DEVELOPMENT OF A CLINICAL DEHYDRATION SCALE FOR USE IN CHILDREN BETWEEN 1 AND 36 MONTHS OF AGE

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Objective To develop a clinical dehydration scale for use in children <3 years of age.

Study design Prospective cohort study of children between 1 and 36 months of age who presented to a tertiary pediatric emergency department (ED) with gastroenteritis. Children were weighed and scored for 12 clinical signs, were rehydrated, and then were reweighed and rescoring when rehydration was completed. Weight change from pre- to post-rehydration was used to assess criterion validity with independent global assessments of dehydration severity by attending physicians and nurses as measures of construct validity. Formal approaches to item selection and reduction, reliability, discriminatory power, validity, and responsiveness were used.

Results 137 children (median age: 18 months) with gastroenteritis were studied. The final dehydration scale consisted of four clinical characteristics: general appearance, eyes, mucous membranes, and tears. The measurement properties were as follows: validity as assessed by Pearson’s correlation coefficient was 0.36 to 0.57; reliability as assessed by the intra-class correlation coefficient was 0.77; discriminatory power as assessed by Ferguson’s δ was 0.83; and responsiveness to change as assessed by Wilcoxon signed rank test was significant at P < .01.

Conclusion Clinicians and researchers may consider this four-item, 8-point rating scale, developed using formal measurement methodology, as an alternative to scales developed ad hoc. (J Pediatr 2004;145:201-7)

Dehydration secondary to gastroenteritis remains a major cause of morbidity and mortality. In the United States, 9% of all hospitalizations of children <5 years of age are because of diarrhea and dehydration.1 One method to measure the magnitude of dehydration is the calculation of percent loss of body weight during the illness.1 However, accurate baseline predehydration weights are not usually available to the clinician. Thus, historically, the measurement of dehydration has been based on several clinical variables scaled into three categories: mild, moderate, and severe dehydration.2,3 These categories, and the clinical variables defining each category, have, however, been developed in an ad hoc manner rather than by using formal measurement methodology. Further, several investigators have examined signs and symptoms of dehydration without placing these variables into a rating scale.4-7

Established methodology for the development of outcome measures (for both acute and chronic health states) in the clinical setting are relatively recent.8-11 Measurement methodology formally considers the following issues relating to scale development: selection of clinical items to be evaluated, assessment of item and scale validity, inter-rater reliability, discriminatory power, and responsiveness to change. Scales developed in this way may be used in clinical practice or as outcome variables in clinical research.

The current use of clinical signs and symptoms of dehydration or categories of dehydration (mild, moderate, severe) for which the measurement properties remain unknown formed the conceptual basis for the a priori development of a clinical scale. In addition, the current use of numerical rating scales in pediatric practice (for example, Apgar

ED Emergency department
scale, acute pain scales, Glasgow coma scale) supported the development of a similar numerical rating scale for the clinical measurement of severity of dehydration. Therefore, the objective of this study was to develop a clinical dehydration scale for use in children with gastroenteritis between 1 and 36 months of age using established measurement methodology.

**METHODS**

As a methodologic framework, Kirshner and Guyatt’s general approach to the development of a health status index along with Streiner and Norman’s textbook on health measurement scales were used.\(^8\)\(^9\) Validity is defined as the extent to which a scale measures what it is intended to measure.\(^9\) Reliability is defined as the extent to which a scale is reproducible or consistent.\(^9\) Discriminatory power is defined as the ability of a scale to discriminate amongst subjects, ie, scores should be spread along the entire possible range.\(^9\) Responsiveness or sensitivity to change is defined as the ability of a scale to detect small but clinically important changes in health status.\(^12\)

**Study Population and Setting**

The intended use of our clinical dehydration scale is as a discriminative (ie, to assess severity) and evaluative (ie, to assess response to therapy) tool for use in children between 1 and 36 months of age, in the emergency department (ED) setting, for whom the attending physician has established the diagnosis of gastroenteritis with dehydration. Subjects meeting these criteria were recruited from the ED at the Hospital for Sick Children in Toronto. The Hospital for Sick Children is a pediatric tertiary care hospital affiliated with the University of Toronto, with approximately 50,000 patient visits to the ED annually. Exclusion criteria were: any cause of dehydration other than presumed gastroenteritis and any other chronic disease, eg, renal, gastrointestinal, cystic fibrosis, including co-existing malnutrition and treatment with intravenous rehydration within the previous 24 hours. Electrolyte measurements were conducted at the discretion of the treating physician, and children found to have hyponatremia (serum sodium <130 mmol/L) or hypernatremia (serum sodium >150 mmol/L) were excluded from the study, as was done by previous investigators,\(^4\) given the possibility that these patients display unique clinical signs and symptoms.

