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Pediatric Dehydration Assessment and Oral Rehydration Therapy

Authors: **Stephen B. Freedman, MDCM, MSc, FRCPC, FAAP,** Assistant Professor of Paediatrics, University of Toronto, Division of Paediatric Emergency Medicine, Toronto, Ontario, Canada; and **Jennifer D. Thull-Freedman, MD, MSc, FAAP**, Assistant Professor of Paediatrics, University of Toronto, Division of Paediatric Emergency Medicine, Toronto, Ontario, Canada.

Peer reviewer: **S. Margaret Paik, MD,** Assistant Professor of Pediatrics, Associate Medical Director Pediatric Emergency Medicine, The University of Chicago, Comer Children's Hospital.

Dehydration, a physiologic disturbance due to a reduction of body fluid, remains a leading cause of morbidity and mortality in children.[1] Under normal conditions, body fluid volume and composition remains constant, with water and electrolyte losses equaling gains. Children are particularly susceptible to dehydration due to their higher fluid requirements relative to weight and to the frequency of acute illnesses associated with vomiting and diarrhea.

Hypovolemia, an absolute reduction in total body water (TBW) with reductions occurring in intra- (ICF) and extracellular (ECF) fluid compartments, presents clinically as dehydration. This physiological disturbance is seen when water losses exceed intake. As water and salt may be lost proportionately or disproportionately, unique forms of dehydration occur and are characterized by their serum sodium concentration: isonatremic/isotonic, hypernatremic/hypertonic, and hyponatremic/hypotonic. This article reviews the assessment of children with dehydration and oral rehydration therapy.

— *The Editor*

Epidemiology and Etiology

Gastroenteritis is the most common cause of acute dehydration worldwide, with a mortality rate of 1.5 million per year in children younger than age 5.[1] In developed countries, where dehydration is less likely to cause mortality, it causes significant morbidity. Annually, gastroenteritis accounts for > 1.5 million outpatient visits, 200,000 hospitalizations, and 300 deaths among children < 5 years of age living in the United States.[2] In addition to gastroenteritis, other etiologies of dehydra-

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tion include reduced intake, increased insensible losses, renal losses, and fluid translocation.

Pathophysiology

Body Composition. At steady state, body water content represents a balance between water ingestion and its distribution, evaporation, and clearance.[3,4] Infant lean body mass is 70% water, divided in a 2:1 ratio between ECF and ICF.[5] The ECF compartment is further divided into interstitial and plasma compartments in a 3:1 ratio, with the former serving as a reservoir that can mobilize water into the plasma compartment during periods of hypovolemia.[5] Maintaining ECF volume is crucial as a loss of >15% is often fatal.[6] TBW (total body water) begins to decline early in infancy and reaches adult values (60%) by 12 months of life, with the majority of the reduction occurring in the ECF compartment.[5]

The ICF and ECF are in osmotic equilibrium because the cell membrane is freely permeable to water. If the osmolality of one compartment changes, then water moves between compartments to rapidly equalize osmolality. Clinically, the primary process usually is a change in the osmolality of the ECF, with a resultant shift of water according to the gradient produced. The movement of water occurs because sodium, the major ECF cation, is confined to the ECF by the cell membrane pumps. Hence ECF volume is directly dependent on the quantity of total body sodium, which is regulated by the ingestion and excretion of sodium.

Children are prone to dehydration due to their high water to body weight requirements,[7] which stems from their high surface area:volume ratio and high metabolic rate. For instance, a 70 kg adult excretes about 40 mL of water/kg/d, and a 3-5 kg infant excretes as much as 100 mL/kg/d. Thus, the smaller the child, the greater the risk of developing dehydration.[8] Fortunately, children tolerate dehydration better than adults because a greater proportion of their TBW is in the ECF compartment.

Although plasma osmolality is tightly regulated, the protection of ECF volume is of primary importance and is maintained at the expense of composition if necessary. A reduction in TBW leads to a rise in plasma osmolality, which is detected by neurons in the hypothalamus *(see Figure 1)*.[9] Stimulation of these osmoreceptors induces antidiuretic hormone (ADH) synthesis. ADH is released and travels to the renal collecting duct, where it triggers a cascade leading to a reduction in water excretion. Simultaneously, the osmoreceptors generate a thirst sensation leading to increased intake. These two mechanisms return TBW and plasma osmolality to normal.

The kidney regulates sodium balance by responding to messages that alter the percentage of filtered sodium reabsorbed. The most important determinant of renal sodium excretion is intravascular volume. Decreased intravascular volume induces the juxtaglomerular apparatus to release renin, which accelerates the formation of angiotensin II, causing an increase in sodium reabsorption and aldosterone secretion. Aldosterone, which is also secreted when the ECF sodium concentration decreases or potassium increases, further increases sodium reabsorption and stimulates potassium excretion. This system is counterbalanced by atrial natriuretic peptide, which is secreted in response to atrial distension, hypernatremia, and angiotensin II. Atrial natriuretic peptide inhibits renin and aldosterone release and raises the glomerular filtration rate, resulting in increased sodium and water excretion.

Etiology of Dehydration

Thirst is the primary defense against dehydration. It may be ineffective in infants who cannot independently acquire fluids, in those who are disinterested due to illness, and those with a depressed level of consciousness. Children with severe developmental delay are at higher risk because of inadequate intake that may stem from swallowing difficulties, neglect, or an inability to complain or to satisfy thirst.

Normal water losses occur through insensible routes (respiratory tract and skin) and *renal excretion.* Insensible skin losses consist of water that permeates through the skin and evaporates, allowing the body to dissipate heat. Losses from the lungs occur as cool and dry air is humidified and warmed. Children may triple pulmonary water losses by increasing depth and rate of respirations. Insensible losses are increased with activity, with fever, and in hot and dry environments.[7] Renal excretion is an

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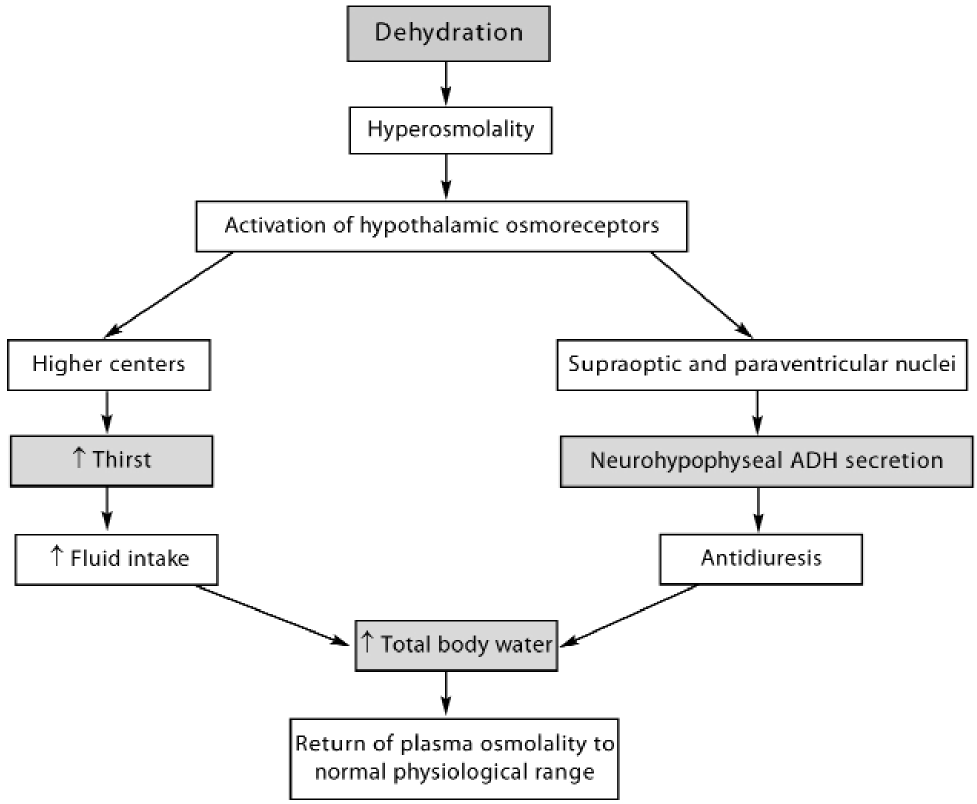
Figure 1. Physiology of Water Homeostasis*



* Adapted from: Moore K, Thompson C, Trainer P. Disorders of water balance. *Clin Med* 2003;3:28-33.

obligatory ECF loss, with the volume depending on glomerular filtration rate, solute load, and the concentrating ability of the kidney.[10] The latter is significantly reduced in newborns. Full-term infants can maximally concentrate urine to only 600 mOsm/kg (versus > 1,000 mOsm/kg for an adult), which impairs their ability to tolerate dehydration.[11]

The volume of lost fluid with diarrhea secondary to a viral gastrointestinal infection varies between 500 and 1000 mL/m^2/d and has a sodium concentration of 30-60 mmol/L.[12] The volume of stool and concentration of sodium are greater with bacterial etiologies.

