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Perioperative Blood Glucose Concentrations in Pediatric Outpatients

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Whether preoperative fasting causes hypoglycemia in healthy infants and small children has not been resolved.[1–8] Limiting the starvation period and administering glucose-containing solutions during surgery may not be necessary as indicated by studies reporting normal blood glucose values in fasting children.[5] Furthermore, some investigators suggest that the stress induced by anesthesia and surgery results in intraoperative hyperglycemia[9] and advise that glucose-free solutions may be used during surgery. Many of these studies, however, involved only a small number of patients and thus may have failed to identify an episode that occurs infrequently.

The purpose of this study was to measure the effect of preoperative fasting on blood glucose in a large number of children undergoing elective outpatient procedures and to determine the effect of a commonly used concentration of glucose in iv fluids required during surgery.

METHODS

Four hundred forty-six children, 1 month to 6 yr of age, scheduled for outpatient minor surgical procedures associated with minimal blood loss, *e.g.*, hernia repair, circumcision, orchiopexy, and eye muscle sugery, were studied. Premature infants and children with cardiac, neurologic, endocrine, or metabolic diseases were excluded. Informed consent and institutional approval for the study were obtained.

The standard preoperative instruction to parents was not to allow children any solids after midnight. Infants less than 1 yr of age were encouraged to drink clear liquids up to 4 h, and children 1–6 yr of age up to 6 h prior to surgery. The patients were unpremedicated. Preoperative blood glucose (BG) determinations were performed 0.5–4 h prior to surgery using the blood sample drawn for complete blood count (CBC). Choice of anesthetic technique was made by the anesthesiologist caring for the patient and was not altered for the purpose of the study (table 1). All patients had BG determinations performed immediately following induction of anesthesia but prior to the iv infusion of any fluid. Patients were assigned randomly to one of two groups for intraoperative iv fluid management. Assignment was based on the day of the week the cases were done. Group A received lactated Ringer's (LR) solution and Group B received 5% dextrose and lactated Ringer's solution (D_5LR). The volume of fluids infused during surgery was determined on the basis of the child's body weight.†† At the conclusion of surgery, BG was redetermined.

All blood samples were centrifuged within 10–20 min of collection, and serum was separated and frozen for later analysis using the glucose-oxidase method (Eastman Kodak, Rochester, NY). Although the glucose oxidase method is extremely precise[11] (coefficient of variation [CV] = 0.6% at 72 mg/dL), the results are not immediately available. Therefore, two other methods of BG determinations were performed on induction and postoperative blood samples using reflectance meter techniques,[12] Accu-Chek bG® (Biodynamics, Indianapolis, IN) and Glucometer® (Ames, Elkhart, IN). The results from these instruments were available immediately, so that any patient who was hypoglycemic[13,14] could be identified and given a glucose-containing infusion instead of subjecting the type of iv fluid therapy to random choice. For the purpose of this study hypoglycemia was defined as a BG concentration less than 50 mg/dL.[13,14]

Groups A and B were analyzed for statistically significant differences by the two-sample t test for continuous variables, and by the Chi-square test for categorical variables. These same statistical tests were applied to two subgroups of patients both receiving LR and showing either an increase or no increase in postoperative blood

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†† Hourly maintenance rate (ml/h):<10kg = wt × 4; 11–20 kg = 20 + wt × 2; >20 kg = wt + 40. A hydrating dose equal to four times the hourly rate was administered during the first hour of surgery.[10]

TABLE 1. Numbers of Patients Receiving Different Anesthetic Agents and Techniques in Each of the Two Groups

	Group A LR (n)	Group B D_5LR (n)
Induction of anesthesia		
Inhalation (halothane)	199	176
Intravenous (thiamylal)	31	25
Intramuscular (ketamine)	6	8
Rectal (methohexital)	1	0
Smooth: Yes/No	185/52	165/44
Intubation: Yes/No	181/56	166/43
Maintenance of anesthesia		
Volatile anesthetics	237	209
Muscle relaxants	50	52
Narcotics	3	4
Regional block*	48	42

* Regional block combined with general anesthesia for postoperative pain relief.

glucose relative to the preoperative value. The paired t test was used to determine the significance of the difference between the preoperative and the postoperative blood glucose concentrations. Least-square linear regression analysis was used to compare the results of the Accu-Chek bG® and Glucometer,® respectively, with the values obtained by the glucose-oxidase method.

