Evaluation of a Clinical Dehydration Scale in Children Requiring Intravenous Rehydration

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KEY WORDS
dehydration, gastroenteritis, clinical score, severity of illness, emergencies

ABBREVIATIONS
AUC—area under the curve
CDS—clinical dehydration scale
CI—confidence interval
ED—emergency department
IQR—interquartile range
ROC—receiver operating characteristic

Dr Freedman is the guarantor of this article and declares that he participated in the design of this study and revisions of the article. Dr Freedman also takes full responsibility for the work and conduct of the study, the integrity of the data, and the decision to publish. Ms Kinlin made substantial contribution to analysis and interpretation of data, drafting of the article for publication, and she has seen and approved the version to be published.

This study is a secondary analysis of data collected as part of a clinical trial, which was registered at www.clinicaltrials.gov (identifier NCT00392145). The main content of the clinical trial has been published by the British Medical Journal. Two other manuscripts arising from the original clinical trial data set are currently under review by other journals. The authors of all manuscripts attest to the fact that all manuscripts contain unique information and minimal if any overlapping content.

WHAT’S KNOWN ON THIS SUBJECT: Evaluating dehydration severity is a challenging task. Clinical dehydration scores that combine multiple clinical findings are promising. One clinical dehydration scale score has been developed and subsequently validated; however, few participants in the derivation and validation studies were significantly dehydrated.

WHAT THIS STUDY ADDS: In children requiring intravenous rehydration, the dehydration scale displayed moderate reliability and weak associations with objective measures. Thus, although the scale can assist in assessing dehydration, it should not be used in isolation to dictate interventions (eg, intravenous rehydration, hospitalization).

abstract

OBJECTIVES: To evaluate the reliability and validity of a previously derived clinical dehydration scale (CDS) in a cohort of children with gastroenteritis and evidence of dehydration.

METHODS: Participants were 226 children older than 3 months who presented to a tertiary care emergency department and required intravenous rehydration. Reliability was assessed at treatment initiation, by comparing the scores assigned independently by a trained research nurse and a physician. Validity was assessed by using parameters reflective of disease severity: weight gain, baseline laboratory results, and length of stay.

RESULTS: Interobserver reliability was moderate, with a weighted $\kappa$ of 0.52 (95% confidence interval [CI] 0.41, 0.63). There was no correlation between CDS score and percent weight gain, a proxy measure of fluid deficit (Spearman correlation coefficient $= -0.03$; 95% CI $-0.18$, 0.12). There were, however, modest and statistically significant correlations between CDS score and several other parameters, including serum bicarbonate (Pearson correlation coefficient $= -0.35$; 95% CI $-0.46$, $-0.22$) and length of stay (Pearson correlation coefficient $= 0.24$; 95% CI 0.11, 0.36). The scale’s discriminative ability was assessed for the outcome of hospitalization, yielding an area under the receiver operating characteristic curve of 0.65 (95% CI 0.57, 0.73).

CONCLUSIONS: In children administered intravenous rehydration, the CDS was characterized by moderate interobserver reliability and weak associations with objective measures of disease severity. These data do not support its use as a tool to dictate the need for intravenous rehydration or to predict clinical course. Pediatrics 2012;129:e1211–e1219
In the United States, gastroenteritis accounts for >1.5 million outpatient visits and 200,000 hospitalizations annually. Treatment guidelines use goal-directed therapy, with recommendations based on assessment of dehydration severity; however, this can be a challenge as there is “a lack of compelling evidence to support efforts to accurately distinguish varying degrees of dehydration on the basis of symptoms and signs.”

METHODS

Setting and Participants

Between December 2006 and April 2010, data were prospectively collected on 226 children ≥3 months of age who presented to The Hospital for Sick Children’s ED (Toronto, Ontario) with gastroenteritis and dehydration requiring intravenous rehydration. The study was approved by the hospital’s research ethics board. Written informed consent was obtained from the guardians of all participants.

