Fluid management in children with diarrhea-related hyponatremic-hypernatremic dehydration: a retrospective study of 83 children

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ABSTRACT

Aim To investigate serum creatinine and electrolyte status of children with diarrhea-related hyponatremic or hypernatremic dehydration.

Methods Medical history of 83 patients admitted to the Pediatric Intensive Care Unit of the Konya Education and Research Hospital, Konya, Turkey with diarrhea, dehydration and electrolyte imbalance was retrospectively evaluated according to the degree of dehydration, serum creatinine, electrolytes, blood gas, approaches to the treatment such as content of given fluid, HCO₃⁻ and acute peritoneal dialysis. Of 65 patients with hyponatremia, 44 (67.7%) were given fluids at appropriate concentration according to their age, and 21 (32.3%) were given fluids at higher concentration. Of 18 hypernatremic patients, 11 (61.1%) were given fluids at appropriate concentration for age, and seven (38.9%) were given fluids at higher concentration.

Results Mean duration of amelioration of serum sodium levels for those admitted with hyponatremia and given fluids at appropriate concentration for age and at higher concentration were 33.9±28.3 h and 53.7±31.6 h, respectively. Mean duration of amelioration of serum sodium levels for hypernatremics and given fluids at appropriate concentration for age and at higher concentration were 34.7±22.1 h and 46.3±32 h, respectively. Four (4.8%) hyponatremic patients and three (3.6%) with hypernatremia were treated with acute peritoneal dialysis. Mortality rate was 6% (five of all patients).

Conclusion The children with severe diarrhea should be closely followed-up as to clinical examination, serum electrolytes, creatinine and blood gases, and because no single intravenous fluid management is optimal for all children, intravenous fluid therapy should be individualized for each patient.

Keywords: diarrhea, dehydration, electrolyte imbalance, fluid management, hyponatremia, hypernatremia
INTRODUCTION

Diarrhea-related dehydration (DR-dehydration) is a significant cause of mortality and morbidity in infants and children worldwide (1). Oral rehydration treatment is the modality chosen in cases of mild to moderate dehydration due to diarrhea in children. However, in cases with moderate to severe dehydration that vomit and cannot orally be fed, intravenous (IV) fluid therapy is indispensable (2). The use of fluid therapy in dehydration still remains controversial among pediatricians. Despite main procedures parallel to each other, each clinic is of specific treatment regimes. The discrepancy may lead to confusion and miscalculation in the management, even causing potentially fatal complications in critical patients (3,4). The following main concepts related to DR-dehydration should be revealed to understand the treatment modalities far better.

The grades of dehydration are categorized into three categories, as mild (<5%), moderate (5-10%) and severe (>10%) in the newborns and children according to the percentage of lost body weight. In children with older age, however, these rates are advised to be utilized as 3%, 6%, and 9% for mild, moderate and severe grades of dehydration, respectively (5). Such physical findings as ill general appearance, sunken eyeballs, dryness of mucous membranes, decreased skin turgor, prolonged capillary refill time, abnormal respiratory pattern, tachycardia and hypotension are beneficial in the determination of severity of dehydration (2,6,7). However, the laboratory findings such as oliguria, increase in the density of urine, increased levels of urea and creatinine, electrolyte imbalance and the existence of metabolic acidosis in blood gas give only supportive evidence (8). Due to diarrhea, dehydration may develop in 3 types as hyponatremic, isonatremic and hypernatremic (9). Amounts of Na+ advised to treat the different forms of dehydration vary from one regime to another (10,11).

Intravenous fluid therapy of dehydrated children consists of three components: the restoration of intravascular volume by expanding the initial volume via giving fluid bolus, fluid deficit therapy to correct dehydration and to replace fluids and electrolytes already lost on presentation, and lastly maintenance fluid therapy to meet physiological fluid requirements during the rehydration phase (12).

A marked consensus is present on such general therapeutic approaches, but discrepancies on the content of fluids to be given still keep on going. In our study, as the pediatric intensive care unit (PICU) of a tertiary hospital admitting patients from low-middle socio-cultural segment, we aimed to determine the type of dehydration and its frequency in children admitted with moderate to severe dehydration and serious electrolyte imbalance, and to discuss our clinical experiences and approaches to hyponatremic vs. hypernatremic patients in light of literature.

