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ACCEPTANCE

This thesis, METHODS OF DETERMINING ENERGY REQUIREMENTS IN CRITICALLY ILL ADULTS BEFORE THE PUBLICATION OF NEW CRITICAL CARE GUIDELINES, by Lindsay Ryan was prepared under the direction of the Master's Thesis Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Master of Science in the Byrdine F. Lewis College of Nursing and Health Professions, Georgia State University. The Master's Thesis Advisory Committee, as representatives of the faculty, certify that this thesis has met all standards of excellence and scholarship as determined by the faculty.

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ABSTRACT

METHODS OF DETERMINING ENERGY REQUIREMENTS IN CRITICALLY ILL ADULTS BEFORE THE PUBLICATION OF NEW CRITICAL CARE GUIDELINES

by
Lindsay Ryan

Background: Energy requirements can be difficult to determine in the critically ill population due to the presence of catabolic stress. The 2009 Guidelines for the Provision and Assessment of Nutrition Support Therapy Parenteral and Enteral Nutrition and in the Adult Critically Ill Patient recommend that energy requirements be calculated by predictive equations or weight-based equations or measured by indirect calorimetry (IC) and that nutrition efficacy may be monitored through nitrogen balance (24-hour Urinary Urea Nitrogen) or non-protein calorie:nitrogen ratio. Very few studies have reported the required energy assessment methods used by Registered Dietitian Nutritionists (RDNs) in the critical care setting and no studies have reported the use of laboratory tests to monitor efficacy of nutrition. The purpose of the study is to examine practices for estimating energy requirements in critically ill patients by RDNs prior to publication of the updated critical care guidelines in 2016.

Methods: The study sample included patients currently included in the trauma registry at Grady Memorial Hospital (GMH). Patients who were in motor vehicle accidents (excluding trains), who were admitted to the Intensive Care Unit at GMH between July 4, 2014 and September 28, 2015, and who required at least five days of mechanical ventilation during admission were included. Demographic characteristics (gender, race, and age), anthropometric characteristics (body mass index classification), clinical

characteristics (number of days on the ventilator, ICU days, time to death)), and nutrition assessment methods (energy assessment method used, weight used in assessment, and laboratory monitoring recommendations) were extracted from the electronic medical record.

Results: The vast majority of Registered Dietitian Nutritionists (98%) used a simple weight-based equation during the initial nutrition assessment. Approximately 1/3 of the Registered Dietitian Nutritionists used the actual patient body weight (36.8%) with the remaining primarily using a recommended body weight based on a selected BMI. Nine different weight-based equations were used with the equation 25-30 kcal/kg used most often (87.9%). Indirect calorimetry was not recommended by the RDNs during the first two weeks of admission for any patient. RDNs recommended prealbumin to monitor nutrition status (within 2 weeks of admission) in 21.6% of patients.

Conclusions: We observed inconsistencies in the equations, weights, and monitoring laboratory tests used by RDNs. This variability can be attributed to a lack of specificity in the 2009 critical care guidelines, which justifies the need for updated recommendations in 2016. Future studies should examine change in nutrition assessment practices by RDNs since publication of the 2016 guidelines.

METHODS OF DETERMINING ENERGY REQUIREMENTS IN CRITICALLY ILL
ADULTS BEFORE THE PUBLICATION OF NEW CRITICAL CARE GUIDELINES

by

Lindsay Ryan

A Thesis

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ABBREVIATIONS

ASPEN	American Society for Parenteral and Enteral Nutrition
BEE	Basal Energy Expenditure
BMI	Body Mass Index
GMH	Grady Memorial Hospital
IBW	Ideal Body Weight
IC	Indirect Calorimetry
ICU	Intensive Care Unit
IQR	Interquartile Range
kcal	Kilocalorie
kg	Kilogram
MST	Malnutrition Screening Tool
NFPE	Nutrition Focuses Physical Exam
RBW	Recommended Body Weight
RDN	Registered Dietitian Nutritionist
REE	Resting Energy Expenditure
SCCM	Society of Critical Care Medicine
SGA	Subjective Global Assessment
SNAQ	Short Nutrition Assessment Questionnaire
TEE	Total Energy Expenditure

CHAPTER I

METHODS OF DETERMINING ENERGY REQUIREMENTS IN CRITICALLY ILL ADULTS BEFORE THE PUBLICATION OF NEW CRITICAL CARE GUIDELINES

Introduction

Determining energy requirements in hospitalized patients is an important component of the nutrition assessment. Energy needs can be difficult to determine in the critically ill due to the presence of catabolic stress. Response to stress occurs in two phases – ebb and flow.¹ The ebb phase happens first and includes shock, hypovolemia, and hypermetabolism.¹ After fluid resuscitation and restoration of oxygen transportation, the flow phase occurs and consists of an altered hormone state and increased circulating glucose and free fatty acids.¹ Energy requirements during the flow phase are usually higher than during the ebb phase.¹ Over or underfeeding can have an array of negative effects on patients, such as immunosuppression, malnutrition, and failure to wean from the ventilator, which highlight the importance of estimating nutrition requirements as accurately as possible.²

There are two ways to determine energy expenditure in critically ill patients: estimating energy requirements with equations or measuring using indirect calorimetry (IC). Indirect calorimetry is a method of determining resting energy expenditure (REE) by measuring the whole-body oxygen and carbon dioxide exchange² and incorporating these results into the abbreviated Weir equation. Predictive equations often use patient information like gender, age, height, weight, and activity or stress level to estimate an energy

expenditure range.³ These include are Harris-Benedict,⁴ Mifflin-St. Jeor,⁵ and Penn State⁶ equations. Another predictive equation is the weight-based equation – simply a calorie range per kilogram of body weight (i.e., 30-35 calories per kilogram). Predictive equations are used with more stable patients and in facilities without IC.

