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Clinical Decision Tool Reviews

Updated Free Water Deficit in Hypernatremia

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Abstract

Calculates free water deficit using estimated total body water in a patient with hypernatremia and guides the amount of replacement fluids required for treatment.

I. HOW TO USE

When to Use

- This tool is applied to patients with hypernatremia to estimate the volume of free water needed to correct sodium to target levels.
- It is commonly used in the management of hypernatremia in older adults, which is more commonly encountered in older patients and those with impaired thirst or thirst response.
- In patients receiving enteral nutrition (tube feeds), the free water deficit formula can then be used to calculate the additional free water needed beyond routine maintenance flushes to correct the elevated sodium.

Pearls / Pitfalls

- The formula only provides a starting point for fluid prescription and cannot replace frequent monitoring. Monitoring sodium levels at 6-8 hours is essential to reassess sodium levels and adjust fluid administration.
- If intravascular volume depletion is suspected, restore volume with isotonic fluids first before correcting the free water deficit.
- The formula significantly underestimates both total body water (by 1.5-2.5L) and free water losses (by 0.5-1L) in dehydrated patients.
- The formula assumes fixed total body water percentages that may not apply to individual patients, especially with patients with altered body composition. E.g., Total body water is generally lower with older age, obesity, or reduced lean body mass and higher with greater lean body mass. Edematous states may increase total body water but make standard weight-based estimates less reliable.
- It does not account for ongoing hypotonic fluid losses such as from diuresis or gastrointestinal losses.
- It would overestimate the correction in cases where potassium repletion is ongoing.
- When urinary losses are substantial, urinary electrolyte-free water clearance can be estimated using urine volume and urine sodium and potassium concentrations to guide replacement of ongoing losses.

Why Use

- Planning initial fluid therapy for hypernatremia and determining infusion rates of hypotonic fluids to achieve the recommended correction rate of approximately 10-12 mmol/L per 24 hours.

II. NEXT STEPS

Advice

Hypernatremia is typically caused by a deficit of free water relative to sodium, and accurate calculation of the free water deficit is crucial to guide appropriate fluid replacement therapy.

The underlying cause of hypernatremia must be evaluated and addressed. Nursing home residents and patients with prolonged ICU stays are particularly vulnerable because of impaired thirst and dependence on caregivers for water access. Other risk factors include enteral nutrition, fever, loop diuretic use, and osmotic di-

uresis. Work-up for diabetes insipidus would need to be considered in patients with polyuria.

Acute hypernatremia develops in less than 48 hours such as in hospitalized patients. Rapid correction is safe and improves prognosis in acute hypernatremia. Chronic hypernatremia lasts 48 hours or longer, allowing brain cells to adapt by accumulating organic osmoles. There is a risk of cerebral edema if chronic hypernatremia is corrected too quickly.

Current expert advice[3] recommends reducing serum sodium at a maximal rate of **0.5 mmol/L per hour or 10-12 mmol/L per day** for hypernatremia of unknown or prolonged duration to prevent cerebral edema and convulsions. Despite emerging evidence favoring faster correction in many scenarios, the 0.5 mmol/L/h threshold remains the formal expert recommendation pending updated consensus statements from professional societies.

These limits should be considered when selecting the target sodium concentration for calculations.

Management

Sufficient free water should be provided either orally or intravenously to correct the serum sodium by up to 10-12 mmol/L in the first 24 hours.

This can be given in the form of additional free water flushes in patients on tube feeds or as infusions of hypotonic fluids such as 5% Dextrose or 0.45% saline.

Hypotonic fluid given by the enteral (oral or feeding-tube) route is preferred whenever feasible. It allows thirst to help self-regulate, and avoids the glucose/volume complications of IV fluids. Early transition back to oral intake is encouraged as the patient stabilizes.

Use IV fluids when the oral or enteral route is not feasible or has failed. For example, impaired consciousness, inability to swallow or protect the airway, persistent vomiting, ileus, or severe dehydration where oral repletion is too slow.

D5W (electrolyte-free water) is the IV fluid of choice when the deficit is essentially pure water, and the patient is hemodynamically stable e.g., diabetes insipidus, insensible/renal free-water losses. It provides maximal free water per liter with no sodium load. Because it carries a glucose load, monitor for hyperglycemia.

0.45% saline is preferred when there is a combined water-and-sodium (hypotonic-fluid) loss, or a degree of volume depletion, but not enough hemodynamic compromise to require isotonic saline.

Frequent monitoring of serum sodium at 6-8 hour intervals is recommended to adjust therapy.

Critical Actions

Rapid correction of hypernatremia can lead to cerebral edema. If overt neurologic symptoms develop treat as a neurologic emergency with consideration of hypertonic saline to acutely raise serum sodium.

Delayed correction of hypernatremia is associated with increased hospital stay and mortality, making prompt recognition and treatment essential.

