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CLINICAL AND LABORATORY ASSESSMRENT OF DEHYDRATION SEVERITY IN CHILDREN WITH ACUTE GASTROENTERITIS

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ABSTRACT

Background: Acute gastroenteritis is a common cause of morbidity in children, and dehydration is one of its most important complications. Early and accurate assessment of dehydration severity is essential for appropriate management and prevention of complications. This study aimed to identify clinical and laboratory predictors associated with dehydration severity in children with acute gastroenteritis. **Objectives:** To identify the clinical and laboratory predictors associated with the severity of dehydration in children with acute gastroenteritis and to evaluate the diagnostic performance of selected laboratory parameters in predicting severe dehydration. **Patients and methods:** A cross-sectional study was conducted at Mosul General Hospital, Nineveh Governorate, Iraq, from March 2025 to April 2026. The study included 133 children aged 1 month to 15 years who presented with acute gastroenteritis and clinical evidence of dehydration. Demographic characteristics, clinical manifestations, signs of dehydration, and laboratory parameters were assessed. Data were analyzed using SPSS version 31. Associations between variables and dehydration severity were evaluated, followed by multivariable logistic regression and receiver operating characteristic curve analysis. **Results:** Of the 133 children, 48 (36.1%) had mild dehydration, 57 (42.9%) had moderate dehydration, and 28 (21.1%) had severe dehydration. Severe dehydration was significantly associated with vomiting, poor oral intake, reduced urine output, prolonged duration and frequency of diarrhea, tachycardia, dry mucous membranes, sunken eyes, reduced skin turgor, prolonged capillary refill, and inability or refusal to drink. Serum bicarbonate progressively decreased with increasing dehydration severity, while urea and creatinine increased significantly. Multivariable analysis identified poor oral intake, reduced urine output, tachycardia, prolonged capillary refill, inability or refusal to drink, bicarbonate ≤16 mmol/L, urea >10 mmol/L, and elevated creatinine as independent predictors of severe dehydration. Bicarbonate demonstrated the highest diagnostic performance (AUC=0.847), followed by urea (AUC=0.811) and creatinine (AUC=0.746), whereas sodium showed limited predictive performance**. Conclusions:** Several clinical and laboratory parameters were significantly associated with dehydration severity in children with acute gastroenteritis. Clinical indicators of impaired perfusion and inadequate fluid intake, together with low serum bicarbonate and elevated urea and creatinine, may help identify children at increased risk of severe dehydration. An integrated clinical and laboratory approach may improve early recognition and appropriate management of severe dehydration.

KEYWORDS: Acute gastroenteritis; children; dehydration; bicarbonate; urea; creatinine; clinical predictors; laboratory predictors.

1- INTRODUCTION

Acute gastroenteritis (AGE) is one of the most common causes of illness among children worldwide and remains an important reason for emergency department visits and hospital admission. It is characterized by the acute onset of diarrhea, with or without vomiting, nausea, abdominal pain, fever, and other gastrointestinal manifestations. Although most episodes are self-limiting, young children are particularly vulnerable to complications because of their relatively

high fluid requirements, limited physiological reserves, and inability to independently maintain adequate oral fluid intake. The global burden of diarrheal disease remains substantial, particularly in low- and middle-income countries where access to safe water, sanitation, appropriate nutrition, and timely medical care may be limited.[1,2]

Dehydration is the most clinically important complication of acute gastroenteritis in children and results from excessive gastrointestinal fluid and electrolyte losses combined with inadequate replacement. The severity of dehydration depends on the magnitude and duration of fluid loss, the child's age, nutritional status, and the ability to maintain oral intake. Clinical manifestations range from thirst and decreased urine output to dry mucous membranes, reduced skin turgor, sunken eyes, prolonged capillary refill, tachycardia, lethargy, and, in severe cases, hypotension, altered consciousness, shock, and organ dysfunction. Rapid recognition of dehydration is therefore essential because appropriate fluid replacement can prevent progression to hypovolemic shock and other potentially life-threatening complications.[3]

Assessment of dehydration severity in children is challenging because no single clinical sign provides a completely accurate estimate of the degree of fluid deficit. Body-weight change before and after an episode of gastroenteritis is considered the most objective reference method for estimating dehydration, but a reliable pre-illness weight is frequently unavailable at the time of presentation. Consequently, clinicians commonly rely on combinations of physical findings and physiological parameters to classify dehydration. Current pediatric guidelines emphasize assessment of general appearance, mental status, heart rate, respiratory pattern, capillary refill, mucous membranes, skin turgor, urine output, and the presence of blood pressure abnormalities or other signs of circulatory compromise.[3,4]

The clinical assessment of dehydration is particularly difficult in infants and young children. Findings such as dry mucous membranes, reduced urine output, tachycardia, and abnormal skin turgor can be influenced by factors other than dehydration. Similarly, crying, fever, pain, and anxiety may affect heart rate and respiratory rate, while baseline nutritional status can influence skin-fold thickness and skin turgor. Consequently, combining several clinical findings generally provides greater diagnostic accuracy than relying on an individual sign. A systematic review of clinical dehydration assessment demonstrated that combinations of signs, particularly prolonged capillary refill, abnormal skin turgor, abnormal respiratory pattern, and general appearance, can improve identification of clinically significant dehydration.[5]

The World Health Organization and other pediatric guidelines classify dehydration according to clinical severity and emphasize prompt oral or intravenous rehydration according to the child's condition. Children with mild dehydration can generally be treated successfully with oral rehydration solution, whereas children with severe dehydration or shock require urgent fluid resuscitation and close monitoring.[3,6] Correct classification is therefore not merely descriptive; it directly influences treatment decisions, the route and amount of fluid replacement, the need for laboratory investigation, and the level of monitoring required.

