Case Studies Exploring Fluid and Electrolyte Imbalance
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Case Studies
1. Choosing the appropriate maintenance fluid
   1. Euvolemic states of AVP excess: Pneumonia
   2. Fluid overload states: Congestive heart failure
   3. Polyuric states: Sickle Cell Anemia
2. Hyponatremia
   1. Acute symptomatic: Post-operative
   2. Chronic: Thiazide diuretics
   3. Central nervous system disease
3. Hypernatremia
   1. Extra-renal losses: Diarrheal dehydration
   2. Decreased oral intake: Cerebral palsy
   3. Central diabetes insipidus

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What are maintenance fluids?
• The amount of solute and water required to replace daily losses
  – Insensible losses: skin, respiratory and GI tract
  – Urinary losses
• The amount and quality of fluids least likely to result in a disorder in hydration or tonicity

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Insensible losses

- 400 cc/m²/d (300 - 800) pediatric
- 600 ml/d adult
- 25% of normal maintenance volume
- Virtually all free water, minimal Na & Cl
- Increases
  - BMR, body temp, activity, ventilation, environmental temp, radiant warmer, phototherapy, burns
- Decreases
  - Body temp, activity, mechanical ventilation

Urinary losses

- 1200 cc/m²/d (400 - 4800) pediatrics
- 1 cc/kg/hr – 1800 cc/d adults
- 75% of normal maintenance volume
- Average urine osmolality
  - 400 mOsm/kg/H₂O (50 - 1200)
  - Each USG of .005 ≈ 150 mOsm/kg/H₂O
- Dependent upon
  - Renal solute load
    - Na + K, Urea
  - Renal concentrating ability
  - Fluid intake

Maintenance fluid requirements

- Pediatrics
  - Daily
    - 100 ml/kg for 1st 10kg
    - 50 ml/kg for next 10kg
    - 20 ml/kg for each >20kg
  - Hourly
    - 4 ml/kg for 1st 10kg
    - 2 ml/kg for next 10kg
    - 1 ml/kg for each kg>20
- Adults
  - ≥2.4 – 2.7 l/d
  - 100 - 110 cc/hr
Case #1: Pneumonia

A 42-year-old business women is attending a convention in Las Vegas and presents to the local ED with a 3d history of fever, chills and productive cough with decreased oral intake.

- WT 65 kg, T 38.5, RR of 42, P 120, BP 112/50.
- Weak and fatigued, bibasilar crackles, mildly dehydrated.
- Chest x-ray BLL pneumonia.
- Blood work is unremarkable.
- The patient is given a 1L bolus of normal saline and feels improved and urinates. She is admitted on continuous IVF and IV antibiotics

What is the most appropriate rate and composition of maintenance IVF?

Non-Hemodynamic Stimuli for AVP Release (0.9% NaCl)

- Central Nervous System
  - Meningitis, encephalitis, brain tumors, head injury
- Pulmonary disease
  - Pneumonia, asthma, bronchiolitis, positive pressure ventilation
- Cancer
- Medications
  - Cytoxan, Vincristine, Morphine, Tegretol, NSAID's, SSRI's
- Nausea, Emesis
- Pain, stress
- Postoperative
  - Orthopedic, ENT
SIADH: Diagnostic Criteria

- Hyponatremia with hypoosmolality
- Urine osmolality less than maximally dilute
  - \( >100 \text{ mOsm/kg/H}_2\text{O} \)
- Urine Sodium excretion increases with salt loading or water loading
- Normal effective circulating volume
  - No edema-forming states
  - Normal blood pressure
- Normal renal function
- Normal adrenal function
- Normal thyroid function

Case #2: Congestive heart failure

- A 72-year-old male with CHF well controlled on low salt diet presents to the local ED with a 3d history of fever, chills and productive cough with decreased oral intake.
- Wt 80 kg, T 38.5, RR of 42, P 120, BP 112/50.
- Bibasilar crackles, mildly dehydrated, without peripheral edema.
- Chest x-ray BLL pneumonia.
- Blood work is unremarkable.
- The patient is given a 1L bolus of normal saline. He is admitted on continuous IVF and IV antibiotics

What is the most appropriate rate and composition of maintenance IVF?