Although renal losses are less frequently the etiology of dehydration, clinicians should consider the kidneys as a source of fluid losses in children with dehydration that is not explained by gastrointestinal and insensible losses. Central and nephrogenic diabetes insipidus results from inadequate antidiuretic hormone (ADH) secretion and an inability to respond to ADH, respectively. They both result in polyuria, hyposthenuria, dehydration, and hyperosmolality. Children with mineralocorticoid deficiency have persistent sodium losses and volume depletion. When the filtered load of certain solutes exceeds the transport abilities of the tubules, an osmotic diuresis results that causes a loss of sodium and its associated anions. Excessive use of diuretic agents, chronic renal failure, and sodium wasting nephropathies also may result in ECF volume contraction.

Risk Factors

Several identified risk factors are associated with the development of dehydration.[13] Breast-feeding plays a protective role, with exclusively breast-fed infants being six times less likely to have dehydrating diarrhea than bottle-fed infants.[14] Children who are breast-fed also are at reduced risk for developing hypernatremic dehydration compared to those who drink formula.[15] The period shortly after weaning appears to be a high risk time for developing dehydration.[14] Risk factor scores have been developed for use in children in developing countries.[16,17] The use of such scores can assist health workers in identifying children who are at risk.

Special Considerations

Hyponatremic Dehydration. Hyponatremic dehydration occurs when relatively greater amounts of electrolytes are lost compared with fluids. For this to occur, there must be impaired free water excretion and the child must have continued access to free water.[18] Such non-osmotic stimulation of ADH secretion occurs frequently in pediatric gastroenteritis and predisposes children to dilutional hyponatremia when intravenous rehydration is performed.[19] Children with cystic fibrosis may lose significant amounts of sodium in their sweat and may present with dehydration and a hyponatremic hypochloremic alkalosis.[20] Other possible etiologies include renal sodium losses due to diuretics, salt-losing nephropathy, and cerebral salt wasting. Clinically, these patients present with exaggerated manifestations of dehydration due to fluid movement into the ICF compartment along the osmotic gradient. The subsequent cellular swelling can lead to cerebral edema and encephalopathy, causing headache, nausea, vomiting, seizures, and respiratory arrest.[18]

Hypernatremic Dehydration. This form of dehydration usually results from a disproportionately greater loss of fluid than electrolytes and is seen in approximately 15% of patients with diarrhea, particularly when it is associated with high environmental temperatures, tachypnea, or fever.[21] It additionally may be seen when hypernatremic solutions are administered and in children with renal disease, diabetes insipidus, and developmental delay.[22] Clinical signs and symptoms are prominent when the increase in serum sodium is large or occurs rapidly. While changes in skin turgor may occur late in these children, an altered level of consciousness may suggest its presence. Tachycardia tends to be less pronounced because plasma volume is better preserved. Other possible findings include hyperpnea, muscle weakness, restlessness, a high-pitched cry, hyperresponsiveness to stimuli, velvety skin, doughy subcutaneous tissue, and increased deep tendon reflexes.[12]

Clinical Diagnosis of Dehydration

The American Academy of Pediatrics (AAP); Centers for Disease Control (CDC); World Health Organization (WHO); and European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) all have developed treatment guidelines based on the clinical assessment of dehydration. The 1996 AAP guidelines divide patients into subgroups of mild (3-5%), moderate (6-9%), and severe ($\geq$ 10%) dehydration *(see Table 1)*.[23] The WHO and 2001 ESPGHAN guidelines divide patients into no signs of dehydration (< 3-5%), some signs of dehydration (5-10%), and severe dehydration (> 10%).[24,25] However, the development of these classification schemes is based on limited data and can be difficult to apply to individual patients who may possess findings from multiple categories. Consequently, such scales classify children with 5-10% dehydration correctly only 33% of the time.[26] The consequences of underestimating and overestimating the degree of dehydration may be significant. Under treatment may result in electrolyte abnormalities, metabolic acidosis, and end-organ damage, while unnecessary interventions from overestimating the degree of dehydration may result in an iatrogenic injury.

Eliciting Clinical Symptoms and Signs. When assessing a young child, clinicians should elicit as much history as possible from caregivers. Important points include number of wet diapers, frequency and amount of vomiting and diarrhea, interest in oral fluids, amount and type consumed, previous physician visits, and the date and value of the child's most recent weight. Caregivers can assist by clarifying their child's activity level and the presence of sunken eyes and tears. The physical examination should begin with assessment of the child's overall appearance, level of activity, responsiveness, and respiratory pattern. Vital signs, including temperature, heart rate, and blood pressure should be measured. The value of specific examination findings will be discussed below.

Determining Degree of Dehydration. While no single historical or physical parameter in isolation is sufficiently accurate to determine the severity of dehydration, the gold standard remains the percent loss of body weight during the illness.[27] Unfortunately, pre-illness weights rarely are known.[27] Signs of dehydration represent tissue desiccation (dry mucous membranes), a compensatory mechanism (tachycardia), or both (prolonged capillary refill). However, the accuracy of most individual clinical signs and symptoms and interobserver agreement for certain signs has been shown to be poor.[28,29] The poor performance of the diagnostic tests discussed in this section may be due their frequent evaluation in children who are "at risk" for dehydration but who are relatively well as opposed to children who are thought to actually be dehydrated.

Caregiver History. Several historical features commonly collected in the evaluation of dehydration have been found to not be strongly predictive: reduced urine output,[29] a history of vomiting, diarrhea, decreased oral intake, prior trial of clear liquids, or prior physician visit.[30] Although the presence of the following historical findings makes dehydration less likely, their absence does not strongly predict the presence of dehydration: not having previously seen a physician and parental report of normal urine output and fluid intake.[30,31]

Clinical Findings. Only three clinical signs have been found to have significant positive pooled likelihood ratios for 5% dehydration: prolonged capillary refill time, abnormal skin turgor, and abnormal respiratory pattern.[29] Sunken eyes and dry mucous membranes are only somewhat helpful, with 95% confidence intervals that approach 1.0.[29] Other commonly evaluated signs all have pooled positive likelihood ratios, with 95% confidence intervals that cross 1.0.[29] However, moist mucous membranes, well appearance, and the absence of sunken eyes can help exclude dehydration.[29]

Capillary Refill Time. Capillary refill time is the time required for return of normal color after application of blanching pressure to a distal capillary bed.[27] Since it was first described in 1947, capillary refill time has been frequently recommended for use in dehydration assessment.[14,27,32] However, it is limited by the absence of a well-defined range of normal, lack of standard site of measurement, significant interobserver variability, and the influence exerted on it by other variables such as ambient temperature.[33-36] Studies have suggested that a prolonged capillary refill time is a specific, but not sensitive finding in dehydration.[31,32,37] In 1988, it was suggested that 2 seconds be used as a cutoff, a value that has subsequently become entrenched in pediatric teaching doctrine.[36] However, subsequent research has found a capillary refill time $\leq$ 1.5 seconds indicates < 5% dehydration; 1.5-3.0 seconds suggests a 5-10% deficit, and > 3 seconds suggests a > 10% deficit.[34]

Skin Turgor. Skin turgor refers to the skin's ability to return to its normal contour after being raised in a pinched fold between the thumb and index finger.[38] In dehydrated patients, this fold may subside more slowly (tenting or ridge sign).[38] This test should be performed on the lateral abdominal wall at the level of the umbilicus.[39] Initial studies evaluated the use of skin turgor in 21 children with diarrhea.[39] Skin turgor time was found to vary directly with weight loss, with a time of 1-2 seconds correlating with a 5-8% weight loss.[39] To date, normal values have not been established, and most clinicians simply quantify response to skin turgor testing as immediate (normal), slightly delayed, or prolonged. Skin turgor measurement appears to have only moderate inter-observer agreement (k = 0.36 - 0.55).[40]

Respiratory Pattern. Dehydrated children with significant metabolic acidosis may manifest hyperpnea (deep, rapid respirations without other signs of respiratory distress). However, interobserver agreement on respiratory rate and pattern is poor.[29]

