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Is This Child Dehydrated?

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CLINICAL SCENARIOS
Case 1

A 20-month-old girl is brought to the emergency department (ED) after 2 days of vomiting and diarrhea. Her father reports that she has not eaten normally since the illness began and now will not drink. She has had 8 stools so far today but he does not think there were any diapers with urine in them. The child appears mildly ill but does make tears while crying. Her respiratory rate and quality are normal, along with her other vital signs. Her mouth is somewhat dry, capillary refill time is 1.5 seconds, and skin turgor is normal. Her serum (blood) urea nitrogen concentration (BUN) is 12 mg/dL and bicarbonate concentration is 19 mEq/L.

Case 2

A 5-month-old boy presents to a health care clinic in a developing country. The child lives in a very rural area and there is no running water in the family home. The child began having nonbloody, profuse, watery stools approximately 7 days ago. The family has World Health Organization (WHO) oral rehydration packets at home that the child has eagerly consumed. He seemed less interested in drinking this morning so his parents began the trip to the clinic. The child is now quiet and hyperpneic. He has sunken eyes and a dry mouth. His

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Context The ability to assess the degree of dehydration quickly and accurately in infants and young children often determines patient treatment and disposition.

Objective To systematically review the precision and accuracy of symptoms, signs, and basic laboratory tests for evaluating dehydration in infants and children.

Data Sources We identified 1561 potential articles by multiple search strategies of the MEDLINE database through PubMed. Searches of bibliographies of retrieved articles, the Cochrane Library, textbooks, and private collections of experts in the field yielded an additional 42 articles.

Study Selection Twenty-six of 1603 reviewed studies contained original data on the precision or accuracy of findings for the diagnosis of dehydration in young children (1 month to 5 years).

Data Extraction Two of the 3 authors independently reviewed and abstracted data for estimating the likelihood ratios (LRs) of diagnostic tests. We eliminated 13 of the 26 studies because of the lack of an accepted diagnostic standard or other limitation in study design. The other 13 studies were included in the review.

Data Synthesis The most useful individual signs for predicting 5% dehydration in children are an abnormal capillary refill time (LR, 4.1; 95% confidence interval [CI], 1.7-9.8), abnormal skin turgor (LR, 2.5; 95% CI, 1.5-4.2), and abnormal respiratory pattern (LR, 2.0; 95% CI, 1.5-2.7). Combinations of examination signs perform markedly better than any individual sign in predicting dehydration. Historical points and laboratory tests have only modest utility for assessing dehydration.

Conclusions The initial assessment of dehydration in young children should focus on estimating capillary refill time, skin turgor, and respiratory pattern and using combinations of other signs. The relative imprecision and inaccuracy of available tests limit the ability of clinicians to estimate the exact degree of dehydration.

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capillary refill time is 3 seconds and his skin turgor is prolonged.

WHY IS THE CLINICAL EXAMINATION IMPORTANT?

Dehydration is one of the leading causes of morbidity and mortality in children throughout the world.[1,2] Diarrheal disease and dehydration account for as much as 30% of worldwide deaths among infants and toddlers; 8000 children younger than 5 years die each day due to gastroenteritis and dehydration.[2-4] In the United States, children younger than 5 years have an average of 2 episodes of gastroenteritis per year, leading to 2 million to 3 million office visits and 10% of all pediatric hospital admissions.[1,5,6] The direct costs of outpatient and hospital visits are more than $2 billion per year, not including indi-

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rect costs to families and society.[4] Despite this aggressive medical care, as many as 300 US children still die each year as a result of gastroenteritis and associated dehydration.[1,6]

Many other childhood illnesses in addition to gastroenteritis are associated with dehydration. Gingivostomatitis, bronchiolitis, pyloric stenosis, and focal bacterial infections such as pneumonia, meningitis, and urinary tract infections can all lead to dehydration. For this reason, the morbidity and mortality related to dehydration are actually much higher than that associated solely with gastroenteritis. Dehydration is such a common concern in pediatrics that clinicians in primary care offices, EDs, and hospital settings all assess volume status as part of their evaluation. This assessment helps guide decision making about therapy and patient disposition.

The American Academy of Pediatrics (AAP), Centers for Disease Control and Prevention (CDC), and WHO have all developed treatment guidelines for gastroenteritis based on the clinical assessment of dehydration. The AAP guideline states that "the treatment of a child with diarrhea is directed primarily by the degree of dehydration present."[4] They recommend clinically deciding whether a patient is mildly (3%-5%), moderately (6%-9%), or severely (≥10%) dehydrated and then treating based on that classification. The CDC uses a similar assessment and scale in its recommendations on the initial management of diarrhea.[1,3] WHO has also incorporated signs of dehydration into the Integrated Management of Childhood Illness Scale, which assists practitioners in developing countries to make treatment and referral decisions.[7]

Inaccurate assessment of dehydration can have important consequences. Unrecognized and untreated fluid deficits can create electrolyte disturbances, acidosis, and end organ damage including cardiovascular instability, renal insufficiency, and lethargy. These complications can produce devastating results including permanent injury or death. Conversely, unnecessary interventions can occur after erroneous assessment that a child has moderate or severe dehydration when he/she is actually euvolemic or only mildly dehydrated.[5] Despite recommendations for oral rehydration in mild or moderate dehydration, this therapy is used in less than 30% of the cases of diarrhea in the United States for which it is indicated.[8] Clinicians may rely on the more invasive intravenous rehydration in part because they overestimate the degree of dehydration. Both overestimating and underestimating the degree of dehydration can increase health care costs and cause unnecessary morbidity.

Pediatrics practitioners generally use the terms *dehydration*, *volume depletion*, and *hypovolemia* interchangeably to represent fluid loss in outpatient settings. Literature that focuses on physiological changes caused by different types of fluid loss differentiates among these terms.[9] Because this discrimination can have unclear clinical implications and in order to simplify discussion, much of the clinical literature combines terminology.[10] Herein, we follow this convention and use the term *dehydration* to represent all fluid deficits except in circumstances such as whole blood loss or significant sodium alteration, where important clinical implications are evident.

The quantification of dehydration is an important and commonly used skill for assessment of pediatric patients. Despite this importance, the utility of the clinical history, physical examination, and laboratory tests to assess dehydration in children has not been systematically reviewed. Most teaching regarding the assessment of dehydration is based on clinical experience and medical tradition. We conducted a systematic review of the literature on the precision and accuracy of history, physical examination, and laboratory tests in identifying dehydration in children between 1 month and 5 years old.