RESULTS

The duration of fast and the mean and range of fasting BG for different age groups are shown in table 2. Two hundred thirty-seven patients received LR (Group A) and 209 received D_5LR (Group B) for intraoperative fluid management. Both groups were comparable for age, sex, weight, duration of fasting, type of anesthetic, duration of anesthesia, and morning or afternoon posting of surgery.

Two patients were found to be hypoglycemic at the time of induction of anesthesia. The first was a 6-yr-old boy, scheduled for afternoon surgery, who had been fasting for 17 h. His admission BG was 69 mg/dL. There was a delay of 3.5 h before induction of anesthesia. Analysis of the blood sample following induction of anesthesia

TABLE 2. Age Distribution, Fluid Infused, NPO Duration, and Fasting Blood Glucose Concentrations (mg/dL)

Age (yr)	Group A (n)	Group B (n)	NPO Duration (h) Mean	NPO Duration (h) Range	Fasting Glucose (mg/dL) Mean	Fasting Glucose (mg/dL) Range
0–1	45	32	6.1	4–8	82	56–125
1–2	45	40	11.0	6–19	84	56–127
2–4	87	72	12.2	8–19	83	47–121
4–6	60	65	12.7	8–17	88	54–156

showed hypoglycemia by both Glucometer® and glucose-oxidase method (49 and 47 mg/dL, respectively). The second was a 15-month-old boy, also scheduled for afternoon surgery, who had been fasting for 19 h. He had a BG of 57 mg/dL on admission; 3 h later his blood glucose following induction of anesthesia was 40 mg/dL, as detected by Glucometer.® Both patients were asymptomatic. They were both given D_5LR intraoperatively after hypoglycemia was recognized.

As a group, patients who received LR during surgery had a mean net increase in BG concentrations from 85 ± 14 (SD) at induction to 111 ± 22 mg/dL postoperatively. Patients who received D_5LR, on the other hand, had a much greater increase in BG concentrations, from 83 ± 14 to 244 ± 60 mg/dL, respectively (fig. 1). The increase in BG concentration in both groups is statistically significant ($P < 0.0001$). A wide range of postoperative BG values was evident in the two groups, as low as 59 mg/dL in a Group A patient, and as high as 504 mg/dL in a Group B patient.

Of the patients who received LR, 17 (12.14%) failed to show an increase or actually had a decline in postoperative BG from the preoperative value. No statistically significant associations were noted with age, type of anesthetic, smoothness of induction, type of surgery, or duration of fasting and the failure of the BG to increase.

In comparing the results of the different methods of BG testing used in the study, we found that for BG values greater than 100 mg/dL, both Accu-Chek bG® and Glucometer® results showed excellent correlations with values determined by the glucose-oxidase method (r = 0.98 and 0.99, respectively) (fig. 2). For the lower glucose values encountered at induction, however, the Glucometer® had a much better correlation with the glucose-oxidase method (r = 0.83), while Accu-Chek bG® values were invariably higher than the glucose-oxidase determination (r = 0.57) (fig. 3).