Table 1. Signs to be Evaluated During Hydration Assessments*

	NONE-MINIMAL DEHYDRATION < 3% LOSS OF BODY WEIGHT	SOME (MILD-MODERATE) DEHYDRATION 3-9% LOSS OF BODY WEIGHT	SEVERE DEHYDRATION > 9% LOSS OF BODY WEIGHT
Mental status	Well, alert	Fatigued, restless, irritable	Apathetic, lethargic, unconscious
Thirst	Normal, slight increase, or refusing	Increased, eager to drink	Very thirsty or too lethargic to indicate
Heart rate	Normal	Normal to increased	Tachycardic with bradycardia in severe cases
Blood pressure	Normal	Normal	Normal to reduced
Pulse quality	Normal	Normal to reduced	Weak, thready
Breathing	Normal	Normal to tachypneic	Deep
Eyes	Normal	Slightly sunken orbits	Deeply sunken orbits
Tears	Present	Decreased	Absent
Mucous membranes	Moist	Dry	Parched
Anterior fontanelle	Normal	Sunken	Sunken
Skin turgor	Instant recoil	Recoil in < 2 seconds	Recoil in > 2 seconds
Capillary refill	Normal	Prolonged 1-2 seconds	Prolonged > 2 seconds
Extremities	Warm	Cool	Cold, mottled, cyanotic
Urine output	Normal to decreased	Decreased (< 1 mL/kg/h)	Minimal (< 0.5 mL/kg/h)

* Adapted from: Practice parameter: the management of acute gastroenteritis in young children. American Academy of Pediatrics, Provisional Committee on Quality Improvement, Subcommittee on Acute Gastroenteritis. *Pediatrics* 1996;97:424-435; King CK, Glass R, Bresee JS, et al; Centers for Disease Control and Prevention. Managing acute gastroenteritis among children: oral rehydration, maintenance, and nutritional therapy. *MMWR Recomm Rep* 2003;52(RR-16):1-16.

Anterior Fontanel. Despite demonstrating substantial interobserver agreement,[30] depression of the anterior fontanel has not been found to be a reliable predictor of dehydration.[41]

Orthostatic Vital Signs. Postural heart rate and blood pressure measurements are frequently used indicators of intravascular volume. However, 43% of 132 euvolemic adults have a "positive" orthostatic finding according to accepted values.[42]

Clinical Scores

To improve diagnostic test properties, several authors have designed clinical scores that consist of several individual signs of dehydration. Two of the original scoring systems[43,44] and their individual signs of dehydration were prospectively evaluated.[33] A skinfold retraction time > 2 seconds, altered neurologic status, sunken eyes, and dry oral mucosa were correlated with percent dehydration. Both scores correlated mild, moderate, and severe dehydration to weight loss of 4%, 5%, and 10%, respectively. Two more recent scales are capable of predicting the presence of mild to moderate dehydration. Gorelick and colleagues evaluated 10 clinical signs in 186 children aged 1 month to 5 years and found the presence of ≥ 3 clinical signs to have a sensitivity of 87% and specificity of 82% for detecting ≥ 5% dehydration.[31] A subset of four factors (capillary refill > 2 seconds, absent tears, dry mucous membranes, and ill general appearance) predicted dehydration as well as the entire set, with the presence of 2 signs indicative of a deficit of ≥ 5%.[31] Similar conclusions were drawn by Friedman and researchers who prospectively recorded findings on 137 children aged 1-36 months.[45] The final scale consisted of 4 variables (general appearance, eyes, mucous membranes, tears), of which 3 were also in the final grouping proposed by others.[31,33,45] The success of these scores is due to their ability to distinguish children with mild to moderate (some) dehydration, from those without dehydration. This is in keeping with an earlier recommendation made by the World Health Organization to classify patients as having none (< 5%), some (5-10%), or severe dehydration (> 10%).[24]

Laboratory Diagnosis of Dehydration

Since clinical assessment is imperfect, it would be useful if a laboratory test could provide an objective method of measuring dehydration that is less subject to reliability and reproducibility problems. However, since laboratory parameters vary with age and the pathophysiology of dehydration is variable, laboratory parameters are subject to inaccuracy.[27] For example, isolated vomiting can present either with high serum bicarbonate due to losses of gastric acid; or low serum bicarbonate due to volume contraction, lactic acidosis, or starvation ketosis. Isolated diarrhea can present with low serum bicarbonate due to stool losses with little dehydration if the child receives adequate volumes of oral rehydration.[27] To complicate matters even more, some children with a significant amount of vomiting develop a contraction alkalosis. As the plasma potassium concentration falls secondary to losses in vomitus, ICF potassium moves out of the cells to replenish ECF stores. To maintain electroneutrality, hydrogen moves intracellularly, causing an ECF alkalosis.

Specific Tests. *Blood Urea Nitrogen (BUN).* Studies evaluating BUN have found that it is significantly higher in children with severe dehydration but not different among those with mild to moderate dehydration.[26] Thus, it can predict 5% dehydration, but only when a cutoff of 45mg/dL is used.[41,46-48] This reduces its sensitivity to 43%.[47] An elevated BUN:creatinine ratio has not been found to predict dehydration.[49]

Acidosis. Base deficits and anion gaps do not accurately predict dehydration.[41,49,50] A serum bicarbonate $\leq$ 15 mEq/L was not strongly predictive of dehydration in one study (LR 1.5; 95% CI 1.2, 1.9),[47] while others have found a concentration < 17 mEq/L to be somewhat helpful with sensitivities of 94% and 77% for severe and moderate dehydration, respectively.[26] On the other hand, a serum bicarbonate > 15 mEq/L significantly reduces the likelihood of dehydration,[26,47] implying that the absence of significant acidosis makes significant dehydration unlikely.

Urinary Indices. Specific gravity as a measure of dehydration was evaluated in 1997 and found not to be significantly correlated with dehydration.[50] A recent study evaluated urine ketones, specific gravity, and urine output and found that none of these correlated with dehydration at presentation; it recommended that urinary parameters not be used to assess fluid status.[51]

Role of Laboratory Testing

Given the limited utility of laboratory investigations and the increasing need for cost containment, laboratory investigations ideally should be performed only in children in whom the test result is likely to be clinically useful. Unfortunately, such criteria have not been well identified in pediatric gastroenteritis. A multicenter study of 813 children attempted to identify high-yield criteria.[52] Nearly 70% had an electrolyte abnormality and 25% met the definition of "clinical significance," with the majority of significant abnormalities being low total bicarbonate. A decision rule requiring 1 of 6 clinical criteria (dry mucous membranes, vomiting, delayed capillary refill, diabetes mellitus, tachycardia, and age < 6 months) had a positive likelihood ratio of only 1.3 for detecting significant abnormalities and would have reduced electrolyte performance by 18%.

In one study, the usefulness of routinely obtaining electrolytes in 182 children receiving intravenous rehydration was assessed.[53] While 48% of children had any electrolyte abnormality, only 10% changed management. These changes included the administration of intravenous glucose to 6 children and potassium to 2. Unlike a previous study that found children with a bicarbonate $\leq$ 13 mmol/L were more likely to be hospitalized,[54] in this larger more recent study, a low serum bicarbonate was correlated with observation unit use but not tolerance of ORT in the emergency department, hospitalization, or return visits. Thus, the use of bicarbonate as strict admission cutoff does not seem justified.

In summary, laboratory testing is an adjunct to a comprehensive clinical examination. It seems reasonable to recommend that electrolytes, renal function, and glucose be obtained in any child in whom severe dehydration is suspected, in children with complex underlying conditions, in children < 3 months of age, and in children with some dehydration for whom a decision has been made to administer intravenous fluids and who do not improve rapidly following volume expansion. All children who will receive prolonged intravenous fluids should have a baseline set of electrolytes performed due to the risk of hyponatremia in children with gastroenteritis secondary to elevated antidiuretic hormone levels.[19] Bedside glucose is likely all that is required for children who require intravenous fluids but do not meet the above criteria.

Novel Techniques to Ascertain Hydration Status

Bioelectrical Impedance. Bioelectrical impedance is a rapid, non-invasive, and inexpensive method of estimating TBW.[55] It measures the resistance to energy flow through the body by measuring the current passing between two electrodes attached to two body parts. TBW estimates are well-correlated in euvolemic individuals with the gold-standard of isotope dilution.[56,57] In vitro dehydration models have found resistance to be increased because less fluid is available to conduct current.[58] However, in human dehydration studies, 6 studies have found impedance to be increased, while 5 have detected a reduction.[55] This variability may be due to other factors such as ambient temperature, electrode placement, subject posture, patient cooperation, and nonconductive surfaces.[55] Thus, bioelectrical impedance is not sufficiently accurate or reliable enough to incorporate into use at present.