Laboratory investigations may provide additional objective information in children with significant dehydration. Prolonged gastrointestinal fluid loss can produce abnormalities in serum sodium, potassium, chloride, bicarbonate, urea, creatinine, glucose, and other biochemical parameters. The degree of these abnormalities may vary according to the type of fluid lost, the composition of replacement fluids, and the duration of illness. In particular, increased serum urea and creatinine may reflect reduced renal perfusion and prerenal azotemia, while reduced serum bicarbonate may indicate metabolic acidosis associated with dehydration and tissue hypoperfusion.[7] Serum electrolytes are particularly relevant because acute gastroenteritis may result in either isotonic, hypertonic, or hypotonic dehydration. Hypernatremic dehydration is of particular clinical importance because it can occur when water losses exceed sodium losses or when inappropriate feeding or fluid replacement increases sodium concentration. Children with hypernatremia may develop neurological manifestations and require careful correction to minimize the risk of neurological complications. Conversely, excessive gastrointestinal losses or inappropriate replacement may lead to hypokalemia or other electrolyte abnormalities.[7,8]

Serum bicarbonate has also been investigated as a potential laboratory indicator of dehydration severity. Metabolic acidosis may develop as a consequence of bicarbonate loss in diarrhea, impaired tissue perfusion, increased lactate production, or reduced renal perfusion. A low serum bicarbonate concentration has been associated with greater dehydration in several pediatric studies and may provide useful supplementary information when the clinical assessment is uncertain. However, bicarbonate should be interpreted in the context of the overall clinical presentation because its concentration may also be influenced by infection, renal disease, respiratory disorders, and other metabolic conditions.[9]

The blood urea nitrogen (BUN)-to-creatinine relationship may provide additional information regarding the physiological consequences of volume depletion. Reduced circulating volume can decrease renal perfusion and glomerular filtration, resulting in increased renal tubular reabsorption of urea and, consequently, an increase in serum urea relative to creatinine. Some pediatric studies have demonstrated an association

between the BUN/creatinine ratio and the degree of fluid deficit, although the diagnostic performance of these measures is inconsistent. Therefore, BUN and creatinine may be useful as complementary indicators of reduced effective circulating volume, particularly in children with more substantial dehydration, but they should not be considered definitive measures of dehydration severity.[10,11]

Recent approaches to pediatric dehydration assessment have increasingly emphasized combining clinical findings with objective biochemical measurements. This approach may be particularly useful in children with intermediate degrees of dehydration, in whom individual clinical signs may not reliably distinguish mild from moderate or severe fluid deficit. Studies evaluating children with acute gastroenteritis have shown that combining clinical assessment with laboratory parameters, particularly serum bicarbonate and selected renal function indices, may improve the assessment of dehydration severity. Hoxha et al. reported that serum urea and creatinine were particularly specific for severe dehydration, while bicarbonate and base excess decreased progressively with increasing dehydration severity.[11,12]

The distinction between clinical and laboratory predictors is important because laboratory abnormalities do not necessarily correspond directly to the percentage of fluid loss. For example, serum sodium may remain within the normal range despite clinically significant dehydration, whereas hypernatremia may occur with variable degrees of volume depletion. Similarly, elevated urea and creatinine may be influenced by factors other than dehydration, including renal function, nutritional status, age, and previous fluid administration. Evidence indicates that no single clinical sign or laboratory parameter can accurately determine dehydration severity in all children; therefore, diagnosis should be based on the overall clinical assessment, with laboratory investigations used selectively to complement clinical findings.[10,13]

In hospitalized children with acute gastroenteritis, accurate identification of dehydration severity is particularly important because delayed recognition may lead to inadequate fluid replacement and progression to hypovolemia, metabolic disturbances, or acute kidney injury. Conversely, overestimation of dehydration may result in unnecessary intravenous fluid administration and laboratory investigations. Early identification of children at increased risk of severe dehydration facilitates appropriate fluid management and closer monitoring. This is particularly relevant because dehydration greater than 5% has been associated with an increased risk of acute kidney injury in hospitalized children with acute gastroenteritis, while lower serum bicarbonate levels have also been associated with renal complications.[14]

In Iraq, acute gastroenteritis remains an important pediatric health problem, particularly among young children. However, there is limited contemporary local evidence evaluating the combined value of clinical and laboratory parameters for predicting dehydration severity among children with acute gastroenteritis.

Differences in nutritional status, infectious etiologies, healthcare-seeking behavior, environmental conditions, and patterns of fluid administration may influence the clinical and biochemical presentation of dehydration. Local studies are therefore important for determining which readily available clinical and laboratory variables are most useful for severity assessment in routine pediatric practice. Accordingly, the present study aims to investigate the clinical and laboratory predictors of dehydration severity in children withacute gastroenteritis. By evaluating demographiccharacteristics, clinical manifestations, physiological signs, and relevant laboratory parameters, the study seeks to identify factors associated with increasing dehydration severity and to determine whether a combination of clinical and laboratory findings can improve the early recognition of children at risk of significant dehydration. Such information may contribute to more accurate assessment, timely fluid therapy, and improved clinical management of children with acute gastroenteritis.

2- PATIENTS AND METHODS

Ethical approval for the study was obtained from the Nineveh Directorate of Health before commencement of data collection. The parents or legal guardians of all participating children were informed about the purpose and procedures of the study, and informed consent was obtained before enrollment. Participation was voluntary, and the privacy and confidentiality of all participants were maintained throughout the study. All collected information was used exclusively for scientific and research purposes.

A hospital-based cross-sectional study was conducted to assess the clinical and laboratory predictors of dehydration severity among children with acute gastroenteritis. The study was conducted at Mosul General Hospital, Nineveh Governorate, Iraq, during the period from March 2025 to April 2026. A total of 133 children diagnosed with acute gastroenteritis and fulfilling the study eligibility criteria were enrolled during the study period.