DISCUSSION

Hypoglycemia can occur in pediatric patients fasting for surgery.[1–4] Various authors define hypoglycemia in children as a BG concentration of 40,[15,16] 50,[13,14] or 60[17] mg/dL. Even at the lower concentration, most children remain asymptomatic, although some may appear lethargic or irritable. The possibility that hypoglycemia may remain undetected during anesthesia has led many authors to recommend the routine use of glucose-containing solutions during surgery.[1–4]

In a study of BG concentrations in 80 children who were fasting prior to surgery, Watson found that 10% had a BG concentration in the hypoglycemic range (≤40 mg/dL).[2] Bevan and Burn[1] found BG concentrations less than 60 mg/dL in 30% of starved children at the time of induction of anesthesia. Thomas reported preoperative hypoglycemia with a BG concentration less than 40 mg/dL only in fasting children who were less than 4 yrs of age and 15.5 kg body weight.[3] Other authors, however, could not confirm that the duration of starvation influenced the preoperative BG concentration.[1,6] Although all these studies collectively represent a large number of patients, caution must be exercised when comparing results from studies done at different times and in various institutions.[6] Differences in the methods of testing and the variable level of stress response resulting from difference in anesthetic techniques and patient population in pooled studies make a meaningful comparison difficult.

Our study includes 446 patients, all studied within a 6-month period, in the same institution. All the blood samples were collected and analyzed in the same laboratory, using the same equipment. We found that periods of fasting longer than 10 h produced hypoglycemia in a small number of healthy children younger than 6 yr of age. Even though parents were given preoperative instructions to minimize the duration of fasting, some patients were fasted for up to 19 h. However, the children

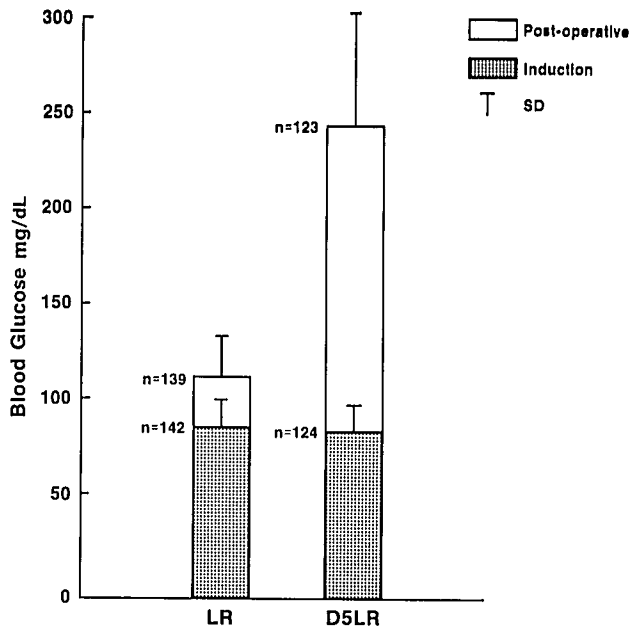

FIG. 1. Perioperative changes in blood glucose concentrations (glucose-oxidase method) when LR and D_5LR are infused during surgery.