Digital Videography. Digitally measured capillary refill time was evaluated in 83 children using a digital video camera with customized graphic software.[59] Frame-by-frame analysis allows the fingertip's exact color to be determined as a rod is pressed against the end of the fingertip for 5 seconds and then abruptly released. The software compares each frame with the precompression frame until an exact color match is achieved. The time between rod release and recovery is calculated. Using postillness weight gain as the gold standard, the area under the receiver operator characteristic curve was 0.99 and the positive likelihood ratio was 11.7 (95% CI 5.4, 22) for detection of a 5% fluid deficit.

End-Tidal Carbon Dioxide. In a prospective convenience sample of 133 children with gastroenteritis, end-tidal carbon dioxide levels and serum bicarbonate concentrations were linearly correlated independent of other predictors of acidosis.[60] Thus, capnography may serve as a noninvasive measure of severity of acidosis.

Oral Rehydration Therapy (ORT)

The cornerstone of dehydration therapy in most children with gastroenteritis is ORT, and its use has resulted in a substantial reduction in the number of deaths due to diarrhea in the last 20 years.[61] To understand the scientific basis for the use and effectiveness of ORT, it is necessary to review basic water, electrolyte, and nutrient absorption in the intestines in the healthy state and during gastroenteritis.

Physiology of Absorption in Health and During Gastroenteritis. In the healthy intestine, balance is maintained between secretion and absorption of water and electrolytes.

Table 2. Composition of Standard, Reduced-Osmolarity WHO-ORS, and Other Commonly Consumed Beverages* §

	Carbohydrate (mmol/L)	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Base (mmol/L)	Osmolarity (mOsm/L)
WHO reduced osmolarity (2002)	75	75	20	65	10	245
WHO-ORS (1975)	111	90	20	80	10	311
Pedialyte®	139	45	20	35	20	250
Enfalyte®	167	50	25	45	34	200
Rehydralyte®	139	75	20	65	30	305
CeraLyte - 50®	222	50	20	N/A	30	220
Apple juice	666	0.4	44	45	N/A	730
Coca-Cola Classic®	622	1.6	N/A	N/A	13.4	650
Ginger Ale	500	3.5	0.1	N/A	3.6	565
Gatorade®	322	20	3	N/A	3	350
Chicken broth	44	260	0.5	260	N/A	450

§ Note the inappropriately high carbohydrate:sodium ratios found in apple juice, coca-cola, ginger ale, and Gatorade.

* Author adapted from King CK, Glass R, Bresee JS, et al. Managing acute gastroenteritis among children: oral rehydration, maintenance, and nutritional therapy. *MMWR Recomm Rep* 2003;52:(RR-16):1-16.

Sodium is the major driving force behind the intestinal absorption of water. It is actively pumped out of intestinal epithelial cells at the basolateral membrane into the interstitial fluid, allowing sodium within the lumen of the intestine to enter the cell by following the gradient that results. Sodium cotransport with other small molecules such as glucose and amino acids also occurs. Sodium-glucose cotransport is the mechanism most contributory to the effectiveness of ORT, as it remains functional during diarrheal disease. The optimal glucose to sodium ratio for the cotransport system is 1:1.[62] Water passively follows the transport of sodium and other electrolytes by crossing the intestinal epithelium between cells.[2] Once in the interstitium, sodium and glucose can then be absorbed by the adjacent capillary bed.

Diarrhea results from the reversal of the normal status of net absorption to net secretion. This can be due to the presence of osmotic forces in the lumen, increased cellular secretion, or a combination of factors. Viruses are responsible for approximately 40% of cases of acute diarrhea in developing countries and more than 80% in industrialized countries.[63] Viral infection results in malabsorption by invading epithelial cells, which causes cell lysis and sloughing of intestinal villi. The immature cells that repopulate the villi are less effective in glucose and sodium absorption. In contrast, diarrhea caused by bacterial infection is more likely to be secretory. *E. coli* and *V. cholerae* promote secretion by producing enterotoxins that activate intracellular messengers. Regardless of etiology, because villous damage tends to be patchy and absorptive function is maintained in surviving cells,[63] ORT can be successfully used.

Oral Rehydration Solution (ORS) Composition

Sodium Content and Osmolarity. In 1971, a standardized ORS was developed by the WHO, which as of 1975 became jointly promoted by the WHO and the United Nations International Children's Emergency Fund (UNICEF). This WHO-ORS contained (in mmol/L): sodium, 90; potassium, 20; chloride, 80; base, 30; and glucose, 111 (2%).[64] This original composition was selected because it was believed to meet the needs of both cholera patients, who may lose more than 120 mmol/L of sodium in stool, and non-cholera patients, who generally have much lower sodium losses.[65] Discussion, however, has persisted regarding the optimal concentration of sodium in a universal solution intended for patients with diarrhea of varying etiologies. Specifically, it was felt that the sodium concentration may be too high for children with non-cholera diarrhea and could cause hypernatremia,[66] especially if used for routine administration as a maintenance solution.[22] For this reason, the AAP recommended in 1985 the use of two solutions: a rehydration solution containing 75-90 mmol/L of sodium, followed by a maintenance solution containing 40-60 mmol/L.[67] An AAP policy statement in 1996 stated that the commercially available ORS containing 45-50 mmol/L of sodium could be used to satisfactorily rehydrate otherwise healthy children with mild to moderate dehydration.[68]

A criticism raised regarding ORT is that the use of standard ORS does not sufficiently reduce stool output or duration and may be less tolerable than lower osmolarity ORS. Thus, researchers have focused on altering ORS composition to achieve a reduction in stool output while restoring or maintaining electrolyte balance and improving tolerability. Solutions with sodium concentrations of 60-75 mmol/L, combined with glucose in the range of 75-90 mmol/L, have been most successful because the 1:1 ratio of sodium to glucose required for optimal cotransport is maintained while providing a reduced osmolar load to the intestines. Several clinical trials have suggested that children who are administered a reduced-osmolarity ORS have reduced stool output, shorter duration of diarrhea, less vomiting, and reduced need for supplemental intravenous fluids compared to those who receive standard WHO-ORS.[62,69,70] *(See Table 2.)* Critics of the reduced sodium content ORS note the variable outcomes and methodological limitations of many of the studies recommending lower osmolarity ORS. Because hyponatremia, which may occur with the use of reduced osmolarity ORS, may result in significant clinical consequences, the benefit to risk ratio was questioned.[65] A meeting of WHO and UNICEF representatives concluded that reduced osmolarity ORS was more effective than standard ORS for non-cholera diarrhea and not inferior to standard ORS for cholera.[71] Thus, in 2002, the WHO introduced a new, lower osmolarity universal ORS formulation.[2] *(See Table 2.)*

Since then, a Cochrane Systematic Review concluded that in hospitalized children, reduced osmolarity ORS when compared to WHO standard ORS is associated with fewer unscheduled intravenous fluid infusions, lower stool volume post randomization, and less vomiting.[72] No additional risk of developing hyponatremia was detected. In further support of the safety of the lower osmolar, lower sodium ORS, a trial of more than 50,000 patients with diarrhea in two hospitals in Bangladesh, with a 20% prevalence of cholera, found the risk of symptomatic hyponatremia to be 0.05%.[73] This prevalence was not higher than in the previous year during which standard osmolarity ORS was used. Although a single ORS composition is given as the recommended formulation, the WHO has published criteria for an acceptable range of ORS formulations (in mmol/L): osmolarity 200-310, glucose at least equal to sodium but not to exceed 111, sodium 60-90, potassium 15-25, citrate 8-12, and chloride 50-80.[71]

Carbohydrate Content. High concentrations of glucose in ORS can exceed the absorptive capacity of the gastrointestinal tract, resulting in an osmotic diarrhea. The substitution of short-chain glucose polymers from rice and other starch sources has been studied as a manner of providing a favorable glucose to sodium ratio and increasing calories while keeping the osmolar load low. Two meta-analyses concluded that rice-based ORS is equally or more effective than traditional ORS in reducing stool output.[74,75] Cereal-based ORS solutions also contain various amino acids and oligopeptides that may further stimulate sodium transport.[76] The disadvantage of recommending a rice-based ORS as the universal solution relates to practicality, with challenges existing in the selection and stability of ingredients. Additionally, preparation and distribution costs may be higher.[77]

Base Precursors. Bicarbonate was a component in the original ORS recommended in 1971 but was changed to citrate in 1975 to improve stability. The theoretical rationale behind the addition of a base precursor to ORS is to correct acidosis and promote sodium absorption. In hospitalized children with diarrhea, a single study found the addition of citrate to ORS results in a faster resolution of acidosis with no change in the duration of vomiting, diarrhea, or hospital stay.[78]

Other ORS Additives. Because various peptides and amino acids are capable of promoting sodium co-transport, they also have been tested as ORS additives. However, data demonstrating clinical improvement in outcomes has been lacking, and preparation of ORS containing these additional components is unlikely to be cost-effective.[2] Non-absorbable carbohydrates, such as amylase-resistant starch, fructo-oligosaccharides, guar gum, and carboxymethylcellulose, are digested by bacteria in the gut, resulting in the production of short-chain fatty acids. These stimulate sodium absorption in the colon, which could serve as an adjunct to small intestine absorption, and also may enhance water and electrolyte contact with microvilli, promoting sodium absorption.[79] However, further data are needed regarding the clinical efficacy and practicality of these additives.