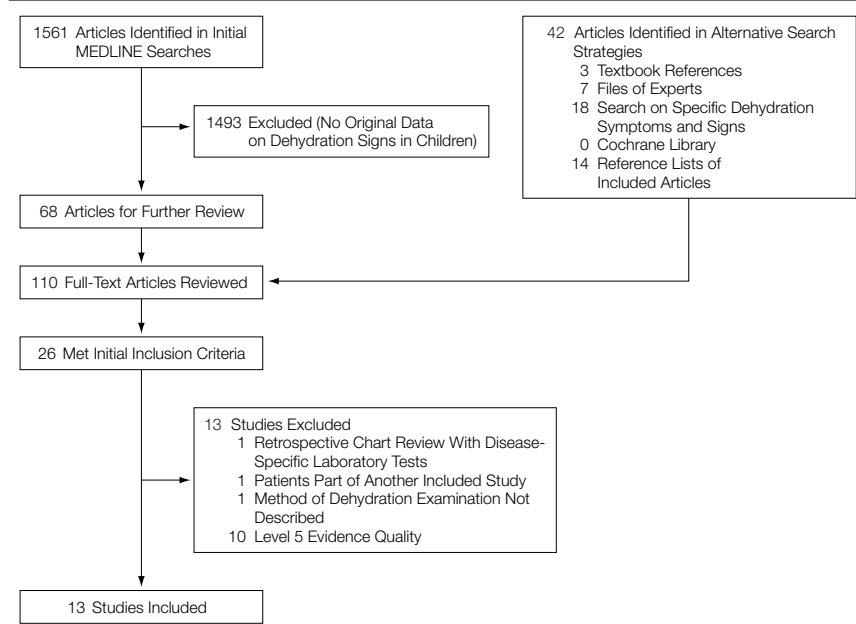## Anatomical/Physiological Origins of Dehydration Signs

Many signs in pediatric assessment are attributed to the fluid and electrolyte shifts caused by dehydration. Early work to understand dehydration in children focused on intracellular and extracellular physiological changes associated with fluid loss. Researchers have fastidiously documented fluid and electrolyte losses in dehydration and have even performed biopsies of the muscle of children with severe diarrhea to understand intracellular fluid and electrolyte shifts.[11] Particularly instructive experiments used radio-labeled albumin to demonstrate that the percentage of body weight lost was directly proportional to the percentage of plasma volume lost.[12] For example, children who had lost 5% of their body weight lost approximately 5% of their plasma volume. Since plasma volume is only a small percentage of total body water, this experiment indirectly demonstrated that the majority of fluid lost in childhood dehydration actually comes from either interstitial or intracellular sources.

The correlation of losses from specific fluid compartments to corresponding physical signs has not been clearly documented. The signs of dehydration appear to represent an actual desiccation of tissue (eg, dry mucous membranes), a compensatory reaction of the body to maintain vital perfusion (eg, tachycardia), or some combination of both (eg, capillary refill time). Although some authors offer more specific explanations of theoretical fluid compartments and their examination correlates, these 3 principles should be sufficient for clinical assessment of patients.

How to Elicit Symptoms and Signs

Pediatrics practitioners often elicit historical points from adult caregivers instead of directly from the patient. When assessing volume status in infants, physicians may ask about number of wet diapers (surrogate for urine output), presence or absence of vomiting and diarrhea, and amount and type of oral intake. Caregivers also frequently report their interpretation of examination signs by clarifying whether the child is active, whether the eyes appear sunken, and whether the child drinks vigorously. Clinicians should ask parents

Figure. Selection Process for Studies Included in Review

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┌─────────────────────────────────┐        ┌────────────────────────────────────────┐
│ 1561 Articles Identified in      │        │ 42 Articles Identified in Alternative   │
│      Initial MEDLINE Searches    │        │    Search Strategies                     │
└─────────────────────────────────┘        │     3 Textbook References                │
                 │                           │     7 Files of Experts                   │
                 │    ┌──────────────────┐   │    18 Search on Specific Dehydration     │
                 ├───▶│ 1493 Excluded (No│   │       Symptoms and Signs                 │
                 │    │   Original Data   │   │     0 Cochrane Library                    │
                 │    │   on Dehydration  │   │    14 Reference Lists of                  │
                 │    │   Signs in        │   │       Included Articles                   │
                 │    │   Children)       │   └────────────────────────────────────────┘
                 │    └──────────────────┘
                 ▼
┌─────────────────────────────────┐
│ 68 Articles for Further Review   │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│ 110 Full-Text Articles Reviewed  │◀──────────────
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┌─────────────────────────────────┐
│ 26 Met Initial Inclusion Criteria│
└─────────────────────────────────┘
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                 │    ┌──────────────────────────────────────┐
                 ├───▶│ 13 Studies Excluded                   │
                 │    │   1 Retrospective Chart Review With    │
                 │    │     Disease-Specific Laboratory Tests  │
                 │    │   1 Patients Part of Another Included  │
                 │    │     Study                              │
                 │    │   1 Method of Dehydration Examination  │
                 │    │     Not Described                      │
                 │    │  10 Level 5 Evidence Quality           │
                 │    └──────────────────────────────────────┘
                 ▼
┌─────────────────────────────────┐
│ 13 Studies Included              │
└─────────────────────────────────┘
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whether they have given a successful trial of clear fluids at home, if the child has been seen by another medical practitioner during the illness, and the date and value of the child's most recent weight measurement.[1,13]

The ability to elicit some examination signs is impaired when pediatric patients are crying and uncooperative. Therefore, assessment of hydration status should progress from the least to the most invasive maneuvers. The examination should begin with the child across the room in a position of comfort (eg, in the parent's lap). Overall appearance, activity, and response of the child to stimulation should be observed. Evaluating the respiratory pattern is important for assessment of dehydration and all other acute illnesses. Respiratory rate should be measured for 60 seconds by observing chest wall movements with the child quiet and comfortable, then compared with age-based norms.[14] In a potentially dehydrated child, the examiner should specifically look for hyperpnea (deep, rapid breathing without other signs of respiratory distress), suggestive of an acidosis.[1] Other vital signs, including temperature, pulse, and blood pressure,

should also be evaluated while the child is comfortable.[1]

