Long-term Measurements of Energy Expenditure in Severe Burn Injury

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Abstract. The objective of this study was to evaluate resting energy expenditure (REE) in spontaneously breathing and artificially ventilated burn patients during the entire intensive care period. In 27 patients with 51 ± 20% body surface area burned (BSAB) the REE was determined via indirect calorimetry. Three groups were formed according to the mortality prognosis index of Zawacki et al. In groups A, B, and C the predicted mortality rates were <20%, 20% to 80%, and >80%, respectively. The frequency of acute respiratory distress syndrome (ARDS), sepsis, renal failure, and mortality increased from group A toward group C. The REE test revealed wide individual variation and was usually overestimated by all tested formulas. The mean REE was comparable in groups A, B, and C during the first 20 days (49 ± 16% vs. 59 ± 21% vs. 57 ± 18% above the REE calculated by the Harris-Benedict equation, or HBEE). The REE of patients in groups A and B declined after this period, whereas the long-term ventilated patients in the prognostically unfavorable group C showed a high REE up to the 45th day, usually accompanied by severe organ dysfunction and major metabolic disorders. During this time a nutritional regimen meeting the actual REE could not be achieved. In the clinical situation when indirect calorimetry is not available, REE can be stated to be 50% to 60% above HBEE in patients with >20% BSAB for at least 20 days. Expecting a stable clinical course in patients with a predicted mortality of <20% (group A), oral nutrition usually seems sufficient after a short period of artificial nutritional support (1 week). Patients with a predicted mortality of more than 20% have a complication-burdened clinical course and a prolonged period of ventilation (groups B and C). These patients need parenteral and enteral nutrition for at least 20 days after trauma to prevent severe malnutrition.

Burn-related trauma represents one of the severest and most complication-ridden types of injury the body can sustain. Depending on the intensity of the trauma, hypermetabolic and catabolic states can persist for several weeks and even months [1, 2]. In this context, nutritional therapy plays a key role in the overall strategy for managing the burn patient. Numerous nutritional formulas have been developed to meet the high resting energy expenditure (REE) of the burn patient [3–6]. Measurements of REE by indirect calorimetry indicate that the formulas used to estimate REE are usually inadequate [2, 7, 8]. Previous studies that applied indirect calorimetry to burn patients showed marked differences with regard to patient populations and periods and frequency of measurements [9]. There is a paucity of long-term studies on REE and data about REE of ventilated burn patients. This study was conducted to evaluate REE in ventilated and spontaneously breathing burn patients during the entire course of intensive care.

Materials and Methods

Patients

A group of 27 male patients were enrolled in a prospective study. The inclusion criteria were second to third degree burn injuries of ≥20% body surface area burned (BSAB), age between 18 and 65 years, and admission to the intensive care unit (ICU) 48 hours after trauma at the latest. Exclusion criteria involved the presence of any preexisting metabolic disorders and artificial ventilation with an inspiratory O2 concentration of more than 60%. Measurements of REE above this limit are less reliable.

The patients were classified according to the mortality index of Zawacki et al., which accounts for factors relevant to the trauma, such as age, BSAB, third degree BSAB, and the patient's pulmonary status (prior pulmonary disease, abnormal PaO2, airway edema) [10]. We set random limits to classify the groups:

Group A: predicted mortality < 20%
Group B: predicted mortality 20% to 80%
Group C: predicted mortality >80%

After the patient was admitted to the hospital, the wound was débrided during general anesthesia. Bronchoscopy was performed if inhalation trauma was suspected. Fluid substitution with Ringer’s lactate during the shock phase was given according to the Parkland formula [11]. The burn wounds were treated with topical silver sulfadiazine or iodine PVP. Deep second and third degree burns were excised early and grafted with autologous or heterologous split-thickness grafts.

Sepsis was diagnosed when four of five of the following criteria were detected: hyperthermia (> 38.5°C) or hypothermia (< 35.5°C), tachycardia (> 100/min) in conjunction with hypotension (systolic pressure < 100 mmHg), tachypnea (> 25/min) or hypoponapnia (PaCO2 < 32 mmHg), leukocytosis (> 15000/mm3) or leukopenia (< 5000/mm3), and signs of organ hypoperfusion (serum lactate > 1.6 mmol/L, oliguria < 30 ml/hr, acute alteration

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in mental status). The presence of an infectious focus (e.g., wounds, catheter, blood cultures) confirmed the diagnoses of sepsis whenever possible. In septic patients invasive measurements of total peripheral resistance, cardiac output, and capillary wedge pressure was performed to monitor the therapy with inotropic or vasopressor agents.