Zinc is necessary for the regeneration of intestinal mucosa, and deficiency has been associated with increased diarrhea severity in developing countries. In populations that are susceptible to zinc deficiency, its administration has been shown to significantly reduce diarrheal duration and frequency during acute gastroenteritis.[80,81] Further research is necessary to determine whether zinc administered with ORT is beneficial to children in developed countries who are less likely to have baseline zinc deficiency.

Several meta-analyses have concluded that probiotics confer a beneficial effect when administered to hospitalized children with acute diarrhea receiving ORS.[82,83] In a study in which *Lactobacillus* GG was administered as an ORS additive to European children with acute diarrhea, those receiving the probiotic agent had a shorter hospital stay and shorter duration of symptoms.[84] As with the other additives discussed, issues of clinical efficacy, practicality, and cost-effectiveness need to be addressed before widespread endorsement can be given.

Available and Recommended ORS. The composition of WHO-ORS differs from many of the commercially available and commonly recommended solutions used for rehydration in North America *(see Table 2)*. Commercially available ORS in North America tends to have a lower sodium concentration and higher carbohydrate content than WHO-ORS. Nonetheless, these solutions have been shown to be both safe and effective.[72,85,86] In 1996, the AAP suggested that a maintenance ORS containing 45-50 mmol/L of sodium can be used for both rehydration and maintenance in children with mild to moderate diarrhea.[68] This policy statement has since been replaced by endorsement of the 2003 CDC guidelines on managing acute gastroenteritis in children.[2] The CDC policy promotes WHO-ORS and recommends commercially available ORS over other commonly used beverages often inappropriately given for rehydration, but it does not give specific ranges of acceptable osmolarity, carbohydrate, or sodium content. ESPGHAN recommends an ORS with 60 mmol/L of sodium and an osmolarity of 200-250 mOsm/L for children in developed countries.[87] The 2006 Canadian Pediatric Society (CPS) guidelines state that the commercially available ORS formulations found in Canada, which are identical or similar to those available in the United States, are safe and effective.[88]

ORT Effectiveness

Despite the proven success of ORT and recommendations for its usage by groups such as the WHO, CDC, AAP, CPS, and ESPGHAN, ORT remains underused by healthcare providers in industrialized countries, where intravenous therapy historically has been the modality of choice for treating dehydration. Intravenous rehydration is recommended by the CDC as first-line treatment for severe dehydration when necessary to restore hemodynamic stability or when airway protective reflexes are compromised by altered mental status;[2] however, many physicians choose intravenous therapy in patients with only mild to moderate dehydration. This may be due to unfamiliarity with published guidelines[89] or to incorrect perceptions regarding the necessity or efficiency of intravenous rehydration. A recent Cochrane review compared oral to intravenous rehydration for treating dehydration due to gastroenteritis in children.[85] Seventeen trials were reviewed, of which 9 were conducted in high-income countries. There was no difference between groups in failure to rehydrate, weight gain, incidence of hyponatremia or hypernatremia, duration of diarrhea, or total fluid intake at 6 hours and 24 hours. Shorter hospital stays were reported in the ORT group. For every 25 children treated with ORT, one would fail and require intravenous therapy. Another meta-analysis reported similar effectiveness for intravenous and oral rehydration therapy and found that children rehydrated by oral or nasogastric routes had fewer adverse events and a shorter hospital stay.[90] More recently, no difference was detected in terms of clinical rehydration at 4 hours between children with moderate dehydration who received intravenous rehydration or ORT, although those in the intravenous group did gain significantly more weight.[86] The hospitalization rate was lower for patients in the ORT group; however, the disposition decision was made after unmasking.

ORT Delivery. A summary of the recommendations made by leading organizations (CDC,[2] AAP,[91] ESPGHAN,[25] CPS[88]) on the appropriate use of ORT is presented.

Implementation of ORT begins with an assessment of severity of dehydration. Caregivers can be trained to recognize signs of dehydration, to begin ORT, and to seek medical attention when necessary. Some of the indications to see a health care provider include young age, presence of other medical conditions, fever, hematochezia, large volume losses, altered mental status, and a lack of response to ORT. A detailed history and physical exam should be performed in all children with suspected gastroenteritis to assess for the presence of dehydration and to rule out non-gastrointestinal causes of illness. Dehydration severity should be assessed as described previously.

The basic principles of ORT are summarized in the ESPGHAN guidelines published in 2001 and a sample emergency department algorithm is provided in Figure 2.

Treatment includes two phases: rehydration and maintenance. In the rehydration phase, which takes place over approximately 4 hours, fluid deficit is replaced. Once rehydration is achieved, ORS is supplemented by realimentation with an age-appropriate unrestricted diet. Breastfeeding should not be interrupted, even in the rehydration phase. Formula given should be full-strength, and changes in formula are usually not necessary given the rare occurrence of lactose malabsorption. Bowel rest is not indicated at any phase of ORT.

For children with minimal or no dehydration, the emphasis should be on maintaining an age-appropriate diet, providing maintenance fluid needs, and replacing losses. ORS may be given for the replacement of losses, but for children who are not dehydrated, fluid needs also may be met through their regular diets. As a general guide, children weighing < 10 kg can receive an additional 60-120 mL of fluid for each episode of vomiting or diarrhea, and those weighing > 10 kg can receive 120-240 mL per episode.

For children with some (mild-moderate) dehydration, the first step of ORT is rehydration, with rapid correction of the fluid deficit. This can be done with 50-100 mL of ORS per kg of body weight over 2-4 hours, plus additional ORS to compensate for ongoing losses. Small volumes, such as 5 mL every 2-5 minutes, should be offered initially and can be increased as tolerated.