Next, the clinician should assess skin turgor and capillary refill time. Skin turgor has been used to diagnose dehydration for more than 50 years and, when abnormal, is also called "tenting" or "inelastic skin."[15,16] To elicit the sign, the examiner should use the thumb and index finger to pinch a small skin fold on the lateral abdominal wall at the level of the umbilicus.[15] The fold should be promptly released and the time it takes to return to normal form measured.[15] Clear norms for this time have not been published and most clinicians simply qualify skin turgor as immediate, slightly delayed, or prolonged. Excess subcutaneous fat and hypernatremia may falsely normalize the turgor in dehydrated children while malnutrition may falsely prolong the recoil time.[15,17-21] Primary skin disorders complicate the interpretation of skin turgor.[19]

To assess capillary refill time, the examiner compresses a superficial capillary bed and estimates the time it takes for normal color to return after the pressure is released. Capillary refill time varies as a function of ambient temperature, site of application, lighting, medications, and

primary (eg, reflex sympathetic dystrophy) or secondary (eg, cardiogenic shock) autonomic changes.[16,18,22-24] Extremes in patient temperature may also affect the capillary refill time; for example, capillary refill times are markedly prolonged after cold immersion.[25] However, Gorelick et al[22] found that fever did not affect the test characteristics in children with vomiting, diarrhea, or poor oral intake. Based on the available studies, and to standardize examination techniques, we recommend assessing capillary refill time on a finger with the arm at the level of the heart in a warm ambient temperature. Pressure should be gradually increased on the palmar surface of the distal fingertip, then released immediately after the capillary bed blanches. The time elapsed until restoration of normal color should be estimated. Although many practitioners use other sites to measure capillary refill time, most studies of this sign use the palmar surface of the distal fingertip.[22-26] Using this approach, values for nondehydrated children are less than 1.5 to 2 seconds.[25]

METHODS
Search Strategy and Quality Review

We identified articles by direct searches of the MEDLINE database via the PubMed search engine. The first and most broad search strategy used *dehydration* and *diagnosis*, *hypovolemia* and *diagnosis*, or *intravascular volume depletion* and *diagnosis*. All were limited by age (all children: 0-18 years) and publication date (January 1966–April 2003). These searches produced 1537 articles. We supplemented this preliminary search with the standardized search technique used in the "Rational Clinical Examination" series (available from the authors). This second search produced 24 additional articles.

Each of the authors reviewed the titles and available abstracts from the 1561 articles, selecting for further review those that appeared to address the evaluation of dehydration in children aged 1 month to 5 years. We did not exclude articles if the study enrolled some children outside of that age range. Through consen-

sus, we identified 68 articles as potential sources of primary data or reviews with potential background information and thorough reference lists.

To ensure a comprehensive literature review, we used additional techniques to identify articles (**FIGURE**). One author (M.J.S.) searched for individual symptoms and signs associated with the diagnosis of dehydration in children. These terms included *capillary refill*, *skin turgor*, *dry cry*, *tears*, *mucous membrane*, *sunken eyes*, *fontanelle* and *dehydration*, *urine specific gravity*, *urine* and *dehydration*, *hemoconcentration*, *BUN*, *urine*, *blood pressure*, *bioimpedance*, *orthostasis*, *respiration*, *parent* and *dehydration*, *pulse*, and *heart rate* (all limit: aged 0-18 years, human, NOT *dehydration* and *diagnosis*). The Cochrane Library, reference lists of pediatric and physical examination textbooks,[27-32] reference lists of all included articles, and articles from the collections of experts in the field were reviewed. Forty-two potential articles were identified from the supplemental searches.

We performed a full review of the 110 retained articles to identify those with primary data comparing dehydration with a symptom, sign, or laboratory value in pediatric patients. Twenty-six articles met these criteria and underwent full quality assessment using an established methodological filter that has been consistently used and described in the "Rational Clinical Examination" series (**BOX**).[33] A second author then checked the initial quality review. The group always arrived at a consensus on the final evidence quality level assigned.

Nine of the 110 articles that underwent a full text review were written in languages other than English. Medical school faculty, residents, or students at our institution who were primary speakers of the written language read each of these articles. Six of these 9 articles did not meet inclusion criteria and were excluded, while 3 were assigned an evidence quality level based on a translation of the article.

No studies on physical examination signs, symptoms, or laboratory results in

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Box. Guidelines for Assigning Quality Levels of Evidence[*]

Level 1

The highest-quality evidence: independent, blind comparisons of test with a valid gold standard; large number of consecutive patients enrolled

Level 2

High-quality study with independent, blind comparison of test with a valid gold standard; small number of consecutive patients enrolled

Level 3

Independent, blind comparison of test with a valid gold standard; patients enrolled in a nonconsecutive fashion, using a subset or smaller group who may have had the condition and generated definitive results on both test and gold standard

Level 4

Nonindependent comparison of a test with a valid gold standard among a "grab" sample of patients believed to have the condition in question

Level 5

Nonindependent comparison of test with a standard of uncertain validity; this standard may incorporate the test result into the gold standard

[*]In an independent comparison, neither the test result nor the gold standard result is used to select patients for the study. In a blind comparison, the test and gold standard are each applied and interpreted without knowledge of the other's results.

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childhood dehydration demonstrated evidence quality criteria for level 1 or 2. Four studies were assigned to level 3, but 1 of these was eventually excluded because the study population overlapped with that in another included study.[22] Twelve studies were initially assigned to level 4, though 1 was excluded because of methodological flaws[12] and another was excluded because of its retrospective design and restriction to children with pyloric stenosis.[34]

We chose the difference between the rehydration weight and the acute weight divided by the rehydration weight as the best available gold standard of percentage of volume lost.[35] Ten articles used gold standards based solely on examination signs or a general dehydration assessment. These were assigned an evidence quality level of 5 and were subsequently excluded. The Figure shows a schematic representation of the methods and **TABLE 1** summarizes the 13 included studies.

