How to interpret symptoms, signs and investigations of dehydration in children with gastroenteritis

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ABSTRACT
Dehydration is a significant cause of morbidity and mortality in children worldwide. Infants and young children are vulnerable to dehydration, and clinical assessment plays a pivotal role in their care. In addition, laboratory investigations can, in some children, be helpful when assessing the severity of dehydration and for guiding rehydration treatment. In this interpretation, we review the current literature and provide an evidence-based approach to recognising and managing dehydration in children.

BACKGROUND
Worldwide, it has been estimated that approximately one in five paediatric deaths can be attributed to dehydration related to gastroenteritis.[1 2] The increased fluid losses from vomiting and diarrhoea can result in rapid fluid and electrolyte shifts leading to dysregulation of physiological mechanisms such as thirst. In extremis, this can lead to volume depletion and dangerous electrolyte imbalances.[1] An understanding of the symptoms, signs and investigations used to assess and manage dehydration is vital for any clinician caring for acutely unwell children. This interpretation therefore focuses entirely on the management of dehydration in children with an acute gastrointestinal illness. Other, less common, causes of dehydration (eg, diabetic ketoacidosis, renal failure, cardiac failure, liver disease and postoperative care) are not covered.

Throughout this interpretation, dehydration will be described as mild (<5% of weight loss), moderate (5%–10% weight loss) or severe (>10% weight loss).[3]

WHAT ARE THE SYMPTOMS AND SIGNS OF DEHYDRATION IN A CHILD?
A number of clinical features were identified from the literature as predictive of dehydration. These are outlined in table 1 and include decreased skin turgor, capillary refill time of >2 s, ill appearance, absent tears, abnormal respiration pattern, dry mucous membranes, sunken eyes, abnormal (weak or feeble) radial pulse, tachycardia and decreased urine output.[4–7] The absence of these signs, among children with gastroenteritis, was highly predictive of the child not having dehydration with a negative predictive value (NPV) of over 90%.[4–7]

Unfortunately, the symptoms and signs listed above and in table 1 were not specific for dehydration; that is, the presence of one or more of the symptoms could not be used to accurately confirm dehydration as present. The most specific symptoms and signs of dehydration were reported as prolonged capillary refill time of >2 s (positive predictive value (PPV) 0.57–0.65) and decreased skin turgor (PPV 0.52–0.57). The remaining symptoms and signs were non-specific for dehydration with a PPV of less than 0.5.[4–7]

Based on these findings, it is reasonable to assume that, in a child with acute gastroenteritis, if all of the symptoms and signs listed are absent, then dehydration is unlikely. The presence of any of the features listed should alert the clinician to the possibility of dehydration while also being mindful that many of the features are non-specific and may indicate other illnesses.

One approach to rising awareness and to standardise care in this area has been the development of clinical decision tools. One such tool validated for use in children (aged 1 month–3 years) is the Clinical Dehydration Scale (CDS),[8] summarised in table 2. Another useful resource is the National Institute for Health and Care Excellence (NICE) clinical guideline 84: 'Diarrhoea and vomiting

Table 1 Summary of studies quantifying the diagnostic performance of clinical signs of dehydration and/or investigating their predictivity of dehydration severity

