Chapter 23
Approach to Hypernatremia in the ICU

23.1 Introduction

Hypernatremia, defined as a serum sodium concentration greater than 145 mEq/L, represents a hyperosmolar condition where there is a deficit of free water relative to sodium. This electrolyte imbalance is critical in the ICU due to its association with high morbidity and mortality, particularly in vulnerable populations such as the elderly and those with impaired thirst mechanisms or altered mental status. The clinical management of hypernatremia requires a nuanced understanding of its etiology, the patient's volume status, and the timing of the onset [1, 2] [Ref: Algorithm 23.1].

23.2 Initial Assessment

23.2.1 Differentiate Between Acute and Chronic Hypernatremia

- The initial step in managing hypernatremia is to determine whether the condition is acute (developed within 48 h) or chronic (developed over more than 48 h or timing unknown). Acute hypernatremia poses a greater risk of neurological sequelae due to the brain's inability to adapt quickly to rapid changes in osmolarity. Conversely, chronic hypernatremia allows for some degree of cerebral adaptation, and rapid correction can lead to cerebral edema. Acute hypernatremia may result from recent administration of hypertonic fluids or massive water loss. Chronic cases are often seen in patients with impaired thirst mechanisms or those with long-standing underlying conditions.

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2025

S. B. Mishra et al., *Mastering ICU Care*,
https://doi.org/10.1007/978-981-95-0179-3_23

23.3 Volume Status Assessment

In the context of hypernatremia, assessing the patient's extracellular fluid (ECF) volume is a pivotal step in identifying the underlying cause and guiding treatment.

Increased ECF volume often points toward hypernatremia resulting from excessive sodium intake rather than from water loss. Sodium is an osmotically active ion that drives water retention in the extracellular compartment, which can manifest clinically in several ways:

1. **Positive Fluid Balance**: This is determined by comparing fluid intake and output. A positive fluid balance occurs when fluid intake exceeds fluid losses, resulting in fluid accumulation in the body. In the setting of hypernatremia, a positive fluid balance indicates that the excess sodium intake is causing water retention, leading to expanded ECF volume.
2. **Elevated Jugular Venous Pressure (JVP)**: Elevated JVP is a clinical sign of increased central venous pressure, reflecting fluid overload in the venous system. This can be assessed by observing the height of the venous column in the neck when the patient is positioned at a 45-degree angle. An elevated JVP often correlates with conditions such as heart failure or excessive intravenous sodium administration.
3. **Peripheral Edema**: The presence of swelling, particularly in the lower extremities, is another hallmark of fluid overload. Edema occurs when excess fluid leaks from the capillaries into the interstitial tissues due to elevated hydrostatic pressure in the veins. This is frequently observed in conditions of sodium and water retention.
4. **Ultrasound Findings (VExUS Grade 2–3)**: VExUS, or venous excess ultrasound grading system, is a relatively newer and noninvasive method used to assess fluid overload. A VExUS Grade 2–3 indicates significant venous congestion, seen in major veins such as the inferior vena cava and hepatic veins, which is consistent with a substantial increase in ECF volume. This finding supports the diagnosis of hypernatremia due to excessive sodium administration.

The VExUS (Venous Excess Ultrasound) grading system assesses venous congestion based on Doppler ultrasound findings in the inferior vena cava (IVC), hepatic veins, portal vein, and intrarenal veins. Here's a detailed description of the criteria for classifying congestion into mild, moderate, and severe categories, including relevant numerical cutoffs:

1. **Inferior Vena Cava (IVC) Findings:** If IVC diameter is >2.0 cm, then measure the hepatic vein, portal vein, and intra-renal vein Doppler pattern.
2. **Hepatic Vein Doppler Patterns:**
   - **Mild Congestion:**
     - **Waveform**: Slight reduction in the normal triphasic waveform, with a possible increase in A wave amplitude and a slight decrease in S wave amplitude.

- **Moderate Congestion:**
  - **Waveform**: Biphasic waveform, indicating significant increase in right atrial pressure.
- **Severe Congestion:**
  - **Waveform**: Monophasic waveform or systolic flow reversal, where the S wave is either absent or reversed, indicating critically elevated right atrial pressure.