**Item Selection and Reduction**

To generate items for the clinical scale, the published literature on the clinical and physiologic manifestations of dehydration was reviewed. In addition, 10 experts in nephrology, gastroenterology, emergency medicine, and general pediatrics were surveyed. The items were then operationalized. Precise clinical definitions were provided for each item.

All clinical characteristics were measured on a 3-point ordinal scale (0, 1, or 2) (Table I). Although it has been found that 5- or 7-point scales minimize the loss of information,\(^9\) a 3-point scale was chosen because of its familiarity to the clinician (eg, the Apgar score) and its compatibility with discriminating definitions for each characteristic.

Items with a low frequency of endorsement were excluded (ie, if ≥95% of subjects scored 0 on that item). Item homogeneity was assessed using the item-total correlation method, with exclusion of those items with a Pearson’s correlation coefficient of <0.20.\(^9\)

**Validity**

Weight change from pre- to post-rehydration was used as the “gold standard” to assess criterion validity.\(^14\)\(^7\)\(^13\)-\(^15\) Construct validity was determined using a hypothetical construct developed a priori, ie, there would be a correlation between the clinical dehydration scale and proxy measures of dehydration severity. The proxy measure was a global assessment of dehydration severity, as rated on a 5-point Likert scale, scored independently by the attending emergency nurse and the attending emergency physician. Criterion and construct validity were quantified using Pearson’s correlation coefficient. Validity was assessed for individual items and for aggregate scales.

**Reliability**

The reliability of the individual items, as well as of the aggregate scale, was assessed by having two observers independently score children with acute dehydration. An intra-class correlation coefficient was used to quantify reliability. For the final aggregate scale, a coefficient of ≥0.60 was considered an acceptable level of agreement.\(^16\)

**Discriminatory Power**

The discriminating ability of the aggregate scale with the highest reliability and validity was assessed using Ferguson’s \(\delta\).\(^17\) This coefficient is expressed as a value from 0 to 1. A minimum value of 0 occurs when all subjects get the same score. A maximum value of 1 occurs when subjects are equally divided among all possible scores (ie, the distribution of scores is rectangular).

**Responsiveness or Sensitivity to Change**

The responsiveness of the aggregate scale with the highest reliability and validity was determined by measuring the change in score in children following a treatment of known efficacy.\(^18\) That is, children receiving rehydration therapy were scored before and after therapy. Because the changes in the ordinal scale were likely to be non-Gaussian, responsiveness was quantified using Wilcoxon signed rank test.

**Final Scale**

The final scale consisted of the combination of items yielding the most valid and reliable score. The final scale was a simple unweighted summation.

**Study Procedure**

Eligible children were identified, on a convenience basis, when a study nurse or physician was available. Four research nurses (all with a minimum of 5 years of ED experience) and
three physicians were involved in recruiting and scoring the patients. Demographic data were gathered: age, sex, duration of illness, presence of diarrhea, vomiting, and fever. The child was weighed and scored for all clinical items prior to the initiation of rehydration. Whenever a second study nurse or investigator was available, a second assessment was performed independently. The ED attending nurse and ED attending physician were both approached independently and asked to rate the degree of the child’s dehydration on a 5-point Likert scale. Rehydration therapy, oral or intravenous, was ordered by the ED staff without regard to the research study; patients received therapy as inpatients or in the observation unit in the ED.

The attending ED or inpatient pediatrician determined the time at which rehydration therapy was considered complete, and the child was then weighed and re-scored by the study personnel. All weights were recorded without clothes or diapers, using the same designated research study scale (Scale-Tronix Pediatric Scale model 4800, accuracy 5 gm, Global Medical Products, Inc, Mississauga, Ontario). The percentage weight change was calculated as (final weight-initial weight)/final weight × 100.

