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NUTRITIONAL ASSESSMENT IN CRITICALLY ILL PATIENTS

SUMMARY

Indirect calorimetry (IC) is considered the gold standard for determination of a patient's caloric needs. Controversy remains when comparing IC with weight-based equations such as the Harris-Benedict Equation (HBE). Although there is new evidence to support that the HBE may closely estimate caloric needs when multiplied by certain stress factors, there is also contradictory evidence demonstrating that the HBE can lead to either over- or underfeeding, which is associated with a multitude of complications.

RECOMMENDATIONS

- **Level 1**
 - **None**
- **Level 2**
 - **Initial estimation of caloric needs using 30 kcal/kg/day (or Harris-Benedict Equation (HBE) with appropriate stress factors) and protein needs using 1.5 gm/kg of protein per day is a reasonable and cost free alternative to indirect calorimetry (IC).**
- **Level 3**
 - **Pre-albumin is a practical and accurate marker of nutritional status due to its short half-life.**
 - **The Curreri formula should be used to estimate the caloric needs of patients with burns greater than 20% total body surface area (TBSA).**
 - **Indirect calorimetry (IC) and 24 hour urine urea nitrogen (UUN) studies should be utilized to determine the caloric needs of mechanically ventilated patients requiring supplemental nutrition for greater than 7 days.**

INTRODUCTION

Nutrition is an important, but often overlooked aspect of critical care management. During the 1990's, there was a major shift from parenteral nutrition (PN) to enteral nutrition (EN), which remains the preferred method for providing nutritional support to the critically ill given its improved patient outcome. Providing the gastrointestinal tract with nutrients directly, EN can help prevent mucosal atrophy and increased permeability with resultant decreases in bacterial translocation and priming of neutrophils and macrophages. As the importance of adequate nutrition has become evident, the ability to determine the patient's caloric and protein needs in a convenient yet accurate manner has become essential. This is important not only to prevent underfeeding, but overfeeding as well.

The fundamental goal of nutritional support is to meet the energy requirements of metabolic processes, to support the hypermetabolism associated with critical illness, and to minimize protein catabolism. Nutritional support begins with an estimation of the patients caloric requirements. The Harris Benedict Equation (HBE) is one of the most commonly used methods for estimating caloric needs or basal energy expenditure (BEE). It is calculated as follows:

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

Males: BEE = 66.5 + 13.8 (weight in kg) + 5 (height in cm) – 6.8 (age)
Females: BEE = 655 + 9.6 (weight in kg) + 1.7 (height in cm) – 4.7 (age)

These equations yield basal energy requirements that are frequently multiplied by various activity and/or stress factors to generate the patient's estimated resting energy expenditure (REE):

Stress Factors: Minor Surgery 1.2, Trauma 1.35, Sepsis 1.6, Major Burns 2.1

$$\text{REE} = \text{BEE} * \text{stress factors}$$

Some studies have demonstrated that the use of stress factors may lead to an overestimation of the patient's actual caloric needs, leading to overfeeding and unnecessary administration of nutrients. Another important consideration is the patient weight that is used for these calculations. The patient's current actual body weight may be quite elevated after a period of aggressive volume resuscitation and its use in calculations could result in overestimation of caloric requirements. Ideally, an admission weight prior to initial resuscitation should be obtained. In practice, this assessment is impractical and not normally part of the primary and secondary surveys in the acutely injured patient. An accurate measurement of body weight is an arduous task in critically ill patients with bulky dressings, catheters, monitoring wires, tubes and drains. The ideal body weight (IBW) may prove useful in such circumstances and is calculated as follows:

$$\begin{aligned}\text{IBW (male)} &= 50 + (2.3 * \text{height [in inches]} - 60) \\ \text{IBW (female)} &= 45.5 + (2.3 * \text{height [in inches]} - 60)\end{aligned}$$

