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Applied nutritional investigation

Effects of intraoperative nutrients administration on energy expenditure during general anesthesia

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ABSTRACT

Objectives: Recent reports have shown that intraoperative infusions of glucose and amino acids exert anticatabolic effects. The appropriate dosages of these amino acids and glucose during general anesthesia remain unknown.
Methods: Patients who underwent esophagectomy for thoracic esophageal cancer were infused with acetated Ringer's solution that contained glucose and amino acids (B1 group [10 patients]: glucose, 3 g/h; amino acids, 1.2 g/h; B2 group [12 patients]: glucose, 4.5 g/h; amino acids, 1.8 g/h) or did not contain glucose and amino acids (C group, 10 patients). The measured energy expenditure was measured by indirect calorimetry. Nitrogen balance was measured during the anesthesia, and the lengths of the hospital stay were recorded.
Results: Resting energy expenditure (B1: 1230 ± 228; B2: 1317 ± 282; C: 1012 ± 153 kcal/h; B2 vs C, $P < 0.05$) and nitrogen balance (B1: −1.78 ± 0.78 g; B2: −0.85 ± 0.98 g; C: −2.94 ± 2.4 g; B2 vs C, $P < 0.05$) differed significantly between the B2 and C groups. The lengths of the hospital stay differed between the B2 and C groups (B1: 29 ± 15 d; B2: 18 ± 6 d; C: 37 ± 27 d; B2 vs C, $P = 0.06$).
Conclusions: The administration of amino acids and glucose increased measured energy expenditure, alleviated nitrogen balance, and may decrease the length of the hospital stay.

Introduction

The physiological benefits of the administration of exogenous nutrients during general anesthesia remain unclear. Recent reports have indicated that intraoperative infusions of glucose and amino acids exert anticatabolic effects [1]. Therefore, perioperative nutrient administration should confer considerable benefits. Nevertheless, the appropriate dosages of amino acids and glucose that need to be administered during general anesthesia remain unknown. Underfeeding causes respiratory muscle dysfunction, impairs wound healing, and increases the risk of bloodstream infection [2–5], whereas overfeeding causes metabolic disturbances and organ (hepatic and respiratory) dysfunction [6,7].

The objectives of this study were to determine the measured energy expenditure (mEE) and nitrogen balance of patients during surgery under general anesthesia, with or without the administration of amino acids. We prospectively identified the effects of amino acid and glucose infusion on the postoperative outcomes.

Methods

This single-center, prospective observational study was approved by the Ethics Committee at Tohoku University Hospital. Written informed consent was obtained from all 32 patients enrolled in the study. We registered our clinical trial (UMIN000017393).

Thirty-two patients who underwent esophagectomy for thoracic esophageal cancer were divided into three different groups. Patients, nurses, and surgeons were unaware of whether amino acids or acetated Ringer's solution was given [8]. Otherwise, this study was not blinded, and participants were not randomly assigned. There were no malnourished patients. In the B1 group, 10 patients were infused with 3 g/h glucose, 1.2 g/h amino acids (BFLUID, Otsuka Pharmaceutical Factory Inc., Tokushima, Japan), and acetated Ringer's solution. In the B2 group, 12 patients were infused with 4.5 g/h glucose, 1.8 g/h amino acids, and acetated Ringer's solution. In the C group, patients were infused with acetated Ringer's solution. From the time that single-lumen tube ventilation was initiated after one-lung ventilation for the thoracotomy, the energy expenditure was measured every hour using indirect calorimetry (E-COVX, GE Healthcare/Datex-Ohmeda,

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Helsinki, Finland). There were no leaks in the ventilator circuit and around the tracheal tube cuffs. The fractional inspired oxygen concentration was 0.4, and the respiratory quotient remained in the normal range (0.67 to 1.3) [9].

All patients fasted overnight before operation. A 5% glucose solution was administered before surgery. No patients were premedicated. General anesthesia was maintained with the intravenous administration of 1% propofol via target-controlled infusion, remifentanil, rocuronium, and thoracic epidural anesthesia. The patients' end-tidal carbon dioxide pressure was maintained between 35 and 40 mm Hg by mechanical ventilation with volume control ventilation (tidal volume; 7 mL/kg of predicted body weight) and positive end-expiratory pressure was maintained at 5 cm H_2O. The anesthetic agents were adjusted to produce a bispectral index value of 40 to 60. Temperatures in the operating rooms were kept around 23°C. No warmed infusions were used. After operation, 1000 to 1500 mL of acetated Ringer's solution was administered to all patients until the next morning.

We measured the nitrogen balance, serum glucose concentration, and bowel temperature during anesthesia. Nitrogen balance was derived from the volume of nitrogen infusion minus the output of urinary nitrogen during anesthesia using the following formula: Nitrogen balance = nitrogen intake − (urine urea nitrogen + 1 g × lengths of anesthesia h/24), where 1 g equals the fecal nitrogen loss per day.

The basal energy expenditure (BEE) was calculated with the following formulas for men [BEE = 66 + (13.8 × body weight kg) + (5 × height cm) − (6.8 × age)] and women [BEE = 655 + (9.6 × weight kg) + (1.85 × height cm) − (4.7 × age)].

