Fluids, Electrolytes and Nutrition

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Session Summary

This session will review electrolyte management and common electrolyte disorders to prepare the participant for certification exams.

Session Objectives

Upon completion of this presentation, the participant will be able to:

- discuss impact of gestational and chronologic age on fluid and electrolyte homeostasis;
- list the differential diagnosis for the most common electrolyte imbalances: hypo- and hypernatremia, hypo- and hyperkalemia, and metabolic acidosis and alkalosis;
- calculate sodium and potassium deficit replacement;
- discuss management of the most common electrolyte disorders.

Test Questions

1. You have a 28 wk infant on DOL 2 with reported repeat central K of 7.7 mEq/L. Which management modality is best for removing potassium from body?
   a. Calcium gluconate bolus
   b. Furosemide q12h
   c. Glucose bolus followed by insulin infusion

2. The chemistry panel on admission of a 25 weeker showed the following: Na 130, K 4.2, Ca 8.8. The resident wants to add NaCl to the IVF. What do you think?
   a. Add maintenance sodium because apparently his kidneys are losing the sodium
   b. Do nothing
   c. Repeat the lab because you do not believe it

3. You have studied hard preparing for you NCC exam and know that which of the following will increase with advancing gestational age?
   a. Extracellular fluid
   b. Intracellular fluid
   c. Total body water
4. You have a term infant with hypoxic-ischemic encephalopathy who is 36 hr old and undergoing head cooling. The morning labs reflect a serum Na of 121 and it was reported the infant is up 130 gm overnight. The total fluids of D10 TPN were ordered for 60 ml/kg/day but the infant did require PRBC transfusion and normal saline boluses x 2, placing actual fluids for the 24hr at 100 ml/kg/day. The infant’s urinary output was 0.8 ml/kg/hr. The most likely diagnosis for this infant is:
   a. Dilutional hyponatremia
   b. Inadequate sodium supplementation
   c. Syndrome of inappropriate antidiuretic hormone

5. You have a 36 wk late preterm infant who is 5 days old and has weaned off IVF overnight while the mother was exclusively breast feeding the infant. The labs this AM show a serum Na of 156 as well as an elevated serum osmolality. The infant’s weight is down 40 gram. The attending ordered urine osmolality which was reported as significantly low. The most likely diagnosis for this infant is:
   a. Diabetes insipidus
   b. Fluid deficit (dehydration)
   c. Syndrome of inappropriate antidiuretic hormone

6. A 32-week, DOL2 infant with overwhelming sepsis and hypotension has a metabolic acidosis on this AM’s labs. The morning labs reflect: Na 141, K 3.2, Cl 106, and CO2 16. Calculating the anion gap, how would you classify this metabolic acidosis?
   a. Metabolic acidosis with increased anion gap
   b. Metabolic acidosis with low anion gap
   c. Metabolic acidosis with normal anion gap

**References**


**Session Outline**

See presentation handout on the following pages.
Fluids, Electrolytes and Nutrition

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Body fluid composition

TBW = ECF + ICF

Normal Physiologic Weight Loss
- Normal changes
  - Decreased TBW -> increased ICF and decreased ECF
- Term Infants
  - Lose up to 5-10% of birth weight in 1st five days
- Preterm Infants
  - Lose up to 15-20% of birth weight
Renal Water Loss

- Will discuss more in depth in renal session
- Preterm infants have immature Na and water homeostasis due to:
  - Decreased glomerular filtration rate
  - Reduced proximal/distal tubule reabsorption
  - Ability to concentrate urine reduced
  - Decreased bicarbonate, potassium and hydrogen ion secretion
- Renal function matures with age

Cloherty, Eichenwald, Hansen & Stark, 2012

Insensible Water Loss

- Evaporation of non-measurable water losses
- Major routes
  - Skin – up to 70%
  - Respiratory tract – up to 30%

Factors Affecting Insensible Water Loss

- Increased IWL
  - Decreasing gestational age and/or birthweight
  - Increased environmental temperature above NTE or body temperature
  - Skin breakdown
  - Congenital skin defect, such as large omphalocele, gastroschisis, neural tube defects or epidermolysis bullosa
  - Radiant warmer
  - Phototherapy (controversial)

Factors Affecting Insensible Water Loss

- Decreased IWL
  - Humidity
  - Use of plastic heat shield or double-walled isolette
Endocrine Control of Water Metabolism

