RECALL

3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct.

LANGUAGE

9	( )	Name a pencil, and watch (2 points)
		Repeat the following "No ifs, ands or buts." (1 point)
	( )	Follow a 3-stage command: "Take a paper in your right hand, fold it in half, and put it on the floor" (3 points)
	( )	Read and obey the following: CLOSE YOUR EYES (1 point)
	( )	Write a sentence (1 point)
	( )	Copy design (1 point)
30	( )	Total score

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Glucose Concentrations for Routine Intravenous Infusion in Pediatric Outpatient Surgery

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The effects of preoperative fasting on perioperative blood glucose concentrations in healthy pediatric patients have been studied extensively.[1–8] Most children have normal levels of blood glucose in spite of fasting, and respond to anesthesia and surgery with an increase in blood glucose.[9] These findings have led some authors to advise that glucose-free solutions may be safely used during surgery in children.[5] Other authors, however, still recommend routine use of glucose-containing solutions.[1–4] We recently found that asymptomatic hypoglycemia may be present in some otherwise healthy children presenting for elective outpatient surgery.[1] Moreover, we found that, although the majority of healthy children have a significant hyperglycemic response to surgery, some fail to show an increase, or even manifest a decrease, in blood glucose concentrations after surgery. Administration of a 5% glucose-containing solution prevents hypoglycemia, but results in moderate to marked postoperative hyperglycemia.[1]

We first propose to evaluate the effect of preoperative fasting on blood glucose concentrations in children undergoing elective outpatient surgery; and, second, to determine whether the use of solutions containing less than 5% glucose would maintain physiologic blood glucose concentrations without inducing hyperglycemia.

METHODS

One hundred sixty-two children, ranging in age from 1 month to 6 yr, were studied. All were scheduled for elective outpatient surgical procedures associated with minimal blood loss, including inguinal hernia repair, circumcision, orchiopexy, and eye muscle surgery. Premature infants and children with cardiac, neurologic, endocrine, or metabolic diseases were excluded. The study was approved by our Institutional Review Board, and informed consent was obtained from the parent of each patient.

Parents were instructed not to allow their children to eat any solid food after midnight of the day preceding surgery. Infants less than 1 yr of age were allowed to drink clear liquids up to 4 h, and children 1–6 yr of age up to 6 h, before surgery. None of the patients received preoperative medication prior to surgery. Choice of anesthetic technique was made by the patient's anesthesiologist, and was not altered for the purpose of the study. Preoperative blood glucose determinations were performed using the blood sample for complete blood count drawn between 30 min and 4 h prior to induction of anesthesia. A second blood glucose determination was performed immediately following induction of anesthesia but prior to the iv infusion of any fluid.

Patients were randomly assigned to one of three groups for intraoperative iv fluid management; assignment was based on the day of the week on which sur-

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TABLE 1. Age, Weight, Duration of Fasting, Induction Blood Glucose, Anesthesia Time, and Intraoperative Rise of Blood Glucose in Patients who received Lactated Ringer's (LR), 1% Dextrose and Lactated Ringer's (D1 LR), and 2.5% Dextrose and Lactated Ringer's (D2.5 LR) Solutions

	Group A (LR) (n = 54)	Group B (D1 LR) (n = 56)	Group C (D2.5 LR) (n = 52)
Age (m) ± SD	34 ± 22	35 ± 22	30 ± 19
Weight (kg) ± SD	14 ± 5	14 ± 5	13 ± 5
Duration of fasting (h) ± SD	11 ± 4	12 ± 4	11 ± 4
Induction blood glucose (mg/dL)	78 ± 9	83 ± 11	81 ± 13
Duration of anesthesia (min) ± SD	58 ± 17	62 ± 22	64 ± 21
Intraoperative change of blood glucose (mg/dL)			
Mean ± SD	30 ± 20	40 ± 24	59 ± 27
Range	−2 to 86	−12 to 90	21 to 125