We measured the number of days of intubation and the lengths of the intensive care unit (ICU) stay and hospital stay. The length of the hospital stay was determined from the time of the operation to discharge from the hospital.

All patients were of American Society of Anesthesiologists physical status class I or II. Patients were excluded from this study when they had severe heart disease, severe hepatic disease, renal insufficiency, or severe chronic obstructive pulmonary disease. The diabetic patient was not included in this study.

Apparatus

A compact modular metabolic monitor (E-COVX) was used to measure oxygen consumption (PO_2) and carbon dioxide production (PCO_2) using indirect calorimetry [8], which has been described in detail previously [10]. The machine uses the Weir formula for converting PO_2 and PCO_2 and displays a 5-min average for resting energy expenditure (REE). REE (kcal/d) was calculated using the following formula: $(5.5 \times PO_2) + (1.7 \times PCO_2) - (2 \times \text{urinary urea nitrogen})$. REE was the measured value during this study.

Data were analyzed using repeated measures analysis of variance, Scheffé tests, Kaplan-Meier statistics, and Mann–Whitney *U* tests. *P* values <0.05 were considered statistically significant.

Results

Ten patients each were enrolled in the B1 group and C group. Twelve patients were enrolled in the B2 group. The weights and body mass indexes did not significantly differ between the three groups (Table 1). Age was significantly lower in the B2 group than in the B1 and C groups ($P < 0.05$). mEE was significantly higher in the B2 group (1230 ± 228 kcal/d) than in the C group (1012 ± 153 kcal/d). However, the BEE was almost the same in the three groups (Table 2). The total caloric contents that were intravenously infused during anesthesia, including propofol, divided by each mEE (per hour) were 48% in the C group, 83% in the B1 group, and 91% in the B2 group. Nitrogen balance was −1.78 ± 0.78 g in the B1 group, −0.85 ± 0.98 g in the B2 group, and −2.94 ± 2.4 g in the C group (B2 group versus C group, $P < 0.05$). The blood glucose levels in the three groups were higher after surgery than before surgery ($P < 0.05$). The bladder temperature after surgery was significantly higher in the B2 group (37.6 ± 0.5°C) than in the C group (36.4 ± 0.6°C; $P < 0.01$). The number of days of intubation and the length of the ICU stay did not differ among the three groups (Table 3). The lengths of the hospital stay (number of days from the time of the operation to discharge from the hospital) were 29 ± 15 d in the B1 group, 18 ± 6 d in the B2 group, and 37 ± 27 d in the C group (B2 group versus C group, $P = 0.06$) (Table 3). Kaplan-Meier plots of the lengths of the hospital stay indicated that the length in the B2 group was shorter than that in the C group ($P = 0.01$).

The first day after surgery, the blood urea nitrogen did not differ among the three groups (14 ± 2 mg/dL in the B1 group, 14 ± 5 mg/dL in the B2 group, and 15 ± 4 mg/dL in the C group). There were no hypertriglyceridemia patients after surgery in this study.

Discussion

This report found that the intraoperative infusion of glucose and amino acids during general anesthesia increased energy expenditure, alleviated nitrogen balance, and may decrease the length of the hospital stay.

Glucose infusion, even at a relatively low rate, suppresses surgery-induced muscle protein breakdown [11]. The intravenous provision of small amounts of glucose was associated with a decrease in amino acid oxidation and with protein-sparing actions during colorectal surgery [9]. Intravenous infusion of 1% or 5% glucose significantly suppressed the increase in urinary nitrogen and 3-methylhistidine excretion, and the inhibitory effects did not differ between the groups administered 1% or 5% glucose [9]. In the B2 group, the percentage of glucose was 0.8% of the total fluid intake. There were no significant differences in the serum glucose concentrations among the three groups at the end of the surgery in our study. It has been reported that glucose infusion causes severe hyperglycemia during surgery because of insulin resistance [12]. In addition, hyperglycemia is a risk factor for postoperative complications [13]. In the three groups in the present study, the plasma glucose levels were significantly higher after surgery compared with before surgery. This was a normal response to surgery that caused insulin-resistance. However, severe hyperglycemia was not noted in any of the three groups. Several interventions (preoperative carbohydrate

Table 1
Baseline characteristics of the study

	C group	B1 group	B2 group
No. of participants	10	10	12
Male; female	9; 1	9; 1	10; 2
Duration of anesthesia	9 h 58 m ± 1 h 23 m	11 h 32 m ± 48 m	10 h 35 m ± 1 h 9 m*
Height (cm)	160 ± 8	167 ± 8	165 ± 9
Weight (kg)	61 ± 11	57 ± 13	55 ± 10
BMI (kg/m^2)	22 ± 4	22 ± 3	20 ± 3
Age (y)	74 ± 2	68 ± 2	61 ± 2*,†
Fluid (mL)	4783 ± 1008	5490 ± 1039	5209 ± 1155

BMI, body mass index
Results are expressed as mean ± SD
* $P < 0.05$ versus C group.
† $P < 0.05$ versus B1 group.