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Intraoperative baseline oxygen consumption as a prognostic factor in emergency open abdominal surgery

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ABSTRACT

Background: A new anesthesia system, the E-CAIOVX (GE Healthcare) enables the continuous monitoring of oxygen consumption (VO_2) and carbon dioxide elimination (VCO_2) during the surgical operation. The aim of this study was to evaluate the prognostic role of intraoperative baseline VO_2 and VCO_2 in an emergency open abdominal operation.

Methods: A total of 103 patients who had an emergency open abdominal operation were enrolled in the study. VO_2 and VCO_2 were continuously measured from the induction of anesthesia to the end of the operation.

Results: There were significant correlations between intraoperative baseline VO_2 and body surface area (BSA; $P < .001$, $r = 0.68$), VO_2 and tidal volume ($P < .001$, $r = 0.59$), and VO_2 and baseline body temperature ($P < .0001$, $r = 0.49$). Also, there were significant correlations between intraoperative baseline VCO_2 and BSA ($P < .001$, $r = 0.70$), VCO_2 and tidal volume ($P < .001$, $r = 0.70$), and VCO_2 and body temperature ($P < .001$, $r = 0.41$). Fifteen (14.6%) of the 103 patients died within 4 months after the operation without having been discharged from hospital. Baseline VO_2/BSA was higher in surviving patients (123.7 ± 23.6 mL/min · m^2) than the deceased (103.8 ± 15.6 mL/min · m^2; $P = .002$). There was no significant difference in baseline VCO_2/BSA levels between surviving (106.2 ± 20.1 mL/min · m^2) and deceased patients (99.4 ± 21.4 mL/min · m^2). In multivariate analysis, baseline body temperature lower than 36.2°C ($P = .02$), serum albumin less than 3.0 g/dL ($P = .002$), and baseline VO_2/BSA less than 111.9 mL/min · m^2 ($P = .03$) were independent factors.

Conclusion: Baseline low VO_2/BSA less than 111.9 mL/min · m^2 was one of the poor predictors for the prognosis of an emergency open abdominal surgery.

1. Introduction

Cardiopulmonary exercise testing (CPET) variables, including peak oxygen consumption (VO_2), minute ventilation/carbon dioxide production (VCO_2) slope, oxygen uptake efficiency slope, and exercise oscillatory ventilation are typically used for examining heart functions or exercise tolerance [1].

Recently, there have been some reports referring to the usefulness of preoperative CPET, especially the anaerobic threshold (AT), in predicting postoperative outcomes after major abdominal surgery [2–4], gastric bypass surgery [5], hepatic resection [6], liver transplantation [7–9], colorectal surgery [10–12], pancreaticoduodenectomy [13], and vascular surgery [14,15]. The peak VO_2 and AT describe the exercise capacity that characterize the upper limits of exercise intensities that can be accomplished aerobically [2]. These indicate the capability of the cardiopulmonary system to deliver oxygen to the peripheral tissues, as well as the ability of the tissues to use that oxygen [8]. The AT proved to be a good prognostic marker in many of the abdominal operations.

In most cases, requiring emergency open abdominal surgery, physical examinations such as a cycle ergometer, or even the lung functional test could not be performed. So, AT cannot be applied as a possible prognostic marker in emergency abdominal operations. Recently, a new anesthesia system, the E-CAIOVX (GE Healthcare, WI, US), has become available in our hospital, and the module enables the continuous monitoring of VO_2 and VCO_2 during an operation.

The aim of this study was to evaluate the prognostic roles of intraoperative baseline VO_2 and VCO_2 in an emergency open abdominal operation.

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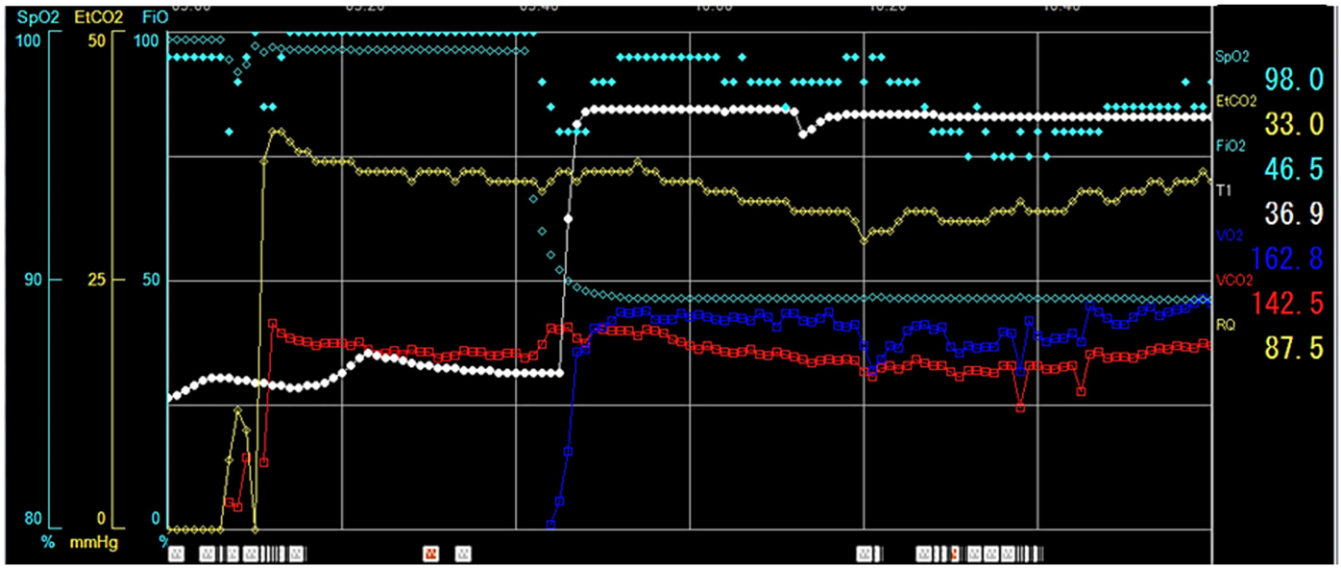

