Short Communication

Energy expenditure measured using indirect calorimeter after minimally invasive esophagectomy in ventilated postoperative patients

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Minimally invasive esophagectomy has recently become popular after the laparoscopic technique was developed. However, the postoperative energy expenditure in patients undergoing this procedure has not been evaluated. Therefore, we hypothesized that postoperative resting energy expenditure (REE) following minimally invasive esophagectomy is lower than that estimated using the Harris-Benedict equation. Fifteen patients who underwent esophagectomy by thoracoscopy in the prone position were analyzed. After esophagectomy, an indirect calorimeter measured the energy expenditure during ventilation in the ICU. These values and the estimated basal energy expenditure values were compared using the paired t test. The mean age was 66±10 years and mean duration of ventilator use in the ICU was 697±70 mins. The acute physiology and chronic health evaluation II (APACHE II) and sequential organ failure assessment (SOFA) scores at the time of ICU admission were 13±4 and 2±1, respectively. The average temperature, heart rate, and respiratory rate during ventilation were 36.2±0.6°C, 67±9 beats/min, and 12±2/min, respectively. The average REE during ventilation was 985±167 kcal/day (18.1±3.4 kcal/kg/day). The estimated REE was 1191±159 kcal/day. The average REE measured using the indirect calorimeter during ventilation was significantly lower than the estimated REE (83±10% of the estimated REE, $p<0.001$). In conclusion, the REE measured by an indirect calorimeter after minimally invasive esophagectomy at early postoperative stage under sedation was significantly lower than the REE estimated using the Harris-Benedict equation.

Key Words: minimally invasive esophagectomy, indirect calorimetery, Harris-Benedict equation, intensive care unit, resting energy expenditure

INTRODUCTION

Traditional esophagectomy is considered to be highly invasive, resulting in the highest mortality rates of all of the elective gastrointestinal surgeries, with rates as high as 23%.[1] Recently, minimally invasive esophagectomy has been performed due to reduce mortality and morbidity. Intrathoracic procedure in esophagectomy by thoracoscopy in the prone positioning is one of the minimally invasive esophagectomy. Previous study described that pulmonary complication frequency were significantly lower and the duration of intensive care unit (ICU) stay and hospital stay were significantly shorter in minimally invasive esophagectomy than that in traditional esophagectomy.[2]

Nutrition therapy has become popular and some studies have been conducted after esophagectomy.[3,4] In these studies, energy requirements were determined using the Harris-Benedict equation (HBE). However, when resting energy expenditure (REE) is estimated using the HBE, underfeeding and overfeeding have been reported in 70% of patients;[5] ICU patients require more accurate feeding owing to their condition. It has also been reported that REE measured using indirect calorimetry following traditional esophagectomy was 1.17 times the REE calculated by the HBE.[6] To the best of our knowledge, postoperative REE in patients undergoing minimally invasive esophagectomies has not been determined using an indirect calorimeter. We hypothesized that postoperative REE following minimally invasive esophagectomy is lower than that estimated using the HBE.

METHODS

This study was approved by the ethics committee of our hospital, which waived the need to obtain informed consent owing to the retrospective design. Consecutive patients who underwent esophagectomy by thoracoscopy in the prone position and received mechanical ventilation using ventilators with an integrated calorimeter, between

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April 2012 and September 2013, were included.

The following data were obtained from electronic patient records: patient characteristics; duration of anesthesia, surgery, one-lung ventilation, prone position, and ventilation in the ICU; total amount of infusion, bleeding, and urine during anesthesia; acute physiology and chronic health evaluation II (APACHE II) and sequential organ failure assessment (SOFA) scores at ICU admission; temperature, heart rate, and respiratory rate during ventilation in the ICU; and the REE and respiratory quotient (RQ) for each hour during ventilation.

The surgical procedure was performed consistently for each patient. First, a lymphadenectomy in the neck was performed in the supine position. The patient was then placed in the prone position. During the thoracic procedure, a lymphadenectomy, mobilization of the middle and lower esophagus, and division of the cervical esophagus were performed. Following the thoracoscopy, the patient was returned to the supine position. After the total laparoscopic gastric mobilization, tube formation was performed through a small incision. Finally, esophagogastric reconstruction was performed at the neck, and the stomach was pulled up through the posterior mediastinal route.

The patients received pressure-controlled ventilation (tidal volume, 6-10 mL/kg; FiO_2, 0.3-0.5) in the ICU under dexmedetomidine and propofol sedation. Ventilation setting and the doses of these sedative agents were adjusted by each physician. Patients were extubated when a spontaneous tidal volume of 5-6 mL/kg, pressure support ≤5 mmHg, positive end-expiratory pressure (PEEP) of 5 mmHg, respiratory rate <20 breaths/min, and partial pressure of oxygen (PaO_2) >120 mmHg with FiO_2<0.4 were achieved in the ICU. However, the individual physicians made the final decision regarding extubation. Patients received a parenteral solution at a rate of 34 kcal/hr (ELNEOPA No.1 Injection, 560 kcal/L, 12% glucose, 2% amino acid, no lipids; Otsuka Pharmaceutical Factory, Tokushima, Japan) after the ICU administration. Blood glucose was maintained at <150 mg/dL using an artificial pancreas (STG-55, Nikkiso, Tokyo, Japan). Continuous enteral feeding via a jejunostomy tube commenced after extubation.

