Take Home Messages
*Nephrology*

Dr. Ajay K. Singh

IRIM 2012

### Hypernatremia

- \( \frac{U_{\text{osm}}}{U_{\text{osm}}} < 800 \text{ mOsm/kg} \)
- \( \frac{U_{\text{osm}}}{U_{\text{osm}}} > 800 \text{ mOsm/kg} \)
- Renal H2O loss
- Osmotic diuresis
- DI
- CDI
- NDI

- Insensible H2O loss
- GI H2O loss
- Na\(^+\) intake

- Replace free water deficit (50% in first 24 hr, no more than 0.5 mM/hr)
- Replace ongoing free water losses
- Treat underlying cause
  - Desmopressin for CDI
  - No specific Rx for NDI (attempt to reduce urine output with Na restriction, thiazides or give supratherapeutic dose of desmopressin)

### Hyponatremia

- \( \frac{P_{\text{osm}}}{P_{\text{osm}}} > 290 \text{ mOsm/kg} \)
- Normal
- \( \frac{P_{\text{osm}}}{P_{\text{osm}}} < 275 \text{ mOsm/kg} \)

- Excess H2O intake
- High ADH
- Defective urinary dilution

- Hypovolemia
- ECV depletion
- SIADH

- Renal loss
- Extrarenal loss
- CHF
- Nephrotic
- Liver failure

### Management of hypernatremia

- Replace free water deficit (50% in first 24 hr, no more than 0.5 mM/hr)
- Replace ongoing free water losses
- Treat underlying cause
  - Desmopressin for CDI
  - No specific Rx for NDI (attempt to reduce urine output with Na restriction, thiazides or give supratherapeutic dose of desmopressin)

### Hypoosmolal hyponatremia

- Correct serum Na\(^+\) by 1.6 for every 100 mg/dL Δ in glucose
**Hypoosmolal hyponatremia**

<table>
<thead>
<tr>
<th>Volume status</th>
<th>Dehydration*</th>
<th>Addison’s</th>
<th>Diuretics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypovolemic</td>
<td>Euvolemic</td>
<td>Edematous</td>
<td>CHF*</td>
</tr>
<tr>
<td>U_Osm</td>
<td>&lt; 100</td>
<td>&gt; 100</td>
<td>Nephrotic*</td>
</tr>
<tr>
<td>SIADH</td>
<td>Polydipsia</td>
<td>Liver failure*</td>
<td>Renal failure*</td>
</tr>
</tbody>
</table>

* Uₙa < 20 = Extrarenal cause of ECV depletion

**Rate of correction of hyponatremia**

- Acute (< 48 hr) or symptomatic
  - 1-2 mEq/l per hour
- Chronic (> 48 hr) including SIADH and asymptomatic
  - 0.5 mEq/l per hour
- Do not exceed Δ 12 mEq/L in 1st day, or correct to > 120-125 mEq/L

**Hyperkalemia**

<table>
<thead>
<tr>
<th>↑ Intake</th>
<th>Decreased urinary K⁺ excretion</th>
<th>24 hr urine K⁺ &lt; 40 mEq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell shift</td>
<td>Metabolic acidosis</td>
<td>Hyperglycemia</td>
</tr>
<tr>
<td>β-blocker</td>
<td>Digitalis</td>
<td>Hyperkalemic periodic paralysis</td>
</tr>
<tr>
<td>Cell lysis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Treatment of hyperkalemia**

- Stabilize membrane excitability
  - Calcium chloride or gluconate, 1 g IV
- Increase K⁺ entry into cells
  - Glucose 25 g and insulin 10 U
  - β₂-adrenergic agonist (albuterol 10-20 mg inh)
  - NaHCO₃
- Removal of excess K⁺
  - Cation exchange resin (Kayexalate)
  - Diuretics
  - Dialysis
- Dietary K⁺ restriction

