These handouts are only meant as a guide while you follow the presentation on the screen. Sometimes the speaker will change some of the slides. If you would like the “1 slide per page” handouts, please ask your on-site BCSLS Telehealth site coordinator, in your lab.

Urine Osmolality and Electrolytes

Why do we do it?
What does it mean?
and What can go wrong?

BCSLS Telehealth Presentation
December 2011
Richard Cleve

Outline

• Definitions
• Osmometry
• Applications
  – Polyuria
  – Hyponatraemia
  – Renal Failure
**Definition**

- **Concentration**
  - Number of moles per L of solution
- **Osmolarity**
  - number of osmoles per L of solution
- **Osmolality**
  - number of osmoles per kg solvent
- **Tonicity**
  - non-penetrating osmoles
- **Plasma osmolarity is 1-2% less than osmolality**

**Colligative properties**

- **Parameters proportional to # osmoles:**
  - Depressing freezing point
  - Elevating boiling point
  - Increasing osmotic pressure
  - Lowering vapour pressure

**Osmolality Measurement**

<table>
<thead>
<tr>
<th>Method</th>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP↓</td>
<td>ΔT ≈ -1.86 C°/osm</td>
<td>Simple, common</td>
</tr>
<tr>
<td>BP↑</td>
<td>ΔT ≈ +0.52 C°/osm</td>
<td>Organic compounds unstable.</td>
</tr>
<tr>
<td>VP↓</td>
<td>ΔP ≈ -0.3 mmHg/osm</td>
<td>Volatile chemicals invalidate</td>
</tr>
<tr>
<td>OP↑</td>
<td>ΔΠ ≈ 17000 mmHg/osm</td>
<td>Technically hard</td>
</tr>
</tbody>
</table>
Why “≈” in those equations?

Freezing point osmometry
Freezing Point Analytical Interferents

- High viscosity
- Particles

Specimen

Dew Point
Methods

• Freezing point depression
  – Almost exclusive method now
  – Large coefficient so good CV's
  – Simple, robust instruments
• Dew Point
  – Invalid for volatiles

Alternative Test

Refractometry correlates with osmolality
—weaker correlation with dipstick SG and osmolality
Limitation: glucose and protein lessen relationship

Specimen

• No special preparation
  – Usually need serum/plasma results
• Random urine
  – Acute conditions/decisions
  – Simple to collect
  – Creatinine improves interpretation
• Timed urine
  – More reliable (Na excretion is variable)
Normal values

• No normal values for urine electrolytes & osmolality
• Range of physiologically expected results
  – U.osm 50-1200 mosm/kg
  – Range narrows as one ages
• “Expected” values depend on clinical picture

Urine Osmolality

• Typical values
  – 500-800 mosm/kg (24 hour)
  – 300-900 mosm/kg (random)
  – After 12 hours fasting >850 mosm/kg
  – A.m. specimen ≈3 times serum osmolality

• Increased
  – Dehydration
  – SIADH
  – Adrenal insufficiency
  – Glycosuria
  – Hypernatraemia
  – High protein diet

• Decreased
  – Diabetes insipidus
  – Excess fluid intake
  – Renal insufficiency
  – glomerulonephritis
Urine Osmolality Cautions

- EtOH
- Extremes of protein in diet
- Diuretics

Other Specimens

- Pleural, ascitic
  - In equilibrium with serum
  - Thus, equal to serum
  - Rarely indicated
  - No special requirements for measurement

Faecal specimens

- Rare test for cause of diarrhoea
- F.osm - 2(F.Na + F.K)
  - <50: non-osmotic
  - >150: osmotic diarrhoea
    - Laxatives
    - Malabsorption (including lactose intolerance)
    - Sorbitol, mannitol, lactulose
- Limitation:
  - bacterial activity ↑'s gap
  - Only very watery specimens
Clinical Indications

- Polyuria
- Hyponatraemia
- Renal failure
- Low anion-gap metabolic acidosis

Polyuria

Case

- 65 year old
- c/o going to the w/c 4 or 5 times/night
- Constantly thirsty
- Drinks 4 or 5 L of ice cold water/day
- Urine output measured at 3.5 L/day
**Normal Urine Output**