- Antidiuretic hormone (ADH) or arginine vasopressin
  - Syndrome of inappropriate ADH secretion (SIADH)
  - Nephrogenic diabetes insipidus (DI)

SIADH

- Etiology
  - Perinatal depression, IVH, PPV, sepsis, hypotension, meningitis, pneumothorax, pain
- Clinical findings
  - Weight gain, hyponatremia, decreased urine output, increased urine osmolality, decreased plasma osmolality
- Treatment
  - Free water restriction, NaCl replacement, Lasix therapy

Nephrogenic Diabetes Insipidus (NDI)

- Etiology
  - Insensitivity of renal tubule to ADH, congenital defects, secondary causes
- Clinical findings
  - Increased Na hypotonic urine, serum hypertonicity, increased Ca, decreased K
- Treatment
  - Hydrate, electrolyte replacement, diuretic therapy (thiazides)
Monitoring Fluid Balance

- History
- Physical exam
- Weight
- Intake and output
- Lab monitoring
- Physiologic/environmental factors, i.e. humidity in isolette

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Case Study

- 24 week, DOL 3
- BW 580 gm, current weight 470 gm
- Isolette with 70% humidity, double phototx
- TF (TPN): 115 ml/kg/day
- UOP: 1.8 ml/kg/hr
- Labs: Na 151, BUN 31, Creatinine 0.6
- What do you think?

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Phases of Fluid Management

- Initial fluid management
  - Prevent shock and hypoglycemia
- Prediuretic phase
  - Consider body weight, serum Na and urine output
- Diuretic phase
  - Prone to hypernatremia
- Post diuretic phase (maintenance)
  - Increase TF, consider nutritional needs
Maintenance Fluid Requirements

<table>
<thead>
<tr>
<th>Birthweight (gm)</th>
<th>IWL (ml/kg/day)</th>
<th>DOL 1-2</th>
<th>DOL 3-7</th>
<th>DOL 8-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;750</td>
<td>100+</td>
<td>100-200</td>
<td>120-200</td>
<td>120-180</td>
</tr>
<tr>
<td>750-1000</td>
<td>60-70</td>
<td>80-150</td>
<td>100-150</td>
<td>120-180</td>
</tr>
<tr>
<td>1001-1500</td>
<td>30-65</td>
<td>60-100</td>
<td>80-150</td>
<td>120-180</td>
</tr>
<tr>
<td>&gt;1500</td>
<td>15-30</td>
<td>60-80</td>
<td>100-150</td>
<td>120-180</td>
</tr>
</tbody>
</table>

TF = IWL + sensible water loss + growth

Affect of Common Disease States on FEN Management

- **HIE**
  - Restrict fluid to <60ml/kg/day
  - Avoid fluid overload, potentially worsening cerebral edema
  - Initially, limit K and during recovery, need to replace Na
- **RDS**
  - Individualize fluids

- **PDA**
  - Avoid fluid overload?
  - Be careful with pharmacologic therapy and impact on renal function
- **CLD**
  - Avoid fluid overload
    - Balance fluid needs and increased caloric needs
  - Be careful with diuretic therapy
    - Watch for lyte abnormalities, screen for osteopenia

- **Abdominal wall defects**
  - Need increased TF secondary to IWL
- **S/P abdominal surgery**
  - Increase TF d/t third spacing
  - With third spacing, intravascular fluid leaks into tissue and bowel wall lumen
Electrolyte Content of Body Fluids

<table>
<thead>
<tr>
<th>Fluid Source</th>
<th>Na⁺ (mmol/L)</th>
<th>K⁺ (mmol/L)</th>
<th>Cl⁻ (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bile</td>
<td>120-140</td>
<td>5-15</td>
<td>90-120</td>
</tr>
<tr>
<td>Diarrheal stool</td>
<td>10-90</td>
<td>10-80</td>
<td>10-110</td>
</tr>
<tr>
<td>Ileostomy</td>
<td>45-135</td>
<td>3-15</td>
<td>20-120</td>
</tr>
<tr>
<td>Small intestine</td>
<td>100-140</td>
<td>5-15</td>
<td>90-120</td>
</tr>
<tr>
<td>Stomach</td>
<td>20-80</td>
<td>5-20</td>
<td>100-150</td>
</tr>
</tbody>
</table>