The 2009 “Guidelines for the Provision and Assessment of Nutrition Support Therapy Parenteral and Enteral Nutrition and in the Adult Critically Ill Patient” recommend that energy requirements be calculated by predictive equations or weight-based equations or measured by IC.⁷ Assessment of nutrition efficacy may be monitored through nitrogen balance (24-hour Urinary Urea Nitrogen) or non-protein calorie:nitrogen ratio.⁷ Authors of the more recently published “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 (ASPEN)”, suggest using indirect calorimetry to determine energy needs; if IC is not available, a predictive equation or a weight-based equation should be used.⁸ Very few studies have reported the methods of assessing energy requirements that have been used by Registered Dietitian Nutritionists (RDNs) in the critical care setting previous to the 2016 guidelines. Those that have been done have shown limited use of IC to determine energy needs.^{9,10} No previous studies have evaluated the use of laboratory monitoring by RDNs to evaluate adequacy of nutrition in the critical care setting.

The purpose of the study is to review electronic medical records for patients on the trauma registry at Grady Memorial Hospital (GMH), a large teaching hospital in Atlanta with a Level 1 Trauma Center, to examine Registered Dietitian Nutritionist practices for estimating or measuring energy requirements in critically ill patients prior to publication

of the 2016 guidelines. The aim of the study is to examine the methods of assessing energy requirements and adequacy of the nutrition recommendation of critically ill patients by Registered Dietitian Nutritionists prior to the 2016 critical care guidelines to justify the need for revision of the 2009 guidelines to improve patient care.

CHAPTER II

Review of the Literature

Nutrition Assessment of Critically Ill Patients

While performing a nutrition assessment on a critically ill patient, the Registered Dietitian Nutritionist determines the energy requirements of the patient in order to make a nutrition care plan. Energy is defined as “the capacity to do work” and is supplied to humans through carbohydrates, fat, protein, and alcohol.³ Energy requirements are the amount of dietary energy intake needed for growth or maintenance. Basal energy expenditure (BEE) is the amount of energy used over 24 hours in an individual at mental and physical rest in a thermoneutral environment. Factors such as age, body size, gender, climate, temperature, and hormonal status affect the BEE. The thermic effect of food is the increase in energy used to consume, digest, and absorb food. Resting energy expenditure (REE) is the energy expended to sustain body functions and homeostasis, including respiration, circulation, pumping ions across membranes, and the synthesis of organic compounds, and can be derived from the addition of BEE and the thermic effect of food. Total energy expenditure (TEE) is the amount of energy expended in a day and is made up of basal energy expenditure, thermic effect of food, and activity thermogenesis.³ Lastly, activity thermogenesis is the energy used during any type of activity including non-exercise activity thermogenesis, and the energy expended during activities of daily living or exercise.¹¹ Energy is measured in kilocalories (kcal).³

Estimating the energy requirements of a patient who is critically ill can be challenging. Patients admitted to the intensive care unit (ICU) may experience a myriad

of clinical problems: burns, traumatic injuries, sepsis, or a mix of conditions.¹ The body's response to stress usually involves accelerated catabolism of lean body mass that results in muscle wasting and negative nitrogen balance. This response occurs during the ebb and flow phases of metabolic stress. The ebb phase happens immediately after injury, involves shock, hypovolemia, tissue hypoxia, hypoinsulinemia, and hypermetabolism.¹ During the ebb phase, caloric needs may be reduced, making the risk of overfeeding higher during the ebb phase.¹² The flow phase occurs after fluid resuscitation and restoration of oxygen transportation.¹ This phase is known for increases in catabolism,¹³ acute phase protein activity, and circulating hormones like insulin, catecholamines, and cortisol.¹ The altered hormone state leads to increased release of substrates including free fatty acids from fat breakdown, free amino acids from muscle breakdown, and glucose from hepatic glucose production. The prevalence of tissue catabolism contributes to negative nitrogen balance¹³ and hyperglycemia.¹ During the flow phase, nutritional needs are typically increased and the risk of overfeeding is lower.^{12,13} The flow phase has more clinical significance because it lasts longer than the short ebb phase.¹³

Due to these complicated processes happening during critical illness, determining a patient's caloric needs during a stay in intensive care can be challenging. Each patient has a different mix of conditions that impact needs, not to mention that caloric needs may change daily. Positive ICU patient outcomes depend on optimal nutrition. Patients in the ICU are more likely to be malnourished or at high risk for malnutrition than other hospitalized patients.¹⁴ In a 7-year study with 6,518 participants from medical and surgical ICUs, malnutrition was assessed by a registered dietitian.¹⁵ Malnutrition was categorized as nonspecific malnutrition or protein-energy malnutrition and malnutrition

was determined using anthropometric measurements, biochemical indicators, clinical signs, malnutrition risk factors, and metabolic stress. Non-specific malnutrition was found in 56% of participants and protein-energy malnutrition in 12%; thirty-two percent were identified as well-nourished. The study looked at all-cause 30-day mortality from the Social Security Death Master File to assess the correlation between malnutrition and death. After adjusting for age, gender, race, medical versus surgical patient type, Deyo-Charlson index, acute organ failure, vasopressor use, and sepsis, malnutrition was a significant predictor of 30-day mortality. The study also concluded that the odds of 30-day mortality of critically ill patients were two-fold greater in those with protein-energy malnutrition opposed to those without malnutrition.¹⁵ This study is one snapshot of the prevalence of malnutrition in the critically ill and the impact of malnutrition on patient mortality. A retrospective chart review on patients in the ICU requiring mechanical ventilation was conducted to find the association between malnutrition and mortality rates.¹⁶ The study used the Subjective Global Assessment tool to assess for malnutrition. The prevalence of malnutrition at admission was found to be 35%. The study also found that mortality rates were significantly higher in the moderately and severely malnourished groups than the well-nourished group.¹⁶ This study reinforces the effect of malnutrition on mortality rates in ICU patients.

