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**ORIGINAL ARTICLE**

# Biochemical and Physiological Predictors of Severe Dehydration in Children Under Five

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## ABSTRACT

**Background:** Acute diarrhea and vomiting in children under five years of age is one of the most serious complications and that is dehydration. If left untreated and unchecked, severe dehydration can quickly lead to electrolyte disorders, metabolic acidosis, renal hypoperfusion, shock and death. Biochemical abnormalities may also give some clues as to the severity and risk of complications, but the clinical signs will still be the first line of diagnosis.

**Objective:** To determine the biochemical and physiological predictors of severe dehydration in children under five years of age.

**Methods:** This descriptive cross-sectional study was conducted at from January 2022 to January 2023. The children were sampled consecutively, and a total of 72 children below age of 5 years with dehydration secondary to acute diarrhea and/or vomiting were included. Demographic, clinical data and physiological parameters such as heart rate, respiratory rate, capillary refill time, blood pressure, peripheral pulse, extremity temperature, skin turgor, sunken eyes, level of consciousness, drinking ability and urine output were documented. Blood samples were drawn to measure the serum sodium, potassium, chloride, bicarbonate, blood urea, serum creatinine and random blood glucose. Children were divided into two groups, non-severe and severe dehydration. The SPSS version 25 software was used for data analysis. The P value was used to determine statistical significance with a cutoff of less than 0.05.

**Results:** Among 72 children, 26 (36.1%) had severe dehydration, while 46 (63.9%) had non-severe dehydration. Severe dehydration was more frequent among infants below 12 months and children with underweight or wasted nutritional status. Physiological predictors significantly associated with severe dehydration included tachycardia, tachypnea, capillary refill time greater than two seconds, low blood pressure, cold extremities, weak peripheral pulse, sunken eyes, very slow skin pinch, lethargy or unconsciousness, and poor urine output. Biochemical abnormalities including low serum bicarbonate, raised blood urea, raised serum creatinine, hyponatremia, hypernatremia, and hypokalemia were significantly more common in children with severe dehydration. On multivariate analysis, capillary refill time greater than two seconds, very slow skin pinch, poor urine output, low serum bicarbonate, and raised blood urea were independent predictors of severe dehydration.

**Conclusion:** Severe dehydration was common among children under five presenting with acute diarrhea and vomiting. Delayed capillary refill time, very slow skin pinch, poor urine output, low bicarbonate, and raised blood urea were important predictors of severe dehydration. Early recognition of these physiological and biochemical indicators can help guide timely management and reduce dehydration-related complications.

**Keywords:** Severe dehydration, children under five, diarrhea, biochemical predictors, physiological predictors, electrolytes, bicarbonate.

## INTRODUCTION

Dehydration is one of the biggest clinical issues in children younger than 5 years and the leading contributor to pediatric morbidity and hospitalisation in developing countries where diarrhoeal diseases are still a common cause of morbidity in children. Acute diarrhoea and vomiting can cause rapid loss of water and electrolytes resulting in dehydration within a short period of time. Young children are at special risk because their bodies contain more water, need more energy, have less renal concentrating ability, and cannot communicate weakness or thirst as effectively as older children. Dehydration, if unrecognized and not corrected early, can develop to circulatory collapse, metabolic changes, acute kidney failure and death[1-3].

Generally, the extent of dehydration in children is judged clinically. Physiological signs include rapid heart rate, delayed capillary refill, weak peripheral pulse, cold periphery, sunken eyes, decreased skin turgor, lethargy, irritability, decreased urine output and decreased drinking ability. These signs are significant because they can be evaluated rapidly at the bed-side, especially in the emergency and outpatient settings. However, in some cases, clinical assessment can be challenging, particularly in infants, malnourished children or children who are also febrile and septic. Thus, a combination of physiological assessment, with biochemical markers may yield a better assessment of children at risk for severe dehydration [4-6].

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As dehydration progresses, biochemical changes take place. Diarrhea and vomiting can cause fluid and electrolyte imbalance, with problems such as sodium and potassium imbalance, low blood bicarbonate, high blood urea and high blood creatinine. Low bicarbonate could be a sign of metabolic acidosis due to loss of bicarbonate in the stool and inadequate tissue perfusion. Elevated urea and creatinine levels indicate decreased renal flow in the setting of hypovolemia. Clinically relevant electrolyte disturbances include hyponatremia, hypernatremia, and hypokalemia that can result in seizures, arrhythmias, and altered consciousness, and can cause delayed recovery if not properly detected and treated [7-9].

