A Different Approach to the Nutritional Therapy in Intensive Care Units: Nutrition Software (ICNUS)

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Critically Ill Patients and Stress Response

Critically ill patients have complex treatment needs, often with multiple organs affected. Critically ill patients are a heterogeneous population, which includes patients with traumatic injuries (e.g. injuries to the skeletal system, brain, thorax, or abdomen) or burns, systemic infections, surgical complications (e.g. major blood loss or respiratory failure) and multiple organ failure. However, a common feature of the most critical illnesses is that they all give rise to severe metabolic stress, and many critically ill patients often develop systemic inflammation. In addition, they also have increased metabolic requirements; therefore, the need for a nutritional support must also be considered (1, 2).

In critically ill patients, the stress response directly influences neuroendocrine function. Changes in secretion of numerous hormones/neurotransmitters, such as acetylcholine, growth hormone and cortisol, combine to increase the body's basal metabolic rate, wherein substrates are mobilised to release energy sources (3-7). Hypercatabolism triggered by conditions of severe stress therefore increases the body's requirement for energy and protein. The increased metabolic requirements of critically ill patients are likely to accelerate the development of malnutrition, which must be considered when managing their treatment strategy (7).

Compared with healthy individuals, the protein turnover is increased and more often than not, dietary protein intake is considerably reduced. Under conditions of stress, body proteins are broken down rapidly, and urinary nitrogen excretion is increased beyond normal levels. Since amino acids released from the breakdown of protein in the muscles, bones and skin are used to support, in part, to increase synthesis of proteins involved in the stress response (e.g. immunoglobulins, acute phase proteins, fibrinogen and albumin), at the whole-body level, a negative nitrogen balance occurs. Therefore, owing to catabolism in combination with a lack of physical activity and the hormonal milieu, critically ill patients may lose lean body mass (4, 8). An international observational study has shown that an additional 1000 Kcal nutrition provision results in an improved 60-day mortality and higher ventilator-free days (9).
Within the intensive care unit (ICU), patients with different pathologies have different protein requirements and elevated nitrogen excretion. Indirect calorimetry (IC) measurements have shown that the resting metabolic rate is also increased in patients who have undergone surgery, sustained trauma or burns, or with sepsis (10).

**Intensive Care Nutrition Software**

Nutritional support is provided along with intensive organ support modalities in intensive care patients. Our biggest asset in planning the therapy and support is careful observation of the patients. In the presence of severe, life-threatening problems, these observations often require usage of multiple equipment and devices simultaneously. To assess invasive blood pressure monitoring, electrocardiography (ECG), pulse rate, central venous pressure, peripheral oxygen saturation (SpO₂), end-tidal CO₂ partial pressure (P\textsubscript{ETCO\textsubscript{2}}), body temperature, intracranial pressure/cerebral perfusion pressure, intra-abdominal pressure and urine output, we need devices, such as bedside monitors, respiratory mechanics measurements of the ventilators, metabolic monitors, pulse-wave analysis units, hemofiltration units and many from a broad spectrum.

The evaluation and analysis of multiple forms of data from this wide range of devices determines our approach in therapy and support. The process of transcribing and evaluating this data on paper by support staff, nurses and doctors in the ICU may be time consuming, particularly in patients with a significantly long length of stay.

The use of medical software specifically designed for ICU greatly improves the assessment of the data to enhance the quality of support and therapy for the patients and to reduce the workload of nurses and physicians. Most importantly, it facilitates to improve the management of time and workflow for the benefit of the patients.

The bedside computerised information system (iMDsoft-Metavision) used in our ICU for almost 2 years has helped us ensure paper-free patient management. Every as...
pect of nutrition should be carefully observed to facilitate an efficient nutritional support. To determine the nutritional regime, to achieve the target of energy-level, to correct potential errors, to use Nutrition Risk in Critically Ill (NUTRIC) score (11) for reducing potential hazards and to assess the risk of malnutrition we concluded that a different approach was needed and thus developed and implemented Intensive Care Nutrition Software (ICNUS) with a new window on the screen (Figure 1).