PATIENTS AND METHODS

Eighty-three patients with moderate to severe DR-dehydration and requiring IV fluid therapy, admitted to the PICU of Konya Education and Research Hospital, Turkey, between January 2011 and January 2013, constituted the patient group of the retrospective study.

In the first place, patients aged 1 month and 16 years, and with serum levels of Na+ ≤130 or >150mEq/L were scanned from hospital records. A total of 83 patients (65 hyponatremic and 18 hypernatremic) were included into the study, and their files were retrospectively assessed. Only those receiving IV fluid treatment because of intolerance of oral rehydration therapy were included into the study, and those with diseases, such as chronic renal failure, metabolic disorder, endocrinopathy, pneumonia, heart failure and central nervous system disorder were excluded from the study.

In the assessment, the scores related to age, gender, degree of dehydration (moderate or severe), serum creatinine, Na+, K+, Cl-, content of given fluid (appropriate for age and at higher concentration), outcomes of patients and whether the management of HCO3- was administered or not, and whether acute peritoneal dialysis treatment was started or not, were determined. Also, it was determined whether the management of Na+ deficit was given or not, and the durations spent for the increase of serum Na+ level over 130mEq/L in hyponatremic patients and for the fall of serum Na+ level under 150mEq/L in hypernatremic patients. Then, these durations were categorized as the first 24h, 25-48 h, 49-72 h and >72 h.

In our clinic, infants aged between 1-9 months are given fluids with the content of N/4 (a quarter, NS; and, three quarters, 5% dextrose), and
infants >9 months and children are given N/3 (a third, NS; and, two thirds, 5% dextrose). However, as higher concentrated fluids, N/3 is given to infants aged between 1-9 months, and N/2 (one-to-one, NS and 5% dextrose) is given to infants of >9 months and children.

Results were expressed as mean±standard deviation. Normally distributed data were assessed by the Kolmogorov-Smirnov test. Analysis of data was based on non-parametric statistical methods due to the small size of samples and abnormal distribution of variables. The Mann-Whitney U test for paired comparisons was used for subgroup analysis. One-way variance analysis was performed to compare mean serum Na⁺ levels according to categorized durations. In order to detect in what groups there are significant differences, Tukey’s test was performed. A p<0.05 was accepted as statistically significant.

An approval was obtained from the Ethics Committee of Konya Education and Research Hospital, Turkey.

RESULTS

Mean age rate of 83 patients was 31.3±4 months, and 42 (50.6%) and 41 (49.4%) of patients were males and females, respectively (Table 1). Moderate dehydration in 58 (69.9%) and severe dehydration in 25 (30.1%) patients were found, and the number of those admitted with hyponatremia and hypernatremia was 65 (78.3%) and 18 (21.7%), respectively. While mean age rate of hyponatremic patients was 37.5±42.4 months (min=1, max=144), the rate for hypernatremics was 8.7±16 months (min=1, max=72). The fact that younger patients tend to be hypernatremic was remarkable, and the difference was statistically significant (p=0.001). Although a negative correlation was observed between age and degree of dehydration, no significant difference was found (r=-0.119, p=0.286).

Among hyponatremic patients, 44 (67.7%) were given fluids at appropriate concentration for age, and 21 (32.3%) were given fluids at higher concentration (Table 2). Of those with hypernatremia, 11 (61.1%) were given fluids at appropriate concentration for age, and seven (38.9%) were given fluids at higher concentration.

Of hyponatremic patients, the treatment of Na⁺ deficit was given to 13 (20%) and the treatment of HCO₃⁻ deficit to seven (10.8%). Four (6.2%) patients were treated with acute peritoneal dialysis. While the treatment of HCO₃⁻ deficit was given to six (33.3%) patients in hypernatremia group, three (16.7%) were treated with acute peritoneal dialysis. Mean duration of amelioration in patients with hyponatremia was 40.3±30.6 h (elevation of serum Na⁺ level over 130 mEq/L), and mean duration of amelioration in hypernatremic patients was 39.2±26.1 h (fall of serum Na⁺ level lower than 150 mEq/L).