Clinical signs are commonly used for categorization of dehydration, but there is still a need to determine which of the physiological and biochemical parameters best correlate with severe dehydration in children under five years of age. This is particularly important in resource-limited environments, where delayed presentation, poor nutritional status, failure to obtain early oral rehydration, and poor access to laboratory resources may lead to complications. Identifying reliable predictors may help the clinician focus on high risk children to receive a more urgent start of fluid therapy, laboratory monitoring and close follow-up[10].

The present study was conducted to determine the biochemical and physiological predictors of severe dehydration in children under five years of age. The study aimed to compare clinical signs and laboratory parameters between children with severe and non-severe dehydration and to identify the strongest predictors that may help in early diagnosis and timely management.

## METHODOLOGY

This descriptive cross-sectional study was conducted at from January 2022 to January 2023. The study was designed to determine the biochemical and physiological predictors associated with severe dehydration among children under five years of age. A total of 72 children presenting with acute dehydration secondary to diarrhea and/or vomiting were included in the study after fulfilling the selection criteria. The study population consisted of children aged less than five years who were brought to the pediatric outpatient department or emergency unit with clinical features suggestive of dehydration.

Children aged 1 month to 59 months were included who presented with acute diarrhea, vomiting, decreased oral intake, decreased urine output, sunken eyes, lethargy, and/or irritability. Children with chronic kidney disease, congenital heart disease, known metabolic disorders, chronic diarrhea > 14 days, severe acute malnutrition with complications, which required separate management and children who received intravenous fluid prior to biochemical sampling were excluded as their biochemical parameters might have been altered. Children who didn't have parental/guardian consent were also excluded from the study.

A non-probability consecutive sampling technique was used. The children that arrived during the study period were all included until the required sample size of 72 children had been reached. The study purpose, data collection process and keeping patient information confidential were explained and written informed consent was obtained from the parents/guardians. The institutional ethical review committee gave the ethical approval prior to the beginning of data collection.

Demographic information such as age, gender, place of residence, weight and nutritional status was documented on a pre-designed proforma after enrolment. A thorough clinical history of the mother or father/carer was obtained including the length of time the child had been vomiting, number of loose stools a day, urine output, use of oral rehydration solution and treatment before presentation. Clinical assessment and weight-for-age and weight-for-height, where available, was used to assess nutritional status.

Detailed physical exam was performed by the attending pediatric clinician for each child. Physiological parameters were measured when the animal was presented prior to the start of any intravenous fluid treatment. These included heart rate, respiratory rate, temperature, blood pressure, peripheral pulse volume, condition of extremities, level of consciousness, skin turgor, presence of sunken eyes, thirst, ability to drink and urine output. Tachycardia, tachypnea, delayed capillary refill time, cold extremities, weak pulse, hypotension, lethargy, very slow skin pinch and reduced urine output were deemed as important physiological indicators of the severity of dehydration.

Dehydration was categorized using the usual clinical criteria as non-severe dehydration and severe dehydration categories. Children that were classified as having mild or moderate dehydration were placed in the non-severe dehydration group and children that were classified as having severe dehydration were those that presented with the features mentioned above. The classification was based on the initial clinical examination prior to definitive fluid therapy.

Prior to initiating intravenous fluid therapy, blood samples were drawn in an aseptic manner when possible. Biochemical investigations were done for serum sodium, serum potassium, serum chloride, serum bicarbonate, blood urea, serum creatinine and random blood glucose. Complete blood count was also obtained, if available, which included hemoglobin, hematocrit, and total leukocyte count. Serum electrolyte abnormalities were noted as hyponatremia, hypernatremia, hypokalemia, hyperkalemia and hypo-bicarbonatemia within standard pediatric values. Hypoperfusion or renal involvement due to dehydration was believed to be suggested by elevated blood urea and serum creatinine levels.

The data collected were entered and analyzed on SPSS version 25. Measurements of quantitative variables like age, serum sodium, potassium, bicarbonate, blood urea, creatinine and random blood glucose were presented as mean and standard deviation. Qualitative variables like dehydration, severity of dehydration, tachycardia, delayed capillary refill time, sunken eyes, poor urine output, electrolyte imbalance and raised urea were presented as frequency and percentage. Both children with severe and non-severe dehydration were grouped. The biochemical and physiological parameters were compared between the two groups.

Categorical variables were compared between the severe and non-severe dehydration group using either the chi-square test or Fisher's exact test. Normally distributed continuous variables were analysed using the independent sample t test and non-normally distributed variables were analysed using Mann–Whitney U test. A p value of $<0.05$ was deemed to be statistically significant. These variables that were found to be significantly associated with severe dehydration were subsequently evaluated as possible predictors. Logistic regression analysis was performed to determine the independent biochemical and physiological factors associated with severe dehydration in children under 5 years.