Acute renal failure was diagnosed when serum creatinine level exceeded 3 mg/dl and the patient required hemofiltration. Acute hepatic failure was defined as an elevation of total serum bilirubin > 2 mg/dl and glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) to twice the normal range.

The study was approved by the local ethics committee and was conducted according to the principles established in the Declaration of Helsinki.

**Nutritional Regimen**

Enteral feeding via a nasogastric tube was initiated as early as possible after admission using a commercially available liquid formula (Osmolite; Abbott, Wiesbaden, Germany). Enteral feeding was combined with parenteral nutrition starting on the first postburn day. Blood glucose levels were kept to a maximum of 12 mmol/L by administering glucose of not more than 5 to 6 g/kg daily. If needed, insulin up to 4 IU/hr was administered intravenously. Parenteral amino acids (Thomaeamin N 15%; Delta-Pharma, Pfullingen, Germany) were given to achieve a total amino acid supply of 1.5 to 2.0 g/kg daily. A dosage of up to 1.5 g/kg daily was established for the administration of fat emulsions (Lipoveno¨s 10% and 20%; Fresenius, Bad Homburg, Germany). In patients breathing spontaneously last only 30 minutes because the hood was not tolerated longer. Indirect calorimetry was performed daily during the first postburn week and twice a week thereafter.

**Biochemical Parameters**

Serum glucose, urea, creatinine, bilirubin, GOT, GPT, gamma-GT, triglycerides, amylase, lipase, pseudocholinesterase, alkaline phosphatase, free fatty acids, lactate, and pyruvate were measured. The 24-hour urine creatinine, urea, and total nitrogen (Mikro-Kjehldahl) were assayed. All laboratory parameters were determined daily during the first postburn week and twice a week thereafter.

**Statistics**

We used the SAS statistics program to analyze the statistical data. The discrete variables were evaluated using Fisher’s exact test. For analyzing the course parameters, we combined the data from the individual patients up to postburn day 65 into 13 five-day blocks, the means of which were used for statistical comparison. The patient groups were statistically compared with regard to the course parameters initially using the Kruskal-Wallis test. If significance was achieved, a pair comparison was conducted using the Mann-Whitney U-test. Data are presented as means and standard deviations. Because the patient population declined over the course of the study owing to recovery or death, we selected the median with the upper and lower quartiles for the graphic illustrations as a more reliable measure.

**Results**

**Patient Population and Clinical Course**

In groups A, B, and C the predicted mortality corresponding to Zawacki et al. was 8.8 ± 6.8%, 45 ± 10.8%, and 96 ± 6%, respectively. Age, BSAB, third degree BSAB, and incidence of inhalation injury increased from group A toward C. The worse the prognosis index, the higher was the frequency of sepsis and multiple-organ failure. The periods of ventilation, artificial nutrition, and ICU stay increased as a function of the poor prognosis index (Tables 1, 2).

### Table 1. Patient population.

<table>
<thead>
<tr>
<th>Group*,**</th>
<th>Predicted mortality (%)</th>
<th>Age (years)</th>
<th>Burned BSA (%)</th>
<th>3° burned BSA (%)</th>
<th>Inhalation injury</th>
<th>HBEE (kcal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n = 8)</td>
<td>8.8 ± 6.8 (0–18)</td>
<td>27.0 ± 5.7</td>
<td>35.4 ± 9.2</td>
<td>6.6 ± 9.3</td>
<td>0/8</td>
<td>1766 ± 133</td>
</tr>
<tr>
<td>B (n = 10)</td>
<td>45.0 ± 10.8 (27–59)</td>
<td>39.0 ± 5.7</td>
<td>42.7 ± 13.4</td>
<td>11.8 ± 16.1</td>
<td>5/10</td>
<td>1852 ± 184</td>
</tr>
<tr>
<td>C (n = 9)</td>
<td>96.0 ± 6.0 (81–100)</td>
<td>42.0 ± 7.5</td>
<td>74.1 ± 11.9</td>
<td>42.4 ± 26.3</td>
<td>7/9</td>
<td>1883 ± 165</td>
</tr>
</tbody>
</table>

Data are given as mean ± standard deviation (range).

BSA: body surface area (m²); HBEE: calculated resting energy expenditure by the Harris and Benedict formula.

*p < 0.05 (A vs. B, A vs. C, B vs. C); **p < 0.05 (A vs. B, A vs. C).