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Changes in the Respiratory Quotient during Surgery with or without Carbohydrate Loading

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ABSTRACT

Usually glucose is used as an energy source intraoperatively, and recently maltose containing fluids was introduced as intraoperative fluid supply. However, the optimal dosage and form of intraoperative carbohydrate have not yet been known. The authors compared changes in the RQ during surgery without any energy source supply, and with administration of glucose or maltose in twenty eight males and females to know the effects of carbohydrates administration on RQ during surgery and to estimate the optimal dosage and form of intraoperative carbohydrates. Patients in group 1 received no carbohydrates during the operation; in groups 2 and 3, patients were given 0.25g glucose/kg and 0.5g glucose/kg/hr respectively, and patients in groups 4 and 5 received maltose at the speed of 0.25g/kg/hr, respectively. No differences in RQ were observed before the beginning of surgery among groups. In group 1, the RQ decreased from 0.85 ± 0.08 (X ± S.D.) to 0.72 ± 0.04 at 150 min after the beginning of the operation. In groups 2 and 3 (the glucose groups) and group 4 (the maltose group), the RQ also had fallen at 150 min, from 0.86 ± 0.06 to 0.74 ± 0.06 (group 2), 0.86 ± 0.05 to 0.80 ± 0.05 (group 3), 0.86 ± 0.03 to 0.81 ± 0.03 (group 4). Group 5 was the only group in which we could not observe any significant change of RQ during surgery (0.85 ± 0.06 to 0.84 ± 0.03).

Without carbohydrates administration, the RQ decreased to nearly 0.7, indicating that the main energy source of the patients changed from carbohydrates to lipids. This reduction of RQ during operation can be inhibited with administration of carbohydrates, which suggests that the administered carbohydrates were utilized as the energy source during the time of surgery, and maltose 0.5g/kg/hr is thought to be suitable for intraoperative use as an energy source.

Key words: *Energy metabolism; energy expenditure; respiratory quotient Carbohydrates; maltose, glucose Intraoperative period*

Physiologic responses to trauma, such as hypermetabolism, glucose intolerance and amino acid catabolism, commonly occur during the perioperative period[8]. During surgery, the reaction of the human body to both starvation and injury requires gluconeogenesis from amino acids and free fatty acids. This gluconeogenesis from amino acids might be the main cause of the catabolism of amino acids during surgery, and it can be reduced by the administration of glucose during surgery[5]. An energy source is essential for the intraoperative care of patients undergoing surgery not only to reduce amino acid catabolism but also to provide adequate support for hypermetabolism[9]. Usually glucose containing fluid is used as intraoperative energy source, and maltose was introduced in these years. However, the optimal dosage and form of intraoperative carbohydrates have not yet been known. Recently, development of a computerized technique made the measurement of gas exchange values easier[2-4], and so gas exchange values are more frequently used in determinations of the energy source in humans[1,6,13]. Hagerdel et al (1983) reported the effects of the intraoperative administration of glucose on postoperative changes in respiratory quotient (RQ) and speculated that administered glucose might be used as the energy source during surgery[11]. The questions raised by their study are: 1) was the postoperative change in the RQ reported by Hagerdel the consequence of an intraoperative changes in RQ, and 2) how did the administered carbohydrates affect changes in the RQ during the time of surgery. The purpose of this study was 1) to quantitate the changes in the RQ with time during surgery without any energy source administration, 2) to know the effects of glucose or maltose administration on RQ during operation and, if possible, 3) to estimate the optimal dosage and form of intraoperative carbohydrate.