Eligibility criteria were a diagnosis of acute gastroenteritis, evidence of dehydration, and a decision to administer intravenous rehydration therapy. The diagnosis of gastroenteritis was at the discretion of the supervising physician; “acute” implied <6 days of symptoms. Dehydration was defined based on the presence of one of the following features as assigned by a trained research nurse: (1) CDS ≥3 (Table 1); (2) capillary refill time ≥2 seconds; (3) abnormal skin turgor, with prolonged retraction time and “tenting”; or (4) abnormal respiratory pattern (>50 breaths per minute for children aged <12 months; >40 breaths per minute for children aged ≥12 months).

All potentially eligible children underwent a trial of oral rehydration therapy conducted with administration of 5 mL of a flavored oral rehydration solution through a syringe every 5 minutes, with the rate increased based on tolerance and the child’s weight. For children with persistent vomiting, ondansetron was administered orally. Subsequently, based on the success of oral rehydration, the decision regarding the need for intravenous rehydration was made by the responsible physician, unaware of the CDS score assigned by the nurse.

Exclusion criteria were weight <5 kg; presence of a significant underlying disease that would affect hydration assessment (eg, renal insufficiency, diabetes mellitus); suspicion of previously undiagnosed cardiac or renal disease; history of abdominal surgery or presence of an acute surgical abdomen; history of significant head, chest, or abdominal trauma within 7 days; evidence of hypotension, hypoglycemia (<2.8 mmol/L), or hyperglycemia (>11.0 mmol/L); and previous study enrollment.

Procedures

Children were assessed for eligibility once the treating physician had determined that intravenous rehydration was required. Eligible children then had CDS scores assigned by a research nurse and the responsible physician, who was blinded to the score recorded by the nurse and unaware that interobserver scores would be calculated. Thirty-one physicians, who received no formal training in using the CDS but were provided with standardized definitions (Table 1), assigned scores. All children had the following investigations performed at the time of intravenous insertion (Advia IMS Integrated Modular System [Bayer, Elkhart, IN], accuracy = ±0.3 mmol/L): sodium, potassium, chloride, pH, bicarbonate, carbon dioxide, glucose, blood urea nitrogen, and creatinine. CDS scores were subsequently documented by the research nurse every 30 minutes for 4 hours.

Patient Assessment and Data Collection

Data elements collected included basic demographics, historical variables (eg, number of vomiting episodes in the preceding 24 hours), and clinical
examination features (e.g., heart rate). The respiratory rate was measured for 60 seconds by observing chest wall movements with the child quiet and comfortable. Capillary refill was assessed at the fingertip by using a standardized technique. Skin turgor was assessed by pinching a small skin fold between the thumb and index finger on the lateral abdominal wall at the level of the umbilicus.

Weight gain was recorded at the time of disposition determination or at discharge for admitted children. Percent weight gain was calculated as the difference between discharge and triage weights, divided by the triage weight. Other outcome data recorded included physician willingness to discharge the child at time 2 hours measured by using a Likert scale, the need for hospitalization, and total length of stay (ie, from initiation of intravenous rehydration to ED or hospital discharge). Data were entered into a secure database and double-checked for accuracy by the senior investigator (S.B.F.).

### Outcomes

Our primary outcome was the interobserver agreement between 2 independent raters’ CDS scores (ie, reliability). We sought to determine the agreement of (1) individuals with extensive experience and training using the score with (2) individuals with limited training; the latter group representing the real-world model. The secondary outcome was validity. Criterion validity, which is based on a scale’s correlation with an accepted “gold standard,” was assessed by using weight change as a proxy measure for percent dehydration. Construct validity, which reflects the scale’s correlation with other measures predicted by theory, was evaluated by using parameters thought to be reflective of dehydration severity: (1) number of episodes of vomiting and diarrhea before presentation to the ED, (2) respiratory rate, (3) capillary refill time, (4) serum bicarbonate, (5) serum pH, (6) physician assessment of readiness for discharge documented by using a Likert scale, and (7) length of stay. Discriminative validity, the ability to discriminate between individuals with a given characteristic/outcome and those without, was explored for the outcome of hospitalization. The scale’s responsiveness to change was evaluated through comparison of scores before and after intravenous rehydration, a treatment of known efficacy.

