# An Approach to Dehydration in Children

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## Introduction

Hi everyone!

My name is Catherine Korman, and I am a fourth-year medical student at McGill University. In today's episode of PedsCases, we are going to discuss the approach to dehydration in children. This episode was created in collaboration with Dr. Preetha Krishnamoorthy, a Pediatric Endocrinologist at the Montreal Children's Hospital and the Director of Pediatric Undergraduate Education at McGill University and Dr. Robert Sternszus, a Hospitalist Pediatrician and an Associate Professor of Pediatrics and Health Sciences Education at McGill University.

## Clinical Case

Let's start off with a clinical case!

Emma is an 18-month-old female brought to the emergency department by her mother due to decreased oral intake and diarrhea over the past 2 days. According to her mother, Emma has had approximately six episodes of watery diarrhea per day. She has also vomited twice, with both episodes being non-bilious and non-projectile. Emma is refusing milk but is taking sips of water. Her mother reports a decrease in urine output, with only one wet diaper in the past 12 hours. There is no history of fever, blood in the stool, recent travel, or sick contacts. Emma is fully immunized and has no significant past medical history.

On examination, Emma is irritable but consolable. Her mother notes that she is less active than usual. Her current weight is 10 kg, down from a previous weight of 10.9 kg. Vital signs are: HR 150 bpm, RR 30, BP 90/60 mmHg, Temp 37.1ºC. She has decreased skin turgor and cool extremities. Her mucous membranes are dry, and her eyes appear slightly sunken. The fontanelle is also slightly sunken. Capillary refill is mildly delayed at 2-3 seconds. Urine output is estimated to be less than 0.5 mL/kg/hr.

This scenario is a classic example of dehydration in pediatric patients, most commonly due to gastroenteritis. During this podcast, we will revisit and highlight the key findings of this case.

## Objectives

After listening to this podcast, the learner will be able to:

1) Define and estimate the severity of dehydration in children.
2) Identify indications for oral versus intravenous rehydration therapy.
3) Explain how to manage fluid and electrolyte imbalances in children with dehydration.

## Definition and Causes of Dehydration

Dehydration is a frequent presentation in pediatric patients.[1-3] While fluids are lost through normal bodily functions such as urine production, insensible losses from the skin, and stool,[3] dehydration refers to excessive fluid loss. In pediatric literature, the term is often used interchangeably with hypovolemia. Hypovolemia can result from inadequate fluid intake, third-spacing of fluids, or excessive fluid losses (e.g., increased gastrointestinal losses or stoma output).[1]

Inadequate fluid intake is an important factor to consider when creating your differential diagnosis for a child with hypovolemia. A child might have inadequate fluid intake, particularly if they are unwell, as children often stop drinking or feeding when sick. Young infants,[4] children with autism who have baseline limited dietary or fluid preferences,[5] and children with medical complexity[6] are pediatric subpopulations particularly at risk for dehydration due to limited intake. Thus, it is important to get a thorough feeding history from caregivers when initially assessing the patient.

The pathophysiology of third-spacing is complex, but it can occur in a variety of conditions. These include kidney disease, heart failure, liver disease, malnutrition, increased vascular permeability from systemic inflammation, bleeding into a third space and ascites due to acute intra-abdominal pathology.[1]

Gastroenteritis is one of the many causes of excessive fluid loss, as it results in gastrointestinal losses, notably vomiting and/or diarrhea.[7,8] Other causes of excessive fluid loss that can lead to hypovolemia in the pediatric population include insensible losses from the skin (e.g., fever, burns), major bleeding, and urinary losses (e.g., glucosuria, diuretic therapy, diabetes insipidus).[1]

Revisiting Emma with this in mind, her dehydration likely stems from excessive gastrointestinal fluid loss based on her history of vomiting and diarrhea. However, it is important to complete a thorough history and physical examination to ensure there are no other factors contributing to her degree of dehydration.