Fluid overload states (Fluid and sodium restriction)

- AKI
  - Acute glomerulonephritis
    -APSGN
    -RPGN
  - Acute tubular necrosis (ATN)
- Edematous states
  - Congestive heart failure
  - Cirrhosis
  - Nephrosis
**Pathophysiology of Edematous States**

- CHF
- Cirrhosis
- Nephrosis

↓ Cardiac output
↓ Peripheral vasodilation
↓ Oncotic pressure

Effective circulating volume depletion

↓ renin angiotensin aldosterone

↑ AVP

↑ Sodium and water retention

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**Case #3: Sickle cell disease**

- A 21-year-old AA college student with SS Dz presents to the local ED with a 3d history of fever, chills and productive cough and is having an acute pain crisis.
- Wt 72 kg, T 38.5, RR of 42, P 120, BP 112/50.
- Bibasilar crackles, mildly dehydrated, without peripheral edema.
- Chest x-ray BLL pneumonia.
- Blood work is unremarkable.
- The patient is given a 1L bolus of normal saline. She is admitted on continuous IVF and IV antibiotics

- What is the most appropriate rate and composition of maintenance IVF?

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**Polyuric States: AVP resistance**

- Nephrogenic diabetes insipidus
- Renal dysplasia
- Obstructive uropathy
- Sickle cell disease
- Recovering ATN
- Post-obstructive diuresis
- Bartter’s syndrome

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Case #4: Postoperative hyponatremia

- A 28-year-old female undergoes an appendectomy.
- Post-op IVF D5 0.45% NaCl @120 ml/hr.
- 12 hrs later she develops headache, nausea and vomiting Rx with Zofran and Dilaudid.
- 24 hr later she is confused and combative. En-route to head CT she suffers a generalized tonic-clonic seizure.
- Biochemistries reveal serum Na 122 mEq/L, K 4 mEq/L, BUN 5 mg/dl, creatinine 0.7 mg/dl, osmolality 238 mOsm/kg H2O, urine osmolality 550 mOsm/kg, urine sodium plus potassium concentration 100 mEq/L.
- How would you manage this?

Pathogenesis of Hyponatremic Encephalopathy

- Children <16 years of age
- Menstruant Women
- Post-operative patients
- Hypoxemia
- Underlying brain edema
Clinical Features of Hyponatremic Encephalopathy

- Headache, nausea, emesis, lethargy
- Respiratory depression, respiratory arrest
- Impaired response to verbal & painful stimuli
- Decorticate and decerebrate posturing
- Obtundation
- Hypertension
- Dilated pupils
- Seizures

Treatment of symptomatic hyponatremia

- 1cc/kg of 3% NaCl (513 mEq/L) will increase SNa by 1 mEq/L
- 2 cc/kg bolus of 3% NaCl (513 mEq/L) over ten minutes. Maximum 100 cc.
- Repeat bolus 1-2 times as needed until symptoms improve.
- Goal: 5-6 mEq/L increase in serum sodium in first 1-2 hrs
- Monitor PNa post bolus or every 2 hours
- Correct PNa until awake and alert (5-10 mEq/L)

Case #5: Thiazide induced hyponatremia

- An 80 yr-old women fell in her home. She is evaluated in the ED and is found to have a hip fracture.
- She was recently started on HCTZ for HTN. She has been on an SSRI for depression following the loss of her husband and is taking NSAID's for pain associated with osteoarthritis.
- Her vitals are stable. She is lethargic and disoriented but otherwise appears well.
- Lab work reveals Na105 mEq/L, K 3.2 mEq/L, total CO2 30 mEq/L, BUN 32 mg/dl, creatinine 1.0 mg/dl, osmolality 215 mOsm/kg. Urine Na 15 mEq/L, K 20 mEq/L, osmolality 250 mOsm/kg
How would you manage this patient?

A. 0.9% NaCl bolus?
B. 3% NaCl bolus?
C. Fluid restriction?
D. Lasix?
E. Mannitol?
F. Vasopressin 2 antagonist?
G. Demeclocyline?

Chronic mild hyponatremia induces an unsteady gait

Figure 1. Mechanism of bone injury from chronic hyponatremia in the elderly.
Follow up

- The patient is given a 100 cc bolus of 3% NaCl and admitted to the floor on 1L oral fluid restriction.
- The thiazide diuretic is discontinued.
- Urine output 500 ml/hr
- Blood work is repeated in 4 hours.
- SNa 115 mEq/L, urine osm 60 mOsm/kg, Urine Na & K < 10 mEq/L
- What now?