### Sample Size

This study used data collected as part of a clinical trial and, as such, is a secondary data analysis. It was estimated post hoc that enrollment of 226 participants would provide 80% power to detect an interobserver correlation as low as 0.35 when the κ coefficient under the null hypothesis is 0.20 with significance set at .05 (PASS 2008, NCSS, LLC, Kaysville UT).

### Analysis

Characteristics of the study sample were described with frequency counts and percentages for categorical variables; means and SDs or medians and interquartile ranges (IQRs) were used for continuous variables. Dichotomous variables were compared by using the $χ^2$ test or Fisher’s exact test. Continuous variables were compared by using the $t$ test or Wilcoxon rank-sum test, as appropriate, depending on data normality. CDS score refers to the total score assigned by the research nurse at treatment initiation; this value was used in all analyses unless otherwise specified. A $P$ value <.05 was considered statistically significant.

Interobserver reliability was evaluated via calculation of the quadratic weighted κ statistic ($κ$). Unlike Cohen’s unweighted κ, the weighted coefficient considers partial agreement (ie, penalizes disagreement based on degree of divergence) and is recommended when calculating interobserver agreement for ordinal scales. Quadratic weighting creates mathematical equivalence with the intraclass correlation coefficient for agreement by using a 2-way random-effects model single-measure reliability. Results are interpreted according to the criteria of Landis and Koch, in which $κ$ values of 0.21 to 0.40, 0.41 to 0.60, 0.61 to 0.80, and >0.80 signify fair, moderate, substantial, and almost perfect agreement, respectively. In assessing validity, associations were quantified by using the Pearson correlation coefficient ($r$) or Spearman rank correlation coefficient ($ρ$), depending on the distribution of the data. Significant outliers, defined as values greater than the 75th percentile plus $1.5 \times$ the IQR, or less than the 25th percentile minus $1.5 \times$ the IQR, were identified in

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**TABLE 1** Frieden et al’s CDS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Score of 0</th>
<th>Score of 1</th>
<th>Score of 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>General appearance</td>
<td>Normal</td>
<td>Thirsty, restless, or lethargic</td>
<td>Drowsy, limp, cold, sweaty, or comatose or not</td>
</tr>
<tr>
<td>Eyes</td>
<td>Normal</td>
<td>Slightly sunken</td>
<td>Very sunken</td>
</tr>
<tr>
<td>Mucous membranes</td>
<td>Moist</td>
<td>Sticky</td>
<td>Dry</td>
</tr>
<tr>
<td>Tears</td>
<td>Tears</td>
<td>Decreased tears</td>
<td>Absent tears</td>
</tr>
</tbody>
</table>

Scores for the individual items are summed.

* Higher scores indicate more severe dehydration. Scores range from 0 to 8. A score of 0 correlates with <2% dehydration (positive likelihood ratio 2.2; 95% CI 0.9–5.3), scores of 1–4 correlate with some (5%–6%) dehydration (positive likelihood ratio 1.3; 95% CI 0.9; 1.7), and 5–8 correlates with moderate to severe (≥6%) dehydration (positive likelihood ratio 5.2; 95% CI 2.1; 12.8).

* “Normal” includes children who may be sleeping but are easily aroused to a normal level of consciousness. This assessment takes into account the time of day and the child’s usual pattern as described by the child’s guardian.

* This is assessed on the buccal mucosa and tongue, and not the lips.
the analysis of criterion validity; hence, this analysis was repeated excluding such values. We also evaluated the CDS’s validity as a dichotomous variable, by using cut points recommended in previous validation studies: scores of <5 indicate none or some dehydration; those ≥5 reflect moderate to severe dehydration. In assessing responsiveness to change, CDS scores at time 0, 2, and 4 hours were compared by using the Wilcoxon rank-sum test.

