Fluid And Electrolyte Management
For Sick Kids©

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Program Handouts

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Objectives

- Review concepts of fluid movement and electrolyte control
- Assessment and clinical presentations of fluid volume deficit & overload
- Electrolyte imbalances: causes and management
- Case Studies

Mechanisms Controlling Fluid and Electrolyte Movement

**Diffusion**
- Movement of molecules from an area of high concentration to low concentration
- Electrolytes move easily

**Osmosis**
- Movement of water between two compartments by a semipermeable membrane.
- Osmosis is the major force in body fluid movement.

Question...

- Sam is a 12 year old in septic shock. He has a low to normal BP with the use of Dopamine and volume. Despite therapy he has severe third spacing. What would help with his blood pressure support but ALSO provide some diuresis for the third spacing?  
  - Albumin

**Body Water**

65-80% of body weight is Water

**Intracellular (ICF)**
- Fluid located within cells
- Largest component (2/3): 42% of body weight
- Most stable, fairly resistant to major fluid shifts

**Extracellular (ECF)**
- Consists of interstitial fluid, plasma, and transcellular water
- Reserve fluid
- Replaces either fluid in vessels or cells.

Mechanisms Controlling Fluid and Electrolyte Movement

**Osmotic Pressure**
- Pulling force exerted by colloids in a solution.
- Plasma proteins stay within the vessel and draw fluid towards them.
- Water will move from less concentrated to more concentrated side.
**Albumin**
- Major plasma protein
- Increased albumin concentration results in fluid moving back into the capillaries from the interstitial space
- Decreased albumin concentrations result in fluid leaking into the interstitial space

**Movement of Fluid between Compartments**
- **Hydrostatic pressure** and osmotic pressure regulate the movement of water and electrolytes from one compartment to another.

**Osmolality and Osmolarity**
- Refers to the concentration of a solution which creates its osmotic pressure.
- Serum Osmo is the concentration of particles in the plasma.
  - Normal Serum Osmo: 275–295 mOsm/L

**IV Fluids and their Influences**
- **Isotonic**
  - Equal osmolality as plasma
  - It has no pulling effects (no osmotic pressure)
  - Great for expanding the vascular volume quickly (increase BP)
  - Examples:
    - Normal Saline (sodium and chloride)
    - Lactated Ringers (sodium, chloride, potassium, calcium, and lactate)

- **Hypotonic**
  - Has a lower osmolality than plasma
  - Water is pulled out of vessels into cells.
  - Contraindicated in acute brain injuries—will increase cerebral edema
  - Examples:
    - D5W
    - 0.45% and 0.225% Normal Saline
    - D5 with normal saline
Hypertonic

- Has a higher osmolality than plasma
- Water is pulled from the cells into the vessels.
- Specific situations of use and requires careful control of sodium and serum osmo's.
  - Intracranial hypertension
- Examples:
  - 3% Saline

Question

- A 16 year old is in the ICU 12 hours after a bicycle collision. His CT is negative for bleeding but he remains obtunded and being observed.
- What IV fluids would be dangerous for this client?
  - Hypotonic fluids (D5W)
- Why?
  - Cerebral cells will absorb free water and cause increase in cerebral edema.

Regulation of Fluid Balance

- Water homeostasis results from the balance between water intake and the combined water loss from renal excretion, respiratory, skin, and GI sources.

Maintenance Fluids

- Maintenance fluid is the volume of daily fluid intake which
  - replaces the insensible losses (from breathing, through the skin, and in the stool).
  - allows excretion of the daily production of excess solute load (urea, creatinine, electrolytes etc) in a volume of urine that is of an osmolarity similar to plasma.
- A child’s maintenance fluid requirement decreases proportionately with increasing age (and weight).

Maintenance Fluid Requirements

- Newborn 0 - 72 hrs old
  - 60-100 mL/kg/day
- 0 - 10 kg
  - 100-150 mL/kg/day
- 11 - 20 kg
  - 1000 mL for 1st 10kg + 50mL/kg for each kg > 10kg
- 21 - 30 kg
  - 1500 mL for 1st 20kg + 25mL/kg for each kg > 20kg

Thoughts about Kids...

- The kidneys of an infant or child are functionally immature as compared to the adolescent or adult kidney.
- At this stage of life, the kidney is unable to concentrate or dilute urine. The kidney cannot conserve or excrete sodium or acidify urine.
- The kidneys of an infant or child are less efficient at excreting the metabolic wastes of metabolism. Therefore, the pediatric patient is less able to handle large amounts of solute.
Chemical Regulation of Water

- **Antidiuretic hormone (ADH)** from the posterior pituitary gland causes a **reduction** in the amount of water lost in the urine.