## RESULTS

72 children, aged less than 5 years, presenting with dehydration were included in the study. The mean age of the children was 24.6 ± 13.8 months. The majority of children were between 13 and 36 months and the next most common age range was for children under 12 months. There were 42 (58.3%) males and 30 (41.7%) females, giving a male predominance. In terms of nutritional status, 38 (52.8%) children were of normal nutritional status, 24 (33.3%) children were underweight and 10 (13.9%) children were wasted or severely wasted.

Of the 72 children, 26 children (36.1% of all children) were severely dehydrated and 46 children (63.9% of all children) were not severely dehydrated, including children with mild dehydration and moderate dehydration. More infants and children with poor nutritional status were found to be severely dehydrated. Eleven children (42.3%) in the severe dehydration group were under 12 months old, while 7 (15.2%) in the non-severe group were under 12 months.

Common presenting complaints were diarrhoea and vomiting. 29 (40.3%) children sick for over 48 hours. Children with severe dehydration were significantly more likely to vomit, to have decreased oral intake, fever, and decreased urine output. Duration of diarrhea more than 48 hours was reported in 17 (65.4%) children with severe dehydration as compared to 12 (26.1%) children with non-severe dehydration.

There were clearly differences between children with severe and non-severe dehydration in terms of their physiological parameters. Twenty-three (88.5%) children had tachycardia in severe dehydration and 21 (45.7%) children had tachycardia with non-severe dehydration. Increased capillary refill time, cold extremities, weak peripheral pulses, lethargy, significantly decreased skin pinch and sunken eyes were all associated with significant dehydration.

Biochemical data were also varied amongst the two groups. The mean serum bicarbonate levels were lower and the mean serum urea and creatinine levels were higher among children with severe dehydration. Severely dehydrated children were more likely to have electrolyte imbalance. The prevalence of hypernatremia was 6 (23.1%) and for hyponatremia was 11 (42.3%) among children with severe dehydration. Hypokalemia was also more common in dehydrated children who presented with severe dehydration.

Capillary refill time >2 s, very slow skin pinch, low serum bicarbonate, raised blood urea and poor urine output were the strongest independent risk factors for severe dehydration on multivariate logistic regression analysis. Of these, those with capillary refilling time >2 seconds had the highest odds of severe dehydration.

Table 1: Demographic characteristics of children under five years of age

| Variable | Frequency | Percentage |
|---|---|---|
| Age group | | |
| <12 months | 18 | 25.0% |
| 13–36 months | 36 | 50.0% |
| 37–59 months | 18 | 25.0% |
| Gender | | |
| Male | 42 | 58.3% |
| Female | 30 | 41.7% |
| Nutritional status | | |
| Normal | 38 | 52.8% |
| Underweight | 24 | 33.3% |
| Wasted/severely wasted | 10 | 13.9% |
| Residence | | |
| Urban | 31 | 43.1% |
| Rural | 41 | 56.9% |

Table 2: Severity of dehydration according to age and nutritional status

| Variable | Non-severe dehydration n=46 | Severe dehydration n=26 | p-value |
|---|---|---|---|
| Age <12 months | 7 (15.2%) | 11 (42.3%) | 0.011 |
| Age 13–36 months | 25 (54.3%) | 11 (42.3%) | 0.324 |
| Age 37–59 months | 14 (30.4%) | 4 (15.4%) | 0.158 |
| Male gender | 25 (54.3%) | 17 (65.4%) | 0.359 |
| Underweight/wasted | 16 (34.8%) | 18 (69.2%) | 0.005 |
| Rural residence | 24 (52.2%) | 17 (65.4%) | 0.278 |

Table 3: Clinical presentation of children according to dehydration severity

| Clinical variable | Non-severe dehydration n=46 | Severe dehydration n=26 | p-value |
|---|---|---|---|
| Diarrhea >48 hours | 12 (26.1%) | 17 (65.4%) | 0.001 |
| Vomiting >3 episodes/day | 15 (32.6%) | 19 (73.1%) | 0.001 |
| Fever | 18 (39.1%) | 16 (61.5%) | 0.068 |
| Reduced oral intake | 20 (43.5%) | 22 (84.6%) | 0.001 |
| Poor urine output | 13 (28.3%) | 21 (80.8%) | <0.001 |
| Previous ORS use | 29 (63.0%) | 9 (34.6%) | 0.021 |
| Previous antibiotic use | 11 (23.9%) | 10 (38.5%) | 0.190 |