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PATIENTS AND METHODS

The study was conducted using twenty eight patients, 16 males and 12 females, ASA classification I or II, undergoing general anesthesia for surgical procedures lasting at least 2 hr. Patients with metabolic diseases such as diabetes and lung diseases or those requiring preoperative fluid management were excluded. The study was approved by the Ethical Committee on human studies of the University Hospital, and informed consent was obtained from each patient. The patients were randomly allocated to one of the five groups. Patients in group 1 (n=6) received only lactated Ringer's solution (LR) during the operation (the control group). Patients in group 2 (n=6) received LR with glucose at a speed of 0.25g/kg/hr. Patients in group 3 (n=5) were given LR with 0.5g/kg/hr of glucose. Patients in groups 4 (n=5) and 5 (n=6) received maltose at 0.25g/kg/hr and 0.5g/kg/hr with LR during the operation, respectively. We prepared a 50% solution of each sugar which was administered intravenously through a central venous line using a syringe pump.

The kinds of operations in these 28 patients were as follows: total gastrectomy, 11 cases; partial resection of colon, 6 cases; radical mastectomy, 4 cases; urological surgery, 2 cases; orthopedic surgery, 2 cases; others, 3 cases.

Anesthetic management

Each patient was fasted overnight and premedicated with hydroxyzine (1mg/kg) and atropine (0.01mg/kg) intramusculary, 60 min before anesthesia. Continuous catheterization of an epidural space appropriate for the operation was performed before the induction of anesthesia. Anesthesia was induced with fentanyl 6 to 8 μg per kg and diazepam 10 mg while the patients breathed 100% oxygen. When the patients had become unresponsive, pancuronium 0.1 mg per kg was administered and tracheal intubation was performed. Anesthesia was maintained with an epidural injection of mepivacaine and additional doses of fentanyl and pancuronium. After endotracheal intubation, the tympanic temperature was measured throughout surgery using a Non-a-therm® thermometer.

In order to exclude effects on the measurement of gas exchange values[15], no inhaled anesthetics were used. Respiration was controlled using a mechanical ventilator with an inspired oxygen fraction of 30%.

Measurement of gas exchange values

The patients were ventilated with an ERICA ventilator, and continuous measurement of oxygen consumption ($\dot{V}O_2$), carbon dioxide elimination ($\dot{V}CO_2$) and RQ were made by indirect calorimetry using an Engström Metabolic Computer (EMC), CO_2 analyzer and ERICA® ventilator (Gambro Engström AB, Bromma, Sweden)[3]. All values were calculated in STPD with the use of standard formulas[18]. The volume meter of the ventilator was calibrated with the aid of a syringe with a known volume and the EMC and CO_2 analyzer were calibrated with standard calibration gases before each measurement.

In order to establish a baseline in a reasonably steady state, before the measurements were started, patients were kept on uninterrupted ventilation for more than fifteen minutes after endotracheal intubation[19,21]. The values were calculated as the mean of the preceding 15 min, taken by every 10 min during the operation. The mean value for the 15 min before the first incision (0 min value) in each group was used as a control value. The values of $\dot{V}O_2$ were divided by the body surface area in order to average. Because minimum duration of surgery was 150 min in all 28 cases, we calculated all values up to 150 min for statistical analysis.

Other laboratory examinations

At the time of the first incision and every one hour during the operation, arterial blood gases, blood glucose levels, serum potassium and sodium levels, and ketone bodies both in blood and urine were checked. Serum levels of glutamic transaminase (GOT), glutamic pyruvic transaminase (GPT), lactate dehydrogenase (LDH), alkaline phosphatase, total protein, triglyceride and non-esterified fatty acid (NEFA) were measured before operation, at the end of operation and 1 week after surgery.

Statistical analysis

The values of RQ and $\dot{V}O_2$ in each group were compared with their respective control values and the values between the control group and groups 2,3,4 and 5 at each time were compared using a Student's t-tests. Values were considered significantly different, if they achieved a $p<0.05$ by the t-tests. All values were expressed as the mean ± s.d. except on the figures.

RESULTS

In Table 1, the ages, body surface areas, amount of administrated LR (per kg per hr), initial body temperatures and duration of anaesthesia were shown for each group. No significant differences were observed among the groups. The body temperature did not change significantly with time during the operations in any groups. No patients in this study showed abnormal arterial blood gas values or abnormal values in the serum and urinary potasium and sodium levels.