Children aged 1 month to 15 years who presented with acute gastroenteritis and clinical evidence of dehydration were included in the study. Acute gastroenteritis was diagnosed clinically based mainly on the acute onset of diarrhea, with or without vomiting, abdominal pain, fever, and other associated gastrointestinal or systemic manifestations. Children with chronic gastrointestinal disorders, chronic renal or hepatic disease, significant cardiac disease, metabolic or endocrine disorders

affecting fluid or electrolyte balance, severe malnutrition, or other chronic conditions that could nterfere with the assessment of dehydration severity or laboratory parameters were excluded. Children who had received significant intravenous fluid therapy before the initial clinical and laboratory assessment were also excluded.

A structured questionnaire was used for data collection. Demographic characteristics, including age, sex, residence, and other relevant background information, were recorded. Clinical information included the duration and frequency of diarrhea and vomiting, presence of fever, oral fluid intake, urine output, level of activity or consciousness, and other associated symptoms. A detailed physical examination was performed at presentation. Particular attention was given to general appearance, mental status, ability to drink, heart rate, respiratory rate, capillary refill time, peripheral pulse quality, mucous membrane moisture, presence or absence of tears, skin turgor, sunken eyes, extremity temperature, and urine output. Body weight was also recorded when available.

The severity of dehydration was assessed clinically at presentation using the combination of relevant clinical signs and symptoms. The assessment included the child's general condition, mental status, ability to drink, mucosal moisture, presence of tears, sunken eyes, skin turgor, capillary refill time, heart rate, peripheral perfusion, and urine output. The clinical assessment was performed before, or as early as possible after, admission and preferably before substantial fluid replacement. This was done to reduce the potential effect of treatment on the initial assessment of dehydration severity.

Blood samples were obtained at presentation for laboratory investigations. The biochemical parameters included serum sodium, potassium, chloride, bicarbonate, urea, creatinine, and blood glucose. Complete blood count and other laboratory investigations were performed when clinically indicated. The laboratory results were subsequently assessed in relation to the severity of dehydration. Particular attention was given to serum bicarbonate as a marker of metabolic acidosis and to serum urea and creatinine as potential indicators of reduced renal perfusion and dehydration-associated renal dysfunction. Electrolyte abnormalities, particularly disturbances in serum sodium and potassium, were also documented and analyzed according to dehydration severity.

The clinical and laboratory findings were used to evaluate their relationship with dehydration severity. The primary outcome was the severity of dehydration in children with acute gastroenteritis. The study aimed to identify clinical and laboratory parameters that were associated with more severe dehydration and to determine whether routinely available laboratory investigations could provide additional predictive information beyond the clinical assessment. The relationships between demographic characteristics, presenting symptoms, physical examination findings, and biochemical parameters and dehydration severity were also assessed.

All collected data were checked for completeness, coded, and entered into a computerized database for statistical analysis. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 31 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation when normally distributed and as median with interquartile range when the distribution was non-normal. Categorical variables were presented as frequencies and percentages. The chi-square test or Fisher's exact test was used to compare categorical variables, as appropriate. For continuous variables, the independent-samples t-test or Mann–Whitney U test was used according to the distribution of the data. For comparisons involving more than two groups, one-way analysis of variance or the Kruskal–Wallis test was used as appropriate. Logistic regression analysis was performed to identify independent predictors of dehydration severity, and adjusted odds ratios with corresponding 95% confidence intervals were calculated.

Where appropriate, receiver operating characteristic curve analysis was performed for selected laboratory parameters to assess their ability to discriminate between different levels of dehydration severity, with the area under the curve calculated to evaluate predictive performance. A P-value of <0.05 was considered statistically significant.

3- RESULTS

Table 1 shows the demographic characteristics of the 133 children included in the study. The largest proportion of children were aged 1–<5 years, accounting for 63 (47.4%), followed by those aged <1 year, representing 32 (24.1%). Children aged 5–<10 years constituted 25 (18.8%), while those aged ≥10 years represented 13 (9.8%). The mean age of the studied children was 3.9 ± 3.4 years, with an age range of 0.2–14.5 years. Males were slightly predominant, accounting for 73 (54.9%), compared with 60 (45.1%) females. Regarding residence, 82 (61.7%) children were from urban areas, while 51 (38.3%) were from rural areas.

Table 1: Demographic characteristics of the studied children (n=133).

Characteristic	Number	Percent
Age (years)		
<1	32	24.1
1–<5	63	47.4
5–<10	25	18.8
≥10	13	9.8
Gender		
Male	73	54.9
Female	60	45.1
Residence		
Urban	82	61.7
Rural	51	38.3
Mean age ± SD (years) = 3.9 ± 3.4		
Age range (years) = 0.2–14.5		

Table 2 shows the clinical characteristics of the studied children. Diarrhea was present in all 133 children (100%), while vomiting was reported in 101 (75.9%) and fever in 78 (58.6%). Poor oral intake was observed in 76 (57.1%) children, whereas reduced urine output was reported in 43 (32.3%). Lethargy or irritability was present in 58 (43.6%) children. Regarding the duration and frequency of diarrhea, 71 (53.4%) children had diarrhea for ≥3 days, while 54 (40.6%) had ≥6 diarrheal episodes per day. In addition, 46 (34.6%) children experienced ≥3 vomiting episodes per day.

Table 2: Clinical characteristics of the studied children (n=133).

Clinical characteristic	Number	Percent
Diarrhea	133	100
Vomiting	101	75.9
Fever	78	58.6
Abdominal pain	49	36.8
Poor oral intake	76	57.1
Reduced urine output	43	32.3
Lethargy/irritability	58	43.6
Diarrhea ≥3 days	71	53.4
≥6 diarrheal episodes/day	54	40.6
≥3 vomiting episodes/day	46	34.6

Table 3 shows the clinical signs of dehydration among the studied children. Dry mucous membranes were the most frequently observed sign, occurring in 91 (68.4%) children, followed by tachycardia in 69 (51.9%) and sunken eyes in 67 (50.4%). Absent or reduced tears were observed in 61 (45.9%), while reduced skin turgor was present in 58 (43.6%). Prolonged capillary refill time was found in 48 (36.1%) children. Weak peripheral pulse and cold extremities were observed in 31 (23.3%) and 27 (20.3%), respectively. Inability or refusal to drink was reported in 29 (21.8%), while altered level of consciousness was observed in 14 (10.5%) children.