**Estimating the Degree of Hypovolemia**

When estimating the degree of hypovolemia, two primary methods are utilized: assessing weight loss and evaluating clinical signs.[1,9] The preferred method is to calculate the change in weight by subtracting the current weight from the most recent known weight.[10] However, parents may not always know their child's most recent weight. Therefore, another commonly used method is to assess for signs and symptoms associated with varying degrees of hypovolemia.[8,11]

The parents of a child with mild hypovolemia may only report a history of fluid losses. Sometimes, a reduction in urine output may be noted, though this finding can be difficult to appreciate. Moderate dehydration presents with signs like tachycardia, dry mucous membranes, and delayed capillary refill (greater than 2 seconds), while severe dehydration is more critical, marked by hypotension, mottled extremities, and lethargy, and requires immediate fluid resuscitation.[1,9] Keep in mind that a child presenting with signs of severe dehydration is at increased risk of progressing to hypovolemic shock, with vital signs reflecting tachycardia and decreased blood pressure.[3]

Some sources maintain that in infants, mild dehydration corresponds to approximately a 5% loss in body weight, moderate dehydration to about 10%, and severe dehydration to around 15%. In older children and adolescents, these thresholds are typically adjusted to 3%, 6%, and 9%, respectively.[3] However, more current pediatric guidelines suggest mild dehydration corresponds to a 3–5% loss, moderate dehydration to 6–9%, and severe dehydration to greater than or equal to 10%.[12]

Picture Emma again for a moment. Her weight dropped from 10.9 kg to 10 kg, representing an 8.3% loss, which is consistent with moderate dehydration. However, let's assume you do not have access to her previous weight, which is a common situation in practice. In that case, you would rely on clinical signs such as irritability, dry mucous membranes, slightly delayed capillary refill, tachycardia with normotension and reduced but present urine output. Together, these signs confirm a diagnosis of moderate dehydration. To narrow your estimate within the moderate range, which typically falls between 6% and 9%, you can use your clinical judgment. If the child seems alert, with mildly delayed refill and some urine output, you might estimate closer to 6%. If the child is more irritable or lethargic, with more noticeable signs like sunken eyes and minimal urine, then 8% or 9% is more appropriate. In Emma's case, her symptoms point to about 8% dehydration.

## Clinical Tools for Assessment

To assist clinical providers in determining the degree of hypovolemia, clinical scales have been developed. Designed for children aged one month to five years, the Clinical Dehydration Scale is a validated, four-item scale that assigns scores based on general appearance, eyes, mucous membranes, and presence of tears. It is quick and easy to use, helping to standardize clinical decision-making.[13-15]

The Gorelick Scales are based on clinical signs of dehydration and are also used in children under five, particularly in emergency settings. They demonstrate strong sensitivity for detecting dehydration over 5%.[13,16] These scales have proven useful in developed countries but are less impactful in resource-limited settings.[1]

## Investigations in Dehydration

Investigations including laboratory work are typically performed in children with moderate to severe hypovolemia, as electrolyte and acid-base abnormalities may be present. When evaluating a child with suspected dehydration or hypovolemia, a few key labs can help guide management. These typically include serum electrolytes, blood glucose, blood urea nitrogen, creatinine, and urine studies such as osmolality, specific gravity, and urine sodium.[1]

- Electrolyte abnormalities provide clues not only about why a child is dehydrated, but also about the severity. For example, serum sodium gives insight into the type of dehydration and how urgently it should be corrected, while changes in bicarbonate levels may indirectly reflect the degree of volume depletion.
- A notable elevation in creatinine may signal renal injury.
- An elevated glucose may point towards diabetic ketoacidosis, in which case fluid management may differ.
- On the urine side, concentrated osmolality, elevated specific gravity, or low urine sodium are classic signs of fluid conservation.

One thing has not changed: if you intend to administer intravenous fluids to a child, it is best to draw laboratory tests at the same time to avoid a second needle poke.

Based on Emma's clinical findings, since she appears moderately dehydrated, you decide to order bloodwork to evaluate her electrolytes, kidney function, and acid-base status before initiating rehydration.

## Approach to Fluid Management

When addressing a patient's dehydration, the first step is to determine the degree of dehydration. Based on this, next, decide between oral or intravenous rehydration. Then, choose the appropriate type of fluid, the volume, and the rate at which it should be administered.[2]

Fortunately, guidelines exist to support clinical decision-making at each step. When managing fluid balance, a four-step approach should be prioritized:

1. Restore circulating volume by administering a bolus if necessary.
2. Correct the fluid deficit.
3. Maintain hydration.
4. Replace ongoing losses.

Each step will be addressed individually.

