Original Article

Serum Electrolyte Profiles of Under-five Nigerian Children Admitted for Severe Dehydration Due to Acute Diarrhea

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Abstract

Background: Serum electrolyte disturbances are common in under-five children with acute diarrhea but may remain unrecognized, resulting in morbidity and sometimes mortality. **Objective:** The objective was to assess the type and prevalence of electrolyte abnormalities in severely dehydrated under-five children with acute diarrhea at the point of hospital admission. **Patients and Methods:** This was a descriptive, hospital-based cross-sectional study of children aged 1–59 months with severe dehydration due to acute diarrhea. Serum electrolyte profiles were determined. Outcome measures such as death or survival were recorded. The co-morbidities were also recorded. **Results:** Of the 63 children studied, 50 (79.3%) subjects were aged below 36 months. Vomiting and fever accompanied diarrhea in 33 (52.4%) of the cases. The frequencies of the various types of dehydration were hyponatremic in 41 (65.1%), isonatremic in 17 (27.0%), and hypernatremic in 5 (7.9%) of the children. Of the electrolyte abnormalities observed, hyponatremia and hypokalemia ranked first and second in frequency, respectively. The overall case fatality rate was 6 (9.5%). All the patients that died were aged below 24 months. 5 (83.3%) of the 6 patients that died had a combination of metabolic acidosis in association with one or two other electrolyte abnormalities. 6 (10.5%) of the 57 patients that survived had normal serum electrolyte profiles. **Conclusion:** Hyponatremia, hypokalemia, and metabolic acidosis were the leading electrolyte abnormalities in acute diarrheal illnesses and were responsible for most diarrhea-related deaths, particularly when measles or bronchopneumonia is a co-morbid condition.

Key words: Acute diarrhea, electrolyte disturbances, hypokalemia, hyponatremia, under-five

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Introduction

Acute diarrhea refers to diarrhea of sudden onset, generally for over hours rather than days and lasting for <14 days.[1] In early childhood, the clinical problem of diarrhea arises from the loss of water and electrolytes in the stool in excess of their intake. Electrolytes are ionized molecules found in the blood as well as in various tissues and cells of the body. The main serum electrolytes are sodium, potassium, and bicarbonate with varying distribution and functions.[2] In the extracellular fluid, sodium and chloride are the dominant cation and anion, respectively. Sodium is the principal volume regulator. Potassium is the most abundant cation in the intracellular fluid and contributes to the maintenance of intracellular tonicity and the resting cell membrane potential. Bicarbonate is the main anion in the extracellular fluid and helps regulate blood acidity (pH). The increase or decrease in bicarbonate concentration results in acid-base disorder.[2] Electrolyte disturbances are established risk factors for diarrhea-related deaths.[3] Serum electrolyte measurement is usually unnecessary in children with mild to moderate dehydration. However, laboratory measurements of serum electrolytes are recommended in patients with severe dehydration.[4] The reason for this is that for acid-base and electrolyte abnormalities to occur in diarrheal illnesses, the volume of fluid lost must be sufficiently large to overcome the kidney's ability to adjust excretion to maintain acid-base equilibrium.[5] In children with diarrhea and dehydration, hyponatremia, hypokalemia, and metabolic acidosis are the commonly encountered electrolyte and acid-base disturbances. They are often responsible for diarrhea-related deaths.[6] In the hospitals, a high index of suspicion, knowledge, and timely recognition of the common electrolyte disturbances in acute

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diarrhea are necessary for optimal and effective therapy.[6] Knowledge of pattern of serum electrolyte levels in diarrheal illnesses will help to guide the choice of fluid composition and rate of replacement.