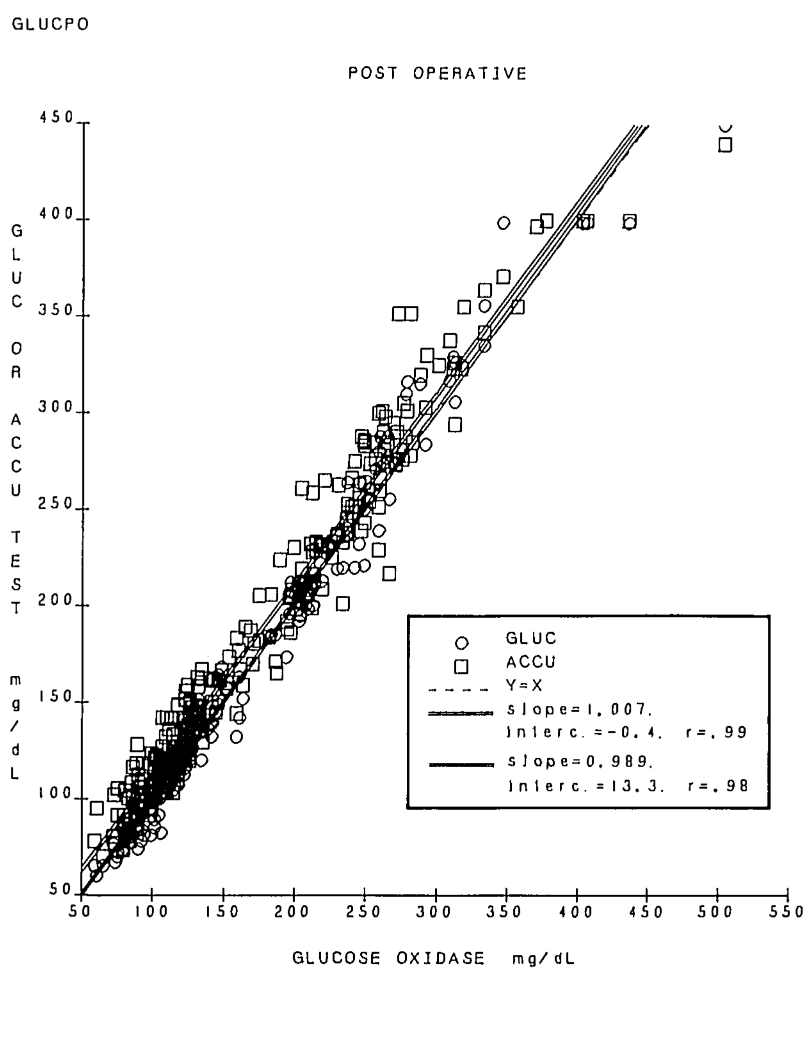

FIG. 2. Comparison of the results of postoperative blood glucose measurements by glucose-oxidase and reflectance (Glucometer and Accu Chek) techniques.

