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THE RELATIONSHIP BETWEEN BLOOD GLUCOSE AND SERUM ELECTROLYTE LEVELS IN CHILDREN WITH ACUTE DIARRHEA*

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SUMMARY: Yurdakök K, Oran O. (Department of Social Pediatrics, Hacettepe University Institute of Child Health, Ankara, Turkey). The relationship between blood glucose and serum electrolyte levels in children with acute diarrhea. Turk J Pediatr 34: 145-152, 1992.

The relationship between simultaneous serum electrolyte and blood glucose levels was studied in 119 moderately or severely dehydrated children with acute infectious gastroenteritis. Their ages ranged between two months to fifteen years. A positive correlation was found between blood glucose and serum sodium levels in the children with serum bicarbonate values below 15 mmol/L. This correlation is more prominent in cases of severe metabolic acidosis with serum bicarbonate values less than 10 mmol/L. No correlation was found between blood glucose, serum potassium and chloride levels. Our results show that a positive correlation between blood glucose and serum sodium levels is present only in cases with metabolic acidosis, which is contrary to classical knowledge. *Key words: blood glucose, serum electrolytes, acute diarrhea, metabolic acidosis.*

Hypoglycemia and hyperglycemia have been reported in patients with acute childhood diarrhea[1-9]. Hypoglycemia has been described as a potentially fatal complication of acute infectious diarrhea whereas hyperglycemia has been associated with the hypernatremic dehydration of acute diarrhea[1-9]. The studies cited suggest that changes in blood glucose levels may occur during diarrheal illness and complicates the course of the disease especially when it is associated with electrolyte disturbances. However, the relationship between blood glucose and serum electrolytes has not been thoroughly investigated in children with diarrhea. The aim of this study was to determine blood glucose and serum electrolyte levels simultaneously and to ascertain if a relationship exists between them. To our knowledge, this is the first time that such a study has been undertaken in dehydrated children with acute gastroenteritis.

Material and Methods

This study was carried out at the Hacettepe University Children's Hospital Oral Rehydration Therapy and Training Unit from July to September 1990. Patients who had received an oral rehydration solution or drugs prior to admission were

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excluded from the study. One hundred and nineteen moderately or severely dehydrated children whose blood samples were drawn simultaneously on admission were included in the study. The degree of dehydration was assessed according to the World Health Organization (WHO) criteria[10]. A complete medical history was obtained and a physical examination was performed on each patient.

There were 78 males and 41 females in the study group. Their ages ranged between two to 15 years. Patients were divided into two groups according to age in order to reduce age-dependent variabilities of clinical and laboratory findings. The first group consisted of 89 children two years of age or under while the second group consisted of the remaining 30 children above two years of age. Clinical and laboratory findings were then evaluated in each group according to serum bicarbonate levels. The nutritional status of the patients was expressed as weight for age percentiles described by the National Center for Health Statistics[11].

Venous blood samples were obtained simultaneously to determine blood pH, glucose and serum electrolyte levels before therapy. The blood pH and serum bicarbonate levels were measured using an automatic blood gas analyzer (AVL 990; Medizintechnik, Austria). Serum electrolyte and blood glucose concentrations were determined by a discrete analyzer with continuous optical scanning (Dacos plus lytes, Coulter Electronics Inc; Florida, USA).

Entry of data into the computer and statistical testing were performed using Epi Info Version 5 software. The results were expressed as a mean ± Standard Deviation. Student's *t* test was used for statistical analysis.

Results

All patients had moderate or severe dehydration. Ten patients with severe dehydration and electrolyte disturbances required hospitalization and were treated intravenously. The others were given the standard WHO glucose/electrolyte solution, and responded well to treatment[10]. Sixty-four patients (53.8%) had body weight/age ratios below the 10th percentile and were considered undernourished.

Hypernatremia (serum $Na^+ > 150$ mmol/L) was present in nine (7.6%) patients. One patient presented with a serum Na^+ level of 170 mmol/L, but had no neurologic symptoms. Hyponatremia (serum $Na^+ < 130$ mmol/L) was documented in four patients, but their levels were not lower than 125 mmol/L. In five patients, serum potassium levels were less than 3 mmol/L.