Adapted from Fanaroff & Martin, 2011

BMP

- Na
- Cl
- BUN
- Ca
- K
- CO2
- Creatinine
- Glucose

Normal serum values:
- Na: 135-145
- Cl: 97-110
- BUN: 3-25
- K: 3.5-5.5
- CO2: 20-28
- Creatinine: 0.3-1
Sodium

- Main extracellular cation
- Normal requirements
  - Initial phase: 0-1 mEq/kg/day
  - Prediuretic phase: 2-3 mEq/kg/day
  - Post diuretic phase: 3-5 mEq/kg/day

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Hyponatremia

- Serum Na < 130 mEq/L
- DDx
  - Factitious
  - Normal ECF
    - Excessive fluid administration (dilutional), Syndrome of inappropriate antidiuretic hormone (SIADH)
  - Inadequate sodium intake

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Hyponatremia

- DDx (continued)
  - ECF excess (hypervolemia)
    - CHF, sepsis, renal or liver failure, NEC (late)
  - ECF deficit (hypovolemia)
    - Renal losses
    - GI losses, 3rd spacing of fluids
  - Medication related
    - Neuromuscular paralysis, indomethacin therapy, diuretic therapy

http://www.austincc.edu/apreview/EmphasisItems/ElectrolyteFluidBalance.html
Hyponatremia

- **Diagnostic evaluation**
  - History and physical
  - Weight pattern
  - Total intake and output
  - Lab studies
    - Serum sodium and osmolarity
    - Random urine for sodium, osmolality and specific gravity
    - \( ? \) CMP to assess renal function
    - \( ? \) Imaging

- **Etiology Clinical Findings**

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Clinical Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal losses</td>
<td>Decreased weight</td>
</tr>
<tr>
<td></td>
<td>Increased urine Na and volume</td>
</tr>
<tr>
<td></td>
<td>Decreased urine osmo and specific gravity</td>
</tr>
<tr>
<td>Extrarenal losses</td>
<td>Decreased weight</td>
</tr>
<tr>
<td></td>
<td>Decreased urine Na and volume</td>
</tr>
<tr>
<td></td>
<td>Increased urine osmo and specific gravity</td>
</tr>
<tr>
<td>Other causes</td>
<td>Increased or normal weight</td>
</tr>
<tr>
<td>(SIADH, CHF, renal failure, excess water infusion, cirrhosis, nephrotic syndrome)</td>
<td>Decreased urine Na and volume (except if SIADH or water excess, urine Na may be increased or normal)</td>
</tr>
</tbody>
</table>

Hyponatremia + increased weight gain

<table>
<thead>
<tr>
<th>SIADH</th>
<th>Volume overload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased UOP</td>
<td>Increased UOP</td>
</tr>
<tr>
<td>High urine osmo</td>
<td>Low urine osmo</td>
</tr>
</tbody>
</table>

Hyponatremia Management

- **Symptomatic hyponatremia is medical emergency**
  - 3% Hypertonic sodium chloride
  - 1-3 ml/kg over 15 minutes, followed by 1-2 ml/kg/hr until Na > 120 mmol/L; other sources state 6 ml/kg over 6 hr
  - Monitor closely for fluid overload and pulmonary edema
Hyponatremia Management

- Asymptomatic hyponatremia management is based on underlying cause
  - Replace deficit – don’t forget to include maintenance needs
    - Inadequate Na intake
    - Medication related – only need to increase Na needed
  - Restrict fluids
    - SIADH and volume overload

Hyponatremia Management

- Calculating Na deficit
  \[(CD - CA) \times Vd \times Kg = \text{mEq required}\]
- Let’s practice – 1.5 kg infant with a Na 120
  \[(130 - 120) \times 0.6 \times 1.5 = 9 \text{ mEq}\]
- Remember, this only corrects the deficit
- Must replace slowly for risk of neuro damage!

Hyponatremia

- Serum Na ≥ 150 mEq/L
- DDx
  - Hypovolemia/dehydration (decreased ECW)
  - Excess sodium intake (increased ECW)
  - Medication related

Hyponatremia

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<tr>
<td>Renal losses</td>
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<td>Increased urine Na and volume</td>
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<td></td>
<td>Decreased specific gravity</td>
</tr>
<tr>
<td>Extrarenal losses</td>
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</tr>
<tr>
<td></td>
<td>Decreased urine Na and volume</td>
</tr>
<tr>
<td></td>
<td>Increased specific gravity</td>
</tr>
<tr>
<td>Other causes</td>
<td>Increased weight</td>
</tr>
<tr>
<td>(Exogenous Na,</td>
<td>Relatedly decreased urine Na and volume</td>
</tr>
<tr>
<td>mineralocorticoid</td>
<td>Relatively increased specific gravity</td>
</tr>
<tr>
<td>excess, hyperaldosteronism)</td>
<td></td>
</tr>
</tbody>
</table>
**Hypernatremia Management**