Statistical Analyses

We report precision data as a range of κ values obtained directly from the published results. Two-by-two tables were created from the published information

regarding accuracy and were used to calculate point estimates and 95% confidence intervals (CIs) for the sensitivity, specificity, and likelihood ratios (LRs) for each test.[36] One author provided original data to calculate these values since they were not caculable from the original publication.[18] We created these 2×2 tables for detecting both 5% and 10% dehydration when data were available. A range of values was provided when only 2 studies evaluated an individual diagnostic test. If more than 2 studies evaluated a test, then we combined the results using a random-effects model. Data for meta-analysis were not weighted based on the quality of included studies. Statistical tests were performed using STATA software, version 7.0 (Stata Corp, College Station, Tex).

We performed tests of heterogeneity for data used in all meta-analyses and found significant heterogeneity for most signs. Analysis of data using a random-effects model is complicated by the presence of heterogeneity. However, combining data in this manner allows clinicians to make general summary "best estimates" of utility based on all of the included studies. Furthermore, the degree of uncertainty between LRs

of summary estimates was more obvious with the broad range of 95% CIs as opposed to the narrower range for the individual point estimates. Thus, the summary LRs minimize the risk of clinicians being overly confident about the utility of clinical findings.

RESULTS
Precision of Symptoms and Signs

Porter et al[13] evaluated the agreement between parental observation of examination signs and the signs elicited by trained ED nurses. The κ value demonstrated substantial agreement beyond chance when assessing for a sunken anterior fontanelle (κ=0.73) and presence of cool extremities (κ=0.70). There was moderate agreement on general appearance (κ=0.46), presence of sunken eyes (κ=0.49), absence of tears (κ=0.57), and presence of dry mouth (κ=0.52).

Three included studies reported interrater agreement among clinicians ranging from chance to good agreement (TABLE 2).[16,35,37] Agreement on respiratory rate and pattern may be no better than that which occurs by chance. The other signs had higher levels of agreement, though the range of κ levels for these findings was broad.

Accuracy of Symptoms, Signs, and Laboratory Studies

Symptoms. Three studies evaluated the accuracy of history taking in assessing dehydration.[13,35,38] All 3 of these studies evaluated history of low urine output as a test for dehydration. In the pooled analysis, low urine output did not increase the likelihood of 5% dehydration (LR, 1.3; 95% CI, 0.9-1.9). Porter et al[13] showed that a history of vomiting, diarrhea, decreased oral intake, reported low urine output, a previous trial of clear liquids, and having seen another clinician during the illness prior to presenting to the ED yielded LRs that lacked utility in the assessment of dehydration. However, their data did suggest that children who had not been previously evaluated by a physician during the illness might be less likely to be dehydrated on presentation (LR, 0.09; 95% CI, 0.01-1.37). Similarly, parental report of a normal urine output decreases the likelihood of dehydration (Gorelick et al[35] reported an LR of 0.27 [95% CI,

0.14-0.51] and Porter et al[13] reported an LR of 0.16 [95% CI, 0.01-2.53]).

Examination Signs. TABLE 3 is a comprehensive list of individual physical examination signs and their test characteristics in evaluating children for 5% dehydration. Signs were included when they were evaluated in 2 or more studies, and calculations based on pooled results were performed when evaluated in 3 or more studies.

Three signs were evaluated in multiple studies, had a clinically helpful pooled LR in detecting 5% dehydration, and had 95% CIs wholly above 1.0. Capillary refill time was evaluated in 4 different studies, and the pooled sensitivity of prolonged capillary refill time was 0.60 (95% CI, 0.29-0.91), with a specificity of 0.85 (95% CI, 0.72-0.98), for detecting 5% dehydration.[16,35,38,39] The LR for abnormal capillary refill time was 4.1 (95% CI, 1.7-9.8). This was the highest value among examination signs with pooled results. Abnormal skin turgor had a pooled LR of 2.5 (95% CI, 1.5-4.2)[15,18,35,38,39] and abnormal respiratory pattern had a pooled LR of 2.0 (95% CI, 1.5-2.7).[18,35,38,39]

Table 1. Summary of Included Studies

Source	Evidence Quality Level	Country	Setting	No. of Participants	Age Range	Inclusion Criteria
Porter et al,[13] 2003	3	United States	Emergency department	71	1 mo to 5 y	Chief complaint of vomiting, diarrhea, or poor oral intake
Laron,[15] 1957	4	United States	Hospital	21	1 mo to 3.5 y	Admitted with diarrhea
Saavedra et al,[16] 1991	4	United States	Hospital	32	2 to 24 mo	Admitted with diarrhea
Duggan et al,[18] 1996	4	Egypt	Gastroenteritis clinic	135	3 to 18 mo	Acute diarrhea and dehydrated
Gorelick et al,[35] 1997	3	United States	Emergency department	225	1 mo to 5 y	Chief complaint of vomiting, diarrhea, or poor oral intake
Duggan et al,[37] 1997 (precision only)	3	Egypt	Gastroenteritis clinic	100	2 mo to 4 y	>5 stools in last 24 h
MacKenzie et al,[38] 1989	4	Australia	Hospital	102	<4 y	Admitted with gastroenteritis and dehydration
English et al,[39] 1997	3	Kenya	Hospital	119	>1 mo	Admitted with malaria and coma, respiratory distress, or prostration
Plata Rueda and Diaz Cruz,[40] 1974	4	Columbia	Hospital	100	<73 mo	Admitted with diarrhea and dehydration
Vega and Avner,[41] 1997	4	United States	Emergency department	97	2 wk to 15 y	Dehydrated and needed intravenous fluids
Amin et al,[42] 1980	4	Indonesia	Hospital	36	<24 mo	Admitted with diarrhea and dehydration
Teach et al,[43] 1997	4	United States	Emergency department	40	2 wk to 12 y	Dehydrated and needed intravenous fluids
Yilmaz et al,[44] 2002	4	Turkey	Emergency department	168	1 to 21 mo	Received intravenous fluids and hospitalized for gastroenteritis and dehydration

Presence of cool extremities or a weak pulse or absence of tears also may be helpful tests for dehydration. Absence of tears had a pooled LR of 2.3 (95% CI, 0.9-5.8), but the potential utility is limited by a wide 95% CI that crosses 1.0.[13,35,38] Two studies examined a weak pulse quality as a test for dehydration. One study found a reasonably precise LR for weak pulse of 3.1 (95% CI, 1.8-5.4),[35] but in the other study, the 95% CI was too wide to make a reasonable estimate (LR, 7.2; 95% CI, 0.4-150).[18] The 2 studies that evaluated cool extremities as a test of dehydration found imprecise point estimates for the LR positive in detecting 5% dehydration (LR, 18.8; 95% CI, 1.1-330[18] and LR, 1.5; 95% CI, 0.2-12[13]).