The REE was measured using an Engström device (GE Healthcare Japan, Tokyo, Japan), which consists of a ventilator and an indirect calorimeter. Although this device calculated the REE breath-by-breath, the REE was recorded every 15 mins in our hospital. The indirect calorimeter measured oxygen consumption and carbon dioxide production at every respiratory cycle. The indirect calorimeter software calculated the REE using Weir's equations in addition to the RQ. The Weir's equations was as follows; $REE = (3.94 \times VO_2 + 1.11 \times VCO_2) \times 1.44$. VO_2 was oxygen consumption and VCO_2 was carbon dioxide production.[6] The REE was measured between the ICU admission and extubation. In this study, all of patients were extubated on postoperative day (POD) 1. Therefore, we collected the REE and RQ only during ventilation under dexmedetomidine and propofol sedation.

Data are expressed as mean ± standard deviation (SD). REE measured using the indirect calorimeter and that estimated using the HBE were compared using paired t-tests. Statistical analyses were performed using JMP 9.0 (SAS Institute Japan, Tokyo, Japan), and $p<0.05$ was considered statistically significant.

RESULTS

A total of 15 patients (3 women and 12 men) were analyzed. The mean age was 66±10 years, mean body mass index was 21.6±3.5 kg/m^2, and mean duration of ventilator use in the ICU was 697±70 mins (Tables 1 and 2). The APACHE II and the SOFA scores at the time of ICU admission were 13±4 and 2±1, respectively. The average temperature, heart rate, and respiratory rate during ventilation were 36.2±0.6°C, 67±9 beats/min, and 12±2/min, respectively (Table 2). The REE at the time of ICU admission was 1058±185 kcal/day (19.3±2.8 kcal/kg/day), and the average REE during ventilation was 985±167 kcal/day (18.1±3.4 kcal/kg/day). The estimated REE was 1191±159 kcal/day. The REE measured using the indirect calorimeter at the time of ICU admission and the average REE during ventilation were significantly lower than the estimated REE (89±9% and 83±10% of the estimated REE, respectively [$p<0.001$ and $p<0.001$, respectively]) (Table 2). The average RQ at the time of ICU admission was 0.82±0.10, and the average RQ during ventilation was 0.86±0.04.

DISCUSSION

In the present study, the REE measured using indirect calorimetry under sedation following minimally invasive esophagectomy was 83% of that estimated by the HBE. Guidelines developed in the United States recommend the estimation of energy requirements using predictive equations or by indirect calorimetry.[7] In addition, the guidelines also recommend that predictive equations should be used with caution, as they provide a less accurate measure of energy requirements than indirect calorimetry.[7] The target based on the HBE might be overfeeding after minimally invasive esophagectomy at early postoperative stage in ventilated patients under sedation.

Table 1. Patients' background and operation data

	N=15
Age (yrs)	66±10
Height (cm)	160±7
Weight (kg)	55±10
Body mass index (kg/m^2)	21±4
Gender, Female, n (%)	3 (20)
Stage (I/II/III/IV)	2/2/8/3
Preoperative nutrition therapy, n (%)	14 (93)
Preoperative chemotherapy, n (%)	13 (87)
Preoperative radiotherapy, n (%)	0 (0)
Red blood cell counts before surgery (10^4/L)	364±55
White blood cell counts before surgery (10^3/L)	6.7±2.5
Albumin before surgery (g/dL)	4.1±0.3
C-reactive protein before surgery (mg/dL)	0.9±2.3
Duration of anesthesia (mins)	668±69
Surgery (mins)	605±64
One lung ventilation (mins)	228±37
Prone position (mins)	255±40
Total amount of infusion during anesthesia (mL)	3441±488
Urine during anesthesia (mL)	1138±384
Bleeding during anesthesia (mL)	205±123

Data are expressed as the mean±SD.

Table 2. Patients' data in intensive care unit

	N=15
APACHE II score at ICU admission	13±4
SOFA score at ICU admission	2±1
Temperature at ICU admission (°C)	36.4±0.7
Average temperature during ventilation (°C)	36.2±0.6
Heart rate at ICU admission (beats/min)	75±11
Average heart rate during ventilation (beats/min)	68±9
Respiratory rate at ICU admission (/min)	11±2
Average respiratory rate during ventilation (/min)	12±2
Use of catecholamineat ICU admission, n (%)	2 (13)
Red blood cell counts POD 1 (10^4/L)	318±60
White blood cell counts POD 1 (10^3/L)	10.9±4.1
Albumin POD 1 (g/dL)	2.5±0.3
C-reactive protein POD 1 (mg/dL)	4.5±2.0
Estimated basal energy expenditure (kcal/day)	1191±159
Energy expenditure at ICU admission	
(kcal/day)	1058±185
(kcal/kg/day)	19.3±2.8
% of HBE	89±9
Result of paired t test	p<0.001
Average energy expenditure during ventilation	
(kcal/day)	985±167
(kcal/kg/day)	18.1±3.4
% of HBE	83±10
Result of paired t test	p<0.001
Respiratory quotient at ICU admission	0.82±0.10
Respiratory quotient during ventilation	0.86±0.04

Data are expressed as the mean±SD.
APACHE II: acute physiology and chronic health evaluation II;
SOFA: sequential organ failure assessment;
POD: postoperative day; HBE: Harris-Benedict equation.