- Management based on underlying cause
- If due to excess Na intake, remove or decrease Na, consider diuretic therapy
- If hypovolemia/dehydration, replace water deficit slowly
  - Serum Na should decrease no more than 0.5 mEq/L/kg/hr
  - Target correction over 12-48hr period

**Potassium**

- Main intracellular cation
  - Role: maintain normal cardiac rhythm, skeletal muscle contraction, acid-base balance, and transmission/conduction of nerve impulses
- Normal requirements
  - Added once good UOP is established
  - Initial phase: None
  - Pre-diuretic phase: 1-2 mEq/kg/day
  - Post diuretic phase: 2-3 mEq/kg/day

**Hypokalemia**

- Serum K < 3 mEq/L
- DDx
  - Decreased intake
  - Renal losses
  - GI losses
  - Medication related
    - ***Most common cause in NICU setting***
  - Metabolic alkalosis
  - Endocrinopathies

**Diagnostic evaluation**

- Physical exam
- Lab studies
  - Repeat central potassium level
  - Random urine for electrolytes
  - CMP with serum Mag
  - Blood gas
  - Endocrine studies, serum insulin and C-peptide
  - Imaging/Diagnostic studies
    - Abdominal x-ray, head MRI
    - EKG
Hypokalemia

<table>
<thead>
<tr>
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<tr>
<td>Decreased K stores</td>
<td>Increased urine K</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
</tr>
<tr>
<td>Decreased K stores Normal BP – Renal causes</td>
<td>Increased urine K</td>
</tr>
<tr>
<td>Decreased K stores Normal BP – Extrarenal causes</td>
<td>Decreased urine K</td>
</tr>
<tr>
<td>Normal K stores</td>
<td>Increased urine K</td>
</tr>
</tbody>
</table>

Hypokalemia Management

- Management based on underlying cause
- Emergency correction: 0.5-1 mEq/kg/dose over 30-60 min minimum
- If symptomatic but not life threatening, correction given over 12-24hr to allow slow normalization of serum levels
- Too large or rapid of bolus may cause cardiac arrest

Calculating K deficit

\[(CD - CA) \times Vd \times Kg = \text{mEq required}\]

Let's practice – 1.5 kg infant with a K 2.8

\[(4.0-2.8) \times 0.3 \times 1.5 = 0.54 \text{ mEq}\]

Remember, this only corrects the deficit

Hyperkalemia

- Central serum K > 6.5 mEq/L
- CHECK for ECG changes
- DDx
  - Factitious
    - Lab error, traumatic heel stick (hemolysis)
  - Increased K+ load
    - Iatrogenic (excess supplementation); tissue destruction, bleeding or hemolysis; PRBC or exchange transfusion
  - Decreased K+ removal or excretion
    - Acute renal failure (ARF), Congenital adrenal hyperplasia (CAH), immature renal function in ELBW (especially 1st 48 hr)/preterms
Hyperkalemia

- Diagnostic evaluation
  - Physical exam
  - Lab studies
    - Venous serum sample
    - Serum and urine electrolytes
    - Endocrine studies
  - EKG

### Etiology Clinical Findings

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<tr>
<td>Increased K stores</td>
<td>Increased urine K</td>
</tr>
<tr>
<td>Increased K stores</td>
<td>Decreased urine K</td>
</tr>
<tr>
<td>Normal K stores</td>
<td>Normal urine K</td>
</tr>
</tbody>
</table>

Hyperkalemia Management

- Hyperkalemia with EKG changes is a medical emergency

  1. 10% Calcium gluconate
     - 100 mg/kg/dose over 10-15 min, preferably central line
  2. NaBicarb
     - 1-2 mEq/kg/dose over 10-30 min
  3. Insulin/glucose (D10W) infusion
     - D10W 2-3 ml/kg IV push
     - 0.05-0.1 U/kg bolus, the continuous insulin infusion
  4. Albuterol
     - 0.1-0.5 mg/kg/dose

