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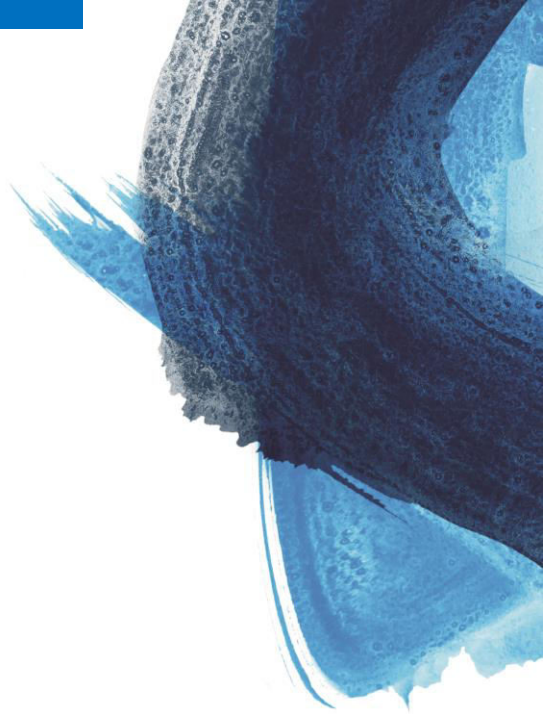

Are Complex Predictive formulae Superior to Kcal/kg when Estimating Energy Requirements in the Critically Ill?

Author: Pete Turner, Nutrition Support Dietitian, The Ulster Hospital

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A Debate at BAPEN 2017

The 2017 BAPEN Annual Conference was held in Birmingham in November. Of particular interest to dietitians was a symposium organised by the Parenteral and Enteral Nutrition Group (PENG) of the BDA entitled **"Estimating Nutritional Requirements – when is less more?"**

The new PENG "Pocket Guide to Clinical Nutrition" is due for launch in Spring 2018 and will feature among others a completely new adult requirements section. Dr Elizabeth Weekes detailed the huge amount of work done by five dietitians undertaking five systematic reviews to develop an evidence based approach for estimating nutritional requirements. One interesting feature is that stress factors will no longer be included due to inconsistencies in the literature and the confusion caused by attempting to apply them in clinical settings. The use of equations to predict energy expenditure is also controversial. One area where this is particularly true is critical care as predictive formulae can be compared to measured energy expenditure using indirect calorimetry in ventilated patients. In order to highlight these issues the motion "Complex predictive formulae are superior to kcal/kg in estimating energy requirements of critically ill adults" was debated by Ella Segaran, critical care dietitian from Imperial NHS Trust London and myself.

Ella argued in favour of using complex formulae. She started by quoting a paper by Arabi et al[1] which states that measuring or estimating energy expenditure is a key part of the patient's treatment and asks the question 'what is the optimum method?' Ideally a predictive formula would incorporate age, gender, muscle mass, disease, illness severity, surgery, paralysing agents, temperature, ventilator settings , physical activity and pain. Furthermore, it is necessary to identify safe, minimal and maximal amounts for the different nutrients and at the different stages of acute illness to avoid under and overfeeding[2]. These amounts might be specific for the different phases in the time course of a disease [2] so the optimum formula would take this into account. Using the frequently quoted value of 25kcal/kg usual weight for estimating intensive care unit (ICU) patient's requirements recommend by the American College of Chest Physicians[3] may not be ideal for the following reasons : It is a rule of thumb with unclear origins, the term usual weight is undefined and it does not encompass extremes in weight, age or patient type.This may lead may to poor predictive value with the risk of over or underfeeding.

Several ICU specific formula have been developed, including Pen State (PSU), Faisy, Brandi, Swinamer, Ireton Jones and Toronto. The PSU (m) is a modified version of the Mifflin St Joer equation that includes temperature and minute ventilation. It demonstrated good correlation with measured energy across all groups of ICU patients in a study by Frankenfield[4], with 67% accuracy (≤ 10% measured energy expenditure) versus 35% accuracy for 25kcal/kg. In 13 patients

Frankenfield demonstrated that daily repetition of PSU (m) correlated better with the daily fluctuations in measured energy expenditure than the static value of 25kcal/kg. The conclusions were all predictive equations have an element of inaccuracy compared to IC but, the PSU (m) equation appears to be more precise than 25 kcal/kg. PSU (m) is designed to be used in mixture of ICU patients, including obese & elderly. This helps you think about the clinical parameters and track EE over the duration of critical illness.

It was then up to me to outline the case for Kcal/kg. I started by quoting the results and conclusions from recent studies, in high impact peer reviewed journals, of predictive formulae. Tatucu-Babet [5] reviewed 18 studies comparing 13 equations including PSU (m) with measured energy expenditure in mechanically ventilated adults and concluded that "large discrepancies exist between predictive equation estimates and indirect calorimetry (IC) measurements in individuals and groups". Rousing[6] compared several equations including PSU (m) to IC in a group of critically ill adults and found that "all predictive equations were accurate in less than 50% of patients with an RMSE ≥15%" leading to the conclusion "this study confirms the inaccuracy of predictive equations". De Waele[7] compared several equations including PSU (m) in a large group of critically adults and found "Calculated values correlated very weakly with IC – derived measurements", going on to conclude "In critically ill adults, measured REE poorly correlated with measured values , regardless if what formula was used". De Waele looked at the equations in specific groups of patients such as age and BMI. PSU (m) was one of the better equations, but showed at best only modest correlation (R^2 0.52) in the age group 18-64, poor correlation (R^2 0.32) in age 65 - 79 and very poor correlation(R^2 0.14) in patients over 80yrs. For BMI PSU (m) showed virtually no correlation whatsoever (R^2 0.01) in the <18.5 kg/m^2 group, poor correlation (R2 0.37) in BMI 18.5 – 29.9kg/m^2 and modest correlation (R^2 = 0.52) in BMI >30kg/m^2. This study suggests PSU (m) should not be used at all in low BMI patients – a group of special interest to dietitians. One key point that comes out of all the studies is that although some equations show modest correlation in groups, there can be a large variation in individuals leading to significant errors in specific patients.

