DC. Malnutrition syndromes: A conundrum vs continuum. *JPEN J Parenter Enteral Nutr*. 2009; 33(6):710–716. [PubMed: 19892905]
34. Jensen GL, Mirtallo J, Compher C, et al. Adult starvation and disease-related malnutrition: A proposal for etiology-based diagnosis in the clinical practice setting from the International Consensus Guideline Committee. *JPEN J Parenter Enteral Nutr*. 2010; 34(2):156–159. [PubMed: 20375423]
35. Mourtzakis M, Prado CM, Lieffers JR, Reiman T, McCargar LJ, Baracos VE. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. *Appl Physiol Nutr Metab*. 2008; 33(5):997–1006. [PubMed: 18923576]
36. Montano-Loza AJ, Meza-Junco J, Prado CM, et al. Muscle wasting is associated with mortality in patients with cirrhosis. *Clin Gastroenterol Hepatol*. 2012; 10(2):166–173.e1. [PubMed: 21893129]
37. 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(5):967–974. [PubMed: 21242788]
38. Arabi YM, Tamim HM, Dhar GS, et al. Permissive underfeeding and intensive insulin therapy in critically ill patients: A randomized controlled trial. *Am J Clin Nutr*. 2011; 93(3):569–577. [PubMed: 21270385]

Figure.

(A) Percent energy received for patients in standard care vs intensive medical nutrition therapy groups for the median length of intensive care unit stay. (B) Percent protein received for patients in standard care vs intensive medical nutrition therapy groups for the median length of intensive care unit stay.

Table 1
Characteristics for critically ill patients in a medical intensive care unit (ICU) stratified by feeding group and nutritional status

Variable	Standard care (n=24)	Intensive medical nutrition therapy (n=25)	P value	Normally nourished (n=25)	Malnourished ^a (n=24)	P value
	← mean ± standard deviation →	← mean ± standard deviation →		← n (%) →	← n (%) →	
Age	55.2±16.4	56.92±14.8	0.70	54.1±13.4	58.1±17.4	0.37
Energy targets	1,899±400	2,007±293	0.28	2,102±281	1,800±353	0.002 *
Protein targets	75±16	81±14	0.17	85±12	71±15	<0.001 *
Admission glucose (mg/dL)^a	154 (83)	131 (54)	0.30	130 (42)	155 (90)	0.22
	← mean ± standard deviation →	← mean ± standard deviation →		← n (%) →	← n (%) →	
Sex						0.64
Female	14 (58)	15 (60)	0.90	14 (56)	15 (63)	
Male	10 (42)	10 (40)		11 (44)	9 (38)	
Race/ethnicity			0.06			0.25
White	14 (58)	9 (36)		14 (56)	9 (38)	
Black	10 (42)	11 (44)		10 (40)	11 (46)	
Hispanic/other	0	5 (20)		1 (4)	4 (17)	
Body mass index	29.3 (8.8)	29.1 (8.3)	0.93	32.5 (7.3)	25.7 (8.3)	0.004 *
Nutritional status^b			0.18			
Normal	11 (46)	14 (56)				
Moderate	12 (50)	7 (28)				
Severe	1 (4)	4 (16)				
ICU diagnosis			0.35			0.46
Sepsis	4 (17)	6 (24)		5 (20)	5 (21)	
Respiratory Failure	11 (46)	14 (56)		11 (44)	14 (5)	
Gastrointestinal	3 (13)	0 (0)		1 (4)	2 (8)	
Other	6 (25)	5 (20)		8 (32)	3 (13)	
APACHE^c II score	23.6 (8.0)	24.8 (11.0)	0.66	23.4 (9.4)	25.0 (10.1)	0.56
APACHE IV score	76.6 (35.0)	83.0 (26.0)	0.47	77.4 (31.1)	82.4 (30.9)	0.57

Variable	Standard care (n=24)	Intensive medical nutrition therapy (n=25)	P value	Normally nourished (n=25)	Malnourished ^a (n=24)	P value
Enteral nutrition initiation	18 (75%)	23 (96%)	0.01	21 (84%)	20 (87%)	0.99
Parenteral nutrition initiation	3 (13%)	5 (20%)	0.70	4 (16%)	4 (17%)	0.99
ICU length of stay (d)	8.0 (5.5)	13.5 (7.2)	<0.05	11.1 (7.7)	10.5 (6.2)	0.76

^aTo convert mg/dL glucose to mmol/L, multiply mg/dL by 0.0555. To convert mmol/L glucose to mg/dL, multiply mmol/L by 18.02. Glucose of 154 mg/dL=2,775 mmol/L.

^bPatients classified as moderate (n=19) or severely (n=5) malnourished utilizing subjective global Assessment were collapsed into one category.

^cAPACHE=Acute Physiology and Chronic Health Evaluation.

* Statistically significant at $P<0.05$.

Table 2
Barriers to providing enteral nutrition (EN) in a medical intensive care unit for patients receiving standard care or intensive medical nutrition therapy (MNT)

Reason	Standard care (n=24)	Intensive MNT (n=25)	P value
Airway management	30	33	0.51
EN related	11	17	0.57
Gastrointestinal bleed	0	15	<0.001 *
Ileus	4	16	0.02 *
No enteral access	2	3	0.85
No EN prescription	23	15	0.02 *
Other	0	1	0.99
Surgery	0	2	0.21
Unstable	4	2	0.26

* Statistically significant at $P < 0.05$.