Hyperkalemia Management

- Hyperkalemia with EKG changes is a medical emergency
  - Furosemide
    - 2 mg/kg/dose q12h IV or 4 mg/kg/dose q12h po
  - **Kayexelate-cation exchange resin (should not be used in ELBW)**
    - 1 gm/kg intrarectally q6h
  - **Dialysis/exchange transfusion**
- **last resort**

Hyperkalemia Management

- Hyperkalemia without EKG changes
  - Remove all K+ from IVF and/or discontinue supplementation
  - Keep Ca and Mag levels in normal ranges
  - Correct acidosis
  - Ensure adequate fluid intake
  - Consider Lasix

**Putting it all together**

<table>
<thead>
<tr>
<th>Prevent effects on cardiac muscle</th>
<th>Shift K back into cell</th>
<th>Remove K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca Gluonate</td>
<td>Sodium bicarbonate/THAM</td>
<td>Lasix</td>
</tr>
<tr>
<td>Gluc/insulin infusion</td>
<td></td>
<td>Kayexelate</td>
</tr>
<tr>
<td>Albuterol</td>
<td></td>
<td>Exchange transfusion</td>
</tr>
</tbody>
</table>

Chloride

- Extracellular anion
- Normal serum values: 98-113 mEq/L
Hypochloremia

- Serum Cl < 98 meq/L
- DDx
  - Decreased intake
  - Chloride losses

Hyperchloremia

- Serum chloride > 110 mEq/L
- Uncommon in newborn period
- DDx
  - Excessive intake

Serum CO2

- Measure of blood bicarbonate level
- Low serum CO2 – metabolic acidosis
- High serum CO2 – metabolic alkalosis

Minerals/Salts

- Calcium, magnesium and phosphorous – see endocrine/metabolic lecture
Acid-Base Balance

- Extracellular pH: 7.34 – 7.45
- Also review ventilation lecture

Acute Compensation

- Maintained by intracellular and extracellular buffers

Chronic Compensation

- Balance between intake/production and metabolism/excretion of acid

Metabolic Acidosis

- Anion gap (mEq/L) = (Na) – ([Cl-] + [HCO3-])
- Normal range: 8-15
  - Up to 18 in preterm

http://www.austincc.edu/apreview/EmphasisItems/Electrolyte-fluid-balance.html
Metabolic Acidosis

- With normal anion gap (increased Cl-)
  - Renal causes, increased GI losses (diarrhea, ileal drainage), HAL, meds
- With increased anion gap (normal Cl-)
  - Lactic acidosis, ARF, IEM
- With low anion gap
  - Rare

Metabolic Alkalosis

- Etiologies
  - With low urine chloride (< 10 mEq/L)
  - With high urine chloride (> 20 mEq/L)
  - Hypochloremic metabolic alkalosis probably one of the most common disorders seen due to diuretic therapy
Metabolic Alkalosis

- Management
  - If mild – moderate, may not require therapy
  - Treat underlying cause
  - Adjust or discontinue alkali solutions
  - Assess whether diuretic dose can be decreased or held temporarily; consider changing to chronic diuretic therapy if on furosemide therapy

Nutrition General Principles

- Goal = provide adequate calories to promote growth
- Calories should be from non-protein calories
- Factors that affect growth
  - Gestational age, weight, thermal environment, activity, disease process
- Preterm goal: 110-140 kcal/kg/day for growth

Caloric Intake

<table>
<thead>
<tr>
<th>Parenteral (TPN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal: provide adequate caloric intake and nutrients for growth</td>
</tr>
<tr>
<td>CHO : dextrose</td>
</tr>
<tr>
<td>Proteins: amino acids (Trophamine)</td>
</tr>
<tr>
<td>Fats: 20% Intralipids</td>
</tr>
<tr>
<td>Trace elements</td>
</tr>
<tr>
<td>Multivitamins</td>
</tr>
<tr>
<td>Electrolytes: Na and K (mEq/kg/day) + salt</td>
</tr>
<tr>
<td>Macro Minerals (Mg and Ca)</td>
</tr>
</tbody>
</table>
Calculating Calories (kcal/day)

- **CHO**
  - Dextrose: (ml/day of IVF) x (3.4cal/g) x (% dextrose)
  - Feeds: (ml/day of feeds) x (amount kcal/oz)
    - Example 20cal/30ml or 24cal/30ml

- **Fats**
  - 20% IL: (ml/day of IL) x (2kcal/ml)

- **Protein**
  - Gm/kg/day amino acid (AA): (g/day of AA) x (4kcal/g)

Questions???