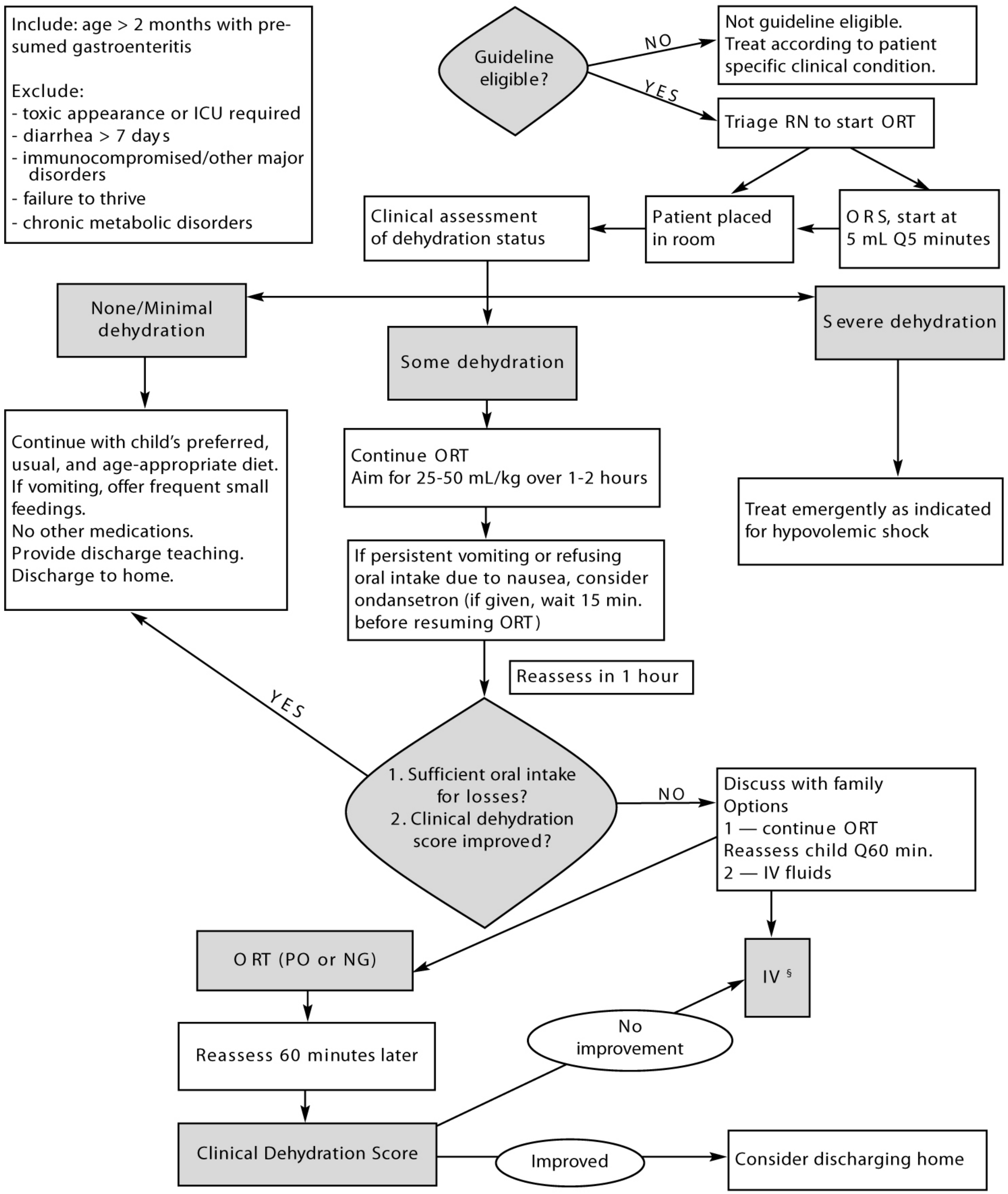
Children with severe dehydration resulting in shock or compromise of protective airway reflexes should be initially managed with isotonic intravenous rehydration to restore hemodynamic stability. When perfusion and mental status return to normal, ORT can be initiated.

Role of Continued Feedings During ORT. Despite overwhelming evidence of the importance of continued feedings during gastroenteritis and ORT, many practitioners still recommend some degree of diet restriction as part of their routine management of gastroenteritis.[92,93] This is usually due to concerns that feeding will worsen vomiting or that malabsorption of nutrients will lead to an osmotic diarrhea, thereby increasing dehydration and acidosis. However, strong evidence exists in support of continued feeding during ORT, and its importance has been emphasized in all major guidelines.[2,25,88,91]

Early refeeding has clear nutritional and clinical benefits. This is especially important in developing countries, where repeated episodes of gastroenteritis contribute to malnutrition. Breastfeeding has been shown to reduce the volume and number of diarrheal stools, and breastfed infants should be encouraged to nurse on demand, including during the rehydration phase of ORT. This promotes optimal nutrition for the infant and avoids adverse effects on the maternal milk supply.[2,94] Formula fed infants should continue their usual formula, without dilution, immediately upon rehydration. Although laboratory evidence of lactose malabsorption has been demonstrated, clinical lactose intolerance is rare. A meta-analysis of clinical trials since 1985 showed no significant clinical advantage of lactose-free formu-

Continued on page 23

Figure 2. Algorithm for Evaluation and Management of Acute Gastroenteritis in Children > 2 Months of Age*



§ If IV access difficult, consider NG — 50 mL/kg ORS over 3 hours instead. Continue ORT during IV therapy.

Key: ORT = oral rehydration therapy; ORS = oral rehydration solution; PO = by mouth; NG = nasogastric

* Adapted from: Cincinnati Children's Hospital Medical Center Evidence Based Care Guideline for Children with Acute Gastroenteritis. Available at: http://www.cincinnatichildrens.org/NR/rdonlyres/3E10E126-FEAF-4E33-AB62-AFDBAE3D5268/0/mgmtalgorithmgastroenteritis.pdf. Accessed 1/4/08.

las, except in infants with severe malnutrition or severe dehydration at the beginning of treatment.[95] The addition of soy fiber to formula does not affect stool quantity or nutritional status, but may result in shorter duration of liquid stools. Although not nutritionally significant, this may improve parental acceptance of formula.[96]

Children whose usual diet includes solid foods should continue their usual diet during diarrhea and ORT. In a European study of 230 children, 80% of whom had mild dehydration, children who resumed their usual diet immediately following a 4-hour rehydration period had higher weight gain and no worsening of diarrhea compared to children who were prescribed a restricted diet for the first 20 hours after rehydration.[97] Furthermore, the incidence of lactose intolerance in each group was negligible. Rigid dietary prescriptions, such as the BRAT (bananas, rice, applesauce, toast) diet, should be avoided because the restrictive nature is likely to result in suboptimal intake of calories and certain nutrients. In general, it is rational to limit foods high in simple sugars because the osmotic load may worsen diarrhea. It is not necessary to eliminate fatty foods, as fats are often an important source of calories and may slow intestinal motility.[2] A reasonable dietary suggestion for refeeding would be to promote a diet adequate in calories that contains age-appropriate and culturally appropriate food, low in simple sugar, such as breast-milk or formula, complex carbohydrates, meats, fruits, vegetables, and dairy products. Future research may determine whether specific nutrients or functional foods such as prebiotics (ingredients that promote the growth of beneficial colonic bacteria) or probiotics (live microorganisms that beneficially affect the host) have a role in improving clinical outcomes.

Emergency Department ORT Implementation. Despite the existence of guidelines endorsed by major children's health organizations, the treatment of dehydrated children in emergency departments remains variable. Physicians frequently state that they are knowledgeable about ORT guidelines; however, their practice patterns do not follow published guidelines.[93,98,99] Familiarity with the guidelines actually may be less than that stated, since knowledge in the above studies was measured by self-report. It has been demonstrated that emergency physicians who are more aware of published guidelines are more likely to use ORT in patients with mild to moderate dehydration.[89] A survey of pediatric emergency medicine fellowship program directors in Canada and the United States found that although all surveyed physicians used ORT in some circumstances, less than 7% used ORT in all circumstances recommended by the AAP, with many indicating that intravenous rehydration was more appropriate than ORT for children with mild to moderate dehydration.[99] Additionally, many responded that ORT was associated with increased length of stay and a greater staff time requirement.

Emergency departments that have implemented ORT clinical practice guidelines have demonstrated reductions in length of stay and admissions.[100] In Cincinnati, an evidence-based pediatric gastroenteritis guideline adapted from the AAP and CDC recommendations was developed by an interdisciplinary team. Extensive education of the medical staff, house-staff, community pediatricians, and nursing staff occurred. Following implementation, annual gastroenteritis admissions decreased by 33%, length of stay was reduced, and the proportion of admitted children advanced to regular diets by the time of discharge increased from 5% to 76%.[101] The authors attribute the project's success not only to the strength of the guidelines but also to the enhanced dialogue among participating physicians, reassuring them that they were following best practices in accordance with expert and peer opinion.

Limitations and Perceived Barriers to ORT Use. Although the use of ORT is appropriate for diarrhea of all etiologies and in all age groups, there are some limitations to its use. ORT is contraindicated in severe dehydration, when protective airway reflexes may not be intact, or in the presence of paralytic ileus or obstruction. The presence of true carbohydrate malabsorption may limit the success of ORT, but this occurs in less than 1-5% of cases of acute diarrhea.[2]

The presence of ongoing fluid losses often discourages clinicians from continuing ORT. However, even patients with stool losses exceeding 10 mL/kg/hour generally improve with ORT. The presence of vomiting frequently is cited as a reason for choosing intravenous rehydration instead of ORT.[93,98,99] The evidence does not support this rationale, as vomiting usually does not limit the success of ORT. In studies of ORT versus intravenous therapy, which include children with vomiting, the failure rate of ORT is only 4%.[90] Another effective alternative to intravenous rehydration is nasogastric rehydration.[102] It allows for feeding at a slow, steady rate and has been found to be as efficacious and more cost-effective than intravenous rehydration.[102] Ondansetron may be used as an adjunct to ORT for children with persistent vomiting and dehydration due to gastroenteritis evaluated in an emergency department. Although such use is off-label at present, several well designed clinical trials have documented a decrease in length of stay, increased oral intake, and reduced intravenous rehydration.[103,104] However, the routine use of antiemetics is not recommended,[2] and the decision to use an antiemetic should be made on an individual basis.