*Restoring Circulating Volume*

Rehydration in patients with mild or moderate dehydration may involve oral rehydration therapy at a rate of 50 mL/kg for mild dehydration or 100 mL/kg for moderate dehydration, administered over a period of 4 hours.[3,9] Oral rehydration solutions like Pedialyte, breast milk, or apple juice diluted with water are great options. Like Goldilocks finding the "just right" porridge, the ideal solution balances water, electrolytes, glucose, and citrate or bicarbonate to perfectly rehydrate.[17] When vomiting is a barrier, adding an anti-emetic like ondansetron can improve the success of oral rehydration.[18]

If a patient with mild or moderate dehydration cannot or will not drink orally, fluids may be given via NG or G-tube. Intravenous therapy should be chosen in cases where the patient may not tolerate enteral fluids. This could include patients with uncontrollable vomiting, altered mental status, or an evolving acute abdomen. Other considerations may include patients with electrolyte abnormalities, who require careful correction, those who are unable to receive oral rehydration therapy, or cases in which oral rehydration therapy cannot be administered safely or effectively.

For patients with severe dehydration, a 20 mL/kg bolus of an isotonic solution should be administered prior to the initiation of maintenance fluids. Since its concentration is approximately equal to that of plasma, it is an effective means of restoring circulating volume, as it can easily distribute across the intravascular and interstitial spaces. Normal saline and Ringer's Lactate are the most common isotonic crystalloids administered in this patient population.[19-21] While earlier recommendations suggested administering fluid boluses over 5 to 15 minutes, current guidelines advise delivering them over a 20-minute period.[3] Repeat boluses may be administered as needed upon reassessment (up to a maximum of 3 fluid boluses). A smaller 10 mL/kg intravenous bolus may also be considered in patients with moderate hypovolemia, depending on the clinical context.[2]

When signs and symptoms of intravascular volume depletion resolve, you may move on to the next step of managing fluid balance: correcting the fluid deficit.

Let's return to Emma's bedside. Her presentation is consistent with moderate dehydration, and you have two options for restoring circulating volume. First, you may attempt oral rehydration therapy at a rate of 100 mL/kg over a period of four hours. For Emma, who weighs 10 kg, this would mean roughly 1,000 mL of oral rehydration solution over four hours. That said, if you feel she might not be able to take that full volume, a 10 mL/kg IV bolus, 100 mL over several minutes, can be given first before transitioning back to oral therapy. As always, clinical judgment is key in deciding the best approach. For the sake of this podcast, we will use the intravenous bolus for the remainder of our calculations.

*Calculating Fluid Deficit*

When calculating fluid deficit, you generally want to use the pre-illness weight to determine how much fluid a patient has lost due to illness.

However, as previously mentioned, parents may not be aware of their child's most recent weight. That is where identifying signs and symptoms associated with each degree of hypovolemia becomes especially useful. If a child is 5% dehydrated, then their fluid deficit is equal to 50 mL/kg. If a child is 10% dehydrated, then their fluid deficit is equal to 100 mL/kg. As a rule of thumb, to determine the fluid deficit in mL/kg, simply multiply the estimated degree of dehydration by ten. To obtain the fluid deficit in total mL, just add a "0" to the estimated percentage of dehydration and multiply by the child's weight in kilograms.[22]

Let's apply this to Emma's case. Given that she has approximately 8% dehydration, we can calculate the fluid deficit in mL/kg by adding a "0" to the dehydration percentage, which gives us 80 mL/kg. Next, multiply this value by Emma's weight in kilograms to determine the total fluid deficit in mL. Since she weighs 10 kg, the fluid deficit would be 800 mL.

*Maintaining Hydration*

When rehydration is complete, maintenance therapy should be started. When a child can meet their hydration requirements enterally, a maintenance oral rehydration solution is used. Typically, 100 mL/kg/day will give you a rough estimate of how much the child would need to maintain hydration.[3] If not able to do this by mouth (i.e., significant reduction in feed volume or just not interested in drinking), then we would start intravenous fluids. Some literature suggests using D5NS + 20 mEq/L of KCl, which is the most commonly used rehydration fluid in the pediatric population.[23,24] The potassium prevents the development of hypokalemia.[23,25] Furthermore, due to their increased risk for hypoglycemia, children, particularly infants and young children, are frequently administered maintenance intravenous fluids with glucose.[26] There are two rules to calculate maintenance fluid requirements: the 100-50-20 rule and the 4-2-1 rule, depending on whether you want to calculate daily or hourly maintenance requirements, respectively.[9,27]

If you choose to use the 100-50-20 rule to calculate maintenance fluid requirements, then the requirements may be obtained as follows:

1. 100 mL/kg/day for the first 10 kg
2. 50 mL/kg/day for the next 10 kg
3. 20 mL/kg/day thereafter

If you choose to use the 4-2-1 rule to calculate maintenance fluid requirements, then the requirements may be obtained as follows:

1. 4 mL/kg/hour for the first 10 kg
2. 2 mL/kg/hour for the next 10 kg
3. 1 mL/kg/hour thereafter

Some children may be fed enterally while also receiving intravenous fluids. Remember to adjust maintenance requirements accordingly.