III. EVIDENCE

Evidence Appraisal

The formula's derivation stems from the Edelman equation[1], which demonstrates that serum sodium concentration approximates (exchangeable sodium + exchangeable potassium) / total body water. This relationship provides the theoretical foundation for calculating how much free water must be added to restore normal sodium concentration when hypernatremia develops from relative water deficit.

This formula is derived from physiologic modeling and expert consensus and has not been prospectively validated against clinical outcomes. Despite this, it is widely cited and used in nephrology and critical care literature as a bedside decision support tool.

Cheuvront et al. (2013)[2], showed that the traditional free water deficit equation underestimates total body water by 1.5–2.5 L and free water losses by 0.5–1 L in dehydrated individuals and proposed a modified formula using plasma osmolality instead of serum sodium.

Alternative approaches, including the Adrogué–Madias formula[3], have been validated in clinical practice[4] and demonstrated improved accuracy in predicting serum sodium changes with specific infusates.

Comparative validation studies[5] evaluating multiple sodium prediction equations have reported mean differences between predicted and measured serum sodium concentrations of approximately 3.4–4.5 mmol/L, highlighting substantial inter-individual variability across models.

Given the inherent variability in patient response and the practicality required for bedside use, the conventional Free Water Deficit formula remains useful and the widely accepted clinical decision-making tool.

The conventional 10-12 mmol/L/day ceiling for correction of hypernatremia rests almost entirely on expert opinion extrapolated from neonatal data. In contrast, a growing body of adult evidence suggests that persistent or uncorrected hypernatremia is associated with worse outcomes.

In an unselected Mayo cohort of 25,781 patients, failure to correct hypernatremia into the 138–142 mEq/L range by hospital day 3 was independently associated with higher in-hospital mortality (OR 3.01) and 1-year mortality (HR 1.51).

In a MIMIC-III cohort, Chauhan et al. found no difference in 30-day mortality between rapid and slow correction and no cases of cerebral edema attributable to

rapid correction. Feigin et al., in the largest adult cohort to date, found that faster correction was associated with lower mortality and shorter hospitalization, without neurologic complications. Similarly, Pattamin et al.'s MIMIC-IV target-trial emulation associated early rapid correction with lower 30-day mortality (adjusted HR 0.49) and shorter ICU and hospital stays.

A 2025 meta-analysis of 12 studies found no overall mortality difference with correction >0.5 mEq/L/hour (OR 0.68), although faster correction was associated with lower mortality in patients with admission hypernatremia, severe hypernatremia, and correction initiated within 24 hours. No major neurologic complications were identified at rates <1 mEq/L/hour.

Nevertheless, these predominantly observational data or database emulation remain vulnerable to confounding and cannot exclude that slow correction may be a marker for illness severity rather than cause of poor outcomes. An ongoing randomized trial, SALSA II, is designed to compare rapid intermittent bolus versus slow continuous infusion in severe hypernatremia. It extends the methodology of the SALSA trial which found that rapid intermittent bolus therapy for symptomatic hyponatremia had a similar risk of overcorrection but required less therapeutic relowering than continuous infusion.

Overall, current adult evidence challenges rigid adherence to the traditional 10–12 mmol/L/day correction limit and suggests that timely correction may improve outcomes without increasing neurologic harm. However, pending randomized trial data, correction should remain individualized with frequent sodium monitoring to avoid both persistent hypernatremia and excessively rapid shifts.

Formula

Free water deficit, L = (% total body water, fraction)*(Weight, kg)*([Current sodium/Ideal sodium] – 1)

where % total body water (TBW) is:

- Adult male: 60% (i.e., use 0.6 in the equation)
- Adult female: 50% (0.5)
- Elderly male: 50% (0.5)
- Elderly female: 45% (0.45)
- Child: 60% (0.6)

Facts & Figures

Comparison of predicted versus measured serum sodium (sNa) for the four hypernatremia correction formulae evaluated by Lindner et al. (NDT 2008).

Formula	Overall cohort: predicted – measured sNa (mmol/L, mean ± SD)	Hypernatremic days: predicted – measured sNa (mmol/L, mean ± SD)	Direction of error
Adrogué-Madias	+3.4 to +4.5 (±4.4–4.7)	+5.0 to +6.7 (±3.9–4.3)	Overestimates serum sodium rise
Barsoum-Levine	+3.4 to +4.5 (±4.4–4.7)	+5.0 to +6.7 (±3.9–4.3)	Overestimates serum sodium rise
Nguyen-Kurtz	+3.4 to +4.5 (±4.4–4.7)	+5.0 to +6.7 (±3.9–4.3)	Overestimates serum sodium rise
Lindner	−1.5 (±5.3)	+0.2 (±4.0)	Slightly underestimates overall; near-neutral in hypernatremia

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