More on ADH

- When drinking adequate water, the ADH mechanism is inhibited, and more water is expelled in the urine. ADH is inhibited with a serum osmolality of <280 mmoL.
- Osmotic changes also stimulate the thirst mechanism:
  - A 5-10% blood volume reduction can stimulate the release of ADH.
  - Catecholamines and angiotensin II can modulate the release of ADH.

Example:

- **Diabetes Insipidus:**
  - Deficiency of ADH due to failed synthesis or secretion by the posterior pituitary or both.
  - Results from pituitary and suprasellar surgery, head trauma, cerebral edema, CNS infections.
  - In DI, ADH is deficient and you begin to have no inhibition to water loss. Urine output is excessive (10 mL/kg/hr).

More Examples!

- **Syndrome of Inappropriate ADH:**
  - is a disorder of the body’s inability to secrete water.
  - Excessive amounts of ADH can be secreted in response to stimuli such as pulmonary disease, CHF, increased LAP, PPV, chemo etc.
  - Conditions associated with SIADH:
    - Meningitis
    - Head trauma
    - Cerebral tumors
    - Cerebral hemorrhage
  - So with SIADH, too much ADH is around and you conserve water. There is a decrease in urine output (<0.5 mL/kg/hr).

So What does this have to do with Electrolytes??

- As your serum osmolality changes, so do your electrolyte balances.
- Sodium fluctuations in DI and SIADH can be severe.
  - DI causes increased serum osmo and increased serum sodium
  - SIADH causes decreased serum osmo and decreased serum sodium
- When there are dramatic changes in sodium levels, the brain tries to adapt to maintain fluid balance.
Aldosterone Regulation of Sodium and Water

- $K^+$
- $Na^+$
- Blood Volume
- Cardiac Output
- Blood Pressure

- $\uparrow$ Renin

\[ \text{Conversion of Angiotensin I to Angiotensin II in the lungs} \]

\[ \text{Secretion of aldosterone in the adrenal cortex} \]

Questions

Infants and children have a higher metabolic rate:

a. to support rapid growth
b. because they are smaller
c. due to the higher heart rate
d. due to higher activity levels

Questions:

Infants and small children are at greater risk of dehydration for which of the following reasons

a. they are smaller than adults
b. they have a larger extracellular fluid compartment, immature kidneys, and higher basal metabolic rate.
c. the intracellular compartment is larger
d. they are fed more frequently, thus more dependent on the fluid

Questions:

The immature pediatric kidney is unable to do which of the following:

a. handle large amounts of solute
b. concentrate or dilute urine
c. acidify urine
d. all of the above

So what about those electrolytes?
### Sodium Imbalance

**Imbalance**: (135-145 mEq/L) (Life threatening <120 or >160 mEq/L)

**For water balance and neuromuscular membrane excitability**

**Causes**
- Diuresis
- GI losses
- Starvation
- Hyperglycemia
- Diabetes insipidus
- Diabetic ketoacidosis
- Renal disease
- Paralysis, hyporeflexia
- Cramping, stiffness
- Tetany
- Irritability
- Lethargy
- Hypotension
- Muscle weakness, paralysis
- Coma
- Lethargy/confusion

**Critical ECG findings**
- Flattened, inverted T waves
- P waves
- Widened QRS

**Management**
- Monitor Na levels
- Treat underlying cause
- Frequent neuro assessments
- Fluid replacement
- Monitor Na levels
- Intense thirst
- Muscle twitching
- Muscle weakness
- Coma
- Lethargy/confusion

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### Potassium Imbalance

**Imbalance**: (3.5-4.5 mEq/L)

**Critical for electrical conduction of nerve impulses; particularly cardiac electrical conduction**

**Causes**
- Hemolysis
- Burns
- Adrenal failure/failure
- Water intake
- Heart failure
- SIADH
- DKA & hypoxia
- Burns & wounds
- Fever
- Excessive Na intake

**Clinical S&Ss**
- Muscle weakness
- Paralysis
- Hyperreflexia
- Apnea
- Confusion
- Disorientation
- Lethargy
- Muscle cramps

**ECG Findings**
- Flattened, inverted T waves
- P waves
- Widened QRS
- Asystole
- Ventricular fibrillation

**Management**
- Monitor serum K levels
- Monitor Na levels
- Check acid base status
- Monitor ECG
- Monitor neuro status
- Monitor fluid status
- Monitor intake/ output
- Monitor liver function tests
- Monitor renal function tests

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### Table: Electrolyte Imbalance

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<td>Hypokalemia</td>
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<td>Paralysis, hyporeflexia</td>
<td>Flattened, inverted T waves, absence of P waves, JVPs</td>
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<td>Monitor serum K levels, fluid status, monitor ECG, monitor neuro status, K replacement, administer IV fluids</td>
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**Teleconference Series**

March 6, 2008

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Nursing Grand Rounds
Calcium (iCa 1.15-1.34)

Required for normal skeletal muscle, smooth muscle and cardiac muscle contraction. Also needed for blood clotting.