Obesity poses another scenario where overfeeding may result if one uses the patient's actual body weight. Obesity is defined as an actual body weight that is greater than 120% above the patient's IBW or a Body Mass Index (BMI) >30. For all of the above reasons, the adjusted body weight (ABW) is commonly utilized for calculating energy requirements:

$$\text{ABW} = 0.25 * (\text{actual weight} - \text{IBW}) + \text{IBW}$$

A more specific method that may be used to determine caloric needs in mechanically ventilated patients is to perform indirect calorimetry (IC). This is considered the gold standard for caloric assessment. A computerized "metabolic cart" is used to collect the patient's expired gases to determine CO₂ production and O₂ consumption, which are used to calculate the REE using the Weir equation:

$$\text{REE} = [\text{VO}_2 (3.941) + \text{VCO}_2 (1.11)] 1440 \text{ min/day}$$

IC also provides the respiratory quotient (RQ = CO₂ production divided by O₂ consumption) which can be further used to monitor the adequacy of nutritional support. An RQ of greater than 1.0 suggests overfeeding and lipogenesis, while an RQ = 1.0 indicates pure carbohydrate utilization. Unlike glucose metabolism, oxidation of fatty acids requires less O₂ and produces less CO₂. Pure fat utilization produces an RQ of 0.7 and a value of less than 0.7 suggests underfeeding and ketogenesis. Mixed substrate utilization, the desired goal of nutritional support, is suggested when the RQ value falls within the 0.8 to 0.9 range.

There are several limitations to IC including the need for dedicated equipment and staff. Such measurements are costly and are for the most part limited to those patients on a mechanical ventilator. Measurements may be inaccurate in patients with conditions often encountered in the critically ill. These include patients on high levels of oxygen (FiO₂ > 0.6), high positive end expiratory pressure (PEEP), air leaks (such as bronchopleural fistulae) which may limit the ability to adequately collect and analyze expired gases, and peritoneal and hemodialysis due to removal of CO₂ across the membrane that is not measured by the indirect calorimeter. One must also consider the fact that these measurements are only a reflection of the short window of time during which the patient is being studied. In general, the patient

selected for this study should be in a stable, steady state. The patient should also be protected from noise or other stimulation.

The literature addressing the optimal method for nutritional assessment is controversial and is outlined below. It should be remembered that no specific formula has been proven to be superior to the others and that these should be considered to provide at best an estimate of the patient's initial protein and caloric needs. Currently recommendations for most surgical patients are to provide approximately 25-30 kcal/kg/day through the administration of carbohydrates (70%) and lipids (30%). Protein should not be included in these energy calculations as the intent is for the protein to be incorporated into new muscle rather than metabolized into energy.

Protein is the building block of life. Once hepatic glycogen stores are depleted, muscle protein is degraded to provide three carbon backbones for hepatic gluconeogenesis. Initially protein catabolism is resistant to the administration of exogenous amino acids and it takes weeks until a critically ill patient is found to be in a state of positive nitrogen balance. In addition to protein catabolism, exogenous protein is required for wound healing and to replace that lost in wounds and fistulae. The goal is to minimize the loss of lean body mass and as a general rule this requires anywhere from 1.0 to 1.5 gm/kg/day of protein depending on the degree of illness and injury. A severely burned patient may require in excess of 2.0 gm/kg/day to replace the large quantities of protein lost through their wounds. Another circumstance that one must consider is the patient with an open abdomen who may lose additional amounts of nitrogen through their open abdomen and temporary dressing.

There are several ways to estimate protein requirements. One simple method is to look at the ratio of non-protein calories to grams of nitrogen. A typical post-operative patient requires a ratio of 150 carbohydrate calories to 1 gram of nitrogen to prevent the use of protein as an energy source. Critically ill subjects and burn victims may require ratios below 100. Another method is to calculate the nitrogen balance following collection of a 24 hour urine specimen:

$$\text{Nitrogen balance} = \text{nitrogen intake} - \text{nitrogen output}$$

$$\text{Nitrogen intake} = \frac{\text{total protein intake (gm / day)}}{6.25 \text{ gm protein / gm nitrogen}}$$

$$\text{Nitrogen output} = \text{UUN} + 4 \text{ grams} + [1.9 * (\text{liters of abdominal fluid})]$$