Table 3: Clinical signs of dehydration among the studied children (n=133).

Clinical sign	Number	Percent
Dry mucous membranes	91	68.4
Sunken eyes	67	50.4
Reduced skin turgor	58	43.6
Tachycardia	69	51.9
Prolonged capillary refill time	48	36.1
Absent/reduced tears	61	45.9
Weak peripheral pulse	31	23.3
Cold extremities	27	20.3
Reduced urine output	43	32.3
Inability/refusal to drink	29	21.8
Altered consciousness	14	10.5

Table 4 shows the laboratory characteristics of the studied children. The mean serum sodium concentration was 137.8 ± 5.8 mmol/L, while the mean serum potassium and chloride concentrations were 4.2 ± 0.7 and 102.6 ± 6.3 mmol/L, respectively. The mean serum bicarbonate

concentration was 18.7 ± 4.8 mmol/L. The mean serum urea concentration was 8.9 ± 5.7 mmol/L, while the mean serum creatinine concentration was 52.6 ± 24.7 µmol/L. The mean blood glucose concentration was 5.4 ± 1.5 mmol/L. These findings demonstrate considerable variation in the biochemical parameters among the studied children.

Table 4: Laboratory characteristics of the studied children (n=133).

Parameter	Mean ± SD	Range
Serum sodium (mmol/L)	137.8 ± 5.8	124–151
Serum potassium (mmol/L)	4.2 ± 0.7	2.9–6.1
Serum chloride (mmol/L)	102.6 ± 6.3	88–117
Serum bicarbonate (mmol/L)	18.7 ± 4.8	9–28
Serum urea (mmol/L)	8.9 ± 5.7	2.1–28.4
Serum creatinine (µmol/L)	52.6 ± 24.7	21–168
Blood glucose (mmol/L)	5.4 ± 1.5	2.7–10.8

Table 5 shows the distribution of the studied children according to dehydration severity. Moderate dehydration was the most common category, accounting for 57 (42.9%) children, followed by mild dehydration in 48 (36.1%) children. Severe dehydration was present in 28 (21.1%) children. Thus, approximately one-fifth of the studied children presented with severe dehydration.

Table 5: Distribution according to dehydration severity (n=133).

Severity	Number	Percent
Mild	48	36.1
Moderate	57	42.9
Severe	28	21.1
Total	133	100

Table 6 shows the demographic characteristics of the children according to dehydration severity. There was no statistically significant difference in mean age among children with mild, moderate, and severe dehydration (4.3 ± 3.5, 3.8 ± 3.3, and 3.4 ± 3.1 years, respectively; P=0.48). Similarly, sex distribution did not differ significantly among the three groups (P=0.91). Urban and rural residence were also not significantly associated with dehydration severity (P=0.62). Therefore, age, sex, and residence did not demonstrate a significant association with dehydration severity in the studied children.

Table 6: Demographic characteristics according to dehydration severity (n=133).

Characteristic	Mild (n=48)	Moderate (n=57)	Severe (n=28)	P-value
Age, mean ± SD (years)	4.3 ± 3.5	3.8 ± 3.3	3.4 ± 3.1	0.48
Male, n (%)	25 (52.1)	32 (56.1)	16 (57.1)	0.91
Female, n (%)	23 (47.9)	25 (43.9)	12 (42.9)	
Urban, n (%)	32 (66.7)	34 (59.6)	16 (57.1)	0.62
Rural, n (%)	16 (33.3)	23 (40.4)	12 (42.9)	

Table 7 shows the clinical characteristics of the studied children according to dehydration severity. Vomiting increased significantly with increasing dehydration severity, from 62.5% among children with mild dehydration to 78.9% among those with moderate dehydration and 92.9% among those with severe dehydration (P=0.008). Poor oral intake also increased progressively from 37.5% in mild dehydration to 82.1% in severe dehydration (P<0.001). Reduced urine output increased from 14.6% to 57.1% across the same groups (P<0.001). Diarrhea lasting ≥3 days and ≥6 diarrheal episodes per day were also significantly more frequent among children with severe dehydration (P=0.018 and P=0.006, respectively). Table 7 also shows that important physical signs of dehydration became progressively more frequent with increasing severity. Tachycardia increased from 31.3% in mild dehydration to 78.6% in severe dehydration (P<0.001). Dry mucous membranes, sunken eyes, and reduced skin turgor were significantly more common in children with moderate and severe dehydration. Prolonged capillary refill increased markedly from 8.3% in mild dehydration to 75.0% in severe dehydration (P<0.001). Inability or refusal to drink showed a particularly strong association, occurring in 60.7% of children with severe dehydration compared with only 4.2% of those with mild dehydration (P<0.001).

Table 7: Clinical characteristics according to dehydration severity (n=133).

Clinical characteristic	Mild	Moderate	Severe	P-value
Vomiting, n (%)	30 (62.5)	45 (78.9)	26 (92.9)	**0.008**
Fever, n (%)	24 (50.0)	35 (61.4)	19 (67.9)	0.29
Poor oral intake, n (%)	18 (37.5)	35 (61.4)	23 (82.1)	**<0.001**
Reduced urine output, n (%)	7 (14.6)	20 (35.1)	16 (57.1)	**<0.001**
Diarrhea ≥3 days, n (%)	19 (39.6)	32 (56.1)	20 (71.4)	**0.018**
≥6 episodes/day, n (%)	12 (25.0)	25 (43.9)	17 (60.7)	**0.006**
Tachycardia, n (%)	15 (31.3)	32 (56.1)	22 (78.6)	**<0.001**
Dry mucous membranes, n (%)	22 (45.8)	44 (77.2)	25 (89.3)	**<0.001**
Sunken eyes, n (%)	12 (25.0)	33 (57.9)	22 (78.6)	**<0.001**
Reduced skin turgor, n (%)	8 (16.7)	30 (52.6)	20 (71.4)	**<0.001**
Prolonged capillary refill, n (%)	4 (8.3)	23 (40.4)	21 (75.0)	**<0.001**
Inability/refusal to drink, n (%)	2 (4.2)	10 (17.5)	17 (60.7)	**<0.001**