There are many different ways to screen for, assess, and diagnose malnutrition in the clinical setting. There are malnutrition screening tools that are quick, easy, and can be done by nurses at the bedside; at-risk patients can be further assessed.¹⁷ Examples of these screening tools are the Malnutrition Screening Tool (MST) and the Short Nutrition Assessment Questionnaire (SNAQ).¹⁷ The Subjective Global Assessment Tool (SGA),

which was developed in 1984, is more detailed and takes into account dietary intake, weight changes, gastrointestinal symptoms, functional capacity, physical findings (loss of subcutaneous fat, muscle wasting, and fluid retention), and disease state.¹⁸ Recently, there has been a push for Nutrition Focused Physical Exam (NFPE) to become a staple in nutrition assessment. The NFPE includes using inspection, palpation, percussion, and auscultation techniques to identify muscle wasting, subcutaneous fat loss, and edema.¹⁹ In 2012, a consensus statement was released by The Academy of Nutrition and Dietetics and ASPEN that established specific criteria for non-severe and severe malnutrition in the context of acute illness, chronic illness, and social or environmental circumstances.²⁰ Patients must meet two of six criteria (energy intake, interpretation of weight loss, body fat, muscle loss, fluid accumulation, and reduced grip strength) to receive a diagnosis of malnutrition.²⁰

Due to differences in defining, screening, and diagnosing malnutrition in the past and differences in rates of malnutrition among varying disease states, geographical locations, and socioeconomical subgroups, a review of 20 studies found that malnutrition among hospitalized patients can range from 20-50%,²¹ but there are several studies with conclusions outside of these parameters. A large, multi-institutional study pooled data from 105 institutions over two years.²² This study identified all patients over the age of 18 years with an ICD-9 diagnosis of malnutrition upon admission or during their hospital stay. The study period was 2014-2015, which was before the ICD-10 codes were implemented. The ICD-9 malnutrition codes included: other severe protein-calorie malnutrition (262); malnutrition of moderate degree (263 or 263.0); malnutrition of mild degree (263.1); other protein-calorie malnutrition (263.8); and unspecified protein-calorie

malnutrition (263.9).²² Overall, only 5% of patients were diagnosed with malnutrition and 1.4% with severe malnutrition. The author noted a large gap between reported rates of malnutrition when researchers actively aim to identify malnutrition and coded diagnoses of malnutrition during a retrospective study.²² This is supported by a study that found, without a screening protocol in place, the clinical staff only identified 35% of the malnourished patients and 20% of those at risk.²³

Along with malnutrition, over and underfeeding have consequences for the critically ill population. Schlein and Coulter note that complications of underfeeding include immunosuppression, increased risk of nosocomial infection, impaired organ function, and failure to wean from the ventilator.² Overfeeding can result in immunosuppression, hyperglycemia, azotemia, electrolyte imbalance, hepatic steatosis, failure to wean from the ventilator, and hypertriglyceridemia.² It is important to note that both under and overfeeding result in immunosuppression, a complication that should be avoided in sick patients. Immunosuppression can decrease the body's ability to respond to illness, as well as increase the risk for opportunistic infections like *Candida albicans*.²⁴

Additionally, over and under-feeding come with a significant cost. Underfeeding is a risk factor for malnutrition. One study prospectively collected data from 173 medical records and identified patient risk for malnutrition and later compared risk with length of stay.²⁵ At risk was defined as weight for height < 75% ideal body weight, admission serum albumin level < 30 g/L, or $\geq 10\%$ unintentional weight loss within one month prior to admission. The study found that malnutrition increased length of stay by up to 6 days, which translated to approximately \$1,600 per patient per hospital stay when the study was performed in 1994.²⁵ This amount would be much greater today considering current

healthcare costs. Malnutrition also increases risk of pressure ulcers. A 2010 retrospective chart review examined the cost of stage IV pressure ulcers in 19 patients over 29 months.²⁶ The study found the average costs directly related to treating the pressure ulcer and any subsequent complications ranged between \$124,000 and \$129,000.²⁶

Overfeeding can be costly as well. A study measured the REE in 100 consecutive parenteral nutrition patients and found that using the Harris-Benedict equation to estimate caloric needs resulted in the overfeeding of many patients, adding up to 6,947 liters of parenteral nutrition per year that exceeded nutritional needs.²⁷ Nutrition therapy has been found to a cost-effective way to reduce malnutrition and overall healthcare costs associated with it.²⁸

Determining Energy Requirements in Critically Ill Patients

Extensive research has been done on estimating and measuring energy expenditure of the critically ill due to the adverse consequences of over or underfeeding. Energy expenditure can be measured by direct calorimetry, indirect calorimetry, and the doubly labeled water technique or estimated by various predictive equations.³

Direct calorimetry measures energy expended in the form of heat.³ This method requires very specialized and expensive equipment and may not be representative of an individual in a normal environment, so it is not regularly performed.³

Indirect calorimetry calculates REE by measuring the whole-body oxygen and carbon dioxide exchange, which correlates with energy production, since an estimated 80% of energy expenditure is due to oxygen consumption and the rest to carbon dioxide production.² After a patient's oxygen consumption and carbon dioxide production are

measured, the Weir Equation is used to calculate REE.³ Since this number is reflective of 24-hour REE, no activity or stress factor is needed, which leaves less room for human error.² The procedure depends on the equipment used, but typically involves a mouthpiece with a nose clip, a mask that covers the nose and mouth, or a ventilated hood that captures all expired carbon dioxide.³ There are situations when the timing and accuracy of IC may be impacted, like air leaks, use of chest tubes, provision of supplemental oxygen, ventilator settings, continuous renal replacement therapy, anesthesia, physical therapy, and excessive movement.⁸ Additionally, the test should have at least 5 minutes of steady-state measurement, represented by less than 10% coefficient of variation.²⁹

The doubly labeled water technique measures total energy expenditure and it rests on the principle that carbon dioxide production can be estimated from the difference in the elimination rates of body hydrogen and oxygen.³ An oral loading dose of water labeled with deuterium oxide, oxygen-18 is administered, and the elimination rates are measured for 10-14 days. This technique can be used in research, but is not practical for use in critically ill patients.³

Predictive equations are the least accurate means of estimating energy expenditure. There are a variety of equations available, but the Mifflin-St. Jeor,⁵ Harris-Benedict,⁴ and Penn State⁶ are a few of the most widely used equations. Harris-Benedict and Mifflin-St. Jeor were developed for use in healthy people, so application to hospitalized patients is questionable.³ Conversely, the Penn State Equation was created based on data from patients on mechanical ventilation.¹³ Most of these equations require information about the patient including sex, age, height, weight, and activity level to

estimate an energy expenditure range.³ There have been many studies done to estimate the accuracy of predictive equations in critically ill patients. In ICU patients over the age of 18 years, the Harris-Benedict Equation has been found to be 31.76% accurate.³⁰ For those on mechanical ventilation with a BMI under 30 kg/m², the Harris-Benedict Equation has been found to be 21% accurate with a 1.3 activity factor, and 51% accurate with a 1.6 activity factor.³¹ The Mifflin-St. Jeor equation has been found to be between 17.8% in ICU patients on mechanical ventilation³² and 58% accurate with a 1.1 activity factor in medical and surgical patients who underwent IC.³³ The Penn State Equation has been modified to increase accuracy, and two previously used versions, 1998 and 2003a, are considered invalid now.⁶ The Penn State 2003b for ventilated patients was found to be 43% accurate³³ and 72% accurate for medical, surgical, and trauma patients on mechanical ventilation.³⁴