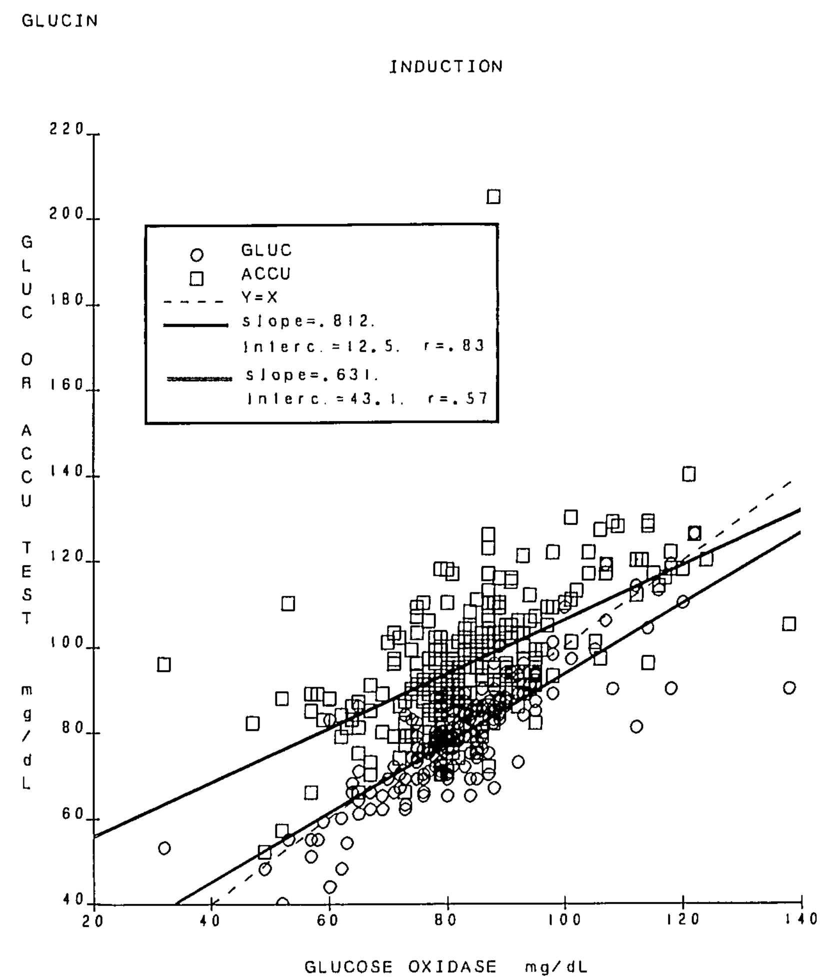

FIG. 3. Comparison of the results of induction blood glucose measurements by glucose-oxidase and reflectance (Glucometer and Accu Chek) techniques.

did not exhibit preanesthetic clinical signs or symptoms of hypoglycemia.

As anticipated, all children receiving glucose-containing solutions intraoperatively responded with an increase in BG concentrations. The finding that most children receiving glucose-free iv fluid solutions demonstrated an increase in their BG concentrations was also expected and confirmed previous findings.[5] Physiologic factors accounting for the hyperglycemic response to anesthesia and surgery include: increased sympathoadrenal activity leading to a decrease in glucose tolerance, decreased glucose utilization, and increased gluconeogenesis. These and similar earlier findings have led some authors to conclude that glucose-containing solutions may not be necessary to maintain adequate glucose concentrations in healthy pediatric patients during surgery.[5] In our series, 17 patients (12%) who received glucose-free solutions failed to increase their BG concentrations, 15 of whom manifested a decline.

To decide on what concentration of glucose, if any, is reasonable for routine use in iv solutions administered to healthy pediatric outpatients undergoing minor surgery, one must consider the relative risks of hypoglycemia and/or hyperglycemia at the infusion rate required to maintain cardiovascular homeostasis. Administration of 5% glucose-containing solutions for that purpose invariably results in hyperglycemia. Elevated BG concentrations in excess of 200 mg/dL in healthy infants and children may lead to osmotic diuresis. The proximal tubules of the kidney usually reabsorb all filtered glucose provided that a threshold limit, normally 180 to 200 mg/dL in plasma, is not exceeded. During anesthesia and surgery this value may be lower, and glucose intolerance may be present.[18] Thus, although the clinical significance of postoperative hyperglycemia is not clear, it is a physiologic trespass that is easy to avoid.

It is unclear why the Accu-Chek bG® gives false high results when measuring low concentrations of blood glucose. Inherent characteristics of the calibration of the instrument as provided by the manufacturer may be responsible for that.

In conclusion, we demonstrated that asymptomatic hypoglycemia is a rare but ever present phenomenon in healthy children fasting for surgery. The stress-induced postoperative increase in BG is not a consistent finding. If a nonglucose-containing solution is used for intraoperative fluid management, intraoperative BG monitoring is suggested, especially if the preoperative fasting period has been prolonged. We found the Glucometer® technique to be an accurate bedside method for BG monitoring even at low BG concentrations.

Because intraoperative administration of 5% glucose-containing solutions invariably results in hyperglycemia, a less concentrated glucose-containing solution might be preferrable for routine intravenous fluid maintenance during surgery in healthy children.

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Venous Air Embolism and Cardiac Arrest during Craniectomy in a Supine Infant

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Venous air embolism (VAE) is a common complication of neurosurgical procedures done in the sitting position.[1] VAE probably occurs in 7-45% of sitting[2-4] and 10-17% of prone procedures[4,5] and occasionally, in the supine[4,6] and lateral positions.[7] This clinical report documents the occurrence of VAE in an infant during a craniectomy in the supine position that resulted in dysrhythmias, hypotension, and cardiac arrest.

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REPORT OF A CASE

A 10-month-old infant born with multiple congenital anomalies was scheduled for a craniectomy to correct a severe anterior plagiocephaly. Two previous anesthetics for insertion of a ventriculoperitoneal shunt and for a hip arthrogram were uneventful. Anesthesia for this procedure was induced by the inhalation of halothane and maintained