Sunken eyes and dry mucous membranes offer little help clinically; both had narrow 95% CIs but pooled LRs of 1.7. An increased heart rate, a sunken fontanelle in young infants, and an overall poor appearance are frequently taught as good tests for dehydration. However, the objective evidence reveals that all have summary LRs of less than 2.0 and 95% CIs that cross 1.0.

Some tests may be clinically useful in decreasing the likelihood of dehydration. Absence of dry mucous membranes (LR, 0.41; 95% CI, 0.21-0.79), a normal overall appearance (LR, 0.46; 95% CI, 0.34-0.61), and absence of sunken eyes (LR, 0.49; 95% CI, 0.38-0.63) had pooled LRs of less than 0.5. Most clinical scenarios will necessi-

tate lower LRs than these to rule out dehydration effectively.

Clinicians rarely base decisions about dehydration on 1 examination sign but, instead, use the presence or absence of groups of signs. Four studies evaluated clinical prediction models or groups of signs.[18,35,40,41] Vega and Avner[41] evaluated the table similar to that used in many pediatric textbooks and also commonly taught to medical students as the best evaluation tool for dehydration.[30] This scale, displayed in **TABLE 4**, is very similar to the one used by the AAP and CDC in their recommendations for the management of acute gastroenteritis.[1,3,4] The tool uses the assessment of 9 different physical examination findings to classify children as mildly (4%-5%), moderately (6%-9%), or severely (≥10%) dehydrated. In 97 children presenting to the ED with dehydration requiring intravenous fluids, a severe classification on the scale had an LR of 3.4 (95% CI, 1.5-

7.7) for the presence of at least 5% dehydration. Classification of severe dehydration also yielded an LR of 4.3 (95% CI, 2.4-7.8) for at least 10% dehydration. A moderate classification by examination was less useful to diagnose 5% dehydration (LR, 2.1; 95% CI, 0.9-4.8).[41]

Duggan et al[18] evaluated 2 different dehydration assessment scales that classified children as mild, moderate, or severe based on the number of dehydration examination signs present. The authors reported the final mean percentage of dehydration within each group, and these averages increased significantly as the severity assessment increased.[18] This suggests that as more signs of dehydration appear, children tend to be more dehydrated. Plata Rueda and Diaz Cruz[40] also presented groupings of signs and symptoms that attempted to stratify children into different degrees of dehydration. Minor physical examination changes did not

Table 2. Precision of Examination Signs for Dehydration

Finding	Reference	Total No. of Participants	Range of κ Values
Prolonged capillary refill	16, 35, 37	216	0.01 to 0.65
Abnormal skin turgor	35, 37	184	0.36 to 0.55
Abnormal respiratory pattern	35, 37	184	−0.04 to 0.40
Extremity perfusion	35	100	0.23 to 0.66
Absent tears	35, 37	184	0.12 to 0.75
Sunken fontanelle	37	100	0.10 to 0.27
Sunken eyes	35, 37	184	0.06 to 0.59
Dry mucous membranes	35, 37	184	0.28 to 0.59
Weak pulse	35, 37	184	0.15 to 0.50
Poor overall appearance	35, 37	184	0.18 to 0.61

Table 3. Summary Test Characteristics for Clinical Findings to Detect 5% Dehydration

Finding	Reference	Total No. of Participants	LR Summary, Value (95% CI) or Range		Sensitivity (95% CI)	Specificity (95% CI)
			Present	Absent		
Prolonged capillary refill	16, 35, 38, 39	478	4.1 (1.7 to 9.8)	0.57 (0.39 to 0.82)	0.60 (0.29 to 0.91)	0.85 (0.72 to 0.98)
Abnormal skin turgor	15, 18, 35, 38, 39	602	2.5 (1.5 to 4.2)	0.66 (0.57 to 0.75)	0.58 (0.40 to 0.75)	0.76 (0.59 to 0.93)
Abnormal respiratory pattern	18, 35, 38, 39	581	2.0 (1.5 to 2.7)	0.76 (0.62 to 0.88)	0.43 (0.31 to 0.55)	0.79 (0.72 to 0.86)
Sunken eyes	13, 18, 35, 38	533	1.7 (1.1 to 2.5)	0.49 (0.38 to 0.63)	0.75 (0.62 to 0.88)	0.52 (0.22 to 0.81)
Dry mucous membranes	13, 18, 35, 38	533	1.7 (1.1 to 2.6)	0.41 (0.21 to 0.79)	0.86 (0.80 to 0.92)	0.44 (0.13 to 0.74)
Cool extremity	13, 18	206	1.5, 18.8	0.89, 0.97	0.10, 0.11	0.93, 1.00
Weak pulse	18, 35	360	3.1, 7.2	0.66, 0.96	0.04, 0.25	0.86, 1.00
Absent tears	13, 35, 38	398	2.3 (0.9 to 5.8)	0.54 (0.26 to 1.13)	0.63 (0.42 to 0.84)	0.68 (0.43 to 0.94)
Increased heart rate	18, 35, 38	462	1.3 (0.8 to 2.0)	0.82 (0.64 to 1.05)	0.52 (0.44 to 0.60)	0.58 (0.33 to 0.82)
Sunken fontanelle	13, 18, 38	308	0.9 (0.6 to 1.3)	1.12 (0.82 to 1.54)	0.49 (0.37 to 0.60)	0.54 (0.22 to 0.87)
Poor overall appearance	13, 35, 38	398	1.9 (0.97 to 3.8)	0.46 (0.34 to 0.61)	0.80 (0.57 to 1.04)	0.45 (−0.1 to 1.02)

Abbreviations: CI, confidence interval; LR, likelihood ratio.

significantly change the likelihood of dehydration; however, the presence of abnormal skin turgor on the abdomen, thorax, extremities, and face combined with sunken eyes, dry mucous membranes, and a sunken fontanelle did increase the likelihood of 10% dehydration (LR, 3.7; 95% CI, 1.6-8.1).[40]