Magnesium (1.3-2.2 mEq/L)

Needed to prevent overexcitability of muscles

Assessment: Volume status

- Intake? PO/DNS? IVF?
- Output? Urine? Stool? Gastric? Drains?
- Level of Activity/Consciousness?
- Heart rate, rhythm, blood pressure?
- Respiratory rate and quality?

Assessment: Volume Overload

- Weight gain
- Edema
- Dyspnea, crackles and/or wheezing
- Jugular vein distension
- Increased pulse pressure
- Hypertension
- S3 gallop
- Full/bulging fontanel
Edema
- Fluid movement between the vascular and interstitial compartment is regulated by hydrostatic pressure and osmotic pressure.
- Low serum protein results in decreased oncotic pressure in the capillaries leading to leaking of fluids into the interstitial space. Hence, the administration of albumin to increase cellular protein and increase oncotic pressure.
- Increased fluid in blood vessels causes vascular congestion, leading to fluid leaking from vessels.

Diagnostic & Lab Changes
- BUN and HCT due to hemodilution
- Low serum osmo (<275mOsm/kg)
- Low serum sodium (<125mEq/L)
- Chest x-ray may show pleural effusions
- Arterial blood gases may show:
  - Low PO₂
  - Low CO₂ then as pulmonary edema progresses to hypoventilation and respiratory failure the CO₂ rises
  - Low pH with rising CO₂

Causes
- Hypervolemia and edema
  - Renal failure
  - CHF
  - Excessive fluid resuscitation
- Water intoxication
  - Excess of free water (improperly prepared formula)
- SIADH
  - Excess production or release of ADH

Management of Fluid Overload
- Restrict intake
- Promote excretion
  - Diuretics
  - Albumin
- Monitor during treatment
  - Respiratory status
  - I&O
  - Edema status
  - Labs- especially electrolyte imbalances (Na, K) during drug therapy

Case Scenario 1
- A ten year old boy Joey is admitted to the PICU with a diagnosis of meningitis. After 8 hours of being in the ICU you note his recent Na is 120, urine osmo is 200, BP 138/92, urine output < 0.3mL/kg/hr, generalized edema, LOC and confusion.
- What could most likely be occurring?
  a. DI
  b. Too little ADH secretion
  c. SIADH
  d. Acute DKA

Rationale
- Conditions associated with SIADH:
  - Meningitis
  - Head trauma
  - Cerebral tumors
  - Cerebral hemorrhage
Rationale

- SIADH causes hyponatremia
- Remember: Na+ and serum osmolarity are maintained by homeostatic mechanisms involving thirst, ADH and renal filtration.
- Increase in serum osmo stimulates hypothalamic osmoreceptors which in turn cause an increase in thirst, therefore increase in ADH.

\[ \begin{align*}
&\text{Na}_i, \text{serum osmo} \\
&\text{urine Na}_i, \text{urine osmo, 1SG}
\end{align*} \]

Case Scenario 2

- A 5 year old girl develops SIADH following neurosurgery. Her neuro vital signs are stable but her serum sodium level is 128mEq/L, serum osmo is 256mOsm/L, urine SG is 1.022 and urine output is 1mL/kg/hr. Which of the following would be the treatment of choice?
  a. Fluid restriction to 50% of maintenance requirements
  b. Administration of 3mL/kg of 3% NaCl solution
  c. Lasix 3mg/kg
  d. Administration of hypertonic saline and diuretics

Rationale

- Treatment of choice for SIADH not complicated with a severely low Na and seizures is fluid restriction.
- If severe symptoms such as seizures or cerebral edema, hypertonic saline and diuretics are administered.

Case Scenario 2 cont.

- You would identify the SIADH patient at severe risk for seizures and cerebral edema by all of the following except:
  a. Lethargy
  b. Hyperthermia
  c. Hypothermia
  d. Abnormal reflexes

Rationale

- Seizures and cerebral edema in SIADH is due to severe hyponatremia.
- This causes hypothermia, lethargy, abnormal reflexes, abdominal cramping, diarrhea, hypotension, tachycardia...
- Hyperthermia is associated with hypernatremia.

