Anesthesiology
59:48–50, 1983

Intraoperative Fluid Management Influences Carbon Dioxide Production and Respiratory Quotient

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The authors studied the effects of glucose-containing *versus* non-glucose-containing solutions for intraoperative fluid management on CO_2 production and respiratory quotient (RQ) during the first postoperative hour. Three groups of patients were studied. Patients in Group 1 received normal saline during the operation and first postoperative hour; patients in Groups 2 and 3 received 5% glucose in half normal saline during the operation. This solution was continued through the postoperative period for patients in Group 2, while patients in Group 3 were given normal saline postoperatively. All patients received 500–1000 ml during the first hour and 500 ml/h thereafter. During the first postoperative hour, CO_2 production and O_2 consumption were measured every 15 min.

RQ was significantly higher in Group 2 (0.93 ± 0.01) than in Group 1 (0.77 ± 0.01) ($\bar{x}$ ± SEM, $P < 0.05$). CO_2 production was about 20% higher in Group 2 than in Group 1. There were no differences in O_2 consumption between Groups 1 and 2. In Group 3, RQ decreased significantly (from 0.97 ± 0.04 to 0.87 ± 0.03) during the first postoperative hour but remained higher than in Group 1. The authors conclude that intraoperative administration of glucose-containing solutions increases RQ postoperatively; this effect can be reversed partially by changing to glucose-free solutions in the postanesthetic period. (Key words: Carbon dioxide: measurement; production. Fluid balance: intraoperative. Metabolism: glucose; respiratory quotient.)

INTRAVENOUS GLUCOSE SOLUTIONS are used commonly for perioperative fluid management. Because large volumes sometimes are required to replace ongoing fluid losses and preexisting deficits, it is possible for patients to receive large quantities of glucose perioperatively. Parenteral nutrition with hypertonic glucose solutions has been reported to increase CO_2 production and respiratory quotient (RQ).[1] Difficulty in weaning patients from mechanical ventilation also has been reported following high glucose loads.[2]

The purpose of our study was to quantitate the effect of intraoperative glucose solutions on CO_2 production, O_2 consumption, and RQ in the immediate postoperative period.

Methods

We studied 21 men, ASA classification I or II, undergoing spinal or general anesthesia for surgical procedures lasting at least 1 h. We excluded patients with diabetes, as well as those undergoing transurethral resection of the prostate. Each patient granted informed consent for participation in the study, which was approved by the Institutional Human Studies Committee.

Patients fasted overnight. Before induction of anesthesia they were randomly assigned to one of three groups with seven patients in each group. Patients in Group 1 received only normal saline (NS) during the operation and the first postoperative hour. Patients in Group 2 received 5% glucose in half normal saline (D5 ½ NS) during the same period of time. Patients in Group 3 were given D5 ½ NS during the operation, which was changed to NS upon arrival in the recovery room. All patients received 500–1000 ml of fluid during the first hour of anesthesia and 500 ml of fluid during each subsequent hour of the study.

Immediately after operation, the patients were allowed to breathe room air for at least 10 min as they were taken to the recovery room, where their expired O_2 concentration, CO_2 concentration, and minute ventilation were measured via face mask or mouthpiece (with nose occluded) using a Beckman Metabolic Measurement Cart.®[3,4] Patients who were shivering, complaining of pain, or unable to tolerate the face mask or mouthpiece were excluded from the study. Oral temperature was measured on arrival in the recovery room using an IVAC digital thermometer.

We calibrated the spirometer with a supersyringe at the beginning of each day; the O_2 and CO_2 analyzers were calibrated hourly with standard calibration gases. The patients breathed room air throughout the first postoperative hour. Mixed expired O_2 and CO_2 concentrations and exhaled volume were measured for 30 s and confirmed in triplicate during periods of stable ventilation; the replicates varied by less than 10%, verifying the existence of near steady-state gas exchange. Measurements were repeated every 15 min; O_2 consumption, CO_2 production, and RQ were calculated with the use of standard formulas.

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Received from the Departments of Anesthesia, University of Pennsylvania, and Philadelphia Veterans Administration Medical Center, Philadelphia, Pennsylvania. Accepted for publication January 4, 1983. Supported in part by a grant from Beckman Instruments, Inc. Presented in part at the Annual Meeting of the American Society of Anesthesiologists, Las Vegas, Nevada, October 1982.

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0003-3022/83/0700/0048 $00.95 © The American Society of Anesthesiologists, Inc.