Although the cost of administering ORT is generally less than intravenous rehydration in the emergency department, it can be a significant barrier in the out-of-hospital setting where the cost is borne by the family. The price of commercially available ORS is often more than $5/L, and the cost may not be covered by insurance. Providing ORS to families may help reduce this impediment while simultaneously reinforcing the importance of ORT. In one study, this resulted in a 25% decrease in unscheduled return visits.[105]

Refusal due to lack of palatability is an often cited barrier.[98] This is usually less of an issue in children who are actually dehydrated. The flavoring of ORS with juice causes significant changes in composition without significantly improving palatability.[106] In one study, the addition of a small amount of unsweetened Kool-Aid powder, Jell-O powder, or juice (1:4 ratio) to Pedialyte resulted in small changes in composition; however, palatability was not assessed.[107] Frozen ORS is a more palatable alternative for some children.[108]

Time is another frequently mentioned barrier to ORT. Seventy-seven percent of surveyed PEM fellowship directors stated that the additional time required for ORT relative to intravenous rehydration is a barrier to its use.[99] However, the mean length of time required for intravenous rehydration is reported to be greater than 5 hours.[109] In a randomized trial comparing length of stay, those who received ORT were discharged sooner than those who received intravenous rehydration, although the disposition decision was made without masking to treatment group.[110]

Expectations of parents and referring physicians also may influence the decision regarding method of rehydration. Parents often bring their children to the emergency department because oral intake at home had failed, and referring physicians may reinforce the expectation that intravenous therapy will be provided in the emergency department. The development of guidelines and educational interventions in conjunction with primary care providers may increase the acceptance of ORT by families and their physicians.[111]

Conclusion

Dehydration continues to be a major problem in developed nations. Clinicians need to be capable of distinguishing children with mild to moderate ("some") dehydration from those with none or minimal dehydration to minimize morbidity and optimize resource use. Clinical dehydration scales provide the optimal method of detecting children who require rehydration. For the majority of children, laboratory investigations provide little additional information and should not be routinely performed. The widespread use of ORT has significantly reduced the burden of gastroenteritis around the world. Despite its endorsement for use in children with evidence of dehydration it remains underused. The majority of cited barriers to its use have not been supported by evidence. Ongoing education and the implementation of evidence-based practice guidelines show promise in increasing ORT use for children with dehydration.

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CME Questions

11. Which of the following regarding signs and symptoms of dehydration is correct?
    A. The accuracy of most individual signs and symptoms is excellent.
    B. The interobserver agreement for most signs is excellent.
    C. Reduced urine output is a strong predictor of dehydration.
    D. Parental report of normal urine output reduces the likelihood of dehydration.

12. Which of the following regarding body fluid composition and homeostasis is correct?
    A. The interstitial compartment serves as a reservoir that can mobilize water into the plasma compartment during periods of hypovolemia.
    B. The ICF and ECF are in osmotic equilibrium because the cell membrane is freely permeable to sodium.
    C. The protection of ECF osmolality is of primary importance and is maintained at the expense of volume if necessary.
    D. ADH release leads to an increase in water excretion.

13. Several dehydration scoring systems have been proposed that use multiple variables to predict the presence of dehydration. Which of the following groups of variables are recommended by most dehydration scoring systems?
    A. Capillary refill time, anterior fontanelle, orthostatic vital signs
    B. General appearance, tears, mucous membranes
    C. Capillary refill time, skin turgor, general appearance
    D. Respiratory pattern, capillary refill time, general appearance

14. Which of the following is true regarding laboratory investigations as predictors of dehydration?
    A. Base deficits and anion gaps are accurate predictors of dehydration.
    B. Blood urea nitrogen is a sensitive marker of dehydration.
    C. Urine specific gravity and ketones do not correlate with dehydration.
    D. They should be performed on all children receiving intravenous rehydration.

15. Which of the following is true regarding ORS?
    A. Cotransport of glucose with sodium is the mechanism most responsible for its effectiveness.
    B. Carbohydrate malabsorption limits the effectiveness of ORS in > 20% of cases of viral gastroenteritis.
    C. Because of the relatively low sodium content of commercially available ORS, it is not appropriate for rehydration of moderately dehydrated children.
    D. Commercially available ORS generally has a lower carbohydrate concentration than WHO-ORS.

16. Which of the following is true regarding ORT effectiveness?
    A. No effectiveness studies have been performed in North America.
    B. ORT is equally effective to intravenous therapy in achieving rehydration in severely dehydrated (> 9%) children.
    C. ORT is as effective as intravenous therapy in achieving rehydration, but IV therapy results in shorter hospitalizations.
    D. The failure rate, according to meta-analysis, is < 5%.

17. Which of the following is a contraindication to ORT?
    A. Ongoing vomiting
    B. Stool losses >10 mL/kg/hour
    C. Blood in stool
    D. Impaired protective airway reflexes

18. Which of the following is true regarding the re-feeding of dehydrated children?
    A. Refeeding is most effective when initiated after 12-hours of exclusive ORS.
    B. A regular diet low in simple sugars should be encouraged immediately following a 4-hour rehydration period.
    C. Breastfeeding should be withheld during the first 4 hours of ORT.
    D. Formula-fed infants should be changed to a lactose-free formula until stools become formed.

19. Which of the following is true regarding appropriate ORT recommendations?
    A. Children with minimal (< 3%) dehydration should have their maintenance fluid needs met with ORS.
    B. Children with some dehydration (3-9%) should receive intravenous fluids if they have > 2 episodes of emesis or > 2 diarrheal stools during the rehydration phase.
    C. Children with some dehydration (3-9%) should initially receive 50-100 mL of ORS/kg over 2-4 hours, plus additional ORS to compensate for ongoing losses.
    D. Children with severe dehydration (> 9%) should receive a 4-hour trial of ORT followed by intravenous fluids if ORT is unsuccessful.

20. Which of the following is true regarding barriers to implementation of ORT?
    A. Rehydration using ORT takes more time than with intravenous therapy.
    B. Nasogastric administration of ORS is an effective alternative to oral administration in the child with some (3-9%) dehydration.
    C. Palatability of ORS can be improved without significantly changing its composition by mixing equal portions of juice and ORS.
    D. Cost is usually not a barrier to home ORT because commercially available ORS is less expensive than other beverages.

Answers: 11. D; 12. A; 13. B; 14. C; 15. A; 16. D; 17. D; 18. B; 19. C; 20. B

CME Instructions

Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge.

To clarify confusion surrounding any questions answered incorrectly, please consult the source material. After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a credit letter. When your evaluation is received, a credit letter will be mailed to you.

CME Objectives

The CME objectives for *Pediatric Emergency Medicine Reports* are to help physicians:

a.) Quickly recognize or increase index of suspicion for specific conditions;

b.) Describe the epidemiology, etiology, pathophysiology, historical and physical examination findings associated with the entity discussed;

c.) Correctly formulate a differential diagnosis and perform necessary diagnostic tests;

d.) Apply state-of-the-art therapeutic techniques (including the implications of pharmacologic therapy discussed) to patients with the particular medical problems discussed;

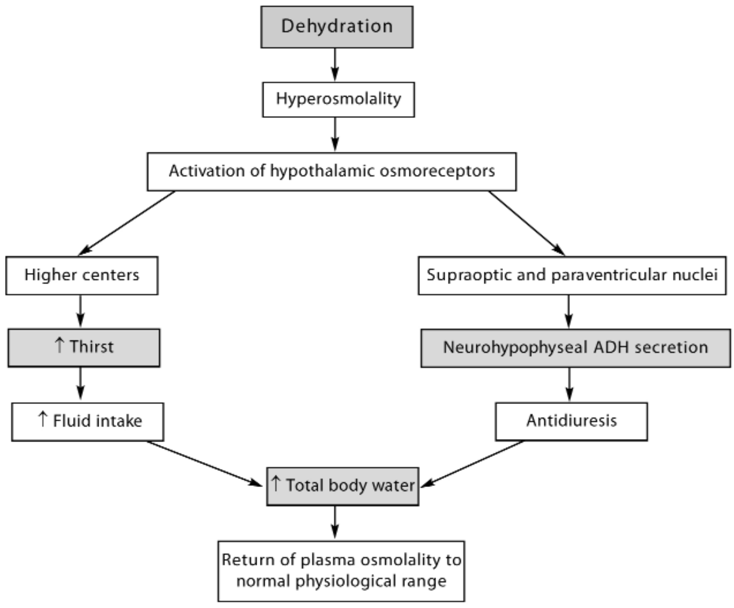
e.) Provide patients with any necessary discharge instructions.