- <50 mL/day: anuria
- <500 mL/day: oligouria
- >3L/day: polyuria

- Depends on individual
  - If hypernatramic or hypovolaemic
    >800 mL/d is polyuria

---

**Water & Electrolyte Balance**

- Na/K/Cl intake
- Protein intake

- Water intake
  - **=900 mosm/1.5 L**
  - **=600 mosm/L**

- Na/K/Cl output
  - **≈400 mosm/day**

- Protein (urea) output
  - **<500 mosm/day**

---

**Water Balance**

- Metabolism 10% 250mL
- Food 30% 750mL
- Beverages 60% 1500mL
- Faeces 4% 100 mL
- Sweat 8% 200 mL
- "Insensible" (skin + lungs) 28% 700 mL
- Urine 60% 1500 mL
Assessing Intravascular Volume

- Clinical (sensitivity ~50%)
  - Orthostatic hypotension
  - Weak pulse
  - Cool extremities
  - HR
  - Skin turgor
  - Mucous membranes
  - JVP
- Investigation
  - Urine Volume & Colour
  - Chest X-ray
  - Haemoconcentration
  - Creatinine, urea
  - Radioactive albumin dilution
  - BNP

Urine Concentration

Water Regulation

<table>
<thead>
<tr>
<th>P.osm</th>
<th>↓P.volume</th>
<th>↓saliva</th>
<th>Dry mouth</th>
<th>↑BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renin/angiotensin</th>
<th>ADH (vasopressin)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>P.osm</th>
<th>↓P.volume</th>
<th>↓saliva</th>
<th>Dry mouth</th>
<th>↑BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADH (vasopressin)</th>
<th>↑P.osm</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>P.osm</th>
<th>↓P.volume</th>
<th>↓saliva</th>
<th>Dry mouth</th>
<th>↑BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renin/angiotensin</th>
<th>ADH (vasopressin)</th>
</tr>
</thead>
</table>
Polyuria Assessment

- Osmolality
- Polyuria
- Flow
- Osmole excretion

Polyuria

- <150 mosm/kg
  - Water diuresis
    - Diabetes Insipidus (P.Na high/normal)
    - Polydipsia (P.Na low/normal)
- >300 mosm/kg
  - Solute diuresis

- <150 mosm/kg
  - Water diuresis
- >300 mosm/kg
  - Solute diuresis

- DM Renal glucosuria
- Excess protein
- Excess catabolism
- Bicarbonaturia
- Ketoacidosis

- Mannitol high low
- NaCl load
- Renal disease

- Diuretics
- U.osm
- Lysis (2Na+K)
- Low osmol diuresis
- Salt water diuresis
- "osmotic" diuresis
- "water" diuresis

- U.osm
- Salt + water diuresis
- Diuretics

- Diabetes Insipidus (P.Na high/normal)
- Polydipsia (P.Na low/normal)
Water Deprivation Test

- Preparation: Patient drinks until 6:00 am morning of test
- Weight, P.osm, P.Na, U.osm, U.Na
- Nothing to eat/drink during test
- Urine hourly
- Stop test if U.osm > 500, P.Na >145, weight loss >10%.
- +/- DDAVP

Water Deprivation Test

<table>
<thead>
<tr>
<th>Time</th>
<th>U.osm</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00</td>
<td>1200</td>
</tr>
<tr>
<td>12:00</td>
<td>500</td>
</tr>
</tbody>
</table>

normal  
Psychogenic polydipsia  
Central DI  
Nephrogenic DI

Give ADH (DDAVP)

time

ADH & plasma osmolality

<table>
<thead>
<tr>
<th>P.ADH (pg/mL)</th>
<th>P.osmolality (mOsm/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>280</td>
</tr>
<tr>
<td>15</td>
<td>310</td>
</tr>
</tbody>
</table>

SIADH  
Normal & Psychogenic polydipsia  
Central Diabetes Insipidus  
Nephrogenic Diabetes Insipidus
Hyponatraemia

Renal Handling

- Average 70 kg male filters approximately 1.2 kg of salt per day!
- Vast majority must be reabsorbed