Moderate or severe metabolic acidosis with blood pH levels below 7.30 was noted in 63 (53.0%) patients. Fourteen patients (11.8%) had blood pH levels below 7.20 and three (2.5%), with blood pH levels less than 7.05, were given intravenous bicarbonate therapy. In 58 patients (48.7%), the serum bicarbonate

level was below 15 mmol/L, and in 15 of them (12.6%) it was less than 10 mmol/L. Acidosis was more prominent in the dehydrated children under two. None of the children above two had serum bicarbonate levels below 10 mmol/L.

Hyperglycemia (blood glucose > 140 mg/dL) in a range between 151-240 mg/dl was documented in 13 patients (10.9%). Hypoglycemia was noted in only one patient with a blood glucose level of 31 mg/dL, who showed no symptoms. Disregarding the age factor, the mean serum sodium level was significantly higher in the hyperglycemic patients than in the rest of the patients (144.8 ± 6.7 mmol/L and 139.2 ± 6.8 mmol/L, respectively; $p < 0.01$), but their serum bicarbonate and blood pH levels showed no statistical significances (15.1 ± 4.7 mmol/L and 15.3 ± 4.6 mmol/L, respectively; $p > 0.05$, and 7.27 ± 0.12 and 7.30 ± 0.09 respectively; $p > 0.05$).

The mean age, body weight, blood glucose, serum potassium and chloride levels, and the mean time since the last feeding on admission were found to be similar according to serum bicarbonate levels in both groups of children (Tables I and II). In children under two, the mean serum sodium levels were found to be higher when their serum bicarbonate levels were below 11 mmol/dL and between 11-15 mmol/dL compared to those with serum bicarbonate levels above 15 mmol/dL ($p < 0.05$ and $p < 0.05$, respectively; Table I). In the second group, serum sodium and blood pH levels showed no statistical differences according to serum bicarbonate levels (Table II).

TABLE I: Clinical and Laboratory Findings of Children Under Two Years of Age with Acute Diarrhea

	Serum HCO_3^- levels			
	<10 mmol/L n: 15	11-15 mmol/L n: 35	>15 mmol/L n: 39	Total n: 89
Mean age (mo)	9.1 ± .7	10.7 ± .2	9.5 ± .5	9.9 ± .4
Body weight (kg)	7.1 ± 2.2	7.9 ± 2.1	7.2 ± 2.1	7.5 ± 2.1
Time since last feeding (hr)	7.3 ± 7.1	5.3 ± 3.7	3.8 ± 3.5	4.9 ± 4.4
Blood pH	7.18 ± 0.11*,***	7.26 ± 0.06*,***	7.33 ± 0.06**,***	7.28 ± 0.09
Blood glucose (mg/dL)	108.2 ± 46.3	102.9 ± 24.6	101.4 ± 22.9	103.2 ± 28.
Serum electrolytes				
Na^+ (mmol/L)	142.2 ± 8.9*	140.7 ± 7.9**	137.1 ± 5.5*,**	139.4 ± 7.
K^- (mmol/L)	4.6 ± 0.9	4.2 ± 0.6	4.3 ± 0.8	4.4 ± 0.8
Cl^- (mmol/L)	108.2 ± 13.7	107.0 ± 13.2	104.6 ± 10.9	105.7 ± 12.

Statistical comparisons:
for blood pH * $p < 0.02$, **,*** $p < 0.001$.
for serum sodium *,** $p < 0.05$.

TABLE II: Clinical and Laboratory Findings of Children Above Two Years of Age with Acute Diarrhea

	Serum HCO_3^- levels		
	11-15 mmol/L n: 8	>15 mmol/L n: 22	Total n: 30
Mean age (mo)	61.5 ± 21.5	74.1 ± 43.1	70.7 ± 8.6
Body weight (kg)	16.8 ± 3.9	22.1 ± 11.1	20.1 ± 9.9
Time since last feeding (hr)	4.5 ± 3.7	3.5 ± 2.1	3.6 ± 2.5
Blood pH	7.33 ± 0.07	7.36 ± 0.04	7.36 ± 0.05
Blood glucose (mg/dL)	132.6 ± 29.0	117.7 ± 30.0	121.7 ± 30.0
Serum electrolytes			
Na^+ (mmol/L)	139.4 ± 4.5	141.5 ± 3.8	140.9 ± 4.0
K^- (mmol/L)	4.0 ± 0.4	4.2 ± 0.7	4.2 ± 0.6
Cl^- (mmol/L)	101.3 ± 12.4	100.6 ± 9.5	100.9 ± 10.0

In all comparisons $p > 0.05$.