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TABLE 1. Comparative Data for Three Groups

	Age (years)	Weight (kg)	Temperature (°C)	Glucose	
				Intraoperative (g)	Total (g)
Group 1 (saline)	49 ± 17	72 ± 5	35.8 ± 0.4	0	0
Group 2 (glucose)	56 ± 16	79 ± 5	35.3 ± 0.9	96.5 ± 15.4	132.9 ± 14.7
Group 3 (glucose to saline)	57 ± 7	71 ± 4	35.4 ± 0.7	110.0 ± 9.2	110.0 ± 9.2

Values are means ± SEM. N = 7 for each group.

Differences between Groups 1 and 2 were evaluated with the use of the two-way analysis of variance; changes occurring in the patients of Group 3 were analyzed with the use of the two-way analysis of variance and Tukey's test for multiple comparisons among means. The correlation between glucose load and respiratory quotient was determined by linear regression. Values of $P < 0.05$ were interpreted as being significant.

Results

Body temperature was below normal in all groups, but there were no significant differences between the groups in age, weight, or body temperature (Table 1). General and spinal anesthetics were distributed relatively equally among the three groups.

Respiratory quotient was significantly higher in Group 2 (glucose, RQ = 0.93 ± 0.01) than in Group 1 (saline, RQ = 0.77 ± 0.01) at all times ($\bar{x}$ ± SEM, $P < 0.05$). RQ did not change with time in these two groups (fig. 1). In Group 3 (glucose → saline), however, RQ decreased from 0.97 ± 0.04 to 0.87 ± 0.03 in the hour after glucose was discontinued. Although this reduction was significant ($P < 0.05$), RQ remained higher than for patients in Group 1, who received no glucose in the perioperative period ($P < 0.05$). Analysis of variance revealed that these observations were independent of the type of anesthesia. There was no correlation between the initial RQ in the recovery room and the amount of glucose administered intraoperatively to patients in Groups 2 and 3 ($r = 0.24$, $P > 0.4$).

CO_2 production did not change with time in any of the groups but was 20% greater in Group 2 than in Group 1 throughout the measurement period. O_2 consumption increased with time in Group 3, although the increase was not statistically significant. Differences in O_2 consumption between groups were not significant (table 2).

Discussion

There is no universal agreement as to which fluids should be used perioperatively in patients who do not have diabetes. In some textbooks, glucose-containing solutions are recommended as maintenance fluids.[5,6] Most elective surgical patients arrive in the operating room with a 500–1500 ml fluid deficit, which is generally replaced within the first 2 hours of surgery.[5,6] Therefore, the amounts of fluid received by our patients were comparable to those used in routine practice.

While it is certainly true that many factors interact to influence respiratory quotient in the perioperative period, we attempted to minimize the influence of factors other than the composition of the intravenous fluids by excluding patients who were shivering, in pain, less than fully awake, hemodynamically unstable, or uncooperative.

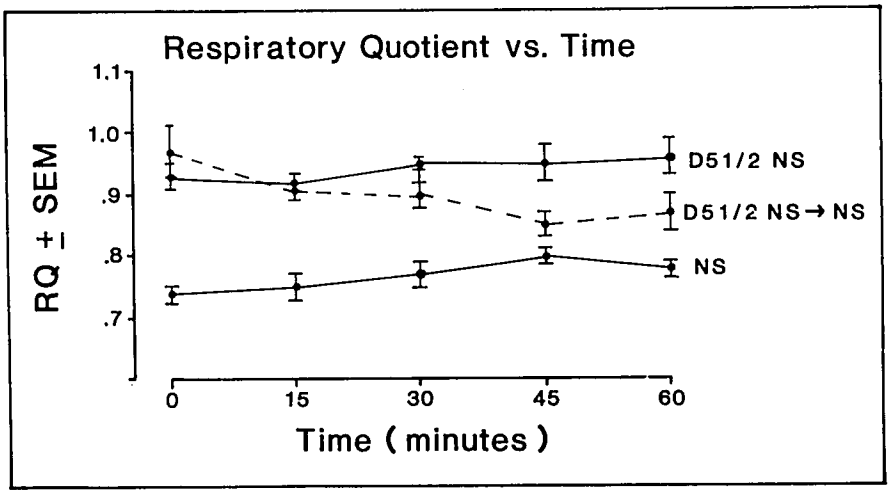

FIG. 1. Respiratory quotient (RQ) *vs.* time for Group 1 (NS), Group 2 (D5 ½ NS), and Group 3 (D5 ½ NS → NS). Each point and bracket represent mean ± SEM for seven patients.