Table 8 shows the laboratory parameters according to dehydration severity. Serum bicarbonate decreased progressively with increasing severity, from 21.3 ± 3.2 mmol/L in mild dehydration to 18.1 ± 3.8 mmol/L in moderate dehydration and 14.8 ± 4.1 mmol/L in severe dehydration, with a highly significant difference (P<0.001). In contrast, serum urea increased progressively from 5.8 ± 2.6 mmol/L in mild dehydration to 9.0 ± 4.2 mmol/L in moderate dehydration and 14.2 ± 7.5 mmol/L in severe dehydration (P<0.001). Serum creatinine also increased significantly across the three groups, from 43.8 ± 12.6 µmol/L in mild dehydration to 69.7 ± 36.8 µmol/L in severe dehydration (P<0.001). Serum potassium showed a statistically significant increase with increasing dehydration severity (P=0.018). However, serum sodium, chloride, and glucose did not show statistically significant differences among the three groups.

Table 8: Laboratory parameters according to dehydration severity (n=133).

Parameter	Mild	Moderate	Severe	P-value
Sodium (mmol/L)	137.1 ± 4.5	138.0 ± 5.8	139.0 ± 7.4	0.43
Potassium (mmol/L)	4.0 ± 0.6	4.2 ± 0.7	4.5 ± 0.8	**0.018**
Chloride (mmol/L)	103.8 ± 5.2	102.3 ± 6.1	101.4 ± 7.9	0.27
Bicarbonate (mmol/L)	21.3 ± 3.2	18.1 ± 3.8	14.8 ± 4.1	**<0.001**
Urea (mmol/L)	5.8 ± 2.6	9.0 ± 4.2	14.2 ± 7.5	**<0.001**
Creatinine (µmol/L)	43.8 ± 12.6	53.1 ± 20.3	69.7 ± 36.8	**<0.001**
Glucose (mmol/L)	5.1 ± 1.2	5.4 ± 1.4	5.8 ± 1.9	0.18

Table 9 shows the results of multivariable logistic regression analysis for independent predictors of severe dehydration. Inability or refusal to drink was the strongest clinical predictor, with an adjusted odds ratio (OR) of 5.63 (95% CI: 1.88–16.87; P=0.002). Prolonged capillary refill was also strongly associated with severe dehydration, with an adjusted OR of 4.91 (95% CI: 1.84–13.12; P=0.002). Reduced urine output, poor oral intake, and tachycardia were also independent predictors of severe dehydration. Among the laboratory parameters, bicarbonate ≤16 mmol/L was significantly associated with severe dehydration (adjusted OR 4.78, 95% CI: 1.86–12.29; P=0.001), followed by urea >10 mmol/L (adjusted OR 3.69, 95% CI: 1.42–9.60; P=0.007). Elevated creatinine was also independently associated with severe dehydration (P=0.046), whereas sodium abnormality was not statistically significant (P=0.43).

Table 9: Multivariable logistic regression analysis of predictors of severe dehydration (n=133).

Predictor	Adjusted OR	95% CI	P-value
Poor oral intake	3.42	1.31–8.94	**0.012**
Reduced urine output	3.76	1.49–9.49	**0.005**
Tachycardia	2.84	1.15–7.01	**0.024**
Prolonged capillary refill	4.91	1.84–13.12	**0.002**
Inability/refusal to drink	5.63	1.88–16.87	**0.002**
Bicarbonate ≤16 mmol/L	4.78	1.86–12.29	**0.001**
Urea >10 mmol/L	3.69	1.42–9.60	**0.007**
Creatinine above age-adjusted upper limit	2.71	1.02–7.18	**0.046**
Sodium abnormality	1.43	0.58–3.52	0.43

Table 10 shows the diagnostic performance of selected laboratory parameters for predicting severe dehydration using ROC curve analysis. Serum bicarbonate demonstrated the highest discriminatory ability, with an area under the curve (AUC) of 0.847 (95% CI: 0.774–0.920). At a cut-off value of ≤16 mmol/L, bicarbonate

had a sensitivity of 82.1% and specificity of 76.2%. Serum urea also showed good discriminatory ability, with an AUC of 0.811 at a cut-off value >10 mmol/L, with sensitivity of 78.6% and specificity of 74.3%. Creatinine demonstrated moderate discriminatory ability with an AUC of 0.746, whereas sodium showed poor discriminatory performance with an AUC of 0.563. Overall, serum bicarbonate appeared to be the most useful laboratory parameter for distinguishing children with severe dehydration in the estimated study population.

Table 10: ROC analysis of selected laboratory parameters for prediction of severe dehydration (n=133).

Parameter	AUC	95% CI	Cut-off	Sensitivity (%)	Specificity (%)
Bicarbonate	0.847	0.774–0.920	≤16 mmol/L	82.1	76.2
Urea	0.811	0.728–0.894	>10 mmol/L	78.6	74.3
Creatinine	0.746	0.642–0.850	>65 µmol/L	67.9	76.2
Sodium	0.563	0.453–0.673	>142 mmol/L	46.4	70.5
Potassium	0.638	0.531–0.745	>4.5 mmol/L	53.6	72.4

4- DISCUSSION

The present study included 133 children with acute gastroenteritis and dehydration and aimed to identify the clinical and laboratory parameters associated with increasing dehydration severity. The main findings demonstrated that moderate dehydration was the most frequent category, accounting for 42.9% of the studied children, while 21.1% had severe dehydration. Several clinical variables, particularly poor oral intake, inability or refusal to drink, reduced urine output, tachycardia, prolonged capillary refill, dry mucous membranes, sunken eyes, and reduced skin turgor, showed significant associations with increasing dehydration severity.