Table 4: Physiological predictors of severe dehydration

| Physiological variable | Non-severe dehydration n=46 | Severe dehydration n=26 | p-value |
|---|---|---|---|
| Tachycardia | 21 (45.7%) | 23 (88.5%) | <0.001 |
| Tachypnea | 14 (30.4%) | 15 (57.7%) | 0.023 |
| Capillary refill time >2 seconds | 10 (21.7%) | 22 (84.6%) | <0.001 |
| Low blood pressure | 4 (8.7%) | 12 (46.2%) | <0.001 |
| Cold extremities | 9 (19.6%) | 20 (76.9%) | <0.001 |
| Weak peripheral pulse | 8 (17.4%) | 19 (73.1%) | <0.001 |
| Sunken eyes | 23 (50.0%) | 25 (96.2%) | <0.001 |
| Very slow skin pinch | 11 (23.9%) | 24 (92.3%) | <0.001 |
| Lethargy/unconsciousness | 6 (13.0%) | 18 (69.2%) | <0.001 |

Table 5: Biochemical profile according to dehydration severity

| Biochemical variable | Non-severe dehydration n=46 | Severe dehydration n=26 | p-value |
|---|---|---|---|
| Serum sodium, mmol/L | 136.8 ± 4.1 | 132.4 ± 6.8 | 0.002 |
| Hyponatremia | 8 (17.4%) | 11 (42.3%) | 0.020 |
| Hypernatremia | 3 (6.5%) | 6 (23.1%) | 0.039 |
| Serum potassium, mmol/L | 3.9 ± 0.5 | 3.4 ± 0.7 | 0.001 |
| Hypokalemia | 9 (19.6%) | 13 (50.0%) | 0.007 |
| Serum bicarbonate, mmol/L | 19.8 ± 3.6 | 14.2 ± 4.1 | <0.001 |
| Low bicarbonate | 14 (30.4%) | 20 (76.9%) | <0.001 |
| Blood urea, mg/dL | 28.6 ± 9.4 | 48.3 ± 16.7 | <0.001 |
| Raised urea | 12 (26.1%) | 19 (73.1%) | <0.001 |
| Serum creatinine, mg/dL | 0.46 ± 0.18 | 0.78 ± 0.31 | <0.001 |
| Raised creatinine | 5 (10.9%) | 11 (42.3%) | 0.002 |
| Random blood glucose, mg/dL | 91.4 ± 18.6 | 82.7 ± 24.5 | 0.092 |

Table 6: Multivariate predictors of severe dehydration

| Predictor | Adjusted Odds Ratio | 95% Confidence Interval | p-value |
|---|---|---|---|
| Age <12 months | 2.41 | 1.02–5.69 | 0.045 |
| Vomiting >3 episodes/day | 3.18 | 1.21–8.36 | 0.019 |
| Poor urine output | 4.72 | 1.68–13.28 | 0.003 |
| Capillary refill time >2 seconds | 6.84 | 2.21–21.15 | 0.001 |
| Very slow skin pinch | 5.96 | 1.87–18.92 | 0.002 |
| Low serum bicarbonate | 4.89 | 1.62–14.74 | 0.005 |
| Raised blood urea | 4.31 | 1.45–12.79 | 0.008 |
| Hypokalemia | 2.27 | 0.83–6.18 | 0.108 |

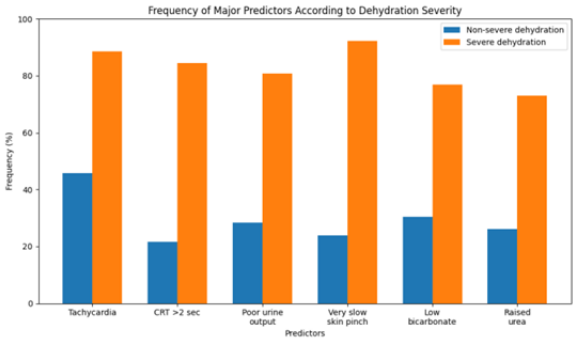


Figure 1: Frequency of major biochemical and physiological predictors according to dehydration severity among children under five years.

In total, severe dehydration was detected in over one third of the children under 5 years. Results indicated that both clinical data and biochemical abnormalities were significant in predicting severe dehydration. Poor urine output, delayed capillary refill, cold extremities, weak pulse, lethargy, sunken eyes and very slow skin pinch were statistically significant clinical and physiological parameters associated with severe dehydration. Of biochemical markers, bicarbonate low, urea raised, creatinine raised, sodium abnormality, and hypokalemia were significantly more prevalent in children with severe dehydration.