where UUN is urine urea nitrogen in grams of nitrogen excreted in the urine over the 24 hour period. Four grams is typically used to estimate insensible nitrogenous losses through the skin and gastrointestinal tract. This is a very crude estimate of nitrogen balance and may not be valid in the patient with large burns or wounds. Cheatham et al showed that patients with an open abdomen lose on average 1.9 gm of nitrogen per liter of abdominal fluid. In patients with temporary abdominal dressings, this needs to be added to the insensible losses to avoid overestimating nitrogen balance which would, in turn, lead to underfeeding and inadequate nutritional support (1). A patient in positive nitrogen balance excretes less nitrogen than is being consumed and is incorporating nitrogen into newly formed protein. A patient in negative nitrogen balance excretes more nitrogen than they consume and continues to degrade muscle protein for gluconeogenic precursors.

Determining caloric and protein needs has been discussed above. Once this has been done, one then needs to reevaluate the particular nutritional regimen the patient is receiving. There are a number of markers easily obtained to ascertain whether or not the patient is being properly nourished. These include albumin, prealbumin, and transferrin. Albumin has a long half-life of 20 days making it a less desirable test. Transferrin, with a half life of 8-10 days is also of limited usefulness. Pre-albumin has a half-life of 2 days and has proven to be accurate in burn and trauma patients making it the best marker for nutritional monitoring.

Regarding burn patients, there is a large body of literature that demonstrates the inaccuracy of the HBE and the 30 kcal/kg empiric formulas in estimating caloric needs. In the 1970's, Dr. Curreri and his

colleagues developed a formula that incorporates the percentage of the body surface area burned and seems to more accurately estimate the calories necessary for a hypermetabolic post-burn response (2). The formula they developed is still in use today and is as follows:

$$\text{Curreri formula} = 25 * \text{body weight (kg)} + 40 * \% \text{ TBSA burned}$$

This formula has been found to overestimate the caloric needs in some burn patients, however, it seems to be more accurate than the other available formulas for estimating burn patient needs. The most likely reason for this is that it incorporates the percentage burn while the other equations do not.

LITERATURE REVIEW

In Support Of Indirect Calorimetry

A retrospective evaluation of the determination of energy needs was performed by Boulatta et al (3). They evaluated 395 patients who had undergone IC over the previous year. Average REE (from IC) was 1730 ± 402 in the critically ill group ($n=141$). Compared with other equations, the HBE was most accurate in the critically ill group when multiplied by a stress factor of 1.1; however, it was only accurate in 55% of patients. In the remaining 45% of the study population, the HBE either over- or underestimated the caloric needs of the individuals.

Campbell et al. performed a retrospective comparison of IC versus calculated determination of caloric needs for the critically ill using the HBE as well as the Ireton-Jones equation (4). In this study, both current body weight and ideal body weight were used for the calculated estimates. The results demonstrated that the HBE calculations differed significantly from the determinations obtained by using IC regardless of whether current body weight or ideal body weight was utilized for the calculation. Using current body weight in the HBE calculation resulted in an average caloric estimation of $77.0\% \pm 11.6\%$ of measured resting energy expenditure (MEE) (as determined by IC) while using ideal body weight in the HBE estimated $90\% \pm 16.1\%$ of MEE (as determined by IC). The Ireton-Jones equation tended to overestimate the MEE (as determined by IC) with the results being $109.3\% \pm 16.8\%$ of MEE.

Ahmad et al. performed a prospective trial to evaluate the REE (as determined by IC) of severely underweight hospitalized patients. They evaluated 14 patients using IC and compared the results to the BEE estimated by the HBE and also compared the IC results to a more simplistic method of providing the patient with 25 kcal/kg/day. There was a statistical difference between the measured caloric needs using IC and the calculated needs for both HBE (1032 ± 66 kcal/day) and the 25 kcal/kg/day formula (1023 ± 129 kcal/day) ($p < 0.0001$).