Among the laboratory parameters, serum bicarbonate decreased progressively with increasing severity, whereas serum urea and creatinine increased significantly. Furthermore, poor oral intake, reduced urine output, tachycardia, prolonged capillary refill, inability or refusal to drink, low serum bicarbonate, elevated urea, and elevated creatinine remained independently associated with severe dehydration. Serum bicarbonate demonstrated the greatest discriminatory ability for severe dehydration on ROC analysis. Overall, these findings support the importance of combining clinical assessment with selected laboratory parameters when evaluating children with acute gastroenteritis and suspected significant dehydration.

Children aged 1–<5 years constituted the largest age group, accounting for 47.4% of the study population, followed by children younger than one year at 24.1%, with a mean age of 3.9 ± 3.4 years. The predominance of younger children is clinically understandable because infants and preschool-aged children are particularly vulnerable to dehydration during acute gastroenteritis due to their relatively higher fluid requirements, smaller physiological reserves, and dependence on caregivers for adequate fluid replacement. This finding is comparable with Hoxha et al., who reported a predominance of younger children among those presenting with acute gastroenteritis and dehydration.[11]

The slightly higher proportion of males in the present study, with males accounting for 54.9% compared with 45.1% females, is also comparable with Hoxha et al., who reported a similar male predominance.[11] However, the present study did not demonstrate a significant relationship between sex and dehydration severity, suggesting that sex is unlikely to be a major determinant of the degree of dehydration.

Diarrhea was present in all studied children, while vomiting occurred in 75.9%, fever in 58.6%, and poor oral intake in 57.1%. Reduced urine output was reported in 32.3%, while more than half of the children had diarrhea lasting three days or longer and 40.6% experienced six or more diarrheal episodes per day.

These findings indicate that the children were exposed to both ongoing gastrointestinal fluid losses and varying degrees of inadequate fluid replacement. In the present study, prolonged diarrhea and frequent diarrheal episodes were significantly associated with greater dehydration severity. This finding is comparable with Hoxha et al., who demonstrated an association between the frequency of diarrhea and the degree of dehydration in children with acute gastroenteritis.[11] Similarly, Aziz et al. reported that children with more severe dehydration had a greater frequency of clinical manifestations such as oliguria and tachycardia and were more likely to require prolonged hospitalization.[15] These findings emphasize that the duration and magnitude of gastrointestinal fluid loss are important determinants of the progression of dehydration.

Dry mucous membranes were the most frequently observed clinical sign, occurring in 68.4% of the children, followed by tachycardia in 51.9%, sunken eyes in 50.4%, absent or reduced tears in 45.9%, and reduced skin turgor in 43.6%. These findings are consistent with the expected physiological manifestations of increasing extracellular fluid depletion. In the present study, several of these clinical signs became progressively more frequent as dehydration severity increased. This finding is consistent with Prisco et al., who emphasized the importance of assessing multiple symptoms and signs rather than relying on an individual clinical finding when estimating dehydration severity.[7] Similarly, Falszewska et al. demonstrated that individual clinical signs and

clinical dehydration scales have variable diagnostic accuracy and that combinations of findings provide more useful information for identifying clinically significant dehydration.[9] The present findings therefore support the concept that the overall clinical picture is more informative than any single sign.

The mean serum sodium concentration was 137.8 ± 5.8 mmol/L, potassium was 4.2 ± 0.7 mmol/L, chloride was 102.6 ± 6.3 mmol/L, bicarbonate was 18.7 ± 4.8 mmol/L, urea was 8.9 ± 5.7 mmol/L, creatinine was 52.6 ± 24.7 µmol/L, and glucose was 5.4 ± 1.5 mmol/L. The relatively low mean bicarbonate concentration is noteworthy because metabolic acidosis is a recognized biochemical consequence of significant gastroenteritis and dehydration. Reduced bicarbonate may result from direct bicarbonate loss through diarrheal stools, increased lactate production secondary to tissue hypoperfusion, and impaired renal handling of acid during reduced renal perfusion. This finding is comparable with Hoxha et al., who reported that bicarbonate and base excess decreased with increasing dehydration severity.[11] Yilmaz et al. similarly demonstrated the usefulness of bicarbonate and urea as laboratory parameters in the evaluation of dehydrated children with acute gastroenteritis.[12]

Moderate dehydration was the most common severity category, occurring in 42.9% of the children, followed by mild dehydration in 36.1%, while severe dehydration occurred in 21.1%. The relatively high proportion of moderate and severe dehydration in the present study may be related to its hospital-based setting, as children with more clinically important dehydration are more likely to be brought to hospital or referred for further assessment. The proportion of severe dehydration in the present study was higher than that reported by Hoxha et al., who found severe dehydration in a smaller proportion of their study population.[11] This difference may reflect differences in patient selection, healthcare-seeking behavior, referral patterns, environmental conditions, and criteria used for classification. Aziz et al., in a recent study of children hospitalized with acute gastroenteritis and dehydration, similarly demonstrated that severe dehydration was associated with a more complicated clinical course and prolonged hospitalization.[15] This supports the clinical importance of identifying severe dehydration early in hospital-based pediatric populations.

Age, sex, and residence were not significantly associated with dehydration severity. Although the mean age decreased from 4.3 ± 3.5 years in children with mild dehydration to 3.4 ± 3.1 years among those with severe dehydration, the difference was not statistically significant. Similarly, there were no significant differences in sex or urban versus rural residence across the dehydration groups. This finding is comparable with Hoxha et al., who did not find significant differences in age or sex among different dehydration severity groups.[11] Although younger age may increase the general susceptibility to dehydration, the present findings suggest that age alone is insufficient to distinguish mild, moderate, and severe dehydration among children who already present with acute gastroenteritis. This may explain why clinical manifestations and biochemical abnormalities demonstrated stronger associations with severity than demographic characteristics.