In developing countries, diarrheal diseases are leading causes of morbidity and mortality among under-five children. It accounts for 15–30% of total outpatient visits in many pediatric clinics in Nigeria and is among the top 10 causes of morbidity.[7] Although diarrhea may generally be mild and only a nuisance in developed countries, it is usually severe and often fatal in developing countries.[7] In Nigeria, it has been documented that diarrhea is the most common causes of death among hospitalized children who are below the age of 5 years.[8] Acute diarrhea kills by causing dehydration which leads to hypovolemia and metabolic acidosis.[8] In Nigeria, there is a paucity of information on the subject of the pattern of electrolyte disturbances among children with acute diarrhea. A published report on the type and prevalence of serum electrolyte abnormalities in the Nigerian children with acute diarrhea were conducted over 35 years ago.[9] In that study, there were no significant changes in mean serum sodium, potassium, and bicarbonate levels with nutritional status of the children.[9]

The aim of the present study was to assess the type and prevalence of electrolyte abnormalities at the point of hospitalization in severely dehydrated under-five children with acute diarrhea.

Patients and Methods

This descriptive cross-sectional study was conducted between January and December, 2012 at St Philomena Catholic Hospital (SPCH), Benin City, Nigeria. SPCH is a centrally located, easily accessible large secondary-healthcare institution that cares for all categories of patients in Edo State. It has a fairly well-equipped laboratory manned by qualified medical laboratory scientists and offers a 24-h laboratory service.

Ethical approval was obtained from Ethics and Research Committee of the University of Benin Teaching Hospital. Permission to conduct the study was obtained from the Hospital Authority and consent was obtained from the parents of the patients.

All children between the age of 1 and 59 months, who presented with acute diarrhea, were recruited into the study at the point of admission. The severity of dehydration was determined using clinical criteria recommended by the WHO.[10] Pretreatment 3 ml of venous blood sample was obtained from each patient. The blood sample was collected into heparin bottles and was taken immediately to the hospital laboratory for analysis. Serum sodium and potassium were determined using flame photometry. Serum bicarbonate concentration was determined using titration method. The subjects were categorized into hyponatremic (serum sodium <130 mmol/L), normonatremic (serum sodium between 130 and 150 mmol/L), and hypernatremic (serum sodium above 150 mmol/L). Hypokalemia was taken a serum potassium <3 mmol/L. Serum bicarbonate concentrations <20 mmol/L were classified as metabolic acidosis.

The data were analyzed using the Computer Package for Epidemiologist (PEPI). Descriptive statistics such as frequencies, means, ratios, standard deviations (SD), confidence intervals, and percentages were determined as appropriate for the variables. The Z-test and Student's *t*-test were used in ascertaining the significance of differences between two proportions and two means respectively, with the *P* value set at <0.05.

Results

Sixty-three under-five children who presented with severe dehydration due to acute diarrhea were evaluated for electrolyte and acid-base status at the point of admission. As shown in Table I, 50 (79.4%) of the subjects were aged below 36 months.

The clinical features of the 63 subjects are presented in Table II. Vomiting and fever accompanied diarrhea in 33 (52.4%) of the subjects.

The means, SD, and 95% confidence intervals (95%) of the serum electrolytes concentrations are shown in Table III. The distribution of the types of dehydration among the subjects, based on serum sodium concentration, was as follows: Hyponatremic dehydration 41 (65.1%), normonatremic dehydration in 17 (27.0%), and hypernatremic dehydration in 5 (7.9%). Two (40.0%) of 5 subjects with hypernatremia had severe metabolic acidosis with serum bicarbonate concentration <10 mmol/L), and both of them died. 57 (90.5%) of the 63 subjects had one form of electrolyte disturbances or the other while the remaining 6 (9.5%) had serum electrolyte concentrations within the reference intervals.

Table I: Age and sex distribution of the subjects

Demographic variables	*n* (%)
Age groups (months)	
<12	28 (44.4)
12-35	22 (34.9)
36-59	13 (20.7)
Total	63 (100.0)
Gender	
Male	34 (54.0)
Female	29 (46.0)
Total	63 (100.0)

Table II: Distribution of clinical features in the 63 subjects

Clinical features	*n* (%)
Duration of diarrhea <3 days*	35 (55.6)
Duration of diarrhea ≥3 days	28 (44.4)
Vomiting present	33 (52.4)
Fever present	33 (52.4)
Used ORT at home	22 (34.9)
Did not use ORT at home	41 (65.1)