The question was how to provide accurate information on energy/protein balance and to detect the risk of malnutrition and related complications at the earliest. ICNUS development was performed in a step-by-step manner. Within a time (minutes, hours and days) frame, we collected all caloric sources continuously, digitally checked for errors in data from our devices, corrected them and day by day enriched our experience with more precise and highly accurate nutritional measurements and evaluations. By using and developing ICNUS, we achieved our final goal where we could statistically analyse the complete stored nutritional status of all our patients.

**Energy (Kcal) Requirements**

The caloric requirements of an individual can be predicted mathematically using various formulae (12, 13); however, it is most accurately assessed by measuring oxygen consumption \( (\text{VO}_2 \text{ mL min}^{-1}) \) and carbon dioxide production \( (\text{VCO}_2 \text{ mL min}^{-1}) \) and subsequently analysed using the Weir formula to calculate the energy expenditure (14). With regard to patients in the ICU, 25–30 kcal kg\(^{-1}\) may be appropriate as the daily caloric requirement (15-17). An observational study showed that reaching clearly defined targets for energy and protein was associated with a decreased hazard ratio of death (18).

The caloric provision can be defined by evaluating the body mass index (BMI), whereby patients with a BMI of <25 kg m\(^{-2}\) and >35 kg m\(^{-2}\) can benefit from hypercaloric feeding and those with BMI from 25 kg m\(^{-2}\) to <35 kg m\(^{-2}\) cannot benefit (16). The strategy used for the implementation of a nutritional support/therapy in our ICU for the critically ill is different regarding the mechanically ventilated and non-ventilated patients.

ICNUS initiates at 07.00 AM every day and collects the caloric need using the arithmetic mean of the Harris–Benedict

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**Energy Calculation**

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<th>Total</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrison multi Fibre</td>
<td></td>
<td></td>
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<tr>
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<tr>
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<td>Impact Glutamin</td>
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<tr>
<td>Isosource Energy</td>
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<td></td>
<td><strong>1537.92 kcal/day</strong></td>
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**Protein Calculation**

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<td>96</td>
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<td>Kabiven Santral</td>
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</tr>
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<td>1392</td>
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</tr>
<tr>
<td>Omegaven</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>67.2 g/day</strong></td>
</tr>
</tbody>
</table>

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**Figure 2. Window for the planning of energy provision using caloric content of different nutrients**

**Figure 3. Window for the planning of protein provision using protein content of different nutrients**
Schofield formulae. The follow-up of the daily caloric need is continuously shown on the screen in real time on a minute and hourly basis (Figure 1).

There is no doubt that the best way to avoid underfeeding in ICU patients is to own and use an accurate tool: the IC device. The general approach must be to reach the energy needs and cover the energy target as close as possible (Deltatrac II is no more produced by the Datex company but E-COVX is a new version of Deltatrac produced by the same company.). In our ICU, the EngströmCarestation ventilator is used; however, we have the opportunity to use the IC (E-COVX gas analysis module) and measure EE, VO₂, VCO₂, and RQ continuously, and all the data are shown and collected in ICNUS within the same periods.

All EN and PN formulas used in the Turkish market were classified within their composition and uploaded to ICNUS as lipid, carbohydrate and protein energy (Kcal) and gram contents (Figures 2 and 3). The data of the fluids and nutrients administered are received from the infusion pumps (B Braun) directly and transferred to the software’s nutrition window with each nutrient supply in Kcal and as per details.
required. If the patient is under mechanical ventilation, the EE is reflected via the IC, but the Harris–Benedict + Schofield (mean Kcal/2) equation values are calculated automatically to visualise the differences between each measurement (Figure 4). The nutritional therapy goal is followed with the calculated energy achieved in percentage as a ratio to the energy provided (Figure 5).