## DISCUSSION

The present study evaluated biochemical and physiological predictors of severe dehydration among 72 children under five years of age. Severe dehydration was observed in more than one-third of the study population, showing that dehydration remains a common and clinically important problem in young children presenting with diarrhea and vomiting. In this study, severe dehydration was more frequent in infants and children with poor nutritional status. This finding is clinically understandable because younger children have higher body water turnover, limited physiological reserve, and greater dependence on caregivers for fluid replacement. Poor nutritional status may further increase vulnerability by reducing immune response, muscle mass, and circulatory reserve, making children more prone to rapid deterioration during acute fluid loss[11-13].

There was a significant association between physiological predictors and severe dehydration. Children with severe dehydration were significantly more likely to have tachycardia, CAPRT, weak peripheral pulse, cold extremities, hypotension, lethargy, sunken eyes, and very slow skin pinch. These are in keeping with the normal way children are evaluated for dehydration, which includes altered level of consciousness, sunken eyes, lack of oral intake, poor peripheral blood flow and very slow skin pinch. WHO guidance stresses the importance of clinical assessment as the main approach to classifying dehydration in children with diarrhea and studies that have assessed clinical signs have identified delayed capillary refill time, abnormal skin turgor and abnormal respiratory pattern as some of the most useful physical signs to identify clinically significant dehydration [14-16].

In the present study, low urinary output was a very useful clinical indicator of severe dehydration. This is due to decreased renal perfusion because of intravascular volume depletion. Likewise, slow capillary refill and diminished peripheral pulses are signs of poor peripheral perfusion and poor systemic illness severity is represented by lethargy. These signs can be used quickly in emergency situations and can be used before lab results are available, especially in busy emergency situations. The assessment of dehydration, however, should not be based on one sole clinical sign as this may differ depending on age, fever, nutritional status and examiner's opinion. Multiple signs and clinical scales are more accurate diagnostically than any individual sign.

Biochemical abnormalities were also significantly associated with severe dehydration. Children with the severe dehydration had lower mean serum bicarbonate level and higher mean blood urea and serum creatinine level. Low bicarbonate might be due to metabolic acidosis related to loss of bicarbonate in the stool, as well as due to poor tissue perfusion and accumulation of lactic acid during severe dehydration. The raised Urea and creatinine indicate renal hypoperfusion and decreased glomerular filtration rate (GFR) related to volume depletion. Additionally, electrolyte disturbances (hyponatremia, hypernatremia, and hypokalemia) occurred more frequently in severely dehydrated children. Such abnormalities are significant in that they may lead to seizures, arrhythmias, impaired sensorium and delayed recovery if improperly corrected. Other guidelines and reviews also indicate electrophoretic and biochemical (electrolytes, glucose, bicarbonate, urea and creatinine) tests are warranted for children with severe dehydration, shock, altered mental status, and in those who require intravenous rehydration [17, 18].

The multivariate analysis revealed that the following factors were independent risk factors for severe dehydration: capillary refill time greater than two seconds, very slow skin pinch, low bicarbonate levels, raised urea levels, vomiting more than three times per day and poor urine output. The study findings are important because bedside assessment of the patient is essential and should be supplemented with selected biochemical investigations. Early detection of these predictors can be useful in low-resource areas to prioritize children who need immediate fluid resuscitation, close monitoring, and laboratory assessment. The findings also provide support for the importance of early use of ORS at home, training of caregivers, early presentation to the hospital, careful monitoring of urine output and mental status in children with diarrhea and vomiting[19, 20].

There are some limitations in this study. The study was of a relatively small number of children (72) and carried out in one study setting, and results may not be generalizable to other populations of children. Dehydration was judged by clinical criteria and some minor variations by observers may have existed. Certain biochemical parameters including serum osmolality, arterial blood gases etc. were omitted because they were routinely un-available. Nevertheless, this study offers valuable local information that the use of physiological indicators and simple biochemical assays can assist in identifying children at risk for severe dehydration. These predictions need to be confirmed by additional multi-centre studies with larger numbers of children to establish a valid tool and create a simple risk-scoring system for recognising severe dehydration adequately early in children under five years.

## CONCLUSION

Severe dehydration was present in a significant proportion of children under five years presenting with acute diarrhea and vomiting. Delayed capillary refill time, very slow skin pinch, poor urine output, tachycardia, weak pulse, cold extremities, sunken eyes, and lethargy were important physiological predictors of severe dehydration. Among biochemical markers, low serum bicarbonate, raised blood urea, raised serum creatinine, sodium imbalance, and hypokalemia were significantly associated with severe dehydration. The study concludes that early recognition of both clinical and biochemical predictors can improve timely diagnosis, guide appropriate rehydration therapy, and reduce dehydration-related complications in children under five years of age.

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