The research was approved by the Hospital for Sick Children Research Ethics Board and informed parental consent was obtained for all subjects.

Sample Size

A sample size of approximately 30 patients was calculated to be adequate under the following assumptions: the intra-class correlation coefficient for assessing inter-rater reliability would be ≥0.80, α = 0.05, β = 0.20, and 2 measurements per subject19; and the Pearson’s correlation coefficient would be = 0.70, α = 0.05, β = 0.20.20 An interim analysis to test these assumptions indicated that additional patient enrollment was required to ensure the ability to detect an intra-class correlation coefficient of ≥0.70 and a Pearson’s correlation coefficient of ≥0.50.

RESULTS

Study Population

A sample of 141 children were enrolled in the study (Table II). Of these, 94 children had electrolyte measurement ordered by the attending physician. Two patients had hyponatremia and two had hypernatremia; they were excluded, leaving 137 patients in the study. Of the 137 study patients, 94 (69%) were rehydrated intravenously and 43 (31%) were rehydrated orally; 14 (10%) were admitted to the hospital, and 123 (90%) were managed in the ED and the observation unit.

Table I. Item generation

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine output*</td>
<td>↓ Within last 4 h</td>
<td>↓ Last 4-12 h</td>
<td>↓ &gt;12 h</td>
</tr>
<tr>
<td>General appearance</td>
<td>Normal</td>
<td>Thirsty, restless, or lethargic but irritable when touched</td>
<td>Drowsy, limp, cold, sweaty ± comatose</td>
</tr>
<tr>
<td>Capillary refill†</td>
<td>&lt;1.5 sec</td>
<td>1.5-3 sec</td>
<td>&gt;3 sec</td>
</tr>
<tr>
<td>Skin turgor‡</td>
<td>Instant recoil</td>
<td>&lt;2 sec</td>
<td>&gt;2 sec</td>
</tr>
<tr>
<td>Fontanelle§</td>
<td>Normal</td>
<td>Slightly sunken</td>
<td>Very sunken</td>
</tr>
<tr>
<td>Eyes</td>
<td>Normal</td>
<td>Slightly sunken</td>
<td>Very sunken</td>
</tr>
<tr>
<td>Mucous membranes (tongue)</td>
<td>Moist</td>
<td>“Sticky”</td>
<td>Dry</td>
</tr>
<tr>
<td>Tears³</td>
<td>Tears</td>
<td>Decreased tears</td>
<td>Absent tears</td>
</tr>
<tr>
<td>Breathing⁴</td>
<td>1-12 mo</td>
<td>&lt;40/min</td>
<td>40-50/min</td>
</tr>
<tr>
<td>12-36 mo</td>
<td>&lt;30/min</td>
<td>30-40/min</td>
<td>&gt;40/min</td>
</tr>
<tr>
<td>Heart rate⁴</td>
<td>1-6 mo</td>
<td>&lt;175/min</td>
<td>175-185/min</td>
</tr>
<tr>
<td>6-36 mo</td>
<td>&lt;150/min</td>
<td>150-165/min</td>
<td>&gt;165/min</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>1-6 mo</td>
<td>&gt;77 mm Hg</td>
<td>64-77 mm Hg</td>
</tr>
<tr>
<td>6-12 mo</td>
<td>&gt;81 mm Hg</td>
<td>66-81 mm Hg</td>
<td>&lt;66 mm Hg</td>
</tr>
<tr>
<td>12-36 mo</td>
<td>&gt;87 mm Hg</td>
<td>74-87 mm Hg</td>
<td>&lt;74 mm Hg</td>
</tr>
<tr>
<td>Urine specific gravity**</td>
<td>&lt;1.015</td>
<td>1.016-1.03</td>
<td>&gt;1.031</td>
</tr>
</tbody>
</table>

Final four-item clinical dehydration scale is in bold.

BP, blood pressure.