Discriminative validity was assessed as the area under the receiver operating characteristic (ROC) curve. Sensitivity, specificity, positive likelihood ratio, positive predictive value, and negative predictive value were quantified by using a prespecified CDS cutoff of ≥5.11

Because the CDS was developed in a cohort of children <36 months of age, we analyzed the scale’s performance separately for study participants <36 and ≥36 months of age. The CDS’s performance was also evaluated in the subgroup of children with baseline scores ≥5. All analyses were conducted by using Stata version 9.2 (Stata Corp, College Station, TX).

RESULTS

A total of 226 children were enrolled (Fig 1); 92 (41%) had moderate/severe dehydration (CDS ≥5) and 134 (59%) had none/some dehydration (CDS <5) as assessed by the research nurse. Complete interobserver assessments were performed for 208 participants (92%). Participants who had interobserver assessments completed were similar to those who did not. All partially complete physician scores (n=7) were lacking a value for the tear category. These patients were older than the remainder of the study sample (4.36 years vs 2.18 years; P = .03).

CDS Reliability

The overall CDS distribution was different (P = .002) between research nurses and physicians (Fig 2). Interobserver agreement, at the level of the individual patient, between trained nurses and the physicians was moderate (κ = 0.52, 95% confidence interval [CI] 0.41, 0.63, Fig 3). The κ coefficient values for the individual elements of the CDS were as follows: eyes = 0.32 (95% CI 0.18, 0.46), mucous membranes = 0.38 (95% CI 0.26, 0.50), tears = 0.40 (95% CI 0.27, 0.51), and general appearance = 0.49 (95% CI 0.35, 0.60). Reliability was similar for children <36 and those ≥36 months of age (κ for the total score = 0.51 [95% CI 0.40, 0.65] and 0.53 [95% CI 0.27, 0.68], respectively).
Compared with those with none/some dehydration (CDS < 5), participants with moderate/severe dehydration (CDS ≥ 5) had a greater number of diarrhea episodes before ED presentation, lower serum bicarbonate and pH values at baseline, increased capillary refill time, and increased length of stay in hospital (Table 3). The median physician dischargeability Likert score was higher in the moderate/severe category, indicating a decreased willingness to discharge the children at 2 hours after initiation of intravenous rehydration.

CDS scores decreased over time after the initiation of intravenous rehydration therapy (Fig 5). Median scores at 2 hours and 4 hours were significantly changed from baseline ($P < .001$ at both time points), indicating responsiveness of the scale to change.

For the outcome of hospitalization, the area under the ROC curve was 0.65 (95% CI 0.57, 0.73) (Fig 6). Test characteristics were optimal by using a baseline CDS cut point of ≥ 5, which yielded a sensitivity of 62% (95% CI 48, 75), specificity of 66% (95% CI 58, 73), positive likelihood ratio of 1.8 (95% CI 1.3, 2.4), and negative likelihood ratio of 0.59 (95% CI 0.41, 0.84). Positive predictive and negative predictive values were 35% (95% CI 25, 45) and 85% (95% CI 78, 91), respectively. The CDS scores assigned at 2 and 4 hours after treatment initiation had areas under the curve (AUC) of 0.70 (95% CI 0.62, 0.78) and 0.72 (95% CI 0.64, 0.80) respectively. For participants with baseline scores ≥ 5, the area under the ROC curve was 0.53 (95% CI 0.41, 0.65). Discriminative validity of the baseline CDS did not differ significantly between participants < 36 months of age (AUC = 0.66, 95% CI 0.56, 0.76) and those ≥ 36 months of age (AUC = 0.60, 95% CI 0.46, 0.75), $P = .52$.

**DISCUSSION**

In this study, the reliability and validity of the CDS was evaluated in a cohort...
Physician dischargeability Likert score, median (IQR) 4 (2, 4) 4 (2, 4) 3.5 (2, 4) .02
Serum bicarbonate, mean 6.45 6.45 6.45 .01
Similar associations were observed with the initiation of intravenous rehydration.

willingness to discharge 2 hours after episodes of diarrhea, serum bicarbonate and pH, length of stay, and physician percent weight gain, a proxy measure of fluid deficit. There was a modest correlation with other parameters reflective of dehydration severity: episodes of diarrhea, serum bicarbonate and pH, length of stay, and physician willingness to discharge 2 hours after initiation of intravenous rehydration. Similar associations were observed when the CDS’s validity was evaluated as a dichotomous variable by using a cut point of ≥5.