Assessment: Fluid Volume Deficit

<table>
<thead>
<tr>
<th>Mild dehydration (5%)</th>
<th>Moderate dehydration (10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal VS, CR</td>
<td>Looks &amp; acts sick</td>
</tr>
<tr>
<td>Complaint of thirst</td>
<td>Irritable</td>
</tr>
<tr>
<td>Urine SG &gt;1.020</td>
<td>Dry MM, ↓ tears, ↑ HR</td>
</tr>
<tr>
<td></td>
<td>Thirsty</td>
</tr>
<tr>
<td></td>
<td>CR sluggish</td>
</tr>
<tr>
<td></td>
<td>Anterior fontanel sunken</td>
</tr>
<tr>
<td></td>
<td>Urine SG &gt;1.020 and ↓UO</td>
</tr>
</tbody>
</table>
Severe Dehydration (15% loss)

Symptoms:
- Hyperirritable to lethargic
- No tear production
- HR very ↑, BP low and orthostatic
- Skin mottled, cool
- Sunken fontanel
- CR delayed
- Metabolic acidosis

Treatment:
1. Restore intravascular volume and ensure effective systemic perfusion
2. Replace volume and electrolyte deficits
3. Provide maintenance fluid and electrolyte requirements
4. Replace ongoing losses

Points to think of:
- Treat fever - fever increases insensible losses
- Pulse increases 10-20 bpm per degree Celsius increase.
- Tachycardia is an early sign of dehydration/volume depletion
- Decrease in BP is a late sign

More Points...
- Common to see some degree of acidosis
- Why??
  - Bicarb loss in stools and ketone production
  - Hypovolemia causes poor perfusion and increased lactic acid production
  - ↓ renal perfusion results in ↓ glomerular rate which causes ↓ hydrogen ion excretion

Types of Dehydration
- Isotonic/Isotremic: equal losses of all fluid compartments
  - 5-10% loss of body wt. Water loss from ECF.
  - Na+ 130-150
  - Can quickly lead to shock

  Examples:
  - Vomiting and diarrhea and an increase in insensible losses.
  - Hemorrhage
  - Burns

Types of Dehydration
- Hypotonic/Hyponatremic: greater losses of electrolytes
  - Osmotic electrolyte fluid shifts cause Na+ loss in stools and water shifts to ICF, resulting in ↓ intravascular volume and shock.
  - Na+ < 130
  - Requires aggressive fluid resuscitation due to the intravascular volume loss.

  Examples:
  - Severe vomiting and diarrhea
  - Shock and third spacing

Hypotonic/Hyponatremic
- Serum sodium levels less than 120 mEq/L may result in seizures.
- If intravascular free water excess is not corrected during volume replenishment, the shift of free water to the intracellular fluid compartment may cause cerebral edema.
  - Example: same 4yo child replenished with tap water only.
Types of Dehydration

- **Hypertonic/Hypernatremic**: Greater water loss than electrolyte loss, or greater electrolyte intake than water.
  - Osmotic shifts cause water to move into vascular space; S&S develop more slowly
  - Na+ >150
  - Careful not to volume resuscitate too fast due to dropping the Na+ too quickly and causing neuro complications (not faster than 10mEq/24hrs)
- **Examples**:
  - replenished with hypertonic soup, or improperly diluted infant formula
  - Diabetes Insipidus

So What Do We Do?

- **ABC’s-** once you get the airway established
- **IV access-** could be IO, CVL or venous cutdown
- **Bolus if shocky**: 20mL/kg NS
- **Once VS corrected, start maintenance fluids**
- **Daily Na+ requirements**: 3-4mEq/kg/day
- **Daily K+ requirements**: 2-3mEq/kg/day
- **Daily fluids**: D5% in 0.25NS
- Add K+ once u/o is adequate
- Correct hypernatremia slowly.
- Any severe Na+ abnormality correct over 24hrs.

Diagnostic & Lab Changes

- **Serum electrolytes** - for Na+ concentration
  - HCO3 & K+ - to check acidosis
- **BUN, Cr**
  - Normal or high due to hemoconcentration
- **Urine Specific gravity** (high, >1.030 or with DI: <1.010)
  - check if ADH issue

Management of Fluid Deficits

- **Oral replacement**
- **Parenteral replacement**
  - Isotonic dehydration: Isotonic fluids
  - Hypertonic dehydration: Isotonic fluids, hypotonic fluids given slowly to prevent too rapid of rehydration
- **Monitoring**
  - Vitals and neuro status
  - I&O

Case Studies

Emma

Emma is a 15 kg 3 year old girl with down syndrome. She is in the CICU after cardiac surgery. She was doing well post-op and transfer plans were being made when she developed fever and diarrhea.