In those admitted with hyponatremia, mean duration of amelioration of serum Na⁺ level was 33.9±28.3 h in patients given fluids appropriate for age, and 53.7 ± 31.6 h in those given fluids at higher concentrations. The difference was statistically significant (p=0.006). While mean serum Na⁺ level of those given fluids at higher concentration was 124.4±5 mEq/L, the level was 127±3.4 mEq/L in patients given fluids appropriate for age, and the difference was statistically significant (p=0.015).

In those admitted with hypernatremia, mean duration of amelioration of serum Na⁺ level was 34.7±22.1 h in patients given fluids appropriate for age, and 46.3 ± 32 h in those given fluids at hi-
gher concentrations, but no significant difference was found (p=0.586). While mean serum Na⁺ level of those given fluids at higher concentration was 158.6±11.1 mEq/L, the level was 163.4±7.1 mEq/L in patients given fluids appropriate for age, and the difference was statistically significant (p=0.049). All the deaths took place in hyponatremia group, and the rate of deaths was 7.6% (n=5).

The improvement rates of patients with hyponatremia were 44.6% in the first 24 h, 23.1% between 25-48 h, 20% between 49-72 h, and 12.3% after 72 h (Table 3). The improvement rates of patients with hypernatremia were 33.3% in the first 24 h, 27.8% between 25-48 h, 33.3% between 49-72 h, and 5.6% after 72 h. Mean Na⁺ levels of patients with hyponatremia and hypernatremia were 126.2±4.1 mEq/L (range 113–130) and 160.5±9.8 mEq/L (range 151–181), respectively.

### Table 3. A distribution of hyponatremic and hypernatremic patients, and mean Na⁺ levels according to categorized duration of amelioration

<table>
<thead>
<tr>
<th></th>
<th>Hyponatremic Group</th>
<th>Hypernatremic Group</th>
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<tbody>
<tr>
<td>First 24 h, n (%)</td>
<td>29 (44.6)</td>
<td>6 (33.3)</td>
</tr>
<tr>
<td>25-48 h, n (%)</td>
<td>15 (23.1)</td>
<td>5 (27.8)</td>
</tr>
<tr>
<td>49-72 h, n (%)</td>
<td>13 (20.0)</td>
<td>6 (33.3)</td>
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<tr>
<td>&gt;72 h, n (%)</td>
<td>8 (12.3)</td>
<td>1 (5.6)</td>
</tr>
<tr>
<td>Mean Na⁺ level (mEq/L)</td>
<td>126.2±4.1</td>
<td>160.5±9.8</td>
</tr>
<tr>
<td>Mean Na⁺ level in 24 h</td>
<td>127±4</td>
<td>153.8</td>
</tr>
<tr>
<td>Mean Na⁺ level between 25-48 h (mEq/L)</td>
<td>126.7±2.4</td>
<td>159.2</td>
</tr>
<tr>
<td>Mean Na⁺ level between 49-72 h (mEq/L)</td>
<td>126.6±2.1</td>
<td>166.8</td>
</tr>
<tr>
<td>Mean Na⁺ level after 72 h (mEq/L)</td>
<td>121.4±6.7</td>
<td>169</td>
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In hyponatremic patients, compared to mean Na⁺ levels of groups according to categorized durations, the difference among the groups was seen to be significant. The difference was detected to arise from the 4th group. Mean serum Na⁺ levels of the first three groups were close to each other as 127±4mEq/L in those improving in the first 24 h, 126.7±2.4mEq/L in those improving between 25-48 h and 126.6±2.1mEq/L in those improving between 49-72 h. In the 4th group, mean Na⁺ level was 121.4±6.7mEq/L, though.

Among hypernatremic patients improving in the first 24 h, mean Na⁺ level was 153.8 mEq/L; in those improving between 25-48 h, the level was 159.2 mEq/L; among those improving between 49-72 h, the level of Na⁺ was 166.8 mEq/L; and, in the patient improving after 72 h, mean level of Na⁺ was found as 169 mEq/L.