Mifflin-St. Jeor Equation (MSJE)⁵

Men: $RMR = (9.99 \times \text{weight}) + (6.25 \times \text{height}) - (4.92 \times \text{age}) + 5$

Women: $RMR = (9.99 \times \text{weight}) + (6.25 \times \text{height}) - (4.92 \times \text{age}) - 161$

Equations use weight in kg, height in centimeters cm, age in years

Harris-Benedict Equations (HBE)⁴

Men: $RMR = 66.47 + 13.75 (W) + 5 (H) - 6.76 (A)$

Women: $RMR = 655.1 + 9.56 (W) + 1.7 (H) - 4.7 (A)$

Equations use weight (W) in kg, height (H) in cm, and age (A) in years

Penn State Equation 2010⁶

$$\text{RMR} = \text{Mifflin} (0.71) + V_E (64) + T_{\text{max}} (85) - 3085$$

T_{max} = maximum body temperature in the previous 24 hours (degrees Centigrade)

V_e = minute ventilation recorded from ventilator in L per minute³⁵

Penn State Equation 2003b⁶

$$\text{RMR} = \text{Mifflin} (0.96) + V_E (31) + T_{\text{max}} (167) - 6212$$

T_{max} = maximum body temperature in the previous 24 hours (degrees Centigrade)

V_e = minute ventilation recorded from ventilator in L per minute³⁵

Critical Care Guidelines

The 2009 “Guidelines for the Provision and Assessment of Nutrition Support Therapy Parenteral and Enteral Nutrition and in the Adult Critically Ill Patient” recommend that energy requirements be calculated by predictive equations or a weight-based formula or measured by indirect calorimetry.⁷ Monitoring efficacy of nutrition delivered may be assessed from nitrogen balance or non-protein calorie:nitrogen ratio. Serum protein markers including prealbumin, albumin, transferrin, and C-reactive protein are not recommended for use in the critical care setting for laboratory monitoring of nutrition efficacy.⁷

In 2016, the "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 (ASPEN)” was released.⁸ This is a national guideline document for nutrition support in critical care that is adopted by nutrition professionals. In this document, IC is identified as the preferred method for

determining energy requirements.⁸ This is a change from the 2009 guidelines, which but failed to stress a recommendation of IC over predictive equation.⁷

When IC is not available, expert consensus suggests using published predictive equation, like Harris Benedict or Penn State, or a simplistic weight-based equation, such as 25-30 kcal/kg/day.⁸ The 2016 critical care guidelines also recommend high protein, hypocaloric feedings for obese patients.⁸ If IC is available, the target calorie range should be 65-70% of results, and if not available, the suggestion is 11-14 kcal/kg of actual body weight per day for those with a body mass index (BMI) of 30-50 kg/m², and 22-25 kcal/kg ideal body weight (IBW) for a BMI over 50 kg/m².⁸ Regardless of the means of determining energy expenditure, energy expenditure should be reevaluated more than once per week to measure changes in nutritional needs as a patient's status changes.^{8,1}

Predictive or weight-based equations come with some challenges. Predictive equations are only 40-75% accurate,⁸ which suggests that patient's needs may be estimated too high or too low and may result in over or underfeeding. The inaccuracy of these equations is due to changing variables like weight, treatments, body temperature, and medications.⁸ A study compared IC derived resting metabolic rate with the Mifflin St. Jeor equation on 202 critically ill patients and found that over 65% of the patients were hypermetabolic, which the study defined as a measured resting metabolic rate at least 15% higher than that predicted by Mifflin St. Jeor equation.⁹ Additionally, predictive equations are less accurate in the over and underweight and no one equation is consistently more accurate than another in the ICU, not to mention that there are over 200 from which to choose.⁸ Although weight-based equations are simpler to compute, it's recommended to use dry or usual body weight in a patient with edema, anasarca, or who

has undergone volume resuscitation, a category common in critical illness patients. Dry or usual weight can be challenging to obtain and is often dependent on patient or family recall.⁸

Energy Assessment and Monitoring in Practice

Although the recommendation of IC for determining energy expenditure is relatively new, the idea of dietitians using IC in practice is not. In 1996, a paper published in the *Journal of the American Dietetic Association* (now the *Journal of the Academy of Nutrition and Dietetics*) called for clinical dietitians to use IC.³⁵ Until the 2016 ASPEN guidelines, IC was acknowledged as being more accurate than predictive equations, but the importance of using it was not stressed.⁸ The recommendation is clear, but there is very little research on how many practitioners are using IC. In 2015, a cross-sectional survey-based study examined the use of IC by Registered Dietitian Nutritionists throughout the United States.¹⁰ The survey was distributed to 5000 Registered Dietitian Nutritionists to ascertain how they determined the energy needs of their patients. The vast majority of inpatient dietitians surveyed (93.4%) reported using predictive equations to find energy needs of their patients.¹⁰ It is important to note that this study surveyed more than just critical care dietitians and occurred before the 2016 guidelines came out; however, this is still a staggering statistic.

CHAPTER III

Methods

Study Participants

The study sample will include patients currently included in the trauma registry at GMH. Information was requested on persons involved in motor vehicle accidents who passed through the 60-bed medical and surgical ICUs between January 2011 and September 2015. The report yielded 2802 patients and contained a considerable amount of patient information, in the form of 271 variables, with the majority being used for Physical Therapy research. The registry is approved by the GSU IRB and by the GMH Research Oversight Committee. Inclusion criteria for the current study are patients who were in motor vehicle accidents (excluding trains), were admitted to the ICU at GMH between July 4, 2014 and September 28, 2015, and required at least five days of mechanical ventilation during admission.