The relationships between RQ for the various study groups and time during surgery are shown in Fig. 1, and the values of $\dot{V}O_2$ and RQ in all groups at thirty min intervals are listed in Table 2. The control RQ (0 minute value) did not differ significantly among groups. In groups 2, 3, 4 and

Table 1. Summary of clinical data for each group

	age	duration of anesthesia	BSA	LR(ml/kg/hr)	BT
group 1	54 ± 14	300 ± 59	1.54 ± 0.11	7.34 ± 0.71	36.8 ± 0.3
group 2	60 ± 11	288 ± 69	1.60 ± 0.18	7.37 ± 0.89	36.8 ± 0.6
group 3	58 ± 15	293 ± 26	1.67 ± 0.18	7.79 ± 0.39	36.6 ± 0.5
group 4	54 ± 2	303 ± 36	1.59 ± 0.12	7.75 ± 0.23	37.1 ± 0.3
group 5	63 ± 6	283 ± 51	1.46 ± 0.15	7.64 ± 0.57	36.7 ± 0.3

The mean values of the ages (years), duration of anesthesia (min), body surface area (m^2), total amount of administered lactated Ringer's solution (ml per kg per hr) and body temperature (centigrade).
Values are expressed as mean ± s.d.
Abbreviations: BSA = body surface area, LR = lactated Ringer's solution, BT = initial body temperature.
group 1,2,5 : n=6; groups 3,4 : n=5

Table 2. $\dot{V}O_2$ and RQ values during surgery at every thirty min intervals from the beginning of the operation to 150 min later. All values are expressed as the mean ± s.d.

	(min)	0	30	60	90	120	150
group 1	RQ	0.85 ± 0.08	0.82 ± 0.08	0.78 ± 0.07	0.74 ± 0.07	0.72 ± 0.05#	0.72 ± 0.04#
	$\dot{V}O_2$/BSA	115 ± 2.89	115 ± 2.80	118 ± 4.00	119 ± 4.99	118 ± 7.17	122 ± 7.11
group 2	RQ	0.86 ± 0.06	0.79 ± 0.04	0.78 ± 0.04	0.75 ± 0.05#	0.75 ± 0.05#	0.74 ± 0.06#
	$\dot{V}O_2$/BSA	116 ± 7.59	117 ± 8.90	116 ± 10.3	122 ± 14.0	126 ± 13.3	130 ± 13.6
group 3	RQ	0.86 ± 0.05	0.78 ± 0.02#	0.77 ± 0.03#	0.79 ± 0.06	0.80 ± 0.04*	0.80 ± 0.04*
	$\dot{V}O_2$/BSA	118 ± 12.3	126 ± 11.6	127 ± 10.2	128 ± 7.18	129 ± 11.3	130 ± 6.47
group 4	RQ	0.86 ± 0.03	0.85 ± 0.03	0.81 ± 0.05	0.79 ± 0.03#	0.80 ± 0.04*#	0.81 ± 0.03*#
	$\dot{V}O_2$/BSA	120 ± 7.01	122 ± 5.21	120 ± 9.27	126 ± 14.6	122 ± 16.5	122 ± 13.4
group 5	RQ	0.85 ± 0.06	0.82 ± 0.08	0.81 ± 0.06	0.82 ± 0.05*	0.82 ± 0.04*	0.84 ± 0.04*
	$\dot{V}O_2$/BSA	112 ± 12.5	114 ± 9.21	115 ± 9.84	117 ± 12.9	118 ± 8.10	122 ± 11.4

* Significant differences between the control group (group 1) and the study group at each time, $p<0.05$ by t-tests.
\# Significant differences between the control value (0 min value) and the later value for each group, $p<0.05$ by paired t-tests.