Author	Study setting	Inclusion criteria	Exclusion criteria	Sample size	Key results
Caruggi *et al*	2 children's EDs (Italy)	Children aged 9 months–17 years with acute gastroenteritis	Newborn babies (correct age <1 month), children on tube feeding or with chronic poor health (listed)	242	Significant correlation between ▶ CRT and dehydration. ▶ CDS correlated with percentage dehydration and length of stay.
Falszewska *et al*	1 children's ED (Poland)	Children aged 1 month–5 years with acute gastroenteritis	Other causes of dehydration (listed)	128 children	CDS unable to rule out dehydration but was able to predict severity
Gorelick *et al*	1 urban ED (USA)	Children aged 1 month to 5 years with acute gastroenteritis	Symptoms longer than 5 day-duration, history of chronic disease (listed) 12 hours at another health facility and hyponatremia or hypernatremia.	186 children	All these parameters were significantly associated with the presence of dehydration: ▶ Decreased skin elasticity: PPV 0.57, NPV 0.93, sensitivity 0.35, specificity 0.97. ▶ CRT>2 s: PPV 0.57, NPV 0.94, sensitivity 0.48, specificity 0.96. ▶ Ill general appearance: PPV 0.42, NPV 0.95, sensitivity 0.59, specificity 0.91. ▶ Absent tears: PPV 0.40, NPV 0.96, sensitivity 0.67, specificity 0.89. ▶ Abnormal respiration pattern: PPV 0.37, NPV 0.94, sensitivity 0.43, specificity 0.86. ▶ Dry mucous membranes: PPV 0.29, NPV 0.99, sensitivity 0.80, specificity 0.78. ▶ Sunken eyes PPV 0.29, NPV 0.95, sensitivity 0.60, specificity 0.84. ▶ Abnormal radial pulse: PPV 0.25, NPV 0.93, sensitivity 0.43, specificity 0.86. ▶ Tachycardia PPV 0.20, NPV 0.93, sensitivity 0.46, specificity 0.79. ▶ Decreased urine output: PPV 0.17, NPV 0.97, sensitivity 0.85, specificity 0.53.
Mackenzie *et al*	1 children's hospital (Australia)	Children under 4 years admitted with gastroenteritis	Less than 5% dehydration	102 children	Signs of dehydration of >4% ▶ Deep breathing (PPV 0.58, p=0.023). ▶ Decreased peripheral perfusion (PPV 0.65, p=0.024). ▶ Decreased skin turgor (PPV 0.52, p=0.056).
Hoxha *et al*	1 urban hospital (Kosovo)	Children aged 1 month–5 years admitted with gastroenteritis		200 children	The number of episodes of diarrhoea correlate with the degree of dehydration (p=0.004).
Friedman *et al*	1 tertiary children's ED (Canada)	Children between 1 and 36 months of age with gastroenteritis	Any cause of dehydration chronic disease	141 children	General ill appearance, sunken eyes, dry mucous membranes and absent tears were significantly associated with the degree of dehydration: Pearson's correlation coefficients were 0.66, 0.62, 0.74 and 0.74, respectively.
Steiner *et al*	Meta-analysis	26 studies in young children aged 1 month–5 years	13 excluded due to the lack of an accepted diagnostic standard or other limitation in study design	1246 children	Three signs had a clinically helpful pooled LR in detecting 5% dehydration: ▶ Prolonged CRT: LR 4.1 (95% CI 1.7 to 9.8). ▶ Abnormal skin turgor had a pooled LR of 2.5 (95% CI 1.5 to 4.2). ▶ Abnormal respiratory pattern: LR of 2.0 (95% CI 1.5 to 2.7). Low urine output did not increase the likelihood of 5% dehydration (LR, 1.3; 95% CI, 0.9 to 1.9).

CDS summarised in table 2.

CDS, Clinical Dehydration Score; CRT, capillary refill time; ED, emergency department; LR, likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

Table 2 Clinical Dehydration Scale			
Items	**0**	**1**	**2**
General appearance	Normal	Thirsty, restless, or lethargic but irritable when touched	Disoriented, hypotonic, cold or sweaty skin, unconscious
Eyes	Normal	Slightly sunken	Very sunken
Mucous membranes	Moist	'Sticky'	Dry
Tears	Tears	Decreased tears	Absent tears

A score of 0 represents no dehydration (<3%); a score of 1–4, some dehydration (≥3%–6%); and a score of 5–8, moderate/severe dehydration (≥6%).

caused by gastroenteritis in under 5 s: diagnosis and management'.[9]

WHICH SYMPTOMS AND SIGNS ARE BEST FOR PREDICTING THE SEVERITY OF DEHYDRATION?