Data Collection

The trauma registry includes demographic characteristics, diagnostic data, anthropometrics, comorbidities, and ICU mobilization. The following variables were extracted from the existing registry: demographic characteristics (gender, race, and age), anthropometric characteristics (BMI classification), clinical characteristics (number of days on the ventilator, ICU days, time to death), and nutrition assessment methods (energy assessment method used, weight used in assessment, and laboratory monitoring recommendations). The handling and protection of the patients' registry data will be in

accordance with the approved procedures in GSU IRB protocol #H14115. In summary, each patient has received a participant number. A separate secure file that links each participant number with the patient's name and data of birth is maintained by Pam Chitika in the Physical Therapy Department at GMH. Only the participant number (no personal identifiers) will be recorded with the extracted data from the trauma registry and removed from GMH. The type of nutrition assessment method used for patients identified as eligible for the study will be identified from the GMH electronic medical record and recorded as IC, predictive equation, or weight-based equation. No patient identifiers will be extracted from the electronic medical record.

Statistical Analysis

Demographic, anthropometric, clinical and nutrition assessment method characteristics were described using frequency statistics. The assessment and monitoring methods used were compared with the 2009 critical care guideline recommendations. All statistical analysis will be conducted using SPSS (version 25.0, SPSS Inc., Chicago, IL).

CHAPTER IV

Results

The demographic characteristics of the population are shown in Table 1. The majority of the population is male (72.5%). Approximately half of the population is African American (52.3%) and the vast majority is non-Hispanic or Latino (97.4%). The median age of the population was 43 years (Interquartile Range [IQR]; 29.0, 55.5). The BMI distribution of the critical care sample population upon admission is shown in Figure 1. One third of the population has a BMI in the normal range (18.5 – 24.9) and approximately as many are overweight (25.0 – 29.9). The median number of days to discharge was 30 (IQR; 19.5, 46.9) and the median number of days in the ICU was 21 (IQR 15, 32) (Table 2).

Table 1 - Demographic Characteristics of the Total Critical Care Population

Characteristic	Sample (N=193)
Gender; n (%)	
Male	140 (72.5)
Female	53 (27.5)
Race; n (%)	
African American	101 (52.3)
Asian/Other	14 (7.3)
White	78 (40.4)
Ethnicity; n (%)	
Hispanic or Latino	5 (2.6)
Non-Hispanic or Latino	188 (97.4)
Age (years)*	43 (29, 55.5)
Cease to breathe; n (%)	
Alive	174 (90.2)
Dead	19 (9.8)

*Median (Interquartile range; 25%, 75%)

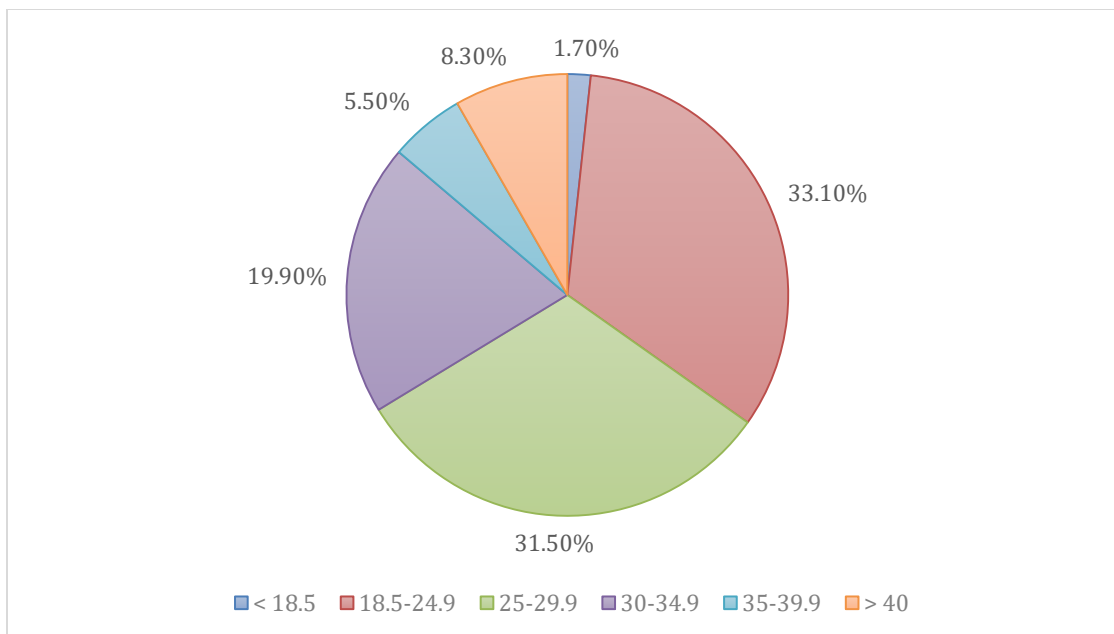


Figure 1. Body Mass Index (kg/m²) Range upon Intensive Care Unit Admission

Table 2 - Clinical Characteristics of the Critical Care Population

Clinical Characteristic	N	Sample
Days to Discharge*	192	30.2 (19.5, 46.9)
Total Days in ICU*	193	21 (15, 32)
Total Days on Mechanical Ventilation*	193	16 (10, 26.5)

*Median (Interquartile range; 25%, 75%)

BMI – body mass index, ICU – intensive care unit

The vast majority of RDNs (98%) used a simple weight-based equation during the initial nutrition assessment (Figure 2). The distribution of patient weight used in these equations is shown in Figure 3. Approximately 1/3 of the RDNs used the actual patient body weight (36.8%) with the remaining primarily using a recommended body weight based on a selected BMI. The simple, weight-based equation 25-30kcal/kg was used in

the majority of assessments (87.9%), but there were a total of 9 different equations used (Table 3). Indirect calorimetry was not recommended by RDNs during the first 2 weeks of admission in any of our population. Prealbumin was recommended to monitor nutrition status (within 2 weeks of admission) in 21.6% of patients, which is inconsistent with the consensus of the 2009 Critical Care Guidelines (Figure 4).