You could now consider how this applies to Emma. Since she may not be able to meet her hydration requirements enterally, you may choose intravenous rehydration using the calculated maintenance rate. Emma weighs 10 kg, so using either the 100-50-20 or 4-2-1 rule, her maintenance fluid requirement would be 100 mL/kg/day or a rate of 4 mL/kg/hour, respectively. When writing your order, make sure to write it in mL/hr, thus in Emma's case 40 ml/hr.

For additional clarity, let us consider another example. If you have a child weighing 15 kg, you would calculate their hourly fluid requirement using the 4-2-1 rule as follows: 4 mL/kg/hour for the first 10 kg gives you 40 mL/hr, and 2 mL/kg/hour for the next 5 kg gives you 10 mL/hr. Altogether, that results in a maintenance rate of 50 mL/hour.

Alternatively, you may attempt oral hydration at a rate of 100 mL/kg over a period of 24 hours if her clinical status improves, and she is able to tolerate fluids by mouth.

*Total Fluid Prescription*

Now that we have administered fluid boluses, determined fluid deficit, and calculated maintenance fluid requirements, we are ready to figure out the total fluid prescription over the next 24 hours.

Here is how it comes together: Total Fluids (24 hours) = Maintenance + (Deficit – Boluses already given).

This brings us back to Emma's presentation. You already know Emma's fluid deficit is 800 mL, and she has received one 100 mL bolus. You calculated her maintenance fluid requirements to be 1,000 mL per day. Therefore, her daily total fluid prescription would be: 1,000 mL (maintenance) + (800 mL deficit – 100 mL bolus) = 1,700 mL per day, which translates to approximately 71 mL per hour.

*Replacement of Ongoing Losses*

Now that we have restored circulating volume and planned how to replace the current fluid deficit and maintain hydration in the absence of further excessive losses, we must not forget to account for any ongoing excessive fluid losses that may occur. Replace ongoing losses as needed. Consider gastrointestinal losses from ongoing diarrhea or vomiting or other less common sources like NG suction or high-output ostomies. These are typically replaced 1:1 with an intravenous fluid similar in composition to stool, such as ½ NS with 20 mEq KCl per L.[23,28]

## Prevention

You know what is even better than mastering the approach to dehydration? Mastering the approach to the prevention of dehydration. Encourage your patients to drink plenty of fluids, especially when it is hot outside.[17] Children are more susceptible to dehydration due to their higher body surface area-to-mass ratio.[29] Furthermore, children have higher total body water content and increased fluid turnover, which also increases their risk of dehydration.[29,30] When children exercise and sweat, they should drink extra fluids. By replenishing their fluid needs with oral rehydration solutions, they can stay healthy, avoid hospital visits, and keep playing outside with their friends, right where they are meant to be.[17]

## To Summarize

In summary, managing pediatric dehydration involves identifying the degree of dehydration, choosing the appropriate method of rehydration, and calculating fluid needs accurately. Initial rehydration may be oral or intravenous, depending on the severity of symptoms and the child's ability to tolerate fluids. Fluid deficit is estimated based on weight loss or clinical signs, and maintenance needs are calculated using either the 100-50-20 or 4-2-1 rule. Total fluid requirements over 24 hours combine maintenance and deficit, minus any boluses already given. And do not forget to account for ongoing excessive losses. With a structured and thoughtful approach, you can effectively restore hydration and support recovery in pediatric patients.

## Take-home Points

1. Dehydration is a frequent presentation in pediatric patients, often resulting from gastroenteritis.

2. When estimating the degree of hypovolemia, clinicians use two methods that have remained unchanged since their introduction: assessing weight loss and evaluating clinical signs.
3. Restoring circulating volume in patients with mild or moderate dehydration may involve oral rehydration therapy at a rate of 50 mL/kg for mild dehydration or 100 mL/kg for moderate dehydration, administered over a period of 4 hours. You should preferentially opt for intravenous rehydration if the patient presents with severe dehydration or in other specific clinical settings.
4. Fluid resuscitation includes four key steps: restoring circulatory volume, correcting fluid deficit, maintaining hydration, and replacing ongoing losses.

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