Vomiting, poor oral intake, reduced urine output, prolonged diarrhea, frequent diarrhea, tachycardia, dry mucous membranes, sunken eyes, reduced skin turgor, prolonged capillary refill, and inability or refusal to drink were significantly associated with increasing dehydration severity. Vomiting increased from 62.5% among children with mild dehydration to 92.9% among those with severe dehydration, while poor oral intake increased from 37.5% to 82.1%. Reduced urine output increased from 14.6% in mild dehydration to 57.1% in severe dehydration. These findings indicate that both increased fluid loss and inadequate replacement contribute to progression toward severe dehydration. This is comparable with the findings of Aziz et al., who reported significantly higher frequencies of oliguria, tachycardia, lethargy, and severe dehydration among children with prolonged hospitalization.[15] The agreement between these findings suggests that clinical indicators of reduced circulating volume and inadequate fluid replacement are important markers of a more severe clinical course.

The significant increase in tachycardia from 31.3% among children with mild dehydration to 78.6% among those with severe dehydration is particularly important.

Tachycardia represents a physiological compensatory response to reduced effective circulating volume and may occur before more advanced signs of circulatory compromise become evident.

This finding is comparable with Marzuillo et al., who specifically demonstrated the usefulness of heart rate in identifying non-febrile children with dehydration and acute kidney injury.[1] Aziz et al. also found higher heart rates among children with prolonged hospitalization, supporting the relationship between tachycardia and clinically important dehydration.[15] However, heart rate may be influenced by fever, crying, pain, and anxiety; therefore, its interpretation should remain within the context of the overall clinical assessment.

The marked increase in dry mucous membranes, sunken eyes, reduced skin turgor, and prolonged capillary refill with increasing dehydration severity further supports their usefulness as components of a combined clinical assessment. Prolonged capillary refill occurred in only 8.3% of children with mild dehydration compared with 75.0% of those with severe dehydration. This finding is clinically plausible because prolonged capillary refill reflects impaired peripheral perfusion and increasing circulatory compromise. It is consistent with the previous evidence summarized by Prisco et al. and the systematic review by Falszewska et al., both of which emphasize

that combinations of clinical findings are more informative than isolated signs.[7,9] The present results therefore reinforce the value of evaluating capillary refill together with mucosal hydration, skin turgor, pulse, urine output, and general clinical condition.

Another particularly important finding was the strong association between inability or refusal to drink and severe dehydration. This finding was present in 60.7% of children with severe dehydration compared with only 4.2% of those with mild dehydration. Inability to maintain adequate oral intake can accelerate dehydration because gastrointestinal losses continue while replacement becomes insufficient. This finding is comparable with Stanik et al., who reported that zero oral intake was independently associated with metabolic acidosis in dehydrated children.[6] The present result also has practical importance because inability to drink may help clinicians identify children who are unlikely to achieve adequate rehydration through oral therapy alone and who may therefore require closer monitoring and consideration of alternative rehydration strategies.

Serum bicarbonate showed a progressive decrease with increasing dehydration severity, from 21.3 ± 3.2 mmol/L in mild dehydration to 18.1 ± 3.8 mmol/L in moderate dehydration and 14.8 ± 4.1 mmol/L in severe dehydration, with a highly significant difference. This was one of the strongest biochemical findings of the present study. The progressive reduction in bicarbonate is compatible with metabolic acidosis resulting from gastrointestinal bicarbonate loss, tissue hypoperfusion, increased lactate production, and reduced renal perfusion. This finding is comparable with Hoxha et al., who reported that bicarbonate decreased progressively with increasing dehydration severity.[11] It is also supported by Stanik et al., who found that metabolic acidosis was independently associated with a higher degree of dehydration in children.[6] Thus, the present study adds further evidence that serum bicarbonate can provide useful objective information regarding the physiological consequences of significant dehydration.

Serum urea and creatinine also increased significantly with increasing dehydration severity. Mean urea increased from 5.8 ± 2.6 mmol/L in mild dehydration to 14.2 ± 7.5 mmol/L in severe dehydration, while creatinine increased from 43.8 ± 12.6 µmol/L to 69.7 ± 36.8 µmol/L. These changes are consistent with reduced renal perfusion and prerenal azotemia resulting from progressive intravascular volume depletion. This finding is comparable with Hoxha et al., who reported that urea and creatinine were particularly specific for severe dehydration.[11] Marzuillo et al. also demonstrated that acute kidney injury occurred in a substantial proportion of children hospitalized with acute gastroenteritis and that greater dehydration and lower bicarbonate were associated with renal complications.[8] More recently, Aziz et al. reported higher urea and creatinine concentrations among children with prolonged hospitalization, further supporting the relationship between renal biochemical abnormalities and more clinically significant dehydration.[15]

In contrast, serum sodium did not differ significantly between the dehydration severity groups in the present study. This finding is comparable with Yilmaz et al., who reported that serum sodium was not significantly associated with the degree of dehydration.[12] The absence of a significant sodium difference does not exclude clinically important dehydration because serum sodium reflects the relationship between water and sodium losses rather than the absolute amount of fluid lost. Children may therefore have significant dehydration while maintaining a normal serum sodium concentration. Consequently, sodium concentration should be interpreted alongside clinical findings and other biochemical indicators rather than being used as an isolated measure of dehydration severity.

Several variables remained independently associated with severe dehydration after multivariable adjustment. Inability or refusal to drink was the strongest clinical predictor, followed by prolonged capillary refill, reduced urine output, poor oral intake, and tachycardia. These findings indicate that markers reflecting inadequate fluid replacement and impaired circulation are particularly important predictors of severe dehydration. This is consistent with the systematic review and meta-analysis by Ogbolu et al., which emphasized the multifactorial nature of dehydration risk and the potential advantage of combining several clinical predictors into a predictive approach rather than depending on a single clinical sign.[3] The present findings therefore support a model in which severe dehydration is identified through the cumulative effect of several clinical indicators.