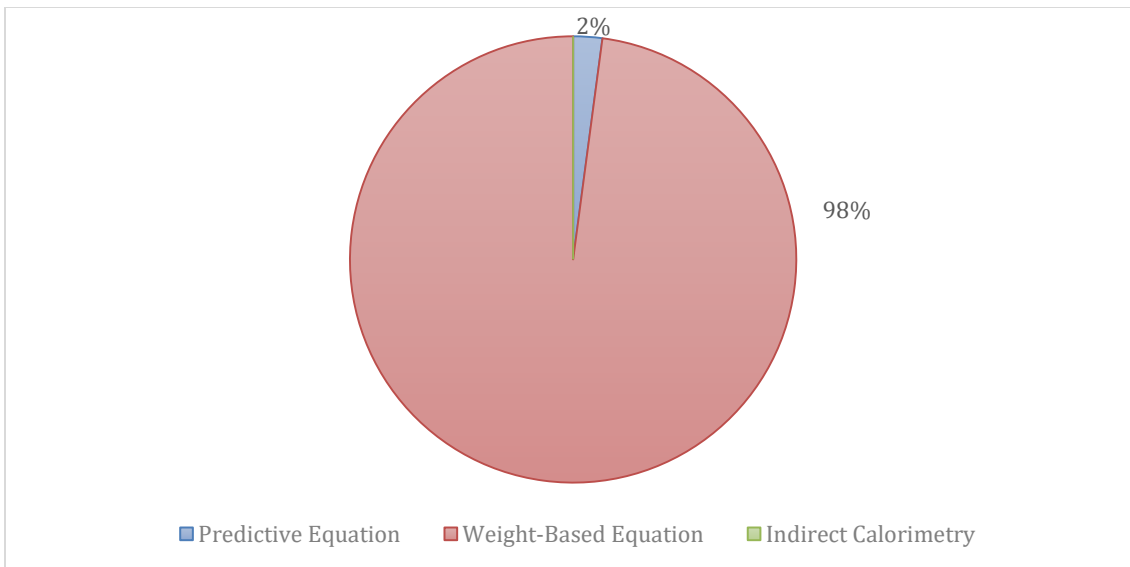
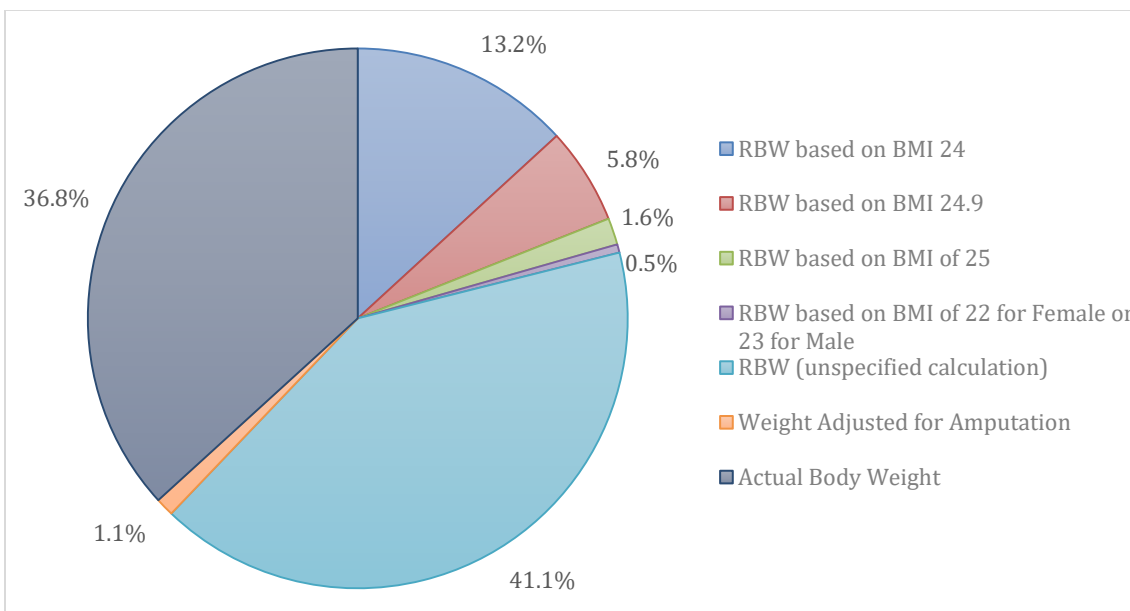


Figure 2. Method of Assessing Energy Requirements in the Initial Registered Dietitian Nutritionist Nutrition Assessment



BMI – body mass index (kg/m^2)

Figure 3. Weight Used in Estimated Energy Requirements Equation during Initial Registered Dietitian Nutritionist Nutrition Assessment

Table 3 - Energy Expenditure Equation Used during Initial Registered Dietitian Nutritionist Nutrition Assessment

Equation Used	Sample
11-14 kcal/kg; n (%)	2 (1.1)
11-16 kcal/kg; n (%)	1 (0.5)
22-25 kcal/kg ; n (%)	6 (3.2)
25-30 kcal/kg ; n (%)	167 (87.9)
30-35 kcal/kg ; n (%)	10 (5.3)
Mifflin St. Jeor Equation; n (%)	1 (0.5)
Penn State 2003b Equation; n (%)	1 (0.5)
Penn State 2010 Equation; n (%)	1 (0.5)
World Health Organization Equation; n (%)	1 (0.5)