Predicting the severity of dehydration is challenging and requires the clinician to interpret and combine a mixture of symptoms and signs. When taking the history, it is important to ask about the number of episodes of diarrhoea and/or vomiting, as well as asking about intake, duration of illness and estimated urine output. Of the reported symptoms, it is the number of episodes of diarrhoea and/or vomiting that correlates best with severity.[10]

During the examination, it is important to make a global assessment of the child's health while also specifically examining for skin turgor, capillary refill time, dryness of mucous membranes, appearance of eyes (sunken or not) and the presence of tears. The individual predictive value of these signs has been discussed already (table 1), and the presence of any one feature should alert the clinician to possibility of dehydration.[4–7 10–12] The greater the number of features, the greater the likely degree of dehydration.[6]

The CDS provides a pragmatic approach to assessing severity (table 2) and can be used to aide decision making.[4 8] Similarly, NICE CG84 provides guidance on assessing severity with features of dehydration listed, including five 'red flag' signs of 'reduced responsiveness, reduced skin turgor, tachycardia, tachypnoea and sunken eyes'.[9]

CAN LABORATORY INVESTIGATIONS BE USED TO ASSESS THE SEVERITY OF DEHYDRATION?

NICE does not recommend routine blood testing in the assessment of dehydration in children. Blood testing is only recommended for children who require intravenous therapy, have signs of shock or where hyponatraemia/hypernatraemia is suspected.[9] When testing is required, NICE only recommends measuring blood sugar, electrolytes, urea, creatinine and a blood gas. This approach is supported by the available evidence summarised in table 3.[7 10 12–18]

Measuring serum urea and creatinine levels is helpful when assessing severe dehydration only with very high serum urea values (greater than 16.7 mmol/L) and creatinine values (greater than 80 μmol/L) reliably predicting severe dehydration.[10 13] Unfortunately, urea and creatinine levels are unhelpful in mild and moderate dehydrations.

Of the tests advised by NICE,[9] the blood gas (specifically bicarbonate levels) correlates the best with severity, as shown in table 4.[12 13 16 17] As a general trend, the lower the venous bicarbonate levels, the greater the severity of dehydration.[10]

WHAT ABOUT OTHER TESTS?

There are a number of other tests that have been suggested as helpful in the assessment of dehydration in children. These include urinary testing (sodium and specific gravity) and blood tests (blood urea nitrogen ('BUN'), BUN to creatinine ratio and uric acid).[12–14 17 18]

Urinary testing for specific gravity is of almost no value when assessing for dehydration and should not be routinely used.[18] Urinary sodium levels may be helpful with a urine sodium of less than 90 mmol/L being shown to be highly sensitive and specific for dehydration.[17] A urinary sodium may therefore be useful in children where the traditional clinical assessment of hydration may be difficult, for example, dehydration in conditions such as nephrotic syndrome.

Blood testing for BUN and BUN/creatinine levels may also be helpful in some. An elevated BUN greater than 45 mg/dL (16 mmol/L) is indicative of at least moderate dehydration,[12] whereas a BUN to creatinine ratio of less than 20 is indicative of an absence of dehydration.[14]

EXPERIMENTAL TESTING

The digitally measured capillary refill time (DCRT) is an innovative approach for predicting dehydration severity. The test requires use of specific software to analyse 'frame-by-frame' the video of one of the child's fingertips both before and after a light pressure is applied for 5 s. Studies have demonstrated that a DCRT of >0.4 s was 100% sensitive (95% CI 75% to 100%) and had a specificity of 91% (95% CI 82% to 97%) for predicting the presence of at least moderate dehydration.[19]

Ultrasound (US) scanning has been proposed as a quick method to determine the severity of dehydration in children. Two different US measures (aorta to inferior vena cava (IVC) ratio and IVC inspiratory collapse) have been studied as methods of estimating dehydration in children. The aorta to IVC ratio demonstrated a sensitivity of 93% and specificity of 59% compared with 93% and 35% for IVC inspiratory collapse.[20] The use of US remains experimental but could become of greater clinical relevance as point-of-care US becomes more widely available.[20]

Table 3 Summary of studies investigating predictivity of dehydration severity of laboratory investigations