Urine Sodium
Dysnatraemia

Amount of salt
\[
\text{mmol} \quad \text{L}
\]
Amount of water

Case

- 6 month old with astrocytoma on vincristine
- P.Na 126 L 135-145 mmol/L
- P.Osm 255 L 280-300 mosm/kg
- U.Na 32
- Cerebral salt wasting vs SIADH

Hyponatraemia

Serum osmolality

Glucose
Manitol
Hyperlipid
Hyperprotein
Dilutional

>300
<280

Hypovolaemic
Euvolaemic
Hypovolaemic

CHF
Renal failure
Cirrhosis
Renal loss
GI loss
Haemorrhage
Skin loss

Hypothyroid
Psychogenic polydipsia

SIADH
Hypocortisol
Case...

- SIADH:
  - Kidneys act to preserve perfusion
  - SIADH = excess of water, hence intravascular volume, in face of low Na.
  - Kidney response is to lose Na
- Cerebral Salt Wasting
  - Inappropriate Na excretion → ↑urine volume → ↓intravascular volume

SIADH

- Laboratory Features
  - ↓S.Na
  - ↓P.osm
  - ↑U.osm (typ. >50 mosm/L)
  - U.Na >20 mmol/L
  - Normal renal, thyroid & adrenals
  - Euvolaemic

SIADH Causes

- Tumour
  - Small cell, bronchogenic CA, pancreatic, Hodgkin’s
- Pulmonary
  - Pneumonia, lung abscess, TB
- Medications
  - NSAID, barbiturates, carbamazepine, TCA, oxytocin
- CNS
  - Brain tumour, encephalitis, SAH, AIP, trauma
- AIDS
- Ventilation
- Post-operative
SIADH Treatment

- Water restriction (~1 L/day)
- Salt
- Weigh daily
- Loop diuretic
- Urea (rarely used)

Cautions

- No renal or adrenal problems
- No bicarbonaturia
  - Obligate excretion of Na
  - E.g. recent vomiting
- No carbonic anhydrase inhibitors
- No acid/base disturbance
- No diuretics

Hyponatraemia

- Reset osmostat
  - Test: water load to further drop S.Na
  - Rarely performed test
  - Only done in patients with mild hyponatraemia
  - SIADH → urine remains concentrated
  - Reset osmostat → urine becomes dilute
- Importance: treatment different
Treatment cautions

• Dangerous to correct too correctly
• Central pontine myelinolysis
• ↑Na by 1-2 mmol/L/h, maximum of 8 mmol/L/day

Hypernatraemia

• Very rarely need urine studies
  – Can be used as an adjunct study

Urine Potassium

• Less predictable due to many influences
  – Potassium intake variable
  – Na effects via aldosterone
  – Hydration
• Range 10-400 mmol/d
• Transtubular potassium gradient
  – Can be calculated
  – Clinically doesn’t add much information
  – Rarely used now
Renal Failure

Renal Failure Classifications

• Duration
  – Acute renal failure
  – Chronic renal failure

• Location
  – Pre-renal
  – Renal
  – Post-renal

Renal Failure

• Pre-renal
  – Dehydration
  – CHF
  – Arterial supply

• Renal
  – Glomeruli
  – Renal tubules
  – Interstitium

• Post-renal
  – Stone
  – Tumour
  – Prostate
### Fractional Excretion

- Corrects for urine concentration
- \[ \text{FENa} = \frac{\text{U.Na} \times \text{P.Cr}}{\text{U.Cr} \times \text{P.Na}} \]
- N.B. match units
  - Plasma creatinine in µmol/L
  - Urine creatinine in mmol/L
- FeNa <1% pre-renal
- FeNa >1% renal

### Case #1

- 50 y.o. goes to the ER with history of vomiting and diarrhoea. Looks dehydrated

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma.Na</td>
<td>140 mmol/L</td>
</tr>
<tr>
<td>Plasma.Cre</td>
<td>150 µmol/L</td>
</tr>
<tr>
<td>U.Na</td>
<td>25 mmol/L</td>
</tr>
<tr>
<td>U.Cre</td>
<td>1 mmol/L</td>
</tr>
<tr>
<td>FENa</td>
<td>2.7%</td>
</tr>
<tr>
<td>U.osm</td>
<td>320 mosm/kg</td>
</tr>
</tbody>
</table>