*As reported by caregiver.
†Measured at fingernail bed after applying just right amount of pressure to blanch the nail bed, in a warm room.
‡Measured by pinching the lateral side of the abdominal wall at the level of the umbilicus; mean of 3 measurements.
§Child in the upright position in a quiet state.
³By history or examination.
⁴Count for 30 sec and multiply by 2.
**Must be sample from before rehydration initiated.
A dehydrated weight and rehydrated weight was recorded for 102 children (74%), allowing for a calculation of percent dehydration for these children. The remaining children were either transferred to their regional hospital EDs or were discharged home at a time when a study nurse or physician was unavailable. There were no significant differences between those children with both a dehydrated and rehydrated weight (n = 102), and those children with a dehydrated weight only (n = 35) on the baseline characteristics, including the baseline clinical score (Table II).

Of the 102 patients for whom percent dehydration was calculated, the distribution was as follows: 16 patients (16%) had no dehydration; 50 patients (49%) were >0% to <3% dehydrated (minimal dehydration); 26 patients (25%) were ≥3% to <6% dehydrated (mild dehydration); 9 patients (9%) were ≥6% to <10% dehydrated (moderate dehydration); and 1 patient (1%) was ≥10% dehydrated (severe dehydration).21

The median time to rehydration was 46.5 hours (range, 6.8-116.6 hours) for the patients admitted to the hospital and 6.5 hours (range, 1.2-25 hours) for the patients managed in the ED and observation unit.

### Item Selection and Reduction

A review of the published literature1-7,13-15,22-28 showed that the clinical characteristics correlating with dehydration severity included: reported urine output, general appearance, capillary refill time, skin turgor, fontanelle, eyes, mucous membranes, tears, respiratory rate, heart rate, blood pressure, and urine specific gravity (Table I). Of these items, fontanelle, urine specific gravity, and blood pressure were excluded because of a low frequency of endorsement.

### Measurement Properties of Individual Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Item-total correlation*</th>
<th>Criterion validity*</th>
<th>Inter-rater reliability†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine output</td>
<td>0.58</td>
<td>0.16</td>
<td>0.64</td>
</tr>
<tr>
<td>General appearance</td>
<td>0.66</td>
<td>0.22</td>
<td>0.55</td>
</tr>
<tr>
<td>Capillary refill</td>
<td>0.43</td>
<td>0.16</td>
<td>0.65</td>
</tr>
<tr>
<td>Skin turgor</td>
<td>0.38</td>
<td>0.29</td>
<td>0.63</td>
</tr>
<tr>
<td>Eyes</td>
<td>0.62</td>
<td>0.38</td>
<td>0.61</td>
</tr>
<tr>
<td>Mucous membranes</td>
<td>0.74</td>
<td>0.34</td>
<td>0.71</td>
</tr>
<tr>
<td>Tears</td>
<td>0.74</td>
<td>0.37</td>
<td>0.66</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>0.39</td>
<td>0.1</td>
<td>0.73</td>
</tr>
<tr>
<td>Heart rate</td>
<td>0.42</td>
<td>0.32</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*Pearson’s correlation coefficient.
†Intra-class correlation coefficient.
Table IV. Measurement properties of the final four-item clinical dehydration scale

<table>
<thead>
<tr>
<th>Measurement property</th>
<th>Statistic</th>
<th>N</th>
<th>Result</th>
<th>95% CI or P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion validity</td>
<td>Pearson’s correlation coefficient</td>
<td>93</td>
<td>0.36</td>
<td>0.17, 0.53</td>
</tr>
<tr>
<td>Construct validity 1 (RN)</td>
<td>Pearson’s correlation coefficient</td>
<td>122</td>
<td>0.51</td>
<td>0.37, 0.63</td>
</tr>
<tr>
<td>Construct validity 2 (MD)</td>
<td>Pearson’s correlation coefficient</td>
<td>120</td>
<td>0.57</td>
<td>0.44, 0.68</td>
</tr>
<tr>
<td>Inter-rater reliability</td>
<td>Intra-class correlation coefficient</td>
<td>58</td>
<td>0.77</td>
<td>0.68, 0.86</td>
</tr>
<tr>
<td>Discriminatory power</td>
<td>Ferguson’s $\delta$</td>
<td>126</td>
<td>0.83</td>
<td>0.77, 0.88</td>
</tr>
<tr>
<td>Responsiveness*</td>
<td>Wilcoxon signed rank test</td>
<td>33</td>
<td>-4.5</td>
<td>&lt; .01</td>
</tr>
</tbody>
</table>

*Median pre-rehydration score: 2 (range, 0-8). Median post-rehydration score: 0 (range, 0-2).

general appearance, had an intra-class correlation coefficient greater than 0.60, indicating an acceptable level of agreement (Table III).