gery was performed. Group A received lactated Ringer's (LR) solution, group B received 1% dextrose and lactated Ringer's solution (D1 LR), and group C received 2.5% dextrose and lactated Ringer's solution (D2.5 LR). The two dextrose solutions were prepared in the hospital pharmacy. Since we have demonstrated in a previous study[1] that 12% of children who receive glucose-free solutions do not demonstrate a rise in blood glucose under these circumstances, our protocol mandated that patients who were hypoglycemic at induction should receive glucose-containing solutions for intraoperative fluid management. This was done for medical and ethical reasons. The hourly maintenance rate (ml/h) of fluids infused during surgery was determined on the basis of the child's body weight: <10 kg = wt × 4; 11–20 kg = 20 + wt × 2; >20 kg = wt + 40.[10] A hydrating bolus of fluid equal to four times the hourly rate (half an assumed 8-h deficit) was administered during the first hour of surgery. At the conclusion of surgery, blood glucose concentration was determined for the third time. 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. The glucose-oxidase method is extremely precise[11] (Coefficient of Variation = 0.6% at 72 mg/dL); however, the results are not immediately available. To identify more quickly any children who were hypoglycemic, blood glucose determinations were performed on induction of anesthesia and at the conclusion of surgery using reflectance meter techniques,[12] Accu-Chek II® (Biodynamics, Indianapolis, IN), and Glucometer II® (Ames, Elkhart, IN). The results from these instruments were available within 2 min, and any patient who was hypoglycemic was given a glucose-containing infusion, instead of subjecting the patient to a random choice of iv fluid. For the purpose of this study, hypoglycemia was defined as a blood glucose concentration less than 50 mg/dL,[13,14] and hyperglycemia as a blood glucose concentration greater than 200 mg/dL.[15]

Groups A, B, and C were tested for differences in their measured variables by analysis of variance. In cases of statistical significance ($P < 0.05$), a two-sample t test for the investigation of specific differences was performed. The results of the blood glucose determinations by the reflectance methods were compared to the glucose-oxidase method by linear regression analysis.

RESULTS

Table 1 summarizes data concerning the duration of fasting, the mean and SD of blood glucose concentrations at the time of induction, duration of anesthesia, and intraoperative change of blood glucose for patients in each group. Two patients were found to be hypoglycemic at the time of induction. The first was a 13-month-old boy, scheduled for morning surgery, who had been fasting for 10 h. His admission blood glucose was 65 mg/dL; analysis of the blood sample collected at induction of anesthesia approximately 2 h later showed hypoglycemia (45 mg/dL). The second hypoglycemic child was a 3½-yr-old boy, scheduled for afternoon surgery, who had been fasting for 8 h. He had a blood glucose of 75 mg/dL on admission; 2 h later, his blood glucose during induction of anesthesia was 49 mg/dL. Both patients were asymptomatic. They were both given D2.5 LR intraoperatively. Their blood glucose concentrations at the conclusion of surgery were normal (112 and 98 mg/dL, respectively).

Fifty-four patients received LR (group A), 56 received D1 LR (group B), and 52 received D2.5 LR (group C). The three groups were comparable for age, and patients of different ages were equally represented in each of the study groups. They were also comparable for weight, duration of fasting and of anesthesia, and hour of surgery. The mean hourly infusion rate was similar in all groups. At that infusion rate, the glucose provided was zero, 128 ± 48, and 317 ± 98 $mg \cdot kg^{-1} \cdot hr^{-1}$ for patients in groups A, B, and C, respectively.

Blood glucose concentrations at the induction of anesthesia were similar in all groups ($P > 0.5$). Patients in group A, who received LR during surgery, had a net increase in blood glucose concentration, from a mean of

78 ± 9.5 (SD) at induction to 108 ± 22 mg/dL postoperatively. Patients who received D1 LR had an increase from a mean of 82 ± 11 to 122 ± 27 mg/dL, while those who received D2.5 LR had an increase from a mean of 81 ± 14 to 139 ± 29 mg/dL (fig. 1). The increase in blood glucose concentration at the end of anesthesia from the induction value in each group was statistically significant ($P < 0.001$). The differences of this increase between each of the groups were also statistically significant ($P < 0.001$). The blood glucose concentrations at the end of anesthesia were as low as 59 mg/dL in one patient in group A and 65 mg/dL in a group B patient, and as high as 198 mg/dL in a group C patient.

The intraoperative changes in blood glucose concentrations are shown in table 1. One patient in group A and two patients in group B had a decrease in blood glucose concentration from induction to end of anesthesia; however, none of the patients became hypoglycemic. Blood glucose concentrations in all patients in group C rose during surgery.

Both Accu Chek II® and Glucometer II® results correlated well with values determined by the glucose oxidase method ($r = 0.95$, SE 10.64, and $r = 0.99$, SE 5.28, respectively) for both low and high blood glucose concentrations.