Gorelick et al[35] created a scale giving equal weight to 10 commonly elicited signs: decreased skin elasticity, capillary refill time greater than 2 seconds, general appearance, absence of tears, abnormal respirations, dry mucous membranes, sunken eyes, abnormal radial pulse, tachycardia (heart rate >150/min), and decreased urine output. The presence of at least 3 of the 10 signs had a sensitivity of 0.87 and a specificity of 0.82 in detecting 5% dehydration (LR positive, 4.9; 95% CI, 3.3-7.2 and LR negative, 0.15; 95% CI, 0.08-0.30). Similarly, 7 of 10 signs had an LR positive of 8.4 (95% CI, 5.0-14.3) in diagnosing 10% dehydration. Based on logistic regression analysis performed by Gorelick et al, capillary refill time, dry mucous membranes, absence of tears, and abnormal overall appearance contained most of the predictive power. A simplified assessment tool using the presence of 2 of these 4 signs yielded an LR positive of 6.1 (95% CI, 3.8-9.8) for diagnosing 5% dehydration.[35]

Laboratory Tests. Six studies evaluated the utility of laboratory tests in assessing dehydration (**TABLE 5**).[38,39,41-44] Five studies evaluated BUN concentration or BUN/serum creatinine ratio as a test for dehydration.[38,39,42-44] Blood urea nitrogen cutoffs of 8, 18, and 27 mg/dL produced LRs ranging from 1.4 to 2.9. Yilmaz et al[44] found that in a group of hospitalized children with gastroenteritis, BUN >45 mg/dL was very specific for at least 5% dehydration (specificity of 1.00). However, this was a small study and the estimated 95% CI for an LR positive was 3 to 730.

Four studies evaluated acidosis as a test for dehydration.[38,39,41,44] The majority of patients enrolled in these studies had acute diarrhea, a potential cause of acidosis. Mackenzie et al[38] and English et al[39] used a base deficit of greater than 7 as the measure of acidosis. (Base deficit estimates the severity of metabolic acidosis by comparing the patient's bicarbonate concentration to historical norms for a given pH and P_{CO_2}.) In both studies, the LR positive was less than 2.0. Although Yilmaz et al[44] found that an absolute serum bicarbonate concentration of less than 15 mEq/L was not helpful (LR for low serum bicarbonate, 1.5; 95% CI, 1.2-1.9), Vega and Avner[41] found that an absolute bicarbonate concentration of less than 17 mEq/L offered some help in diagnosing children with 5% dehydration (LR, 3.5; 95% CI, 2.1-5.8). Teach et al[43] evaluated serum uric acid

Table 4. Example of a Commonly Taught Dehydration Assessment Scale*

Variable/Sign	Dehydration		
	Mild (4%-5%)	Moderate (6%-9%)	Severe (≥10%)
General appearance	Thirsty, restless, alert	Thirsty, drowsy, postural hypotension	Drowsy, limp, cold, sweaty, cyanotic extremities
Radial pulse	Normal rate and strength	Rapid and weak	Rapid, thready, sometimes impalpable
Respirations	Normal	Deep, may be rapid	Deep and rapid
Anterior fontanelle	Normal	Sunken	Very sunken
Systolic blood pressure	Normal	Normal or low	Low
Skin elasticity	Pinch retracts immediately	Pinch retracts slowly	Pinch retracts very slowly
Eyes	Normal	Sunken	Grossly sunken
Tears	Present	Absent	Absent
Mucous membranes	Moist	Dry	Very dry

*Adapted with permission from Vega and Avner.[41]

Table 5. Summary Test Characteristics for Laboratory Tests Assessing Dehydration

Laboratory Value	Reference	Total No. of Participants	LR Summary, Value (95% CI) or Range		Sensitivity, Value (95% CI) or Range	Specificity, Value (95% CI) or Range
			Present	Absent		
Blood urea nitrogen, mg/dL						
>8	38, 39		2.1, 2.4	0.41, 0.76	0.38, 0.71	0.71, 0.82
>18	42, 44		1.4, 2.1	0.17, 0.68	0.63, 0.90	0.55, 0.57
>27	42	36	2.9 (0.9-9.5)	0.66 (0.41-1.06)	0.44 (0.19-0.68)	0.85 (0.69-1.00)
>45	44	168	46.1 (2.9-733)	0.58 (0.49-0.68)	0.43 (0.34-0.52)	0.99 (0.96-1.02)
Blood urea nitrogen/creatinine ratio >40	43	40	2.1 (0.5-8.9)	0.87 (0.62-1.20)	0.23 (0.01-0.46)	0.89 (0.77-1.00)
Bicarbonate, mEq/L						
<17	41	97	3.5 (2.1-5.8)	0.22 (0.12-0.43)	0.83 (0.72-0.94)	0.76 (0.64-0.88)
<15	44	168	1.5 (1.2-1.9)	0.18 (0.08-0.37)	0.93 (0.88-0.98)	0.40 (0.26-0.53)
Base deficit >7 mEq/L	38, 39		1.4, 1.8	0.42, 0.68	0.67, 0.75	0.52, 0.59
pH <7.35	38	102	2.2 (1.2-4.1)	0.71 (0.53-0.95)	0.43 (0.28-0.58)	0.80 (0.70-0.91)
Anion gap >20 mmol/L	43	40	1.8 (0.8-4.2)	0.73 (0.42-1.26)	0.46 (0.19-0.73)	0.74 (0.58-0.91)
Uric acid >600 mmol/L	43	40	1.0 (0.3-3.5)	0.99 (0.69-1.42)	0.23 (0.01-0.46)	0.78 (0.62-0.93)

and an increased anion gap as tests for dehydration but found that abnormal results were not helpful. Urine specific gravity was evaluated by English et al but was not found to be significantly correlated with dehydration.[39] The only laboratory measurement that appears to be valuable in decreasing the likelihood of 5% dehydration is serum bicarbonate. A serum bicarbonate concentration of more than 15 or 17 mEq/L has an LR range of 0.18 to 0.22, reducing the likelihood of dehydration if the child has gastroenteritis.[41,44]

Limitations

The published literature on assessment of dehydration has significant limitations affecting both internal and external validity. As discussed in the "Methods" section, none of the identified studies met the criteria for high-quality (level 1 or level 2) evidence based on the established methodological filter. The best available studies had modest sample sizes, used nonconsecutive patients, and did not compare the included children with those excluded from the study populations. The most common bias in level 4 evidence studies was that they enrolled children already thought to be dehydrated and to need intravenous fluids or who were admitted to the hospital. The diagnostic tests may perform better in children who are thought to be dehydrated compared with children solely at risk of dehydration. Thus, there may be limitations to the generalizability of these results when applied to an unselected group of children simply at risk of dehydration.