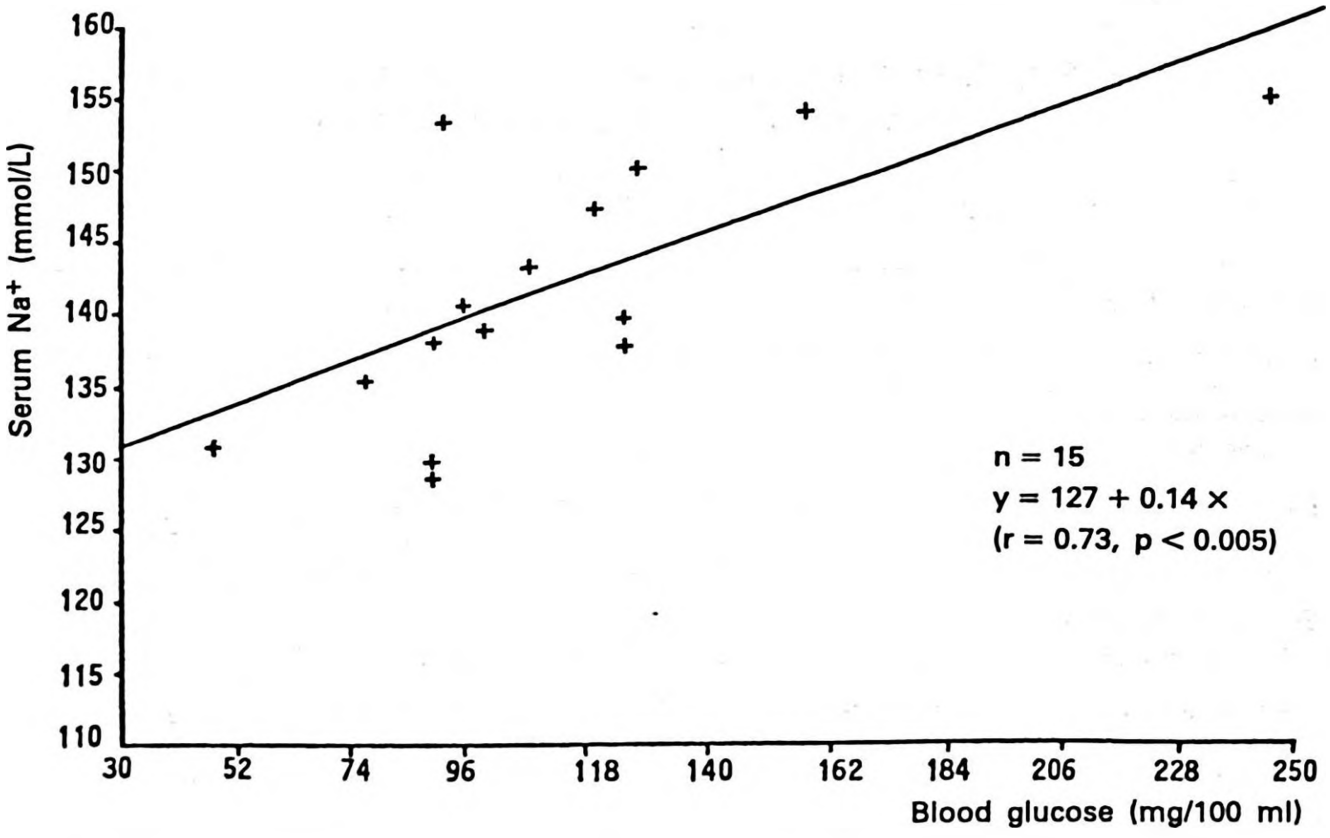

Fig. 1: The relationship between blood glucose and serum sodium values in severely acidotic (serum HCO_3^- level ≤ 10 mmol/L) children under two years of age.