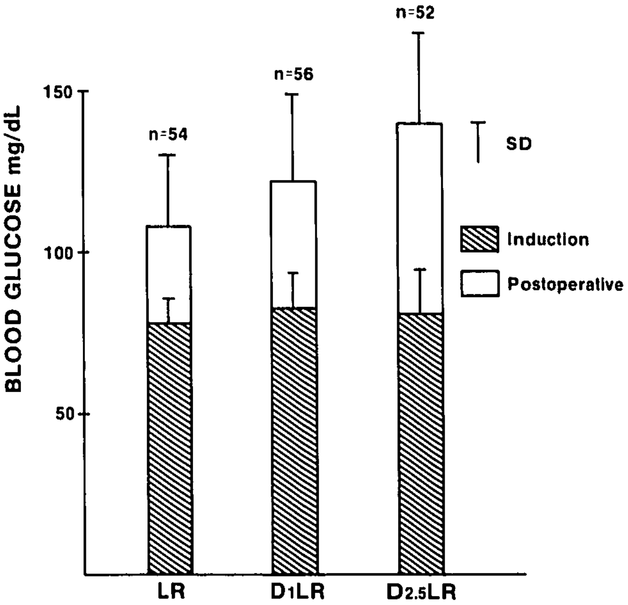

FIG. 1. Mean (±SD) blood glucose concentration (glucose-oxidase method) at induction and end of anesthesia when LR (lactated Ringer's solution), D1 LR (1% dextrose and lactated Ringer's solution), and D2.5 LR (2.5% dextrose and lactated Ringer's solution) are infused during surgery.

DISCUSSION

Hypoglycemia in healthy children has been arbitrarily defined as a blood glucose concentration of 40,[16,17] 50,[13,14] or 60[18] mg/dL. Since hypoglycemia may occur in fasting pediatric patients without clinical signs or symptoms of hypoglycemia, most authors recommend the routine use of glucose-containing solutions during surgery.[1-4] To decide on the optimal concentration of glucose in iv solutions for healthy children undergoing minor outpatient surgery, the relative risks of hypo- and/or hyperglycemia must be considered at the infusion rate selected. Following a period of preoperative fasting, it has been recommended that children receive a hydrating fluid bolus during the first hour of surgery to maintain cardiovascular homeostasis, especially if potent inhaled anesthetics are used.[19] We reported that administration of 5% glucose-containing solutions for that purpose invariably results in moderate to marked hyperglycemia. Although the potentially harmful effects of intra- and postoperative hyperglycemia are not clear, it is an abnormality that can be avoided. Furthermore, hyperglycemia is particularly undesirable should cerebral asphyxia and ischemia occur.[20] One way to avoid hyperglycemia with a 5% dextrose solution is to slow the infusion rate, but this may increase the susceptibility of children to cardiovascular depression when potent inhaled anesthetics are used. Alternatively, a less concentrated glucose solution may be used at the recommended infusion rate, the approach on which our study was based. The usual glucose requirement in healthy children is about 300 $mg \cdot kg^{-1} \cdot h^{-1}$.[21] At our usual rate of fluid administration, D2.5 LR provides the total glucose requirements (317 ± 98 $mg \cdot kg^{-1} \cdot h^{-1}$), whereas D1 LR does not (128 ± 48 $mg \cdot kg^{-1} \cdot h^{-1}$). LR solution provides no glucose. If the latter two solutions are used, the child must depend on endogenous glucose production to provide the glucose needed during surgery. The question of how the children who were hypoglycemic at induction of anesthesia would have responded to administration of glucose-free iv solutions remains unanswered. Since we demonstrated, in a previous study, that 12% of children do not demonstrate a rise in blood glucose under these circumstances,[1] our protocol mandated that hypoglycemic patients receive a glucose-containing solution for intraoperative fluid management.

It is important to note that our results represent the response of patients to our standard fluid regimen, which takes into consideration the volume to be infused and the glucose content of the solution to provide the basic glucose requirements of the surgical patient (±300 $mg \cdot kg^{-1} \cdot h^{-1}$). If solutions containing different glucose concentrations or different rates of infusion are used, appropriate modifications would be required.

Our experience with the various instruments available for bed-side testing of blood glucose indicated that Accu-Chek II® showed excellent correlations both at high and low blood glucose concentrations with values determined by the glucose-oxidase method, whereas Accu-Chek bG® showed excellent correlation only at blood glucose values greater than 100 mg/dL.[1] We found that the Glucometer II® and Accu-Chek II® techniques are accurate bedside methods for blood glucose monitoring, even at low blood glucose concentrations.

In conclusion, we demonstrated that asymptomatic hypoglycemia is a rare but ever-present possibility in healthy children fasting prior to anesthesia. Contrary to accepted opinion, a "stress-induced" intraoperative increase in blood glucose does not occur in all patients. If a solution with no glucose is used for intraoperative infusion, intraoperative monitoring of blood glucose is suggested to insure normal blood glucose concentrations in patients in whom the preoperative fasting period has been excessive. Based on this study, we recommend a 2.5% dextrose-containing iv solution for routine use in children who undergo outpatient surgery.

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