Fig. 1. One hundred three patients underwent an emergency operation under general anesthesia using E-CAIOVX, which enabled the continuous monitoring of intraoperative VO_2 and VCO_2. Baseline VO_2 and VCO_2 were recorded at around the beginning of an operation, the time when VO_2 and VCO_2 represented a plateau portion of a graph.

2. Methods

2.1. Patients

A total of 103 patients who underwent an emergency open abdominal operation in Kumamoto General Hospital between April 2013 and December 2014 were enrolled in this study. In order to measure intraoperative VO_2 and VCO_2 accurately, laparoscopic emergency operations such as laparoscopic appendectomy and laparoscopic restoration of upper gastrointestinal perforation were excluded. All operations were performed under general anesthesia using a patient monitor B650 (GE Healthcare, WI, US) equipped with gas which enables the continuous monitoring of intraoperative VO_2 and VCO_2. Written informed consent was obtained from all the patients.

2.2. E-CAIOVX

All patients were intubated under fraction of inspired oxygen (FIO_2) 1.0 of oxygen. After tracheal intubation, FIO_2 was decreased from 1.0 to 0.5, and this ventilation was maintained during the operation. VO_2 and VCO_2 were calculated according to the parameters measured by the E-CAIOVX (GE Healthcare, WI, US). The apparatus has the ability to measure inspired and expired tidal volumes (TVs) as well as the concentrations of O_2, CO_2, and anesthetic agents. VO_2 and VCO_2 were calculated as follows:

$$VO_2(mL/min) = MV_{insp} \times Fio_2 - MV_{exp} \times FeO_2$$

$$VCO_2(mL/min) = MV_{insp} \times FeO_2 - MV_{exp} \times FiCO_2$$

MV_{insp}	minute volume of inspired gas
MV_{exp}	minute volume of expired gas
Fi	fraction of inspired gas
Fe	fraction of expired gas

2.3. Data acquisition

In all 103 patients, VO_2 and VCO_2 were continuously measured from the induction of anesthesia to the end of the operation (Fig. 1). All data acquired with the monitor B650 of the E-CAIOVX system were stored on the server. In every case, VO_2 and VCO_2 changed over time and appeared almost flat

Table 1
Causes of emergency abdominal operation and clinical characteristics

	Upper gastrointestinal perforation (n = 16)	Lower gastrointestinal perforation (n = 26)	Ileus (n = 42)	Panperitonitis due to appendicitis (n = 15)	Others (n = 4)
Age (y)	76.0 ± 14.2	72.2 ± 14.7	74.1 ± 14.3	69.6 ± 14.8	81.5 ± 13.3
Sex (male/female)	7/9	11/15	16/26	8/7	1/3
BMI (kg/m^2)	21.0 ± 3.2	21.9 ± 4.3	20.2 ± 3.0	22.0 ± 3.6	20.4 ± 4.3
Baseline body temperature (°C)	37.2 ± 0.91	37.0 ± 1.08	36.5 ± 0.80	37.4 ± 0.72	36.4 ± 1.59
Baseline mean arterial pressure (mm Hg)	75.3 ± 10.0	74.3 ± 13.3	71.3 ± 11.9	72.6 ± 11.6	70.0 ± 10.1
Neutrophil (%)	81.3 ± 13.2	78.7 ± 16.0	79.4 ± 11.2	80.9 ± 9.8	85.2 ± 7.4
Hb (g/dL)	10.8 ± 3.0	12.3 ± 2.4	12.5 ± 2.2	13.9 ± 1.7	11.8 ± 1.8
Albumin (g/dL)	2.9 ± 0.7	3.2 ± 0.7	3.6 ± 0.7	3.5 ± 0.6	3.2 ± 0.9
DM (yes/no)	2/14	3/23	2/40	4/11	0/4
ASA score (1E/2E/3E/4E)	0/9/6/1	0/12/12/2	1/29/9/3	0/15/0/0	0/2/1/1
Baseline Spo_2 (%)	99.7 ± 0.5	99.3 ± 1.2	99.3 ± 1.2	99.1 ± 1.3	99.0 ± 2.0
Intraoperative crystalloids infusion (mL)	1673.8 ± 765.2	2426.9 ± 924.4	1578.8 ± 742.8	1873.3 ± 1115.5	1787.5 ± 606.0
Intraoperative RCC transfusion (yes/no)	3/13	3/23	1/41	0/15	1/3
Baseline VO_2/BSA ($mL/min \cdot m^2$)	121.8 ± 32.4	122.0 ± 21.9	118.3 ± 23.1	126.8 ± 19.6	113.7 ± 17.8
Baseline VCO_2/BSA ($mL/min \cdot m^2$)	104.5 ± 28.4	108.2 ± 17.0	103.9 ± 21.8	105.5 ± 13.4	102.8 ± 11.6
Outcome (surviving/dead)	15/1	19/7	37/5	15/0	2/2

ASA indicates American Society for Anesthesiologists.