Positive correlations were found between blood glucose and serum sodium levels in the children under two with bicarbonate levels below 15 mmol/L, but not in the older age groups (Figs. 1, 2). This correlation was very high when the bicarbonate level was less than 10 mmol/L (Fig. 1). There was no relationship found between the blood glucose and serum potassium or chloride levels in all age groups.

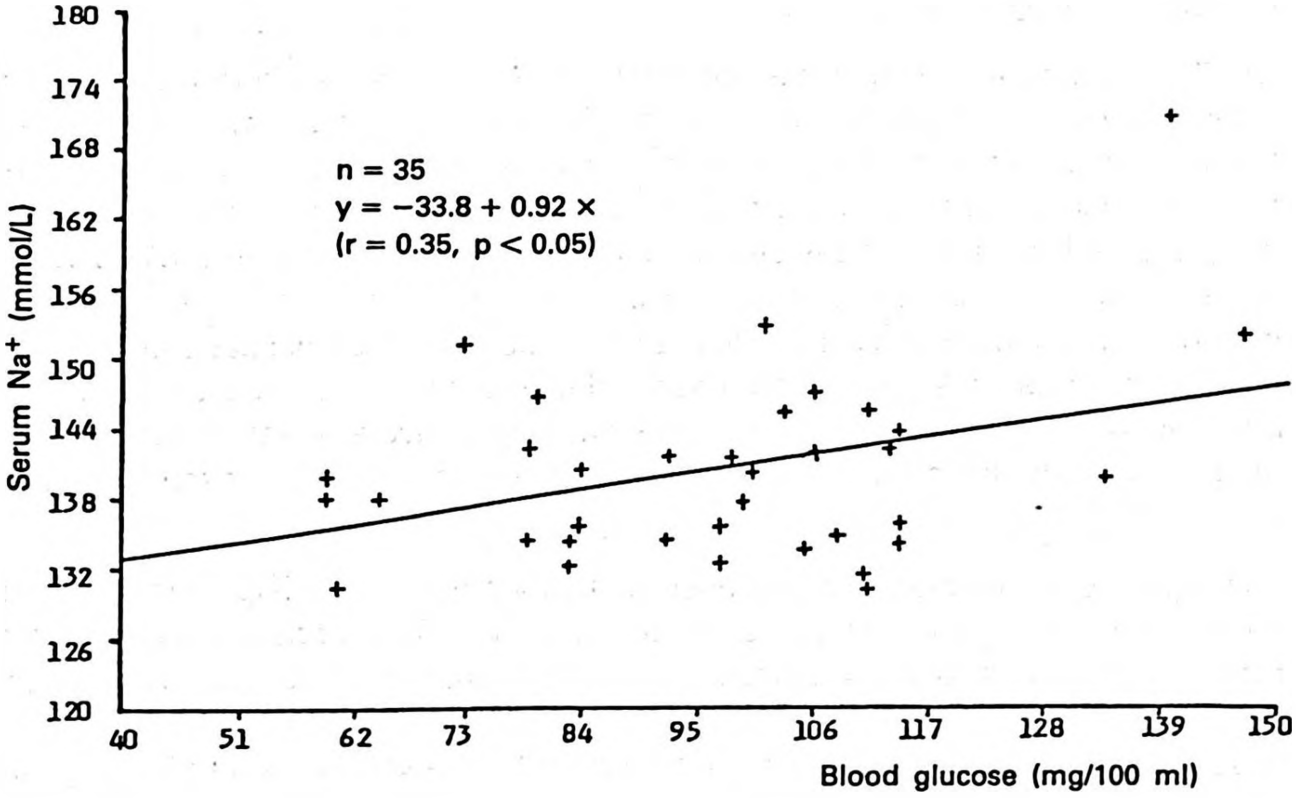

Fig. 2: The relationship between blood glucose and serum sodium values in moderately acidotic children (serum HCO_3^- level between 11-15 mmol/L) under two years of age.