The results of the study by Gorelick et al[35] differed from those of the other included studies. Gorelick et al evaluated the interrater reliability for 10 different physical examination signs. The κ values ranged from 0.40 to 0.75, which were clearly better than those found in the other studies on precision by Saavedra et al[16] and Duggan et al.[37] The accuracy of signs was also generally better in the study by Gorelick et al than in other included studies. The LRs of positive tests were all statistically significant and ranged from 1.8 to 11.7. All 10 of the signs evaluated by Gorelick et al were assessed in other studies. For 9 of the 10 signs, the results by Gorelick et al produced the highest LRs of any included study, which is difficult to explain. The study by Gorelick et al is of high methodological quality in comparison with the other included studies. It achieved an evidence quality level 3 based on nonconsecutive patient selection that did not introduce a clear systematic bias. They enrolled a relatively large group of patients and followed them meticulously. The sensitivity values of the tests were generally similar to those found in other studies, but the specificity was often much higher. The high percentage of true-negative test results may have been affected by a patient population with a relatively low incidence of disease in comparison with patients enrolled in the other studies.[35]

Ten of the 26 articles that met initial inclusion criteria were later found to have a methodological flaw with the diagnostic standard and were excluded from the final analysis. These studies used a gold standard for dehydration based on examination signs or clinical assessment. This represents a circular flaw in assessing the utility of the history taking or examination in establishing dehydration. Conversely, the difference between an ill weight and a rehydrated weight (after illness) appears to be the best pragmatic diagnostic standard for dehydration that has been validated in the literature.[35] However, problems can be introduced by the timing of the rehydration weight. For example, if it is obtained too early, children may still be dehydrated or may actually be overhydrated because of aggressive intravenous fluid administration. The timing of the rehydration weight varied among the included studies, and most studies used additional assessments to validate their perception of a true rehydration weight. For example, Teach et al[43] used the weight when the physical examination findings had normalized and the urine-specific gravity was low. Incorporating other assessments not based on weight into the gold standard could theoretically bias the results. Some studies avoided this problem by documenting the rehydration weight when measured weight remained unchanged over time.[35] Another criticism of a weight-based gold standard is that infants may "gain" a significant percentage of their body weight if they have a full bladder and colon, which they may then "lose" when they void.[20] In studies of large sample size, the weight contribution of a full bladder would be unlikely to have a major effect on the LRs for clinical findings. Additionally, the number of children with weight "gained" or "lost" due to impending or recent voids should balance.

Pediatricians are taught that hypernatremia may alter the test characteristics of signs in dehydration.[30] For example, prolonged skin turgor is less sensitive in detecting significant dehydration in children with diabetes insipidus and pure water loss than in children with diarrhea.[15] Because of this clinical experience, some studies excluded children with significant hypernatremia.[35,39] Other studies used subgroup analysis to demonstrate that assessment had not been affected by hypernatremia.[38,44] Since tests of dehydration are usually applied without any knowledge of the serum sodium level in the patient, it seems appropriate to structure studies without excluding hypernatremic children.

THE BOTTOM LINE

Dehydration is an important cause of morbidity and mortality as a complication of pediatric illness. However, the literature evaluating the symptoms, signs, and laboratory values for assessing dehydration is limited. We found few high-quality studies with accurate gold standards and minimal systematic bias.

The evidence shows that tests of dehydration are imprecise, generally showing only fair to moderate agreement among examiners. Historical points have moderate sensitivity as a screening test for dehydration. However, parental reports of dehydration symptoms are so nonspecific that they may not be clinically useful. The best 3 individual examination signs for assessing dehydration are prolonged capillary refill time,

abnormal skin turgor, and abnormal respiratory pattern. Groups of signs or use of clinical scales improve diagnostic characteristics. Commonly obtained laboratory tests such as BUN and bicarbonate concentrations generally are only helpful when results are markedly abnormal. A normal bicarbonate concentration helps somewhat to reduce the likelihood of dehydration. These laboratory tests should not be considered definitive for dehydration.

The literature reports more than 30 potential tests for detecting dehydration. This large number should not distract clinicians from focusing on signs and symptoms with proven diagnostic utility. Unfortunately, the data also suggest that signs of dehydration can be imprecise and inaccurate, making clinicians unable to predict the exact degree of dehydration. For this reason, we agree with WHO and other groups that recommend using the physical examination to classify dehydration as none, some, or severe.[1,45] This general assessment can then be used to guide clinical management.

SCENARIO RESOLUTIONS
Case 1

The historical clues provided by the father are minimally helpful in assessing the child's dehydration. There are no signs present that increase the likelihood of dehydration. The negative LRs associated with the absence of multiple examination signs and the serum bicarbonate concentration of 19 mEq/L make significant dehydration much less likely. This child probably has no dehydration instead of some or severe dehydration.

Case 2

The hyperpnea, prolonged capillary refill time, and delayed skin turgor all increase the likelihood of dehydration. Since there are multiple signs of dehydration present, the possibility of severe dehydration should be considered and treated appropriately.