You are caring for her today and in report are told that she has had diarrhea for 48 hrs and has not been interested in her bottle. Her fluids are at maintenance only due to her cardiac status.

What questions do you have for the nurse giving you report?

- What are her labs
- VS, I&O
- Have sample been sent for stools?
The nurse tells you that Emma is fluid restricted to 126cc q 3 hrs. Emma cried much of the night and drank 250cc of apple juice during night shift. She had three stools during the night which is much improved, because she had 6 explosive stools for the evening nurse. As the nurse leaves, she tells you that Emma threw up her lasix and pharmacy still hasn’t sent up the replacement dose.

What concerns do you have?
- Fluid depletion

What priorities do you have in caring for her?

Assessing Emma

You note that Emma is cooperative during the assessment and asks for water to drink. She looks very tired, with dark circles under her eyes. You add a blanket because she feels cool.

Vital Signs: T: 36.8 ax, P: 164, R: 28, BP: 86/44

Emma’s lab results
- Na 162
- K 2.2
- Cl 111
- Mg 4
- Cr 1.6
- BUN 58

Thoughts on her labs?
- What orders would you suspect?

Emma is feeling better

- Discontinue fluid restrictions
- Hold all diuretics
- Replace fluid loss
- Replace potassium
- Keep in mind she has a fragile heart and you do not want to tip her over into cardiac failure
- Diarrhea is due to rotavirus not intolerance to feeding, so stooling resolves itself

Assessing Charles


Irritable, breath sounds clear, but infant is tachypneic. Mom attempts to breastfeed but infant is too lethargic to latch on. Fontanel is full.

What about Charles?
- Charles is a 4 month old 6.5 kg infant transferred from the local community hospital following a seizure at home. Mom states that the infant has always done well breastfeeding, but this weekend the infant was left with the PGM so parents could celebrate their anniversary. Mom starts crying and wants to know if the baby is ill because she ran out of EBM and PGM had to use formula.
Priorities for Charles

- Charles’ PGM brings in the powdered formula container she used to feed Charles. She tells you she was mixing 3-5 big bottles at a time. She was adding 1 scoop of formula to 1 bottle of water. The instructions state “one scoop per 4 oz. water.”

- What do you think occurred...what type of problem?
  - Too much free water: hypernatremia and fluid overload
  - Low sodium which if <100 can cause seizures

- What orders do you expect the residents to write?
  - IV fluids
  - Hypertonic saline administration

- What concerns do you have?*
  - More seizures
  - Correcting too fast
  - How often are labs monitored to avoid this?

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Charles’ mom runs into the hallway yelling that she needs a nurse. You go to Charles and find him in the crib, eyes deviated to the right and right arm twitching. While you are assessing him, he becomes apneic.

What do you do?
- Bag, yell for help, expect Dr. to order ativan

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Call a Code for Charles

After bag/mask ventilating him and administering ativan, iSTAT labs are drawn. The labs are handed to you with a sodium of 119 mEq/L.

Why is the sodium low?
- Too much free water and electrolyte loss
- Due to severe hypernatremia: 3% saline administration and Q8h serum osmo’s and serum Na+

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Frankie

A young boy, Frankie, had a skate boarding accident and a subsequent cranotomy due to a head bleed at Harborview. He is transferred to Children’s on POD #3 intubated. His urine output begins to look like clear water and is ~5mL/kg/hr. You suspect:

- a. SIADH
- b. Acute high output renal failure
- c. Overhydration in the OR
- d. DI

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Interpretation of Tests in Diabetes Insipidus:

- Hypernatremia and serum hyperosmolality are due to water loss and hemoconcentration
- Low SG and urine osmolality are due to the kidneys inability to reabsorb water and concentrate urine.

- Remember: High & Dry
Frankie needs...

Frankie suddenly becomes hypotensive, tachycardic and his urine output has increased to 10mL/kg. In light of a shock situation, acute resuscitation of DI includes:

- a. N/S 10-20mL/kg then 1:1 replacement for urine loss
- b. N/S replacement 1:1 and ADH replacement
- c. Allow unlimited drinking of water
- d. Begin CRRT.

Treatment for Central DI:

- Decision to use fluid or ADH replacement therapy or both depends on the severity of the DI.
- In an acute symptomatic stage, resuscitate with NS or LR 10-20mL/kg, reassess, and replace urine 1:1 with hypotonic fluid.

Questions?