A previous evaluation in children 1 month to 5 years of age found the CDS to be useful in predicting the need for intravenous rehydration and length of stay.11 These findings were replicated at a different tertiary care center, where an association between CDS score and use of laboratory tests was documented; however, abnormal results were not significantly different across CDS severity assignments. Nonetheless, the authors concluded that the scale is externally valid, and might be useful in guiding therapy (eg, initiation of intravenous rehydration in triage for CDS ≥5). Their findings, however, may simply indicate that physicians use the clinical findings in the CDS to make treatment decisions; not that children with higher CDS scores require that such treatment decisions be made. Hence, it may be inappropriate to conclude that those clinical findings are necessarily associated with dehydration. In addition, because the assigned CDS score was correlated with the use of intravenous rehydration, it is to be expected that length of stay is prolonged in such patients. Both validation studies were further limited by inclusion of few participants with moderate/severe dehydration. Thus, the performance of the CDS could not be evaluated in such children. In the current study, eligibility was defined based on evidence of dehydration sufficient to require intravenous rehydration. Consequently, we were able to evaluate the CDS in a relatively large number of patients with moderate to severe dehydration. Including only children receiving intravenous rehydration eliminates the potential confounding effect of treatment on length of stay.

of children with gastroenteritis and dehydration. Interobserver reliability was found to be moderate.21 Although responsiveness to change was detected, no statistically significant correlation was identified between CDS scores and percent weight gain, a proxy measure of fluid deficit. There was a modest correlation with other parameters reflective of dehydration severity: episodes of diarrhea, serum bicarbonate and pH, length of stay, and physician willingness to discharge 2 hours after initiation of intravenous rehydration. Similar associations were observed when the CDS’s validity was evaluated as a dichotomous variable by using a cut point of ≥5.

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FIGURE 4
Scatter-plot diagram of percent weight gain at the time of ED discharge (y-axis) by CDS score at treatment initiation (x-axis). Black squares indicate median percent weight gain values (n = 171). CDS did not correlate with percent weight gain (p = −0.03; 95% CI −0.18, 0.12).

TABLE 3 Characteristics of Study Participants

| Parameter | All Participants (n = 226) | Participants With Moderate/Severe Dehydration (CDS ≥5) (n = 92) | Participants With None/Some Dehydration (CDS <5) (n = 134) | P Value*
|-----------|-------------------------|------------------------------------------------|------------------------------------------------|--------
| Age, median (IQR), y | 2.21 (1.36, 3.96) | 2.44 (1.41, 4.24) | .13
| Male, n (%) | 117 (51.8) | 73 (54.5) | .33
| Triage weight, median (IQR), kg | 12.6 (9.98, 16.2) | 13.1 (10.1, 16.7) | .10
| CTAS score, median (IQR) | 3 (2, 5) | 3 (3, 3) | <.001
| Vomiting, median (IQR), episodes | 8 (3, 14) | 7.5 (3, 13) | .83
| Diarrhea, median (IQR), episodes | 4 (0, 10) | 3 (0, 8) | .05
| Heart rate, mean ± SD, beats per min | 127 ± 20 | 130 ± 17 | .15
| Respiratory rate, median (IQR), breaths per min | 28 (24, 30) | 28 (24, 30) | .02
| Capillary refill time, median (IQR), s | 0.70 (0.56, 1.04) | 0.67 (0.55, 0.88) | .001
| Serum pH, mean ± SD | 7.36 ± 0.06 | 7.37 ± 0.05 | <.001
| Serum bicarbonate, mean ± SD, mmol/L | 18.0 ± 3.65 | 19.2 ± 3.39 | <.001
| Physician dischargeability Likert score, median (IQR) | 4 (2, 4) | 5.5 (2, 4) | .02
| Length of stay, median (IQR), h | 5.41 (4.25, 14.6) | 4.88 (4.00, 8.03) | <.001
| Percent weight gain, median (IQR), % | 2.24 (0.67, 4.67) | 2.27 (0.68, 4.96) | .53

CTAS, Canadian Triage and Acuity Scale.