Factors Associated with Cerebral Demyelinating Lesions

- Severe chronic hyponatremia (Na < 115 mEq/L)
- Increase in serum sodium to normal or hypernatremia values
- Change in PNa > 25 mmol/L in 48 hrs
- Hypoxic-anoxic episode
- Hepatic encephalopathy
- Thiazide diuretics/ hypokalemia
- Cancer
- Severe Burns

Cerebral Demyelination Diagnosis

- Symptoms develop between 2 -14 days
- Can be asymptomatic
- Confusion
- Quadriplegia
- Pseudobulbar palsy
- Pseudocoma (“locked in” stare)
- Best diagnosed on MRI at > 14 days
Preventing overcorrection of hyponatremia

• Identify patients at high risk for overcorrection
  – $Na \leq 115 \text{ mEq/L}$
  – Patients at risk for a spontaneous free water diuresis
    • Thiazide diuretics
    • Water intoxication
    • DDAVP®-associated hyponatremia
• Avoid excessive administration of 0.9% NaCl or 3% NaCl
• Monitor for a spontaneous free water diuresis
• Consider DDAVP for $Na \leq 115 \text{ mEq/L}$

Case #6: Central nervous system disease

• A 21-yr-old male soldier develops fever, chills and headache, becomes somnolent and unresponsive and is intubated and admitted to the MICU.
• An LP and MRI is suspicious for viral encephalitis.
• Upon admission the $Na = 142 \text{ mEq/L}$. He is placed on 100cc/hr of 0.9% NaCl and 18 hrs later the $Na = 134 \text{ mEq/L}$, osmolality 275 mOsm/kg. Urine Na 255 mEq/L, osmolality 900 mOsm/kg.
• What do you do?

Hyponatremia in La Crosse Encephalitis


- 21% developed hyponatremia $PNa < 132$
- Hyponatremia main factor for deterioration ($P < .007$)
Management of Hyponatremia in CNS Disease

- Begin 3% NaCl continuous infusion to get SNa > 140 mEq/L.
- Titrate infusion of 3% NaCl and 0.9% NaCl to maintain SNa > 140 mEq/L.
- Avoid fluid restriction due to risk of volume depletion.

Treatment of Hypernatremia

- Depends on the etiology
- First restore circulatory collapse
  - Restore extra-cellular volume
- 2nd: Correct free water deficit
- Free water deficit = 4 ml/kg X Wt kg X (Δ Na)
- Rate of correction
  - Oral feeds always preferred
  - 0.5 mEq/hr safe
  - Would not exceed 20 mEq/24 hour
  - Do not overcorrect
  - Maintain mild hyperosmolality Na > 145
Case #7: Diarrheal dehydration

- 6-mo-old 7 kg male presents with a 3 day Hx of fever vomiting and diarrhea.
- Appears 10% dehydrated
- Na 156, K 5.6, TCO2 12, BUN 40, Cr 0.8
- How would you manage the fluids?

Treatment

- Bolus with 50 cc/kg normal saline
- 150cc/kg/24 hour D5 1/2NS (1.5 maint)
  - 100cc/kg/24h maint + 50cc/kg deficit
  - Add 20 mEq/KCL when urine output and K decreasing
- Resume feeds ASAP with oral rehydration solution
- Change to ¼ NS if ongoing losses or sodium not decreasing

Case #8: Neurologic impairment

- 7-yo 25 kg female MRCP tube fed.
- Presents to the PCP with 5 days of fever, cough and irritability.
- Diagnosed with pneumonia and sent home on oral antibiotics.
- Outpatient labs reveal: Na 184, k 3.7, TCO2 16 BUN 60, Cr 1.4 and called to ED.
- Previous outpatient labs with N 145 – 150
- Urine chemistries. Na 40, osm 1150 mOsm/kg
- What do you do?
**Treatment**

- Bolus 20 – 40 cc/kg 0.9%NS
- Resume tube feeds
- Add 2 X 25 = 50 cc/hr free water NG
- Bolus as needed with 0.9%NS
- Adjust free water as needed
- Decrease rate of hydration when SNa < 160

**Case#9: Central diabetes insipidus**

- Same 7-yr, 25 kg female with MRCP and SNa 184
- But???
- Urine Na<10, Urine osm 250 mOsm/kg
- What would you do different?

**Treatment of CDI**

- Bolus with 0.9%NS to expand ECV
- Begin DDAVP
- Assess urinary response
- Maintenance 0.9% NS
- Titrate D5W to control fall in serum sodium
# Management of hypernatremia

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Treatment</th>
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</thead>
<tbody>
<tr>
<td>A. Sodium and water loss</td>
<td>D5 1/2 NS</td>
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<tr>
<td>• Gastroenteritis</td>
<td></td>
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<tr>
<td>A. Primary water loss</td>
<td>D5 1/4 – ½ NS</td>
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<tr>
<td>• Ineffective breast feeding</td>
<td></td>
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<td>• Neurologic impairment</td>
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<tr>
<td>C. Nephrogenic diabetes insipidus</td>
<td>D2.5 1/8 NS (Acute management)</td>
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<tr>
<td>D. Central diabetes insipidus</td>
<td>Desmopressin acetate</td>
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<td>E. Sodium overload</td>
<td>D5 W</td>
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<td>Diuretics or dialysis may be needed</td>
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