The previously mentioned study by Franekenfield[4] who developed the PSU (m) appears to be the only one that has shown a good correlation with measured energy expenditure. A key point about this study is that they had an accurate dry weight for each patient. How often do we have the luxury of an accurate dry weight in a UK or Republic of Ireland (ROI) ICU? Probably very rarely and in practice patients are often not referred to us until they have a significant degree of oedema from resuscitation when weighing them so carrying out anthropometry is more or less pointless. Both weight and height are required for PSU (m) . Yet, studies have confirmed the inaccuracy of estimated weights and heights in ICU patients[8]. The surrogate methods of determining height are not precise, for example ulna length has a standard error of 4.6cm – enough to make a significant

difference in a calculation. It is highly illogical to use estimated weights and heights in complex calculations and unwise to assume the answer you get has any degree of accuracy. In the absence of an accurate dry weight, using Kcal/kg estimated dry weight is probably the most sensible option, with the realisation that all it gives you is a starting point and monitoring and adjustment are the crucial factors. Looking for signs of over and underfeeding and adjusting the energy prescription according to the clinical judgement of a skilled ICU dietitian is far more important than any complex equation.

Another point to bear in mind is the fact the PSU (m) is a modified version of the Mifflin St Jour equation which was developed in a group of 498 obese and non-obese Americans from mixed ethnic backgrounds. It may be applicable to the population in Frankenfield's U.S. studies, but a potentially flawed assumption is that it will accurately predict energy expenditure in a typical ROI or UK population.

Contrary to Ella's argument, Kcal/kg does not always refer to the static value of 25kcal/kg suggested by ACCP [3]. For example the ESPEN 2006 guidelines for enteral nutrition in the critically ill[9] were ahead of their time as they recognised need to change energy prescription through the phases of ICU admission. They state "avoid excess of 20 – 25kcal/kg in the initial phases of critical illness but provide 25-30kcal /kg in the anabolic flow phase". They also gave specific kcal/kg recommendations for low BMI. Using clinical judgement to recognise the changing phases of critical illness by looking at factors such as hyperglycaemia, insulin requirements , inflammatory markers, ventilation, and possibly prealbumin [10] and adjusting energy levels is a key role for the ICU dietitian. Anyone can plug figures into an equation and work out a feeding rate. The PSU (m) is already included in a company's app which is just one step away from building it into an ICU computer system such as ICIP and making the dietitian redundant.

Several large studies that indicate the safe levels of feeding in the different phases of critical illness have published their findings in Kcal/kg. The EPANIC study[11] showed that giving 30 – 35kcal from enteral nutrition (EN) and parenteral nutrition (PN) in the early phases of critical illness was harmful. The CALORIES[12] trial found that giving slightly less than 20kcal/kg in the early stages did not lead to poor outcomes with PN compared to EN, indicating that it is the amount of nutrition not the route of delivery that is important. This was confirmed in a review by Elke[13] who found that PN only led to poor outcomes when large amounts were given early. Heidegger[14] demonstrated that building up to around 28kcal/kg later in days 4 – 8 was favourable. Compher[15] in a study of 5,672 ICU patients found there was no difference in morbidity or mortality when complex formulae including Ireton-Jones were used compared to Kcal/kg but there were improved outcomes when more energy was given later in ICU stay. Broadly speaking the trend is for less in the acute phase and more in recovery. Complex formulae are designed to estimate

energy *expenditure* which may not equate to *requirements*. It has become clear that we may need to feed below energy expenditure in the very early stages of critical illness and since equations like PSU (m) include factors like temperature and minute volume using them risks giving more in metabolically stressed phases and less in recovery.

Ending on a controversial note it was suggested that some equations have an almost mythical status among dietitians and because of this some practitioners may assume they are accurate and fail to monitor and adjust accordingly.

Kcal/kg used with the monitoring and adjustment of an expert dietitian won the audience vote but in the subsequent discussions involving the panel and audience the following key points were agreed: All methods of estimating requirements in all patient groups including the critically are flawed - they just give a starting point.UUltimately, monitoring and adjustment are more important. Dietitians need to be aware of the limitations of all methods of estimating requirements and promote the importance of their clinical judgement. Although kcal/kg cannot be considered the definitive way of estimating requirements on ICU, it may be the most sensible method of getting a starting point when only estimated weights and heights are available. The PSU(m) may be a good option on ICU where an accurate height and weight are available but it still only gives a starting point. When using it consider a cross check with Kcal/kg to see if your energy prescription is in the ranges suggested as being optimal in recent large trials. In practice experienced dietitians probably use a variety of methods with their energy prescription being a combination of these and clinical judgement.

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