Among our patients, 18 (22%) were determined as hypocalcemic, and five (6%) as hypercalcemic. Of 18 patients with hypocalcemia, 16 were in hyponatremic group, and two in hypernatremic group, while four patients were hyponatremic, and one was hypernatremic in hypercalcemic group. In 17 (20%) patients, acute renal failure was detected (serum creatinine > 1.1 mg/dL). Twelve of these were hyponatremic, and 5 were hypernatremic. While seven of the patients with acute renal failure were administered with acute peritoneal dialysis, the rest were improved with fluid management alone.

**DISCUSSION**

Dehydration, which may be associated with electrolyte imbalance and metabolic acidosis, is the most encountered and dangerous complication in children with diarrhea (13). Prevention of dehydration is the mainstay of diarrhea treatment in children. A child with minimal or no dehydration should be encouraged to continue the usual diet along with drinking adequate fluids (14). If severe dehydration is present, a child with diarrhea should receive IV fluid until stabilized (2).

In patients admitted with severe dehydration or shock, IV restoration is started with normal saline (NS) or lactated Ringer’s solution for 10 to 15 min as 20 ml/kg. The procedure is repeated, if necessary (15,16.). In our clinical practice, we also load NS to the patients admitted with dehydration or shock and if necessary, repeat the load while following-up the patients as to pulse pressure, capillary refill time, mental status and urine output. It is important to closely monitor fluid electrolytes and acid-base status after the initial restoration therapy. Children with plasma pH lower than 7.25, after the initial volume expansion, should be given IV HCO₃⁻ to increase plasma pH to 7.25 (1). As consistent with literature, we also give HCO₃⁻ deficit treatment to patients diagnosed with severe metabolic acidosis in the evaluation of blood gas. Additionally, we add K⁺ of 20 mEq per liter into the patient’s IV fluid after urination and increase the amount up to 60 mEq per liter according to serum K⁺ level.

In rehydration treatment, the aim is to give necessary fluid for both normal metabolic needs and compensating present losses of fluid, but no consensus is present on the content of fluid to be given. While some researchers advocate for gi-
ving isotonic fluids like NS (17,18), others assert that giving hypotonic fluids such as N/2, N/3, N/4 and N/5 is a more convenient approach (19). As consistent with literature (1,20), we categorize our patients as hyponatremic, isonatremic and hypernatremic, and then decide on the content of the fluid to be given.

Because a speed increase in serum Na⁺ level may lead to central pontine myelinosis in patients with hyponatremic dehydration, giving hypernatremic fluids should be avoided. The aim is to increase serum Na⁺ level at the rate of ≤ 2 mEq/L per hour (21). However, patients with serum Na⁺ concentration less than 125 mEq/L are often symptomatic and require infusion of hypertonic 3% saline (0.5 mEq/ml) to increase serum Na⁺ level to 125 mEq/L (1). So, we give Na⁺ deficit treatment if the patient is hyponatremic, and Na⁺ level is <125 mEq/L. We check serum electrolyte levels 8 h after starting the deficit treatment. If serum Na⁺ level is between 125-130 mEq/L, we give fluid at a higher rate than appropriate concentration for age. When Na⁺ level is >130 mEq/L, we give the fluid at appropriate concentration for age.

Because a speed decrease in serum Na⁺ level may lead to cerebral edema in patients with hypernatremic dehydration, giving hypotonic fluids should be avoided. The aim is to decrease the level of Na⁺ at the rate of 0.5 mEq/L per h (12). Hence, if the patient is hypernatremic, and the level is >160 mEq/L, we start rehydration treatment with NS. When serum Na⁺ level is <160 mEq/L, we give fluids at appropriate concentration for age. Four hours after the initial rehydration treatment, we check serum electrolytes and adjust fluid concentration according to the clinical view, urine output and serum Na⁺ level (13,18,22).

Maintenance fluid should be started after the patients are rehydrated (19). We also give our patients IV maintenance fluid, the amount of which is calculated according to Holiday and Segar’s formula, at appropriate concentration for age after rehydration treatment. In our modality, infants aged 1-9 months, and infants >9 and children are given N/4 and N/3 as fluids appropriate for age, respectively. Then, patients are switched to oral normal dieting, as soon as possible.