Studies have indicated that post-operative REE values are higher than those before surgery. Inflammatory responses, such as those related to illness or surgery, often involve cytokines, which increase energy expenditure by 9-10 kcal/d per ng/mL.[8] Potentially, owing to the invasiveness of traditional esophagectomy and the earlier recovery and reduced complications with minimally invasive esophagectomy, a shorter duration of the systemic inflammatory response syndrome has been reported with minimally invasive esophagectomy compared with traditional esophagectomy.[9] In our previous study, minimally invasive esophagectomy reduced intraoperative bleeding and post-operative complications and allowed earlier rehabilitation and discharge compared with traditional esophagectomy despite longer operation time.[2] In addition, the APACHE II and the SOFA scores at the time of ICU admission were low in this study. These data suggested that minimally invasive esophagectomy was actually "minimally invasive". Therefore, we thought that minimally invasive esophagectomy might result in fewer cytokines and this might contribute to a reduction in REE.

Guidelines developed in Europe state that ICU patients should receive 25 kcal/kg/day in the absence of indirect calorimetry measurements.[10] In the present study, the REE of the ICU patients was only 18 kcal/kg/day. Overfeeding in ICU patients can result in complications such as prolonged mechanical ventilation, hyperglycemia, and immune dysfunction.[5] Although optimal energy target after extubation remains unclear, this study presents the first estimate of REE measured using indirect calorimetry following minimally invasive esophagectomy. Therefore, this data might contribute to the estimation of optimal energy targets, at least for patients under sedation.

This study has certain limitations. First, the data represent REE estimates for minimally invasive esophagectomy only. In addition, the REE measurements were only conducted until POD 1 because all of the patients were extubated on POD 1. Furthermore, although minimally invasive esophagectomy was conducted for all esophageal cancer patients since July 2009 in our hospital, a ventilator with indirect calorimetry had only been used since April 2012. Therefore, we could not directly compare the present results with REE measured following traditional esophagectomy. For these reasons, the application of our data is limited. In other words, the application objects were ventilated patients under sedation at early postoperative stage. Furthermore, the REE might be influenced by underlying conditions such as cancer stage, operative time and level of peri-operative inflammation. Therefore, further investigation of REE is required. Second, parenteral nutrition was used during the ICU admission in the present study, which may have affected the REE. However, only approximately 800 kcal/day was provided during ventilation, and the average RQ was 0.86. This indicates that overfeeding did not occur; therefore, parenteral nutrition would have influenced REE only slightly. Finally, a retrospective design was used. However, bias was minimized because the same surgeons and anesthesiologists performed the operations, anesthesia, and postoperative management since July 2009.

In conclusion, the REE measured by an indirect calorimeter after minimally invasive esophagectomy at early postoperative stage under sedation was significantly lower than the REE estimated using the HBE. Therefore, caution should be exercised to avoid overfeeding during post-operative management in the ICU.

AUTHOR DISCLOSURES

All authors have no conflicts of interest or financial or other contractual agreements that might cause conflicts of interest.

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用间接热量计测量微创食管切除术后通气患者的能量消耗

腹腔镜技术开发后，微创食管切除术近来成为流行。然而，接受该手术的患者术后的能量消耗尚未进行评估。因此，我们假设微创食管切除术后患者静息能量消耗（REE）低于用 Harris-Benedict 公式估算的能量消耗。本研究分析了 15 例俯卧位接受胸腔镜食管切除术的患者。在重症监护室（ICU）用间接热量计测量食管切除术后通气患者的能量消耗。使用配对 T 检验，比较测得的能量消耗和估计的基础能量消耗。患者的平均年龄为 66±10 岁，在 ICU 使用呼吸机的平均时间是 697±70 分钟。在 ICU 住院期间急性生理和慢性健康评估 II（APACHE II）和序贯器官衰竭评估的得分分别为 13±4 和 2±1。食管切除通气期间患者的平均体温、心率和呼吸频率分别为 36.2±0.6℃、67±9 次/分和 12±2 次/分，平均 REE 是 985±167 千卡/天（18.1±3.4 千卡/千克/天）。根据 Harris-Benedict 公式估算的 REE 为 1191±159 千卡/天。用间接热量计测量的食管切除通气期间的平均 REE 显著低于估算的 REE（是估算的 REE 的 83±10%，$p<0.001$）。综上所述，用间接热量计测得的微创食管切除术后早期镇静阶段的能量消耗显著低于用 Harris-Benedict 公式估算的能量消耗。

关键词：微创食管切除术、间接热量测定、Harris-Benedict 公式、重症监护室、静息能量消耗