Discussion

There have been reports of abnormalities in serum glucose levels in childhood diarrheal diseases[1-9]. Symptomatic hypoglycemia in acute childhood diarrhea was first described in 13 children by Hirschhorn et al[1]. He and his associates also studied blood glucose levels in children with acute gastroenteritis, and symptomatic hypoglycemia was found due to gastroenteritis in three. Later Jones[2] reported 14 cases of hypoglycemia among 378 dehydrated children due to gastroenteritis. Recently, the incidence of hypoglycemia, as a complication of acute diarrhea, has been reported to be 4.5 percent in children aged 2-15[4]. Although 53.8 percent of our patients had body weight/age ratios below the tenth percentile, hypoglycemia was observed in only one patient. Mean blood glucose levels were found to be above 100 mg/dL in all age groups.

In reported studies, hypoglycemia is observed in both well-nourished and malnourished children, suggesting that malnutrition is not a major factor

contributing to the development of hypoglycemia in patients with acute gastroenteritis[1,2,4]. Predisposing and etiologic factors in the pathophysiology of hypoglycemia in these children remain obscure. Hyperinsulinemia and counter-regulatory hormone deficiencies can not be regarded as a cause of hypoglycemia because Hirschhorn[1] found low plasma insulin levels, and Bennish and co-workers[4] reported elevations in almost all counter-regulatory hormones in hypoglycemic patients.

Our finding that a high positive correlation exists between blood glucose and sodium levels in dehydrated and severely acidotic children may suggest that hyponatremia might also occur along with hypoglycemia in some of the hypoglycemic patients reported above, especially in those with severe acidotic dehydration. But simultaneous serum electrolyte and blood glucose levels were not studied in any of these reports. However, the occurrence of low plasma insulin[1] and high plasma glucagon levels[4] in these hypoglycemic patients permits us to speculate a finding that a decrease in the serum sodium levels could also be a finding in these studies, since insulin is known to have a direct effect on renal tubular sodium handling, and glucagon increases sodium excretion and natriuresis[12].

Although the simultaneous occurrence of hyponatremia and hypoglycemia has not been noted in acute gastroenteritis, the presence of hyperglycemia along with hypernatremia has been reported by several authors[5-8]. Levin and Geller-Bernstein[6] reported hyperglycemia in some dehydrated infants with acute gastroenteritis, and they noted high serum sodium and low blood pH levels in these infants. Later, Roberts[7] reported hyperglycemia in five hypernatremic dehydrated children due to acute gastroenteritis. In the series of Bruck et al[8], six of 28 hypernatremic acidotic infants with diarrhea had hyperglycemia. Stevenson and Bowyer[9] also reported three hyperglycemic cases with hypernatremic dehydration due to acute infectious diarrhea. High blood glucose levels in induced hypernatremia in rats have been demonstrated by Nitzan and Zelmanowsky[13].

Hypernatremia is known to cause severe metabolic acidosis which might be the major determinant of glucose intolerance and the diabetogenic effect of hypernatremia[13-15]. The occurrence of peripheral resistance to insulin and decreased peripheral glucose utilization may contribute to hyperglycemia in patients with acidosis[13,15]. Therefore; despite malnutrition, we may explain the high mean blood glucose concentrations as being due to metabolic acidosis which developed during diarrheal dehydration in our patients. The positive correlation found between serum sodium and glucose levels was also more prominent in the patients with severe metabolic acidosis and the mean serum sodium levels were found to be higher in these patients (Table I). In addition, the simultaneous occurrence of hyperglycemia and hypernatremia has also been reported in other

diseases such as diabetes mellitus, ketoacidotic diabetic coma, nonketotic hyperosmolar coma, severe burns, and acute intracranial injuries[13]. However, these studies and our findings contrast with the classical sodium and glucose relationship, especially reported as occurring in diabetes mellitus. A classical relationship examined mathematically is that for each 1 g/L increase in blood glucose above 1 g/L there is a decrease in the serum sodium concentration by 1.6 mmol/L[16]. But Strand and associates[17] have shown that this negative correlation is not prominent as it is classically known in 100 spontaneous hyperglycemic children. On the other hand, we showed that a positive correlation exists between blood glucose and serum sodium concentrations in acidotic children with gastroenteritis, but not in non-acidotic children. Therefore, we may speculate that the positive correlation between serum sodium and blood glucose levels occurs only in metabolic acidosis and increases with the severity of metabolic acidosis. However, additional studies are needed to arrive at a reliable conclusion.

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