5 the RQ became significantly higher than that of group 1 with time during surgery. In particular, in groups 4 and 5 the RQ values were all higher than those of group 1 after 60 min. It was only in group 5 than the RQ did not change significantly with time, and in group 1 it decreased from 0.85 to 0.72 in 150 min. In groups 2, 3 and 4 the RQ decreased significantly at several times during the operation; however, the degree to which it fell was smaller than that of group 1.

Blood glucose levels increased significantly in all groups. In group 3, the level rose to more than three times the control level at 150 min (Fig. 2).

Serum liver function tests showed no differences between the pre- and postoperative periods, and no cases in this study suffered clinical liver dysfunction. No significant differences in the values of serum triglyceride was observed in each group between pre- and postoperative periods (TG: mg/dl, 83.0 ± 44.1 — 84.3 ± 21.4 (G1), 84.8 ± 44.3 — 102.2 ± 39.9 (G2), 113.3 ± 57.0 — 84.3 ± 38.6 (G3), 79.0 ± 34.1 — 87.4 ± 28.7 (G4), 86.2 ± 28.9 — 80.7 ± 2810 (G5)). Values of serum NEFA showed no significant differences in groups 2, 3, 4 and 5 (NEFA: mEq/L, 0.46 ± 0.06 — 0.43 ± 0.15 (G2), 0.52 ± 0.09 — 0.41 ± 0.15 (G3), 0.44 ± 0.20 — 0.42 ± 0.17 (G4), 0.49 ± 0.21 — 0.48 ± 0.14 (G5)), but elevated post-operatively in group 1 (0.38 ± 0.05 — 0.89 ± 0.38).

DISCUSSION

Although there may be many factors which interact to influence the RQ during surgery[18], we attempted to minimize these background factors: we took care 1) to exclude patients with metabolic disorders or respiratory disorders, who were hemodynamically unstable or whose bleed gases were unstable, 2) to use only one anesthetic method, avoiding the use of inhalational anesthetics, and 3) to check the liver function in the perioperative periods to assure that no metabolic disorders had occurred. As far as carbohydrate administration was concerned, we prepared a fifty percent solution of each sugar and administered it using a syringe pump to maintain the accuracy of the quantity within ± five percents.

The accuracy of indirect calorimetry using EMC is within 7% with an FI_{O_2} = 0.3 for RQ values compared clinically to Douglas's bag method 3). We established that the patients were in a reasonably steady state by ventilating them for more than 15 min in the same mode of ventilation as the actual