Mean serum Na⁺ level of our patients with hyponatremia was 126.2±4.1 mEq/L, and mean duration of amelioration was 40.3±30.6 h. As to hypernatremia, if critical serum Na⁺ level is accepted as 130 mEq/L (1), it may be calculated nearly as an increase of 0.1 mEq/L per hour. Such an increase was lower than ≤ 2 mEq/L per hour recommended in literature (21). The slow increase might have arisen from the fact that both our study group was composed of those with severe hyponatremia, and we utilized hypotonic fluids more frequently in rehydration treatment.

Of 65 patients with hyponatremia in our study, 67.7% and 32.3% were given fluid at appropriate concentration for age and at higher concentration, respectively. Mean duration of amelioration of serum Na⁺ level in patients given fluids at appropriate concentration for age was shorter than those given fluid at higher concentration. It was considered that this difference arose from the fact that patients given fluid at higher concentrations had lower level of serum Na⁺. This finding explained why mean duration of amelioration was longer in those given fluid at higher concentration. On the other hand, when mean Na⁺ values of the groups were compared according to categorized durations in patients with hyponatremia, the difference was seen to be significant only in the 4th group (>72 h); however, mean Na⁺ values of the other three groups were found to be similar. As anticipated, this finding was a sign that lower level of serum Na⁺ was improved in a longer period, and the slow increase might also be appropriate in terms of the risk of osmotic demyelination emphasized in literature (1,23).

Mean serum Na⁺ level of our patients with hypernatremia was 160.5±9.8 mEq/L, and mean duration of amelioration was 39.2±26.1 h. If critical serum Na⁺ level is accepted as 150 mEq/L regarding hypernatremia (1), it may be calculated nearly as a decrease of 0.25 mEq/L per hour, and such a decrease was lower than 0.5 mEq/L per hour recommended in literature (12). Furthermore, mean duration of amelioration of serum Na⁺ level of those with hypernatremia and given fluid at appropriate concentration for age was 34.7±22.1 h. However, mean duration of amelioration in those given fluid at higher concentration was 46.3±32 h. Although it was statistically insignificant, the difference was considered to arise from the fact that patients given fluid at higher concentration had serum Na⁺ at a higher level. Mean serum Na⁺ levels of those given flu-
id at appropriate concentration for age and those given fluid at higher concentration in our study were a sign indicating that higher serum Na⁺ level improved in a longer time, and such a slower decrease in serum Na⁺ level was appropriate as to cerebral edema emphasized in literature (1,24).

The rate of hyponatremic patients found in this study indicated that diarrhea leads to hyponatremia rather than hypernatremia in children. Additionally, the fact that mean age of hypernatremic patients was lower, compared to hyponatremic ones suggested that younger patients tended to hypernatremia rather than hyponatremia. In light of these findings, it may be speculated that patients with DR-dehydration should be evaluated as to electrolyte imbalance, and while infants should be evaluated as to hypernatremia, others, especially pre-school children should be assessed as to hyponatremia.

In a study performed by El-Bayoumi et al., the mortality rate is reported as 8.3% (12). The mortality rate was 7.6% in our hyponatremic patients, whereas the rate was zero in those with hypernatremia. The fact that no mortality was presented in hypernatremic group may be originating from the small number of patients in our study. Still, it may be speculated that especially hyponatremic patients are at a higher risk of death and should be followed-up closely.

In conclusion, the patients admitted to PICUs with diarrhea symptoms should meticulously be evaluated as to clinical examination, and serum electrolytes, creatinine and blood gases should be carefully investigated in those with moderate to severe dehydration findings. Along with IV fluid therapy, the treatments of HCO₃⁻ deficit in case of metabolic acidosis and acute peritoneal dialysis in case of acute renal failure should be also administered, if necessary, and K⁺ should be added into IV fluid of normocalcemic or hypocalcemic patients. No single IV fluid management is optimal for all children. Thus, IV fluid therapy should be individualized on condition that healthcare providers take main guidelines into consideration.

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REFERENCES


19. Coulthard MG. Will changing maintenance intravenous fluid from 0.18% to 0.45% saline do more harm than good? Arch Dis Child 2008; 93:335-40.