*Before presentation. ORT: Oral rehydration therapy

The various serum sodium, potassium, and bicarbonate abnormalities encountered are depicted in Table IV. Of 57 subjects with electrolyte abnormalities, the leading electrolyte abnormality observed was hyponatremia - isolated in 35 (61.4%) or association with other electrolytes imbalance in 8 (14.0%). 20 (35.1%) of these subjects had hypokalemia - isolated in 9 (15.8%) or association with other electrolyte imbalance in 11 (19.3%). Of the 63 subjects, 16 (25.4%) had mixed electrolyte disturbances. 9 (15.8%) of the 57 subjects with electrolyte abnormalities had metabolic acidosis. As shown in Table IV, mixed electrolyte abnormalities involving metabolic acidosis were associated with the highest frequency of diarrhea-related deaths. Overall, case fatality rate was 9.5% (6/63). 5 (83.3%) of the 6 patients who died had a combination of metabolic acidosis in association with one or two other electrolyte abnormalities. None of the 6 patients with normal serum electrolyte profile died. All the patients who died were below the age of 24 months.

Table V shows the prevalence of co-morbidities in association with acute diarrhea and the outcome. Malaria and bronchopneumonia were the first and second co-morbid conditions seen in under-five children with acute diarrhea. In addition, a co-existence of diarrhea with either bronchopneumonia or measles was associated with a high mortality rate.

Table III: Mean serum electrolytes and urea levels of the 63 subjects

Serum electrolytes	Mean (SD) of serum electrolytes levels	95% CI
Sodium (mmol/L)	127.2 (7.4)	125.2-128.8
Potassium (mmol/L)	2.8 (0.6)	2.7-2.9
Chloride (mmol/L)	92.4 (8.5)	90.3-94.5
Bicarbonate (mmol/L)	14.5 (4.4)	13.4-15.6
Urea (mg/dl)	25.1 (16.8)	21.0-29.2

SD: Standard deviation, CI: Confidence interval

Table IV: Pattern of serum electrolyte disturbances and outcome in the under-five children with acute diarrhea

Types of electrolyte disturbances	Survivors (%)	Died (%)	Total (%)
Isolated hyponatremia	35 (61.40)	0 (0.0)	35 (55.6)
Isolated hypernatremia	2 (3.52)	1 (16.7)	3 (4.8)
Isolated hypokalemia	9 (15.79)	0 (0.0)	9 (14.3)
Hyponatremia plus hypokalemia	7 (12.28)	0 (0.0)	7 (11.1)
Hypokalemia plus acidosis	3 (5.26)	1 (16.7)	4 (6.4)
Hyponatremia plus hypokalemia plus acidosis	1 (1.75)	2 (33.3)	3 (4.4)
Hypernatremia plus acidosis	0 (0.0)	2 (33.3)	2 (3.2)
Total	57 (100.0)	6 (100.0)	63 (100.0)

Table V: Co-morbidities in associated with acute diarrhea and outcome

Co-morbidities	*n* (%)	Survivors (%)	Died (%)
Malaria (positive parasitemia)	32 (50.8)	32 (56.1)	0 (0)
Bronchopneumonia (radiologic evidence)	12 (19.1)	10 (17.5)	2 (33.3)
Septicemia (positive blood culture)	8 (12.7)	7 (12.3)	1 (16.7)
Measles (clinical)	7 (11.1)	5 (8.8)	2 (33.3)
None identified	4 (6.3)	3 (5.3)	1 (16.7)
Total	63 (100.0)	57 (100.0)	6 (100.0)