### Case #2

- 50 y.o. goes to the ER with history of vomiting and diarrhoea. Looks dehydrated

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma.Na</td>
<td>140 mmol/L</td>
</tr>
<tr>
<td>Plasma.Cre</td>
<td>150 µmol/L</td>
</tr>
<tr>
<td>U.Na</td>
<td>25 mmol/L</td>
</tr>
<tr>
<td>U.Cre</td>
<td>10 mmol/L</td>
</tr>
<tr>
<td>FENa</td>
<td>0.27%</td>
</tr>
<tr>
<td>U.osm</td>
<td>600 mosm/kg</td>
</tr>
</tbody>
</table>
Interpretation

- FENa <1% -- pre-renal
- FENa >3% -- acute kidney injury
- U.Osm >500 -- pre-renal
- U.Osm <350 -- acute kidney injury
- No gold-standard test
- Acute kidney injury can develop from pre-renal failure

Caution

- Loop diuretics increase FENa
  - Cannot interpret while on diuretics
- Severe protein malnutrition/starvation or wash-out of kidney

RTA
Metabolic Acidosis

- Increased anion gap
  - Relatively straightforward
  - “MUDPILES”
- Normal anion gap
  - Factitious
    - Hypoalbuminaemia
    - Unusual cations (e.g. monoclonal band)
  - HCl or NH₄Cl loading
  - HCO₃⁻ loss
    - GI (diarrhoea, ileus)
    - Renal (proximal RTA, carbonic anhydrase inhibitor)
  - Failure to generate “new” bicarbonate (distal RTA)
  - Gain of an acid with excretion of conjugate base

Acid production

- Typical North American diet produces 1 mmol H⁺/kg body weight/day
- Mainly from protein oxidation
- Buffering acid load consumes equivalent amount of bicarbonate.
- S.pH ~7.4, U.pH ~6.0

Renal Acid-Base: Recovery
Renal Acid-Base: Loss of $H^+$

- Blood
- Renal Tubular Cell
- Urine
- $NaHCO_3$
- glutamine
- glutamate
- $NH_3$
- $α$-KG

Ammonia

- Theoretically can be measured; however, technically very difficult in urine
- Essentially research-only method
- Calculating

Electroneutrality

$Na^+$  $K^+$  $2Ca^{++}$  $2Mg^{++}$  $NH_4^+$  $Cl^-$  $HCO_3^-$  $H_2PO_4^-$  $2HPO_4^{2-}$  $2SO_4^{2-}$  organic anions
Electroneutrality

\[ \begin{align*}
+ \text{Na}^+ & \quad + \text{Cl}^- \\
+ \text{K}^+ & \quad + \text{HCO}_3^- \\
+ 2\text{Ca}^{++} & \quad + \text{H}_2\text{PO}_4^- \\
+ 2\text{Mg}^{++} & \quad + 2\text{HPO}_4^{2-} \\
+ \text{NH}_4^+ & \quad + 2\text{SO}_4^{2-} \\
& \quad + \text{organic anions}
\end{align*} \]
\[ \text{Na}^+ + \text{K}^+ + \text{NH}_4^+ = \text{Cl}^- + 80 \]
\[ \text{NH}_4^+ \sim 80 \text{ mEq/day} \]

Cautions of net charge

- Unmeasured anions → underestimate NH4
  - Ketonuria
  - DKA
  - Drugs (penicillin, salicylates)

Non-Anion gap Metabolic Acidosis

- GI bicarb loss
- Acetazolamide
- NH\textsubscript{4}Cl, HCl
- Low GFR
- Hyperkaemia
- Interstitial dz
- Amphotericin B
Conclusions

Urine Osmolality & Lytes Utility

• Rarely needed, but critical test
  – Polyuria
  – Hypernatramia
  – Supportive role
    • Pre-renal vs renal oliguria
    • Integrity of the medullary interstitium

Summary

• No “normal” ranges – interpret in clinical context
• Cautions:
  – No diuretics
  – No adrenal or thyroid disease
  – Relatively normal diet