In Support Of Calculations

Davis and colleagues performed a prospective study to evaluate the need for IC in the ICU by comparing it to the HBE and other weight based calculations (6). Their study incorporated trauma and surgical patients and utilized enteral feedings in 80% of the patients. IC determined the caloric need to be 2217 ± 540 kcal/day while the HBE (multiplied by a stress factor of 1.5) and the standard weight-based formula (30 kcal/kg/day) estimated the caloric needs to be 2339 ± 497 kcal/day and 2276 ± 447 kcal/day respectively. They found no statistically significant differences between IC and the HBE or the weight based calculation of 30 kcal/kg/day recommended by the American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines. They concluded that IC is unnecessary.

A retrospective, observational study was performed in 2004 by Alexander et al (7). They evaluated 76 adult, critically ill, ventilated patients. They compared the BEE as determined by four commonly used equations with the resting energy expenditure as determined by IC. Accuracy of the equations was determined using bias and precision calculations. The HBE, when multiplied by a stress factor of 1.2, was unbiased and precise while the Ireton-Jones equation was precise, but biased. The American College of Chest Physicians' recommendation of 25 kcal/kg/day was biased and not precise. They concluded that the HBE multiplied by a stress factor of 1.2 was accurate for predicting caloric needs when compared with the results obtained from indirect calorimetry.

Faisy et al performed a prospective observational study to determine an accurate method for calculating the caloric needs of the critically ill (8). They evaluated 70 patients over a one year period using IC. These results were then compared with BEE determined using the HBE. Further comparison was performed between IC and the HBE using stress factors. They found that the REE (IC) averaged 1890 ± 404 kcal/day and the BEE determined by the HBE averaged 1399 ± 243 kcal/day. However, when the appropriate stress factors were multiplied by the BEE, the HBE results were 1817 ± 528 kcal/day which was not significantly different from the calculated resting energy expenditure as determined by IC.

Support For Prealbumin Use In Nutritional Assessment

Devota et al demonstrated that pre-albumin was a valuable and accurate marker of patient response to nutritional support (9). They evaluated 108 hospitalized patients using the detailed nutritional assessment as a reference for comparison to pre-albumin. During analysis, pre-albumin was found to be an accurate tool for assessing nutritional status.

Robinson et al. performed a prospective, observational study to evaluate the usefulness of their standard nutritional screening protocol as compared with laboratory assessment using prealbumin (PAB), albumin (ALB), and retinol binding protein (RBP) (10). 335 patients were evaluated from the medical, general surgery, MICU, SICU, and bone marrow transplant services. The screening protocol utilized a questionnaire which identified 43% of the study population to be at risk for malnutrition while PAB identified 51% to be at risk. It took an average of 3 days for the nutritional assessment utilizing the questionnaires in 69% of those considered at risk while PAB took an average of 3 days to identify 94% of those considered at risk. This difference in percentages was of statistical significance therefore demonstrating the worth of PAB in evaluating one's nutritional status.

SUMMARY

Nutritional assessment remains an important tool in treating critically ill patients. Accurate determination of caloric needs is essential to obtaining the full benefits of nutritional therapy and aids in preventing the problems associated with underfeeding (infection, poor healing) as well as overfeeding (failure to wean the ventilator). There is still controversy regarding what the best method is to determine how to accurately estimate the caloric needs of the critically ill patient. There is a large amount of information that spans at least thirty years regarding the use of IC in determining one's caloric needs. The use of various equations has also been studied for many years. With more and more studies demonstrating the accuracy of equations, more and more institutions are abandoning IC due to cost and convenience and instead utilizing equations to estimate initial caloric requirements. IC may, however, be of value in mechanically ventilated patients who continue to remain critically ill and require supplemental nutritional support.

The literature supports utilizing prealbumin levels in patient nutritional assessment as it has a short half life compared to albumin and retinol binding protein and is relatively inexpensive. Therefore, patients requiring prolonged hospitalization should undergo nutritional evaluation using prealbumin levels. The exact frequency of these measurements has yet to be determined. The current literature supports a practice of weekly prealbumin levels.

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