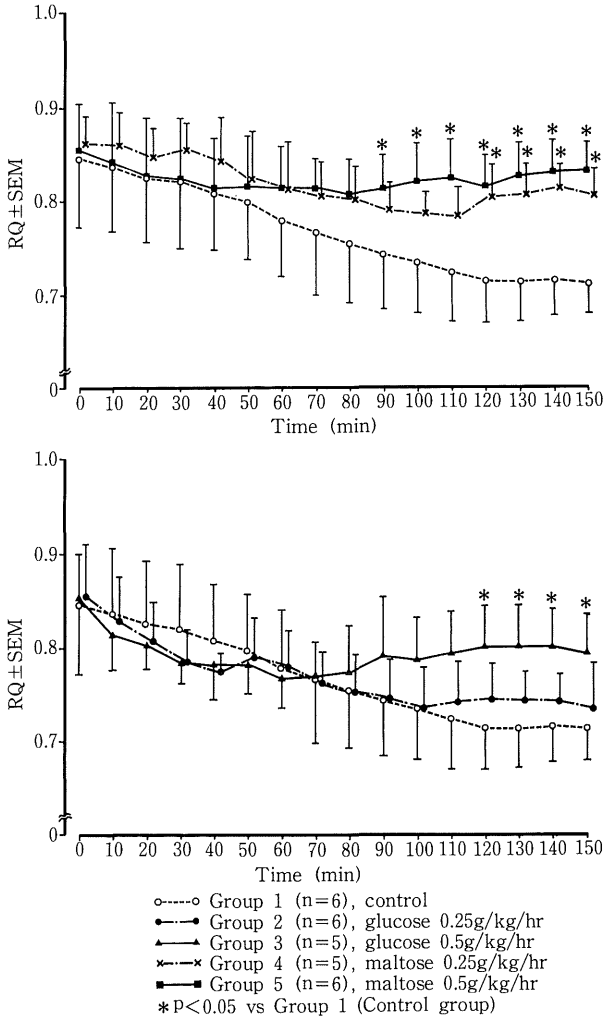

Fig. 1. Mean respiratory quotients for each group from the beginning of surgery to 150 min later taken every ten minutes. The bars represent the standard error of each value. *Significant differences between the control group (group 1) and the study group at each time, $p<0.05$ by t-tests.

measurements with an FI_{O_2} = 0.3. And no patients in this study needed to change ventilatory modes or who required additional anesthetics.

Blood glucose levels are elevated at the end of anesthesia in any group. Even in group 1, the mean reached 6.1mM from 4.4mM and intravenous glucose administration made it more than 15mM in many patients in groups 2 and 3. Similar hyperglycemia during surgery with or without glucose administration has been reported in other studies[14,16], and 0.5 g/kg/hr glucose administration was probably excessive for intraoperative administration. Factors such as low peripheral glucose utilization, increased splanchnic release of glucose, an increase in the peripheral uptake of gluconeogenic substanecs[9,20] and increased plazma glucagon concentrations[17] may account for the hyperglycemic response to surgery.

From the observed gas exchange values, we could determine the changes in the energy source

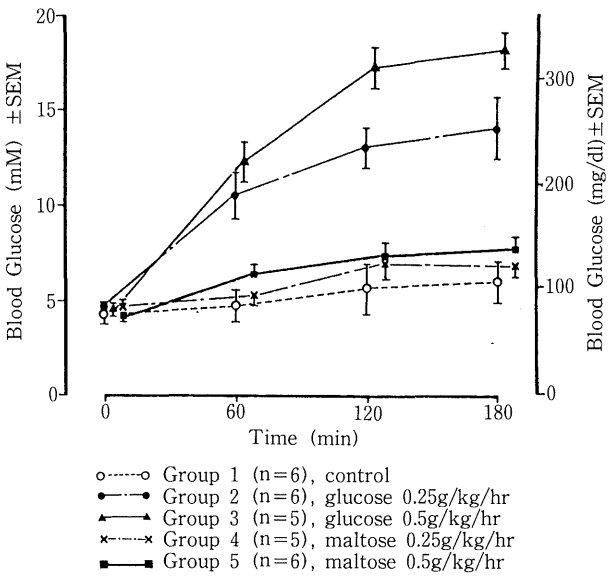

Fig. 2. Mean blood glucose levels for each group from the beginning of surgery to 180 min later; the values were measured every hour. The bars represents the standard error of each value.

used[10]. Without any administration of carbohydrates during surgery (group 1), the RQ decreased nearly to 0.7 at the end of surgery. This suggests that the main energy source of the patients in this group changed from sugar (RQ=1.0) to lipids (RQ 0.7). And elevated serum NEFA levels in group 1 postoperatively might assist this suggestion. However, with sugar administration, the RQ recovered gradually with time and this result indicates that the administrated carbohydrate was used during the time of surgery.

In some textbooks the intraoperative administration of sugar has been recommended in the form of a glucose-containing maintenance fluid[7,12]. From our results, maltose administrated at 0.5 g/kg/hr did not change the RQ intraoperatively, and the blood sugar levels did not change as much as with glucose administration. This quantity of maltose is within the clinically acceptable level[22], that is, approximately 250 ml of 10% of maltose solution per hour. Therefore, maltose at 0.5 g/kg/hr is thought to be suitable for intraoperative use as an energy source.

In conclusion, without carbohydrate administration, the RQ decreased nearly to 0.7 during surgery which suggests that the main energy source of the human body changes from carbohydrate to lipids, and this reduction of RQ during operation can be inhibited with the administration of carbohydrate.

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