Measurement Properties of the Final Scale

A scale that included all nine items was assessed for validity and reliability. Combinations of items with the strongest measurement properties on univariate analyses were tested. The measurement properties were strongest for a scale that included the following four items: general appearance, eyes, mucous membranes, and tears (Table IV). The final four-item clinical scale had the following properties: validity as assessed by the Pearson’s correlation coefficient was 0.36 to 0.57; reliability as assessed by the intra-class correlation coefficient was 0.77; discriminatory power as assessed by Ferguson’s $\delta$ was 0.83; and responsiveness to change as assessed by Wilcoxon’s signed rank test was statistically significant at $P < .01$. At baseline, the median clinical score was 2 (range, 0-8; $n = 126$), and the median clinical score decreased to 0 (range, 0-2; $n = 33$) following rehydration therapy.

DISCUSSION

In this group of 137 children with a median age of 18 months and a diagnosis of gastroenteritis, the following four items in aggregate had the most significant measurement properties for dehydration: general appearance, eyes, mucous membranes, and tears. Many clinicians currently utilize a categorical rating scale (mild, moderate, severe) to measure the severity of dehydration and to guide decision making and therapy. The measurement properties of this informally developed scale remains unknown. Clinicians and researchers may now consider this four-item, 8-point numerical rating scale as an alternative, given its known measurement properties.

The strengths of this study include a restricted age range (<3 years) in the population studied, with exclusion of patients with dehydration secondary to causes other than acute gastroenteritis as well as those with hyponatremic and hypernatremic dehydration. Precise definitions for each of the clinical items were developed a priori. A small group of experienced nurses and physicians were responsible for the clinical scoring. The clinical scale was developed using an explicitly stated methodologic framework to evaluate measurement properties of validity, reliability, discriminatory power, and responsiveness. The four items in this scale are practical and would be easy to teach to a wide range of caregivers.

There were limitations to this study. Weight gain after rehydration was used to measure percentage dehydration as this has been considered the gold standard. There were limitations to this study. Weight gain after rehydration was used to measure percentage dehydration as this has been considered the gold standard. However, the use of a single rehydration weight rather than serial weights differs from previous studies. Gorelick et al. have shown that the median time to achieve a stable weight was 24 hours (range, 12-72 hours) for patients admitted to the hospital. Of the 10% of patients admitted to hospital in this study, the median time to rehydration exceeded this. The time required to achieve rehydration for patients managed in the outpatient setting is not known. Given the potential limitations of weight gain following rehydration as a gold standard to assess validity, in this study we assessed validity using two additional constructs, ie, the assessment of dehydration severity scored independently by the attending emergency nurse and the attending emergency physician.

Finally, not all patients had a post-rehydration weight recorded. However, there was no evidence that this group differed significantly with respect to baseline characteristics, including baseline clinical score (clinical score at baseline was 2 in both groups).

We excluded children known to have hypo- or hypernatremia (4 of 94, approximately 4%) given that these children may manifest different clinical signs. Electrolytes were not measured in 48 children, raising the possibility that some children with abnormal electrolytes were included in the study. However, it is likely that these children represented <2 % of the entire study sample. In addition, some dehydrated children may have been excluded from the study if they did not manifest the clinical signs commonly used by clinicians to establish the diagnosis of dehydration. However, it is likely that these signs are uncommon and may have been eliminated as a result of low frequency of endorsement.

The scale is intended to discriminate among and evaluate the response to therapy in children for whom the diagnosis of gastroenteritis with dehydration has been established. Assessing the diagnostic accuracy (ie, the ability to establish the diagnosis of dehydration) was not the aim of this study. However, a post hoc analysis identified a sensitivity...
of 0.85 (95% confidence interval: 0.73, 0.97) for an “abnormal score” (ie, a score ≥1) as compared with the gold standard (ie, dehydration of ≥3%). Further evaluation of the scale, in a large population may allow further understanding of its diagnostic test properties.