Author	Study setting	Study design	Inclusion criteria	Exclusion criteria	Sample size	Level of evidence (Oxford Centre for Evidence Based Medicine)	Key results
Hoxha *et al*	1 urban hospital (Kosovo)	Prospective cohort study	Children aged 1 month–5 years admitted with diarrhoea and/or vomiting during the 2-year study period		200 children	2	In severe dehydration, creatinine levels (mmol/L) were significantly higher compared with other dehydration degrees (61.65±34.97 vs 41.16±7.49 in mild dehydration, 41.27±10.16 in moderate dehydration) The venous bicarbonate levels (mmol/L) in non-dehydrated patients were 21.1±2.78, in mild dehydration 19.09±2.88, whereas in moderate and severe (>10% wt loss) dehydration, 16.31±3.16 and 12.18±3.78, respectively ($p<0.001$). The base excess (BE) in severe dehydration (−18.96) compared with none (−5.9), mild (−8.57) and moderate dehydration (−12.26) decreased significantly ($p<0.001$).
Tam *et al*	1 tertiary children's ED (Canada)	Case comparison trial	Children aged <18 years with diarrhoea and vomiting who clinically required intravenous fluids for rehydration compared with minor trauma patients who required intravenous needling for conscious sedation		73 cases and 143 controls	2	The following parameters were statistically significant ($p<0.05$) between the control group and the dehydrated group: ► Urine sodium/potassium ratio (2.3 (0–56) vs 0.69 (0–4.4)). ► Urine sodium, fractional sodium excretion (%) (0.52 (0–10.4) vs 0.19 (0–0.89)). ► Serum bicarbonate (mmol/L) (24 (18–30) vs 20 (10–27)). The best markers for dehydration were urine Na<90 mmol/L and serum bicarbonate<21 mmol/L (area under receiver operating characteristic curve=0.798 and 0.821, respectively; sensitivity=75% and 90%, respectively; specificity=74% and 62%, respectively)
Narchi *et al*	1 urban hospital (Saudi Arabia)	Prospective cohort study	Children aged 1 month–5 years, diarrhoea (three or more watery stools) or vomiting for less than 72 hours at presentation and dehydration	Extraintestinal infection; renal, respiratory, cardiac, neurological, or endocrine anomalies; chronic diarrhoea; malnutrition; failure to thrive; and administration of diuretics or intravenous fluids within 1 week of presentation	116 children	2	Reduced serum bicarbonate (<22 mmol/L) occurred in 72 patients (68%), with a significant difference between the three groups (39 in mild, 23 in moderate and 10 in severe dehydration group; $p=0.009$). When the concentration of bicarbonate was studied by age group, it was found to be overall significantly lower in the younger (age <1 year) group ($p=0.01$).
Steiner *et al*	► 5 EDs ► 6 hospitals ► 2 gastroenteritis clinics	Meta-analysis	Twenty-six reviewed studies contained original data on the precision or accuracy of findings for the diagnosis of dehydration in young children aged 1 month to 5 years.	Eliminated 13 of the 26 studies because of the lack of an accepted diagnostic standard or other limitation in study design.	1246 children	1	► Blood urea nitrogen (BUN)>45 mg/dL=LR of dehydration (for at least 5% dehydration) 46.1 (95% CI 2.9 to 733). ► Serum bicarbonate>15 mEq/L=LR of 0.18 (95% CI 0.08 to 0.37). ► Serum bicarbonate<17 mEq/L=LR of 3.5 (95% CI 2.1 to 5.8). ► pH<7.35=LR 2.2 (95% CI 1.2 to 4.1). ► Anion gap>20 mmol/L=LR 1.8 (95% CI 0.8 to 4.2). ► Uric acid>600 mmol/L=LR 1.0 (95% CI 0.3 to 3.5).