3. **Portal Vein Doppler Patterns:**
   - **Mild Congestion:**
     - **Pulsatility**: Slight increase in pulsatility, but still predominantly continuous flow (less than 30% pulsatility index).
   - **Moderate Congestion:**
     - **Pulsatility**: Moderate pulsatility, often between 30% and 50% pulsatility index.
   - **Severe Congestion:**
     - **Pulsatility**: High pulsatility, greater than 50%, often with biphasic flow or even flow reversal.
4. **Intrarenal Vein Doppler Patterns:**
   - **Mild Congestion:**
     - **Waveform**: Continuous monophasic flow below the baseline, with minor pulsatility.
   - **Moderate Congestion:**
     - **Waveform**: Interrupted biphasic flow, corresponding to the S and D waves, indicating moderate congestion.
   - **Severe Congestion:**
     - **Waveform**: Discontinuous monophasic flow, often only showing diastolic phase flow, indicating severe congestion.
5. **VExUS Grading Summary:**
   - **VExUS Grade 0 (No Congestion):** Normal findings across all evaluated vessels.
   - **VExUS Grade 1 (Mild Congestion):** Mild congestion findings, indicated by an IVC diameter of more than 2 cm and any combination of normal or mildly abnormal flow patterns.

- **VExUS Grade 2 (Moderate Congestion):** Moderate congestion, indicated by an IVC diameter of more than 2 cm and one severely abnormal flow pattern.
- **VExUS Grade 3 (Severe Congestion):** Severe congestion, indicated by an IVC diameter of more than 2 cm and two or more severely abnormal flow patterns.

Management
Once increased ECF volume is confirmed, the immediate clinical priority is to halt any further sodium administration to prevent exacerbating the hypernatremia and fluid overload. The subsequent management strategy involves:

1. **Cessation of Hypertonic Solutions**: Any ongoing administration of hypertonic sodium solutions (such as hypertonic saline or sodium bicarbonate) should be stopped immediately. Continued administration would only increase the sodium load and worsen the hypernatremia.
2. **Diuretic Therapy**: Diuretics may be employed to promote the excretion of excess sodium and water. The choice of diuretic depends on the patient's overall condition:
   - **Loop diuretics** (e.g., furosemide) are often preferred as they are potent and act quickly by inhibiting sodium and chloride reabsorption in the loop of Henle. This leads to significant sodium and water excretion, which can help reduce both sodium levels and ECF volume.
   - **Thiazidediuretics** can also be considered, especially if the patient has a mild degree of fluid overload and requires a gentler diuretic effect.
3. **Monitoring Electrolyte Levels**: Careful monitoring of serum sodium and other electrolytes is crucial during diuretic therapy to avoid overly rapid changes in sodium levels, which could lead to complications such as cerebral edema. The correction of hypernatremia should be gradual, especially in chronic cases, to avoid iatrogenic harm.
4. **Fluid Management**: In some cases, it may be necessary to administer hypotonic fluids to aid in the correction of hypernatremia. However, this must be done cautiously to avoid rapid shifts in osmolality. Hypotonic fluids help to dilute the sodium concentration, but the infusion rate should be controlled to align with the target sodium correction rate.
5. **Addressing Underlying Causes**: If hypernatremia and increased ECF volume are secondary to underlying conditions such as heart failure or renal dysfunction, these should be concurrently managed. This might include optimizing heart failure therapy, adjusting other medications, or addressing renal insufficiency.
6. **Ongoing Assessment**: Continuous monitoring of the patient's fluid status, including daily weight, fluid balance charts, and regular physical examinations, is essential. Serial measurements of JVP, edema assessment, and repeat ultrasound examinations can help track the effectiveness of the management plan and guide further adjustments.

23.4 Evaluate for Water Loss

In cases where hypernatremia is present without an increase in extracellular fluid (ECF) volume, the condition is typically secondary to water loss rather than sodium gain. Identifying the source of water loss is crucial for accurate diagnosis and effective treatment. Water loss can occur through various mechanisms:

1. **Insensible Losses**: These include losses through the skin and respiratory tract. Increased insensible water loss can occur in conditions such as fever, high environmental temperature, or hyperventilation.
2. **Gastrointestinal Losses**: Diarrhea, vomiting, or the use of osmotic laxatives can lead to significant water loss. Gastrointestinal losses often present with signs of dehydration and can lead to electrolyte imbalances.
3. **Renal Losses**: This includes water loss due to renal pathologies like diabetes insipidus (central or nephrogenic), osmotic diuresis (as seen in uncontrolled diabetes mellitus), or the use of diuretics. These conditions result in the inability of the kidneys to concentrate urine, leading to excessive water loss.

Identifying the source of water loss is essential as it directs the specific management approach. For instance, treating hypernatremia due to insensible losses would differ significantly from managing hypernatremia due to renal causes.

23.5 Clinical Considerations

When evaluating for water loss, a thorough clinical assessment is necessary:

1. **Patient History**: Investigate any history of conditions or factors that could contribute to water loss, such as recent infections, gastrointestinal symptoms, or medication use (e.g., diuretics).
2. **Physical Examination**: Assess signs of dehydration, including dry mucous membranes, decreased skin turgor, tachycardia, and hypotension. These signs can indicate significant fluid loss.
3. **Urine Output**: A critical component of the evaluation is assessing urine output, which can provide insights into the underlying cause of hypernatremia.