REFERENCES

1. King CK, Glass R, Bresce JS, Duggan C. Managing acute gastroenteritis among children. *MMWR Recomm Rep.* 2003;52(RR-16):1-16.
2. Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet.* 2003;361:2226-2234.
3. Duggan C, Santosham M, Glass RI. The management of acute diarrhea in children. *MMWR Recomm Rep.* 1992;41(RR-16):1-20.
4. American Academy of Pediatrics, Provisional Committee on Quality Improvement, Subcommittee on Acute Gastroenteritis. Practice parameter: the management of acute gastroenteritis in young children. *Pediatrics.* 1996;97:424-435.
5. McConnochie KM, Conners GP, Lu E, Wilson C. How commonly are children hospitalized for dehydration eligible for care in alternative settings? *Arch Pediatr Adolesc Med.* 1999;153:1233-1241.
6. Glass RI, Lew JF, Gangarosa RE, LeBaron CW, Ho MS. Estimates of morbidity and mortality rates for diarrheal diseases in American children. *J Pediatr.* 1991;118(4 pt 2):S27-S33.
7. Gove S. Integrated management of childhood illness by outpatient health workers: technical basis and overview. *Bull World Health Organ.* 2003;75:7-24.
8. Santosham M, Keenan EM, Tulloch J, et al. Oral rehydration therapy for diarrhea: an example of reverse transfer of technology. *Pediatrics.* 1997;100:E10.
9. Mange K, Matsuura D, Cizman B, et al. Language guiding therapy: the case of dehydration versus volume depletion. *Ann Intern Med.* 1997;127:848-853.
10. McGee S, Abernathy WB, Simel DL. Is this patient hypovolemic? *JAMA.* 1999;281:1022-1029.
11. Darrow DC. The retention of electrolyte during recovery from severe dehydration due to diarrhea. *Pediatrics.* 1949;3:129-156.
12. Czaczkes JW. Plasma volume as an index of total fluid loss. *Am J Dis Child.* 1961;102:190-193.
13. Porter S, Fleisher G, Kohane I, Mandl K. The value of parental report for diagnosis and management of dehydration in the emergency department. *Ann Emerg Med.* 2003;41:196-205.
14. Margolis P, Gadomski A. Does this infant have pneumonia? *JAMA.* 1998;279:308-313.
15. Laron Z. Skin turgor as a quantitative index of dehydration in children. *Pediatrics.* 1957;19:816-822.
16. Saavedra JM, Harris GD, Li S, Finberg L. Capillary refilling (skin turgor) in the assessment of dehydration. *Am J Dis Child.* 1991;145:296-298.
17. Bruck E, Abal G, Aceto T Jr. Therapy of infants with hypertonic dehydration due to diarrhea. *Am J Dis Child.* 1968;115:281-301.

18. Duggan C, Refat M, Hashem M, et al. How valid are clinical signs of dehydration in infants? *J Pediatr Gastroenterol Nutr.* 1996;22:56-61.
19. Dorrington KL. Skin turgor: do we understand the clinical sign? *Lancet.* 1981;1:264-266.
20. Leung A, Robson W. Clinical signs of dehydration in children. *Lancet.* 1989;2:1038.
21. Dehydration and fat babies. *BMJ.* 1971;1:125.
22. Gorelick MH, Shaw KN, Murphy KO, Baker MD. Effect of fever on capillary refill time. *Pediatr Emerg Care.* 1997;13:305-307.
23. Gorelick MH, Shaw K, Baker M. Effect of ambient temperature on capillary refill in healthy children. *Pediatrics.* 1993;92:699-702.
24. Brown L, Prasad N, Whitley T. Adverse lighting condition effects on the assessment of capillary refill. *Am J Emerg Med.* 1994;12:46-47.
25. Schriger DL, Baraff L. Defining normal capillary refill: variation with age, sex, and temperature. *Ann Emerg Med.* 1988;17:932-935.
26. Tibby S, Hatherill M, Murdoch I. Capillary refill and core-peripheral temperature gap as indicators of haemodynamic status in paediatric intensive care patients. *Arch Dis Child.* 1999;80:163-166.
27. DeGowin R. *DeGowin & DeGowin's Diagnostic Examination.* 6th ed. New York, NY: McGraw-Hill Co; 1994.
28. Nechyba C. *Harriet Lane Pediatric Handbook.* 16th ed. St Louis, Mo: Elsevier Science; 2002.
29. Sapira J. *The Art and Science of Bedside Diagnosis.* Baltimore, Md: Urban & Schwarzenberg; 1990.
30. Behrman R, Kliegman R, Jenson H. *Nelson Textbook of Pediatrics.* 16th ed. Philadelphia, Pa: WB Saunders Co; 2000.
31. Bates B, Bickley L, Hoekelman R. *A Guide to Physical Examination and History Taking.* 6th ed. Philadelphia, Pa: JB Lippincott Co; 1995.
32. Zitelli B, Davis H. *Atlas of Pediatric Physical Diagnosis.* 4th ed. St Louis, Mo: Mosby; 2002.
33. Holleman DR, Simel DL. Does the clinical examination predict airflow limitation? *JAMA.* 1995;273:313-319.
34. Dawson KP, Graham D. The assessment of dehydration in congenital pyloric stenosis. *N Z Med J.* 1991;104:162-163.
35. Gorelick MH, Shaw KN, Murphy KO. Validity and reliability of clinical signs in the diagnosis of dehydration in children. *Pediatrics.* 1997;99:E6.
36. Simel DL, Samsa GP, Matchar DB. Likelihood ratios with confidence. *J Clin Epidemiol.* 1991;44:763-770.
37. Duggan C, Refat M, Hashem M, et al. Interrater agreement in the assessment of dehydration in infants. *J Trop Pediatr.* 1997;43:119-121.
38. Mackenzie A, Barnes G, Shann F. Clinical signs of dehydration in children. *Lancet.* 1989;2:605-607.
39. English M, Waruiru C, Mwakesi R, Marsh K. Signs of dehydration in severe childhood malaria. *Trop Doct.* 1997;27:235-236.
40. Plata Rueda E, Diaz Cruz G. Clinical and biochemical evaluation of the degree of dehydration in children with acute diarrhea [in Spanish]. *Bol Med Hosp Infant Mex.* 1974;31:561-576.
41. Vega RM, Avner JR. A prospective study of the usefulness of clinical and laboratory parameters for predicting percentage of dehydration in children. *Pediatr Emerg Care.* 1997;13:179-182.
42. Amin SS, Jusniar B, Suharjono. Blood urea nitrogen (B. U. N.) in gastroenteritis with dehydration. *Paediatr Indones.* 1980;20:77-82.
43. Teach SJ, Yates EW, Feld LG. Laboratory predictors of fluid deficit in acutely dehydrated children. *Clin Pediatr (Phila).* 1997;36:395-400.
44. Yilmaz K, Karabocuoglu M, Citak A, Uzel N. Evaluation of laboratory tests in dehydrated children with acute gastroenteritis. *J Paediatr Child Health.* 2002;38:226-228.
45. *A Manual for the Treatment of Diarrhoea.* Geneva, Switzerland: World Health Organization Program for Control of Diarrhoeal Diseases; 1990.