Continued

Table 3 Continued

Author	Study setting	Study design	Inclusion criteria	Exclusion criteria	Sample size	Level of evidence (Oxford Centre for Evidence Based Medicine)	Key results
Teach *et al*	1 tertiary children's ED (USA)	Cohort study	Children aged 2 weeks–12 years with acute (<1 week) dehydration	Diabetes mellitus, diabetes insipidus, known renal insufficiency of any aetiology	57 children	2	The following laboratory parameters were significantly correlated in simple linear regression models to fluid deficit: ► BUN/creatinine ratio (BUN/Cr)=r 0.52 p=0.0005. ► Uric acid=r 0.35 p=0.03. Serum BUN/Cr>20: sensitivity 92.3%, specificity 33.3%, PPV 40%, NPV 90% Serum BUN/Cr>30: sensitivity 61.5%, specificity 70.4%, PPV 50%, NPV 79.2% Serum BUN/Cr>40: sensitivity 23.1%, specificity 88.8%, PPV 50%, NPV 70.1% Serum uric acid >300µmol/L sensitivity 84.6%, specificity 40.7%, PPV 40.7%, NPV 84.6% Serum uric acid>450µmol/L: sensitivity 30.1%, specificity 59.2%, PPV 26.7%, NPV 64% Serum uric acid >600µmol/L: sensitivity 46.1%, specificity 77.8%, PPV 33.3%, NPV 67.7%
Yilmaz *et al*	1 tertiary paediatric department and 1 tertiary children's ED (Turkey)	Retrospective study	Children aged 1–21 months with acute gastroenteritis and dehydration, and treated with intravenous fluid therapy	Patients younger than 1 month or older than 24 months and those with additional health problems, such as malnutrition, urinary tract infections and septicaemia	168	3	At multiple linear regression analysis, dehydration severity correlated strongly to urea (p<0.001) and bicarbonate (p=0.01), but no to sodium (p=0.28). Serum bicarbonate concentrations of 15 mmol/L or more exclude a severe dehydration (PPV=89.6%, NPV=28%).
Vega *et al*	1 tertiary children's ED (USA)	Prospective	Children aged 2 weeks–15 years who have required intravenous fluid for acute dehydration		97	2	Serum bicarbonate level of <17 mEq/L was 77% sensitive for moderate dehydration and 94% sensitive for severe dehydration. When clinical impression was combined with a bicarbonate concentration of <17 mEq/L, sensitivity for prediction of severe dehydration increased to 100%.
Mackenzie *et al*	1 children's hospital (Australia)	Prospective cohort study	Children under 4 years admitted with gastroenteritis		102 children	2	The laboratory findings that pointed to dehydration of 4% or more, in a statistically significant way, were ► Serum urea>6 mmol/L=PPV 0.63, p<0.001. ► pH<7.35=VPP 0.62, p=0.024. ► Base deficit≥7= PPV 0.5, p=0.103. Increasing urea levels were associated with a higher level of dehydration (p=0.505, p<0.001). Reduced blood pH was associated with a higher level of dehydration (p=−0.453, p<0.001). Increasing base deficit was associated with a higher level of dehydration (p=−0.378, p<0.001).
Steinert *et al*	1 children's ED (USA)	Prospective cohort study	Children aged 3–36 months with gastroenteritis, clinically suspected moderate dehydration, need for intravenous rehydration		79 children	2	Urine-specific gravity (r=−0.06, p=0.64), urine ketones (r=0.08, p=0.52) and urine output during rehydration (r=0.01, p=0.96) did not correlate with the initial degree of dehydration.

ED, emergency department; LR, likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

Table 4 Mean±SD of venous bicarbonate and base excess levels in relation to dehydration levels

	Non-dehydrated patients	Mild dehydration	Moderate dehydration	Severe dehydration	P value
Venous bicarbonate levels (mmol/L)	21.1±2.78	19.09±2.88	16.31±3.16	12.18±3.78	0.001
Base excess	−5.9±3.29	−8.57±3.91	−12.26±4.31	−18.96±4.92	0.001

Clinical bottom line

- The assessment of dehydration in children is challenging and requires a detailed history and examination.
- Blood tests should not be performed routinely.
- The greater the number of symptoms and signs, the greater the likelihood of severe dehydration.
- The Clinical Dehydration Scale and National Institute for Health and Care Excellence CG84 are useful tools to help clinicians identify children with dehydration.

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