23.6 Urine Output and Osmolality Assessment

1. **Assess Urine Output and Osmolarity**

Minimal Urine Output (<0.5 mL/kg/h)

- **Clinical Implication**: Minimal urine output is concerning and often suggests a state of prerenal azotemia, which may result from volume depletion due to

dehydration or renal injury. The kidneys, in response to decreased perfusion, attempt to conserve fluid, leading to reduced urine output.
- **Management**: The primary approach to managing hypernatremia in this context involves cautious fluid replacement. Hypotonic solutions such as 0.45% saline or 5% dextrose in water (D5W) are typically used to correct the free water deficit. The correction rate should be carefully controlled, generally not exceeding 0.5 mEq/L/h, to prevent complications such as cerebral edema. Frequent monitoring of serum sodium levels and patient status is essential to guide the rate of correction.

Urine Osmole Excretion Rate (>750 mOsm/Day)
- **Clinical Implication**: A high urine osmole excretion rate indicates that the kidneys are actively trying to conserve water by concentrating urine. This condition is often seen in osmotic diuresis, where substances like glucose (in uncontrolled diabetes) or mannitol draw water into the urine, leading to high osmolarity and significant water loss. Diuretic use can also lead to high urine osmolarity.
- **Management**: Management in this scenario involves addressing the underlying cause of the osmotic diuresis. For instance, in diabetes mellitus, controlling blood glucose levels is crucial. In the case of diuretic-induced hypernatremia, adjusting or discontinuing the diuretic may be necessary. Fluid replacement should be carefully calculated to replace the free water deficit without causing rapid shifts in sodium levels.

23.7 Urine Osmole Excretion Rate (<750 mOsm/Day)

23.7.1 Renal Response to Desmopressin (DDAVP) in Hypernatremia

Rationale
In patients with hypernatremia and minimal urine output accompanied by low urine osmolality, it is essential to differentiate between central and nephrogenic diabetes insipidus (DI). Both conditions result in the inability to concentrate urine, leading to significant water loss and subsequent hypernatremia. The desmopressin (DDAVP) challenge test is a diagnostic tool used to distinguish between these two forms of DI:

- **Central Diabetes Insipidus (CDI)**: Caused by a deficiency in the production or release of antidiuretic hormone (ADH), also known as vasopressin.
- **Nephrogenic Diabetes Insipidus (NDI)**: Caused by renal resistance to the action of ADH, despite normal or elevated levels of the hormone.

The DDAVP challenge test involves administering desmopressin, a synthetic analogue of ADH, and then measuring urine osmolality before and after the administration. The response of urine osmolality to DDAVP helps to distinguish between CDI and NDI.

Interpretation of the DDAVP Challenge Test

1. **Increased Urine Osmolality (Positive Response to DDAVP):**
   - **Mechanism**: In CDI, the kidneys are still capable of responding to ADH, but there is a deficiency in ADH production or release. When desmopressin is administered, it binds to V2 receptors in the renal collecting ducts, promoting water reabsorption and leading to an increase in urine osmolality.
   - **Clinical Implication**: A significant increase in urine osmolality following DDAVP administration (typically by more than 50%) confirms a diagnosis of central diabetes insipidus.
   - **Management**: Treatment for CDI includes ongoing administration of desmopressin to replace the deficient ADH. Fluid replacement should be carefully monitored to correct hypernatremia without causing rapid shifts in serum sodium levels, which could result in cerebral edema.
2. **Unchanged Urine Osmolality (No Response to DDAVP):**
   - **Mechanism**: In NDI, the kidneys are resistant to the action of ADH due to defects in the V2 receptors, signaling pathways, or aquaporin channels in the renal collecting ducts. Therefore, even when desmopressin is administered, the kidneys are unable to increase water reabsorption, resulting in little to no change in urine osmolality.
   - **Clinical Implication**: A lack of increase in urine osmolality after DDAVP administration indicates nephrogenic diabetes insipidus.
   - **Management**: The treatment of NDI focuses on addressing the underlying cause, which may include discontinuing causative drugs (e.g., lithium, certain antibiotics) or correcting electrolyte imbalances such as hypercalcemia or hypokalemia. Pharmacologic treatments like thiazide diuretics or amiloride may also be employed. Thiazides reduce urine output by promoting mild volume depletion, leading to increased proximal tubule reabsorption of sodium and water. Amiloride is particularly useful in lithium-induced NDI, as it blocks lithium uptake in the renal tubules.

23.8 Hypernatremia in Neurosurgical Patients

Hypernatremia is particularly concerning in neurosurgical patients, where it is an independent predictor of poor outcomes, especially in those with severe elevations of sodium (>160 mmol/L). In such patients, the risk of secondary brain injury increases due to the exacerbation of cerebral ischemia. Hypernatremia in neurosurgical cases requires prompt management, including free-water replacement and addressing any volume abnormalities, to prevent complications such as cerebral edema.