Kcal – Kilocalories, kg – kilograms

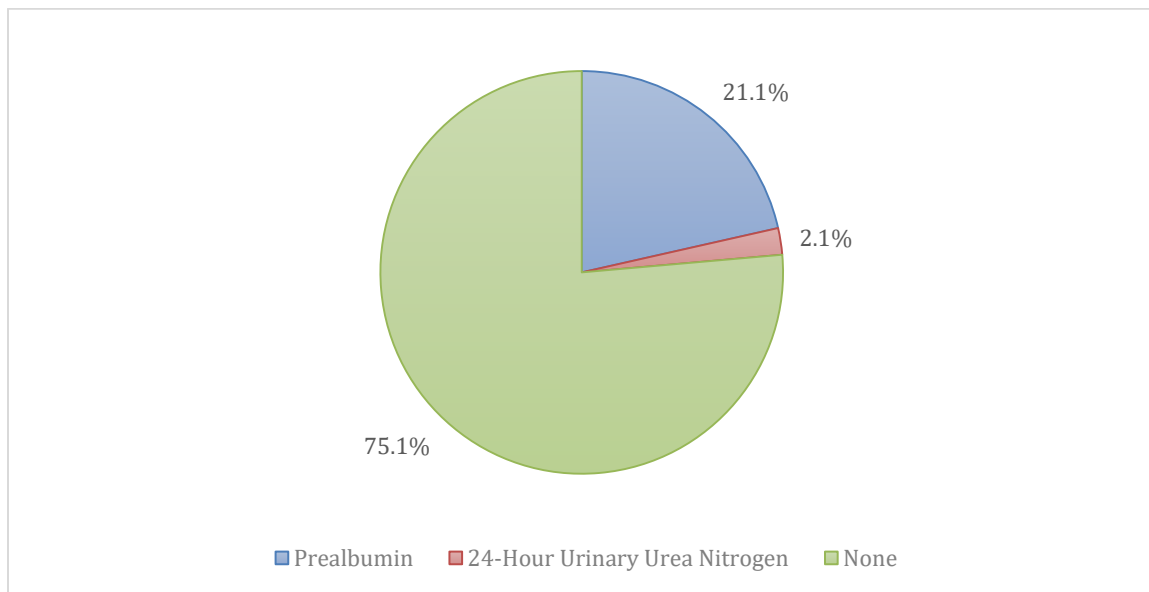


Figure 4. Laboratory Tests Recommended by Registered Dietitian Nutritionist to Monitor Efficacy of Nutrition Therapy

CHAPTER V

Discussion

The vast majority of RDNs (98%) used a simple weight-based equation during the initial nutrition assessment. Approximately 1/3 of the RDNs used the actual patient body weight (36.8%) with the remaining primarily using a recommended body weight based on a selected BMI. A total of nine different equations were used with the weight-based equation 25-30 kcal/kg used most often (87.9%). Indirect calorimetry was not recommended by the RDNs during the first two weeks of admission for any patient. RDNs recommended prealbumin to monitor nutrition status (within 2 weeks of admission) in ~20% of patients over 5 years after the 2009 recommendation.

Comparison with Previous Research and Expectations

The number of RDNs in this study using equations (instead of IC) are higher (98%) than reported by Herrington (93.4%) in 2015.¹⁰ This was surprising because Herrington's survey was distributed to both inpatient and outpatient RDNs. However, the difference in use could be attributed to study design. Some variety in the equations used in the initial nutrition assessments was expected to allow for differences in patient disease state and clinical judgement of the RDNs. We did not expect as much variety in the weights being used in these equations. Some of this variety could be attributed to the lack of specificity of the 2009 guidelines⁷. There is no information in the guidelines to suggest what weight to use in the equations. There was a need for revision leading up to the 2016 guidelines. However, there is only one sentence that addresses weights to be used in equations and it

refers to the equations for obese patients. It reads, “Use of BMI and ideal body weight is recommended for these calculations, while use of adjusted body weight should be avoided.”⁸ Even this sentence is a bit difficult to interpret as ideal, recommended, and adjusted body weight don’t have clear definitions. The 2016 guidelines did have some advantages of including more specific information related to nutrition therapy per disease state and stressed the importance of using IC. The disadvantages include the continued lack of information about weights to use in equations, as well as a gray area surrounding the overweight BMI category. Almost 1/3 of the study population fell into the “overweight” BMI category and there isn’t a clear recommendation to treat them in the normal or obese categories.

This study had a few limitations. We were unable to assess whether IC was contraindicated in patients. Additionally, many of the RDNs did not indicate the method of determining RBW. Finally, we were unable to assess whether there was a change in practice after the 2016 recommendations.

Conclusions

We observed inconsistencies in the equations, weight, and monitoring laboratories used by RDNs during nutrition assessment that can partly be attributed to a lack of specificity in the 2009 guidelines, which justifies the need for updated recommendations in 2016. However, there is still a lack of clarity in the 2016 guidelines. One clinical implication is for clinical nutrition departments to distribute the research with RDNs to ensure that the most up-to-date information is available. Of note, the new obesity guidelines that were included in the 2016 guidelines were proposed in November of 2013 in the *Journal of Parenteral and Enteral Nutrition*.³⁷ This means that during this study

period, the new obesity guidelines had been available for 1.5 years. Additionally, creating policies in the hospital that reflect the guidelines are important. For example, a policy could be made that all patients in critical care must have an IC performed within 2 weeks of admission unless contraindicated. This would mean that RDNs would not have to recommend it, but that it would automatically be conducted. Future research should include the collection of data after the 2016 guidelines were released to assess for a change in practice by RDNs following the change in recommendations.

References

1. Winkler MF, Malone AM. Medical Nutrition Therapy in Critical Care. In: Mahan LK, Raymond JL, ed. Krause's Food & The Nutrition Care Process, 14th Edition. St. Louis, MO: Elsevier; 2017:775-81.
2. Schlein KM, Coulter SP. Best Practices for Determining Resting Energy Expenditure in Critically Ill Adults. *Nutr Clin Pract.* 2014;29(1):44-55.
3. Ireton-Jones CS. Intake: Energy. In: Mahan LK, Raymond JL, ed. Krause's Food & The Nutrition Care Process, 14th Edition. St. Louis, MO: Elsevier; 2017:17-23.
4. Harris JA, Benedict FG. A Biometric Study of Human Basal Metabolism. *Proc Natl Acad Sci U S A.* 1918;4(12):370-373.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1091498/>. Accessed April 2, 2018.
5. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A new predictive equation for resting energy expenditure in healthy individuals. *Am J Clin Nutr.* 1990;51(2):241-247.
6. CI: Best Method to Estimate RMR (2010). Academy of Nutrition and Dietetics Evidence Analysis Library.
https://www.andeal.org/topic.cfm?conclusion_statement_id=251361&cat=4524. Published 2010. Accessed April 2, 2018.
7. McClave SA, Martindale RG, 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 (SCCM) and American Society for Parenteral