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TABLE 2. CO_2 Production and O_2 Consumption *versus* Time

	Time in Recovery Room (min)	CO_2 Production (ml/min)	O_2 Consumption (ml/min)
Group 1 (saline)	0	134 ± 13	179 ± 18
	15	149 ± 13	198 ± 18
	30	148 ± 14	191 ± 18
	45	147 ± 14	183 ± 16
	60	148 ± 16	188 ± 18
Group 2. (glucose)	0	192 ± 28	206 ± 16
	15	161 ± 16	177 ± 12
	30	174 ± 13	183 ± 19
	45	173 ± 23	182 ± 26
	60	179 ± 24	187 ± 24
Group 3. (glucose to saline)	0	171 ± 21	176 ± 21
	15	170 ± 11	185 ± 10
	30	183 ± 14	201 ± 12
	45	163 ± 10	191 ± 11
	60	176 ± 13	203 ± 16

All values are means ± SEM.
N = 7 for each group.

The capabilities of the Beckman Metabolic Measurement Cart® for determination of O_2 consumption, CO_2 production, and RQ have been described recently.[4] With $F_{I_{O_2}}$ = 0.21 and tidal volumes greater than 350 ml (as observed in our patients), measurements of O_2 consumption and CO_2 production are accurate to within 5%; RQ determinations are accurate to within 1.5%. Of course, the use of such a device assumes that near steady-state conditions are met. We established this by performing measurements in triplicate and verifying that minute ventilation, measured CO_2 production, and measured O_2 consumption remained stable to within 10%. Because O_2 consumption, CO_2 production, and RQ did not vary appreciably with time in Groups 1 and 2, it is unlikely that elimination of residual anesthetic gases significantly affected our measurements; in addition, the effect of glucose administration was the same in patients who had spinal anesthesia (no residual gases) and general anesthesia.

It is reasonable to ask if withholding glucose in the perioperative period predisposes patients to hypoglycemia or ketosis. It is well established that there is an increase in serum glucose levels during anesthesia and surgery in normal patients related to increased catecholamine secretion, decreased insulin secretion, and decreased peripheral glucose utilization.[7] Although there may be a small increase in ketone body concentration in fasted patients (2 mM after 48-h fast), these levels are clinically insignificant.[8,9] However, these considerations do not apply to patients receiving insulin or oral hypoglycemic agents or patients with limited hepatic reserve, who should receive glucose perioperatively.[10] Of course, the protein-sparing effect of perioperative glucose must be considered when treating debilitated patients, in whom further wasting of the muscles of ventilation could be detrimental; it is unlikely, however, that withholding glucose for a few hours will cause significant muscle wastage.

We have demonstrated that administration of glucose in the perioperative period increases CO_2 production and RQ, and that eliminating glucose in the postoperative period decreases RQ (although after 1 hour, the RQ remains higher than in those patients who received no glucose perioperatively). The most likely explanation for the differences we observed is that those patients receiving glucose (RQ = 1.0) preferentially metabolized it as an energy source. The lower RQ in patients receiving no glucose probably reflects the importance of lipids (RQ $\approx$ 0.7) as a major energy source in the fasting state. These observations could potentially be of significance in patients with minimal ventilatory reserve.[2]

The authors thank Dr. James Mullen for his help in performing this study.

References

1. Askanazi J, Nordenstrom J, Rosenbaum SH, et al: Nutrition for the patient with respiratory failure: glucose vs. fat. ANESTHESIOLOGY 54:373–377, 1981
2. Askanazi J, Elwyn DH, Silverberg PA, Rosenbaum SH, Kinney JM: Respiratory distress secondary to a high carbohydrate load: a case report. Surgery 87:596–599, 1980
3. Wilmore JH, Davis JA, Norton AC: An automated system for assessing metabolic rate and respiratory function during exercise. J Appl Physiol 40:619–624, 1976
4. Damask MC, Weissman C, Askanazi J, Hyman AI, Rosenbaum SH, Kinney JM: A systematic method for validation of gas exchange measurements. ANESTHESIOLOGY 57:213–218, 1982
5. Harrison RA: Intravenous fluids and acid base balance, Introduction to Anesthesia, fifth edition. Edited by Dripps RD, Eckenhoff JE, Vandam LD. Philadelphia, W. B. Saunders, 1977, pp 309–329
6. Giesecke AH: Perioperative fluid therapy—crystalloids, Anesthesia. Edited by Miller RD. New York, Churchill Livingstone, 1981, pp 865–883
7. Alberti KGMM, Thomas DJB: The management of diabetes during surgery. Br J Anaesth 51:693–710, 1979
8. McGarry JD, Foster DW: Hormonal control of ketogenesis. Arch Intern Med 137:495–501, 1977
9. Clarke RSJ: Anesthesia and carbohydrate metabolism. Br J Anaesth 45:237–241, 1973
10. Blundell CR, Earnest DL: Medical evaluation of the patient with liver disease prior to surgery, Anesthesia and the Patient with Liver Disease. Edited by Brown BR. Philadelphia, F. A. Davis, 1981, pp 127–128

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