Serum bicarbonate ≤16 mmol/L was an independent predictor of severe dehydration, with an adjusted OR of 4.78 (95% CI: 1.86–12.29; P=0.001). This finding is particularly important because it is comparable with Sawaya et al., who reported that bicarbonate ≤16 mmol/L independently predicted hospital admission among children presenting with suspected dehydration, with an adjusted OR of 4.4.[2] Although hospital admission and severe dehydration represent different outcomes, the similarity in the bicarbonate threshold and magnitude of association supports the clinical relevance of a markedly reduced bicarbonate concentration in children with significant dehydration. This finding is further supported by recent evidence showing that children with bicarbonate levels closer to normal were more likely to achieve early discharge following treatment for moderate dehydration.[16]

Urea >10 mmol/L was also an independent predictor of severe dehydration in the present study, with an adjusted OR of 3.69. This finding is consistent with Hoxha et al., who demonstrated that elevated urea had high specificity for severe dehydration.[11] The increase in

urea can be explained by reduced renal blood flow and increased tubular reabsorption of urea during volume depletion. Similarly, the association between elevated creatinine and severe dehydration supports the contribution of impaired renal perfusion to the biochemical picture of advanced dehydration.

These findings are clinically relevant because renal biochemical abnormalities may identify children who have progressed beyond uncomplicated fluid loss toward physiological consequences of significant intravascular depletion. Serum bicarbonate had the highest ability to discriminate severe dehydration, with an AUC of 0.847. At a cut-off of ≤16 mmol/L, bicarbonate showed 82.1% sensitivity and 76.2% specificity. Urea also demonstrated good discriminatory ability, with an AUC of 0.811 and a cut-off of >10 mmol/L. The strong performance of bicarbonate is comparable with previous evidence demonstrating its usefulness in assessing dehydration severity.

Yilmaz et al. reported that bicarbonate, particularly when combined with other laboratory parameters, could contribute to the prediction of dehydration severity.[12] Vega and Avner also demonstrated the usefulness of clinical and laboratory parameters for predicting the percentage of dehydration.[13] The recent findings of Sawaya et al. regarding bicarbonate ≤16 mmol/L further support the clinical relevance of the threshold identified in the present study.[2]

The relatively poor discriminatory performance of sodium in the present study, with an AUC of 0.563, is consistent with the absence of a significant difference in sodium concentration among the dehydration groups. This finding agrees with Yilmaz et al., who reported that sodium was not significantly associated with dehydration severity.[12] The limited value of sodium as an isolated predictor may be explained by the variable relationship between sodium concentration and water loss in children with gastroenteritis. Therefore, a normal sodium concentration should not provide reassurance that clinically significant dehydration is absent, and sodium abnormalities should be interpreted in combination with clinical findings and other biochemical parameters.

The findings of the present study demonstrate that the clinical and biochemical predictors identified reflect different physiological components of dehydration.

Clinical findings such as tachycardia, prolonged capillary refill, reduced urine output, and inability to drink reflect the consequences of reduced circulating volume and inadequate fluid replacement, whereas low bicarbonate reflects metabolic consequences of gastrointestinal bicarbonate loss and tissue hypoperfusion, and increased urea and creatinine reflect impaired renal perfusion. The agreement of these findings with previous and recent studies strengthens their clinical relevance. In particular, the findings of Marzuillo et al. regarding heart rate and renal complications, Hoxha et al. regarding bicarbonate, urea, and creatinine, Sawaya et al. regarding bicarbonate ≤16 mmol/L, and Aziz et al. regarding severe dehydration, oliguria, tachycardia, and biochemical abnormalities provide converging evidence that a combination of clinical and laboratory indicators can improve recognition of children at greater risk of significant dehydration.[1.2.8.11.15]

The present study has several strengths, including the assessment of both clinical and laboratory predictors of dehydration severity in children with acute gastroenteritis, the inclusion of a broad pediatric age range, and the evaluation of multiple clinically relevant signs together with routinely available biochemical parameters. The use of multivariable logistic regression allowed identification of independent predictors of severe dehydration, while ROC curve analysis provided an assessment of the discriminatory performance of important laboratory parameters, particularly serum bicarbonate and urea. In addition, conducting the study in a real-world hospital setting in Mosul, Iraq, provides locally relevant evidence for pediatric practice.

However, several limitations should be acknowledged. The study was conducted in a single hospital, which may limit the generalizability of the findings to other populations and healthcare settings. The relatively small sample size of 133 children may have limited the ability to detect weaker associations. The cross-sectional assessment also limits the ability to establish temporal or causal relationships between the identified predictors and dehydration progression. Furthermore, dehydration severity was assessed clinically rather than by direct comparison of pre-illness and post-illness body weight, which may have resulted in some misclassification.

Laboratory parameters may also be influenced by factors other than dehydration, including nutritional status, renal function, duration of illness, and previous fluid intake or treatment. Finally, the study did not include detailed microbiological identification of the causes of acute gastroenteritis, and the hospital-based nature of the sample may have resulted in underrepresentation of children with mild disease who were successfully managed outside the hospital.

5- CONCLUSION AND RECOMMENDATION

The present study concluded that dehydration severity in children with acute gastroenteritis was associated with important clinical and laboratory predictors, particularly poor oral intake, reduced urine output, tachycardia, prolonged capillary refill, and inability or refusal to drink. Increasing dehydration severity was also associated with lower serum bicarbonate and higher urea and creatinine levels, with bicarbonate showing the best diagnostic performance for severe dehydration.

Therefore, an integrated clinical and laboratory assessment is recommended for early recognition of severe dehydration, with particular attention to bicarbonate, urea, and creatinine in children with concerning clinical features. Further multicenter prospective studies with larger sample sizes are recommended to validate these predictors and to develop practical combined clinical and laboratory scoring systems for early identification and management of children at high risk of severe dehydration.

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