Protein (g) Requirement

Protein requirements in critical illness are increased and ESPEN guidelines recommend an amount of 1.3–1.5 g/IBW. However, some situations, such as obese or oedematous conditions of the severely ill patients, give raise to over-feeding of protein. Therefore, the use of the BMI parameter seems to avoid this situation. ICNUS calculates the protein requirement automatically using the actual body weight (ABW) for the adults using BMI between 20–30 kg m⁻² and the height for BMI <20 kg m⁻² and >30 kg m⁻² using the following equations (11, 17):

- Adults: 20<BMI<30=1,2×ABW (kg)
- Adults: BMI<20=24×height (m)²
- Adults: BMI>30=33×height (m)²

The protein provision is calculated automatically using ICNUS equivalent to the patient’s nutritional requirement without any error, and during administration, the pumps data are observed continuously on the screen. The protein provision is followed with the calculated protein achieved in percentage as a ratio to the protein provided (Figures 4 and 6).

Nutritional Risk in the Critically Ill Score

The NUTRIC risk assessment score (19) and other tools (20) can possibly identify critically ill patients who benefit the most from the nutritional therapy. Unfortunately, the majority of critically ill patients experience harm because they do not receive adequate nutritional intake (21).

ICNUS automatically calculates [without the IL-6 variable, which does not have a strong impact on the NUTRIC score (22)] the data for the NUTRIC scoring system on a daily basis together with APACHE II and SOFA scores and other

![Figure 6. Graph showing in a period of time how the targeted protein provision is reached](image)

![Figure 7. SOFA score calculation obtained from the ICNUS](image)
related (age, number of comorbidities and ICU stay days) parameters in each patient (Figures 7-9). During the ICU stay, daily monitoring of NUTRIC scores gives us the chance to focus more on the provision of the adequate amounts of energy and protein for the calculated energy target when considering mortality as an outcome. ICNUS provides all the details for the accurate information on energy and protein provision and balance in critically ill patients and may allow for the early detection of malnutrition and its complications (Figures 4 and 10).

**Fluid Balance and Weight**

One of the most important observations of the critically ill patients in the ICU is the close monitoring of fluid and electrolyte balance. The clear evidence of fluid administration is that it has life-saving intervention in severe hypovolemia, dehydration and septic shock. However, it can be detrimental and life-threatening when administered in high volumes, and we have to stress the importance that distribution within the body of critically ill patients is unpredictable due to glyco-calyx injury and disturbances of lymphatic flow, fluids are leaving vascular bed and escape to the interstitium (23).
In such situations, changes of weight may arise and therefore errors in the calculations of the energy and protein requirements may be introduced (11). Macro- and micronutrients are administered with fluids, and many other infusions, such as antibiotics, inotropics, vasoactive drugs and electrolytes, given for other purposes are also added to the nutritional flu-
id amount. ICNUS realises with a high accuracy the fluid intake via the connection of the electronic infusion pumps (Braun), reflecting all the needs as fluid volumes entering the body classified as intravenous (IV) fluids, medications, PN and EN solutions and antibiotics (Figure 1).

Another important point is the patient’s weight and the weight gain/loss during long stays in the ICU (Figures 11 and 12). In our unit, the patients are weighed every morning at 07.00 AM at the bedside (Hill-Rom ICU beds) and compared with the antecedent day’s weight data. ICNUS can give the opportunity to place the patient in a steady state with the collected precise data of nutritional therapy, body weight and fluid balance. When the patient is discharged from the unit we have an accurate overview of the weight during the ICU stay (Figures 4, 11 and 12).

One of our nutritional therapy goals is to follow the relationship between cumulative fluid and weight balance. Considering data from these two parameters, we can estimate the insensible loss at patient discharge (Figures 4, 12 and 13).

Experienced clinical nutritionists will aim to individualise therapy to the specific needs of their patients by considering the ICU conditions. But our experience has shown that in the majority of these patients, it seems impossible to achieve the targeted caloric and protein needs for the first 2–4 days, and negative energy and protein balance is inevitable (Figures 5 and 6).

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**References**