There have been few published studies examining the symptoms and signs of dehydration using subsequent weight recovery as the criteria by which to measure the degree of dehydration. Gorelick et al.4 conducted a prospective cohort study to evaluate the performance of common clinical signs in dehydration. The measurement methodology used by these investigators differed from that used in our study. The investigators found that each of the 10 individual clinical signs studied had a low sensitivity and high specificity. The inter-rater reliability for individual signs was generally good to excellent (κ statistic range, 0.4-0.75). Using logistic regression modeling, the investigators found that 4 of the 10 clinical signs (capillary refill >2 seconds, absent tears, dry mucous membranes, and ill general appearance) were independently associated with dehydration and together predicted dehydration as well as the entire set. The investigators were able to demonstrate that the presence of any two or more of these clinical signs indicates a fluid deficit of at least 5%.

MacKenzie et al.5 prospectively studied the clinical signs and symptoms of 102 children <4 years of age with acute gastroenteritis, who were assessed by admitting junior doctors to be ≥5% dehydrated on the basis of history and physical examination. The investigators found the main clinical indicators of mild to moderate dehydration (≥4%) to be decreased peripheral perfusion, deep breathing, and decreased skin turgor. In this study, the clinical variables were not clearly defined a priori, and no attempt was made to examine inter-rater reliability or responsiveness of the clinical findings. Other issues to note are that physicians-in-training were used for the clinical assessments and only hospitalized patients were included in the study.

Duggan et al.6 performed a prospective cohort study examining boys 3 to 18 months of age with acute gastroenteritis, who were receiving intravenous fluid for rehydration in their study. Control Clin Trials 1981;2:93-113.

The four clinical items with the strongest measurement properties identified in the current study show significant overlap with those identified by Gorelick et al and Duggan et al.4,6 These similarities provide additional evidence of the validity of the clinical scale.

We are indebted to the research nurses for their help with patient enrollment and data collection: Pauline Mathews, Audrey Belf-Peters, Jane Ciordes, and Deborah Cutler. We also thank the emergency department physicians and nurses who participated in the study.

REFERENCES

Tetracycline: Studies on Absorption, Distribution, Excretion and Clinical Trial in Children


Chlortetracycline was isolated from Streptomyces aureofaciens in 1944, and in 1953 tetracycline was derived from chlortetracycline by chemists at Pfizer and Lederle pharmaceuticals. Chlortetracycline, which was not developed for humans because of toxicity concerns, is still an additive to animal feed. Schwarzer and colleagues performed a pharmacokinetic study of tetracycline in infants and children seeking to derive dosage guidelines. Recognizing that children are not “miniature adults,” studies of this type were and are needed. In 1994 only five of the 80 drugs most commonly administered to infants and children were labeled for pediatric use. In response to this need, the National Institute of Child Health and Human Development, under the leadership of Dr Duane Alexander, the vision of Dr Sumner Yaffe, and the hard work of Drs George Giaocia and Gilman Grave, established a Network of Pediatric Pharmacology Research Units. These units obtain data that place drug administration to children on a scientific basis. Recently the Food and Drug Administration added funds to the program recognizing the importance of performing such studies with child-friendly protocols with minimal risk to children.

Tetracyclines are deposited in calcifying areas of bones and teeth, and cause discoloration in a dose-dependent manner. Deciduous tooth discoloration occurs if the infant receives tetracycline in utero after 14 weeks’ gestation, and up to the age of 3 months. Mineralization of permanent teeth starts at about 6 months of age and concludes at about 6 years; repeated administration of tetracycline during this period produces life-long discoloration. Tetracycline is still one of the first line antibiotics for plague and tularemia, and there is minimal drug toxicity associated with this use in children.

One interesting feature of the Schwarzer article is that most of the infectious diseases for which the children received tetracycline are those we now know as viral illnesses. Our current understanding of upper respiratory infections place antimicrobial therapy on a more scientific footing. However, in another 50 years we may learn that our current approach to antimicrobial therapy is equally primitive.

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