Discussion

Data from the present study indicated that hyponatremia was the most common electrolyte abnormality encountered in the under-five Nigerian children with severe dehydration due to acute diarrhea. This was in keeping with a report of a previous study among Nigerian children aged 2–24 months with acute diarrhea.[9] The predominance of hyponatremia in dehydrated children with acute diarrhea has also been reported in other studies in Liberia[11] and Nepal.[6] A similar trend in hyponatremia was observed in a study in Zimbabwe.[12] The pathogenesis of hyponatremia in diarrhea is due to a combination of sodium and water loss and water retention to compensate for volume depletion.[13] In addition, it is possible that initially the dehydration may be normonatremic, resulting in the thirst and demand for water by the child. The mother responds by giving water to the child. The hypovolemia will stimulate the release of antidiuretic hormone and water excretion by the kidney will be minimized. In the process, water retention leads to hyponatremia, thus, resulting in higher frequency of hyponatremia as found in the present study. Although hyponatremia is often asymptomatic, it has the potential of causing severe neurological damage and death.[14] In contrast, Nathoo *et al*.[12] in Zimbabwe reported that severe acidosis was the most common in their series, accounting for 45.7% of all the electrolyte disturbances. The reason for the difference their findings and the findings in the present study is not clear.

With regard to the type of dehydration, hyponatremic dehydration was the most common. This finding was in keeping with the reports of previous studies in Nigerian[9] and Nepal.[6] In contrast, normonatremic dehydration was the most common in developed countries.[13] The reason for the difference between developed and developing countries is not clear. However, it might be related to the relatively different sodium content of diarrheal stools, depending on the etiologic agent.[8] It may be related to differences in etiological agents. The etiological agents of diarrhea vary in their frequency depending on whether it is a developed or developing country that is being considered.[1] In this regard, enterotoxins elaborated by some pathogens stimulate receptors at the intestinal mucosal surface, inducing the production of excess cyclic adenosine monophosphate in the enterocytes which inhibits the influx of sodium chloride and water into the villus cells and also stimulates secretion of sodium chloride and water by the cryptic cells. The resultant effect of these two processes is the secretion of large amounts of sodium followed by water into the intestinal lumen with a subsequent loss in of sodium in the diarrheal fluid.[8] Thus,

accounting for the differences in the types of dehydration observed in different geographical regions.

As observed in the other studies,[6,15] hypokalemia was the second common electrolyte abnormality observed in the present series. The frequency of 31.7% observed in the present study was slightly higher than the 27.5% reported from Zimbabwe[12] but lower than the 46.0% reported from Nepal.[6] The high percentages of hypokalemia in these different studies suggested that hypokalemia is a common problem in children with acute diarrhea. Gastric secretions contain up to 20 mmol/L of potassium and diarrheal fluid contains 10–80 mmol/L.[8] Both the metabolic alkalosis which accompanies persistent vomiting and the dehydration resulting from vomiting and/or diarrhea stimulate aldosterone release. Aldosterone excess further potentiates hypokalemia,[14] thereby compounding the potassium loss due to vomiting and diarrhea. In the present series, history of vomiting accompanying the diarrhea was present in over half of the subjects. Thus, contributing to the high frequency of hypokalemia observed in the present study.

The present data indicated that the presence of electrolyte abnormalities in the under-five children with acute diarrhea was associated with a higher risk of death, particularly when hypernatremia co-exists with metabolic acidosis. The two children with hypernatremia co-existing with severe metabolic acidosis died, reflecting the high fatality rate of the combination of these two conditions. In this regard, a combination of hypernatremia and metabolic acidosis is a strong risk factor for death in children with acute diarrhea. The report of the study by Shah *et al*.[6] also suggested that hypernatremia was associated with increased risk of death. Indeed, it has been stated that hypernatremic dehydration is the most dangerous form of dehydration due to the complications of hypernatremia and therapy. Hypernatremia causes serious neurologic damage, resulting from central nervous system hemorrhage and thrombosis.[13] The co-existence of measles or bronchopneumonia with acute diarrhea resulted in higher risk of death, particularly if the patients aged below 24 months.

Conclusion

Hyponatraemia, hypokalemia, and metabolic acidosis were the leading electrolyte abnormalities in acute diarrheal illnesses and were responsible for most diarrhea-related deaths, particularly when measles or bronchopneumonia was a co-morbid condition. The co-existence of these factors with acute diarrhea in children calls for more attention to details if mortality is reduced.

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Conflicts of interest

There are no conflicts of interest.

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