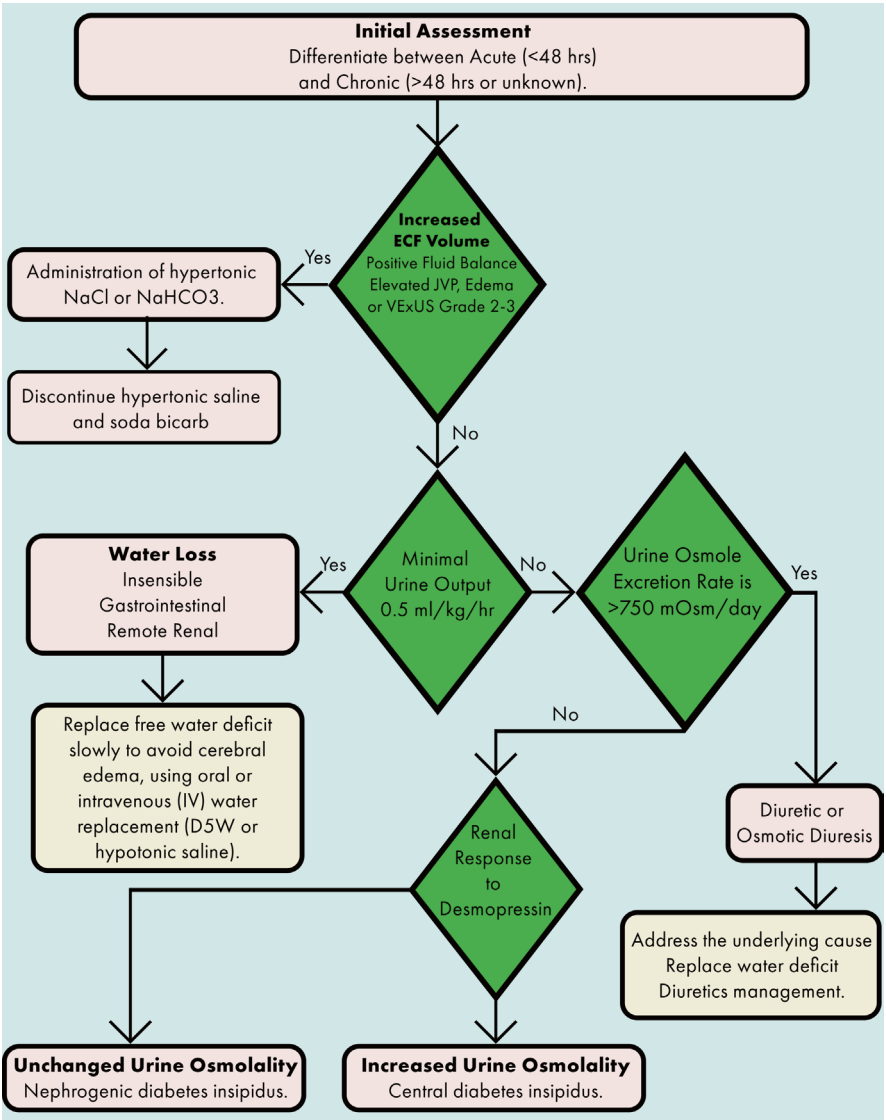
23.9 Monitoring and Preventing Overcorrection

A critical aspect of hypernatremia management is avoiding overcorrection, which can lead to cerebral edema. To prevent this, sodium correction should not exceed 12 mmol/L per day, and diuresis should be carefully monitored. Desmopressin may be used to control rapid water excretion if brisk diuresis occurs during treatment. Regular monitoring of serum sodium, electrolytes, and patient fluid status is essential to ensure safe and effective correction.

23.10 Conclusion

The management of hypernatremia in the ICU requires careful consideration of the patient's volume status, underlying etiology, and the timing of onset. Acute hypernatremia demands prompt but cautious correction to avoid complications, while chronic hypernatremia requires a more gradual approach. By following a structured approach as outlined in this guide, clinicians can effectively address hypernatremia and minimize associated risks.

Algorithm 23.1: Approach to hypernatremia in the ICU



Bibliography

1. Overgaard-Steensen C, Ring T. Clinical review: practical approach to hyponatraemia and hypernatraemia in critically ill patients. Crit Care. 2013;17(1):206.
2. Castle-Kirszbaum M, Kyi M, Wright C, Goldschlager T, Danks RA, Parkin WG. Hyponatraemia and hypernatraemia: disorders of water balance in neurosurgery. Neurosurg Rev. 2021;44(5):2433–58.