* P Values are for comparison between participants with moderate/severe dehydration versus those with none/some dehydration.

* Number of episodes in the 24 hours before ED presentation, as reported by parents/guardians.

* Physician willingness to discharge patient 2 hours after initiation of intravenous rehydration, ranging from 1 (strongly agree that patient is ready for discharge, based on clinical appearance and vital signs) to 5 (strongly disagree that patient is ready for discharge).
Although interobserver agreement was evaluated in the derivation study, it included only 58 paired scores assigned exclusively by research team members.\textsuperscript{10} 
We evaluated the real-world performance of the CDS by including individuals without extensive training in use of the score. Our finding of moderate interobserver agreement, whereas the derivation study found substantial agreement ($k = 0.77$), suggests that the CDS may produce inconsistent results when used by those without formal training. We found, moreover, that even the baseline CDS score assigned by trained nurses was not a clinically useful tool for predicting hospitalization. The AUC did improve, however, when the time 2- and 4-hour CDS scores were used, indicating that the score may have some utility in assessing improvement or predicting hospitalization once treatment is completed.\textsuperscript{24}

The CDS was derived by using weight change as a measure of “true” dehydration status,\textsuperscript{10} with the assumption that ED discharge weight reflects preillness weight. This assumption is questionable, as the ED discharge weight is significantly influenced by the treatments provided. A child who receives a large volume of intravenous fluids will gain a significant amount of weight before discharge even if he or she was euvoletic at presentation. In an ideal world, the score would have been derived by using serial weights after discharge.\textsuperscript{25}

Despite these concerns, the derivation\textsuperscript{10} and validation\textsuperscript{11,12} studies do show that the CDS can accurately identify children with none/minimal dehydration. Our data caution against the use of the CDS to predict outcomes in children with evidence of dehydration and does not support the authors’ suggestion that laboratory tests and intravenous rehydration be initiated in all children with a CDS $>4$.\textsuperscript{12} 
Such a recommendation would likely result in increased intravenous rehydration use, which is already excessive,\textsuperscript{26,27} as most children with moderate dehydration can be rehydrated orally.\textsuperscript{1} Triage nurses should focus on ensuring the success of oral rehydration therapy, as very few children in developed countries have severe dehydration. Furthermore, because vomiting is a major driving force in the use of intravenous rehydration,\textsuperscript{28} antiemetic agents should be used selectively in children with elevated CDS scores.\textsuperscript{29} 

Several limitations should be recognized. First, this study represents a secondary analysis of data collected as part of an intervention trial.\textsuperscript{30} Nevertheless, these data were collected prospectively under supervised and standardized conditions. There should not have been bias to the study question, as participants were randomly assigned to treatment groups, thereby balancing the CDS distribution between groups. Second, the study used an untrained individual who was unaware that interobserver agreement was being evaluated. Although this

**FIGURE 5**
Scores on the CDS at 30-minute intervals. Time 0 represents the initiation of intravenous rehydration therapy. As in a standard box plot, sample medians are depicted by the center lines of the boxes; the upper and lower limits represent the 75th and 25th percentiles, respectively. Means are superimposed as black squares.

**FIGURE 6**
ROC curve for the outcome of hospitalization, based on CDS score assigned at treatment initiation by the research nurse (solid line), 2 hours after treatment initiation (dashed line), and 4 hours after treatment initiation (dotted line); $n = 226$. AUC is 0.65 (95% CI 0.57, 0.73), 0.70 (95% CI 0.62, 0.78), and 0.72 (95% CI 0.64, 0.80), respectively.
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