- and Enteral Nutrition (A.S.P.E.N.). *JPEN J Parenter Enteral Nutr.* 2009;33(3):277-316.
8. McClave SA, Taylor BE, Martindale RG, et al. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). *JPEN J Parenter Enteral Nutr.* 2016;40(2):159-211.
 9. Frankenfield DC, Coleman A, Alam S, Cooney RN. Analysis of Estimation Methods for Resting Metabolic Rate in Critically Ill Adults. *JPEN J Parenter Enteral Nutr.* 2009;33(1):27-36.
 10. Herrington H. Use of Indirect Calorimetry Among Registered Dietitians - ProQuest.
<https://search.proquest.com/docview/1756237335/abstract/49F028B6F8464FCC/PQ/1?accountid=11226>. Accessed January 7, 2018.
 11. Levine JA, Kotz CM. NEAT – non-exercise activity thermogenesis – egocentric & geocentric environmental factors vs. biological regulation, *Acta Physiol Scand.* 2005;184:309-318.
 12. Fraipont V, Preiser J-C. Energy estimation and measurement in critically ill patients. *JPEN J Parenter Enteral Nutr.* 2013;37(6):705-713.
 13. Stahel PF, Flierl MA, Moore EE. “Metabolic staging” after major trauma - a guide for clinical decision making? *Scand J Trauma Resusc Emerg Med.* 2010;18:34.

14. Mauldin K, O'Leary-Kelley C. New Guidelines for Assessment of Malnutrition in Adults: Obese Critically Ill Patients. *Crit Care Nurse*. 2015;35(4):24-30.
15. Mogensen KM, Robinson MK, Casey JD, et al. Nutritional Status and Mortality in the Critically Ill. *Crit Care Med*. 2015;43(12):2605-2615.
16. Bector S, Vagianos K, Suh M, Duerksen DR. Does the Subjective Global Assessment Predict Outcome in Critically Ill Medical Patients? *J Intensive Care Med*. 2016;31(7):485-489.
17. Neelemaat F, Meijers J, Kruizenga H, van Ballegooijen H, van Bokhorst-de van der Schueren M. Comparison of five malnutrition screening tools in one hospital inpatient sample: Comparison of malnutrition screening tools. *J Clin Nurs*. 2011;20(15-16):2144-2152.
18. Fontes D, Generoso S de V, Toulson Davisson Correia MI. Subjective global assessment: a reliable nutritional assessment tool to predict outcomes in critically ill patients. *Clin Nutr*. 2014;33(2):291-295.
19. Green Corkins K. Nutrition-focused physical examination in pediatric patients. *Nutr Clin Pract*. 2015;30(2):203-209.
20. White JV, Guenter P, Jensen G, Malone A, Schofield M. Consensus Statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: Characteristics Recommended for the Identification and Documentation of Adult Malnutrition (Undernutrition). *J Acad Nutr Diet*. 2012;112(5):730-738.
21. Norman K, Pichard C, Lochs H, Pirlich M. Prognostic impact of disease-related malnutrition. *Clin Nutr*. 2008;27(1):5-15.

22. Tobert CM, Mott SL, Nepple KG. Malnutrition Diagnosis during Adult Inpatient Hospitalizations: Analysis of a Multi-Institutional Collaborative Database of Academic Medical Centers. *J Acad Nutr Diet*. 2018;118(1):125-131.
23. Holyday M, Daniells S, Bare M, Caplan GA, Petocz P, Bolin T. Malnutrition screening and early nutrition intervention in hospitalised patients in acute aged care: a randomised controlled trial. *J Nutr Health Aging*. 2012;16(6):562-568.
24. Teitelbaum J, Weiss A, Brewster G, Leyse-Wallace R. MNT in Psychiatric and Cognitive Disorders. In: Mahan LK, Raymond JL, ed. Krause's Food & The Nutrition Care Process, 14th Edition. St. Louis, MO: Elsevier; 2017:860.
25. Chima CS, Barco K, Dewitt ML, Maeda M, Teran JC, Mullen KD. Relationship of nutritional status to length of stay, hospital costs, and discharge status of patients hospitalized in the medicine service. *J Am Diet Assoc*. 1997;97(9):975-980.
26. Brem H, Maggi J, Nierman D, et al. High cost of stage IV pressure ulcers. *Am J Surg*. 2010;200(4):473-477.
27. Foster GD, Knox LS, Dempsey DT, Mullen JL. Caloric requirements in total parenteral nutrition. *J Am Coll Nutr*. 1987;6(3):231-253.
28. Muscaritoli M, Krznarić Z, Singer P, et al. Effectiveness and efficacy of nutritional therapy: A systematic review following Cochrane methodology. *Clin Nutr*. 2017;36(4):939-957.
29. Compher C, Frankenfield D, Keim N, Roth-Yousey L, Evidence Analysis Working Group. Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review, *J Am Diet Assoc* 2006;106:881-903.

30. Costa NA, Marinho AD, Cancado LR. Nutritional requirements of the critically ill patient. *Rev Bras Ter Intensiva*. 2012;24:270-277.
31. Macdonald A, Hildebrandt L. Comparison of formulaic equations to determine energy expenditure in the critically ill patient. *Nutrition* 2003;19:233-239.
32. Kross EK, Sena M, Schmidt K, Stapleton RD. A comparison of predictive equations of energy expenditure and measured energy expenditure in critically ill patients. *J Crit Care*. 2012;27:321.e5-12.
33. Boullata J, Williams J, Cottrell F, Hudson L, Compher C. Accurate determination of energy needs in hospitalized patients. *J Am Diet Assoc*. 2007;107:393-401.
34. Frankenfield D, Smith JS, Cooney RN. Validation of 2 approaches to predicting resting metabolic rate in critically ill patients. *JPEN J Parenter Enteral Nutr*. 2004;28:259-264.
35. Frankenfield D. Validation of an equation for resting metabolic rate in older obese, critically ill patients. *JPEN J Parenter Enteral Nutr*. 2011;35(2):264–269.
36. Porter C, Cohen NH. Indirect calorimetry in critically ill patients: role of the clinical dietitian in interpreting results. *J Am Diet Assoc*. 1996;96(1):49-57.
37. Choban, P., Dickerson, R., Malone, A., Worthington, P., Compher, C., & American Society for Parenteral and Enteral Nutrition. (2013). A.S.P.E.N. Clinical guidelines: nutrition support of hospitalized adult patients with obesity. *JPEN. Journal of Parenteral and Enteral Nutrition*, 37(6), 714–744.
<https://doi.org/10.1177/0148607113499374>