In Future Issues: **Viral Myocarditis**

PEDIATRIC Emergency Medicine Reports
The Practical Journal of Pediatric Emergency Medicine

Dehydration Assessment and Oral Rehydration

Physiology of Water Homeostasis*



* Adapted from: Moore K, Thompson C, Trainer P. Disorders of water balance. *Clin Med* 2003;3:28-33.

Signs to Be Evaluated During Hydration Assessments*

	NONE-MINIMAL DEHYDRATION < 3% LOSS OF BODY WEIGHT	SOME (MILD-MODERATE) DEHYDRATION 3-9% LOSS OF BODY WEIGHT	SEVERE DEHYDRATION > 9% LOSS OF BODY WEIGHT
Mental status	Well, alert	Fatigued, restless, irritable	Apathetic, lethargic, unconscious
Thirst	Normal, slight increase, or refusing	Increased, eager to drink	Very thirsty or too lethargic to indicate
Heart rate	Normal	Normal to increased	Tachycardic with bradycardia in severe cases
Blood pressure	Normal	Normal	Normal to reduced
Pulse quality	Normal	Normal to reduced	Weak, thready
Breathing	Normal	Normal to tachypneic	Deep
Eyes	Normal	Slightly sunken orbits	Deeply sunken orbits
Tears	Present	Decreased	Absent
Mucous membranes	Moist	Dry	Parched
Anterior fontanelle	Normal	Sunken	Sunken
Skin turgor	Instant recoil	Recoil in < 2 seconds	Recoil in > 2 seconds
Capillary refill	Normal	Prolonged 1-2 seconds	Prolonged > 2 seconds
Extremities	Warm	Cool	Cold, mottled, cyanotic
Urine output	Normal to decreased	Decreased (< 1 mL/kg/h)	Minimal (< 0.5 mL/kg/h)

* Adapted from: Practice parameter: the management of acute gastroenteritis in young children. American Academy of Pediatrics, Provisional Committee on Quality Improvement, Subcommittee on Acute Gastroenteritis. *Pediatrics* 1996;97:424-435; King CK, Glass R, Bresee JS, et al; Centers for Disease Control and Prevention. Managing acute gastroenteritis among children: oral rehydration, maintenance, and nutritional therapy. *MMWR Recomm Rep* 2003;52(RR-16):1-16.

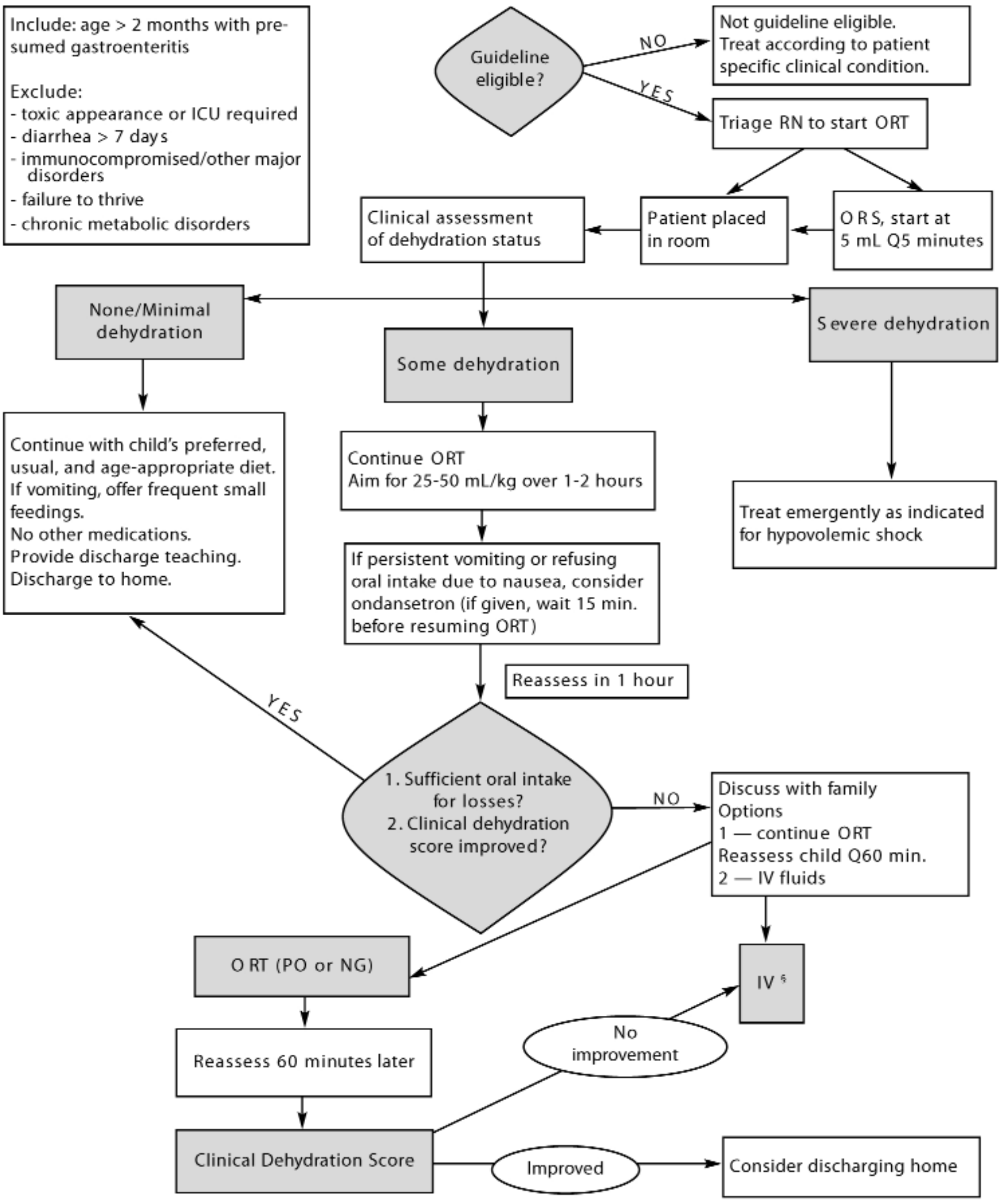
Composition of Standard, Reduced-Osmolarity WHO-ORS, and Other Commonly Consumed Beverages* §

	Carbohydrate (mmol/L)	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Base (mmol/L)	Osmolarity (mOsm/L)
WHO reduced osmolarity (2002)	75	75	20	65	10	245
WHO-ORS (1975)	111	90	20	80	10	311
Pedialyte®	139	45	20	35	20	250
Enfalyte®	167	50	25	45	34	200
Rehydralyte®	139	75	20	65	30	305
CeraLyte - 50®	222	50	20	N/A	30	220
Apple juice	666	0.4	44	45	N/A	730
Coca-Cola Classic®	622	1.6	N/A	N/A	13.4	650
Ginger Ale	500	3.5	0.1	N/A	3.6	565
Gatorade®	322	20	3	N/A	3	350
Chicken broth	44	260	0.5	260	N/A	450

§ Note the inappropriately high carbohydrate:sodium ratios found in apple juice, coca-cola, ginger ale, and Gatorade.

* Author adapted from King CK, Glass R, Bresee JS, et al. Managing acute gastroenteritis among children: oral rehydration, maintenance, and nutritional therapy. *MMWR Recomm Rep* 2003;52:(RR-16):1-16.

Algorithm for Evaluation and Management of Acute Gastroenteritis in Children > 2 Months of Age *



§ If IV access difficult, consider NG — 50 mL/kg ORS over 3 hours instead. Continue ORT during IV therapy.

Key: O RT = oral rehydration therapy; ORS = oral rehydration solution; PO = by mouth; NG = nasogastric

* Adapted from: Cincinnati Children's Hospital Medical Center Evidence Based Care Guideline for Children with Acute Gastroenteritis. Available at: http://www.cincinnatichildrens.org/NR/rdonlyres/3E10E126-FEAF-4E33-AB62-AFDBAE3D5268/0/mgmtalgorithmgastroenteritis.pdf. Accessed 1/4/08.

Supplement to *Pediatric Emergency Medicine Reports*, February 2008: "Pediatric Dehydration Assessment and Oral Rehydration Therapy." *Authors: Authors:* **Stephen B. Freedman MDCM, MSc, FRCPC, FAAP,** Assistant Professor of Paediatrics, University of Toronto, Division of Paediatric Emergency Medicine, Toronto, Ontario, Canada; and **Jennifer D. Thull-Freedman MD, MSc, FAAP**, Assistant Professor of Paediatrics, University of Toronto, Division of Paediatric Emergency Medicine, Toronto, Ontario, Canada.