**DDX of hypokalemia**

<table>
<thead>
<tr>
<th>Cellular shift</th>
<th>GI loss</th>
<th>Urinary K wasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalemia</td>
<td>Vomiting*</td>
<td>24 hr U_K &gt; 25 mEq</td>
</tr>
<tr>
<td>Insulin</td>
<td>Diarrhea</td>
<td></td>
</tr>
<tr>
<td>β-agonist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypokalemic periodic paralysis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Also renal K⁺ wasting

**Acid Base Disorders**

<table>
<thead>
<tr>
<th>pH</th>
<th>PCO₂/HCO₃⁻</th>
<th>Primary disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>↑ HCO₃⁻</td>
<td>Metabolic alkalosis</td>
</tr>
<tr>
<td></td>
<td>↑ PCO₂</td>
<td>Respiratory alkalosis</td>
</tr>
<tr>
<td></td>
<td>↓ HCO₃⁻</td>
<td>Metabolic acidosis</td>
</tr>
<tr>
<td></td>
<td>↓ PCO₂</td>
<td>Respiratory acidosis</td>
</tr>
</tbody>
</table>
High anion gap metabolic acidosis
- Methanol
- Uremia
- Diabetic ketoacidosis
- Paraldehyde
- Iron/isoniazid
- Lactic acidosis
- Ethylene glycol & ethanol
- Salicylates

Rhabdomyolysis
Toluene abuse

Type B lactic acidosis (metformin, NRTI)
D-lactic acidosis
Propylene glycol
5-oxoprolineuria

DDx of a non-gap metabolic acidosis
- Diarrhea
- RTA

I
Classic distal

II
Proximal

IV
Hyporeninemic hypoaldosteronism

DDx of RTA

<table>
<thead>
<tr>
<th></th>
<th>Proximal</th>
<th>Classic distal</th>
<th>Hyporenin hypoaldo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum K</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Urine pH</td>
<td>Variable</td>
<td>&gt; 4.5</td>
<td>&lt; 4.5</td>
</tr>
<tr>
<td>Other features</td>
<td>Fanconi (low PO4, glycosuria)</td>
<td>Nephrocalcinosis ± CaPO4 stones</td>
<td></td>
</tr>
</tbody>
</table>

Definition of Acute Injury (AKI)
- Rapid Deterioration (days) in Renal Function leading to:
  - Reduced Clearance of Toxins (Bun, Creat)
  - Altered Regulation of Electrolytes/Acid-Base (K⁺, H⁺)
  - Expanded Extracellular Volume

Evaluation of Patient with AKI
- History: Prior Evidence of Renal Disease, Proteinuria, HTN, Diabetes
  - Did Rise in Creatinine Occur During Hospitalization? (late finding with AKI)
    - Look for causes: drugs (otc), contrast agents, hypotension (?surgery) that Precede the onset
  - Is Creatinine High Upon Presentation?
    - acute vs chronic renal failure
    - old data, renal ultrasound
    - blood work not usually helpful

Evaluation (Continued)
- Review of ALL Medications, Family History
- Social History-IVDA, Hepatitis or HIV Risks
- Physical Exam
  - Vital Signs, Volume Status, Edema
  - Specific Organ Abnormalities
- Laboratories (minimum):
  - Urinalysis, electrolytes, Ca⁺, Mg⁺, PO4, CBC
- Radiologic: Renal Ultrasound; R/O obstruction and assess Renal Size/Texture
**Laboratory Findings - ARF**

**Prerenal vs ATN**

<table>
<thead>
<tr>
<th>Index</th>
<th>Prerenal Anemia</th>
<th>Oliguric Acute Renal Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUN/Prx Rate</td>
<td>&gt;101</td>
<td>10-151</td>
</tr>
<tr>
<td>Urine sodium (Uosm), mEq/L</td>
<td>&lt;10</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Urine osmolality, mOsm/L H2O</td>
<td>&gt;300</td>
<td>&lt;300</td>
</tr>
<tr>
<td>Fractional excretion of sodium</td>
<td>&lt;1%</td>
<td>&gt;2%</td>
</tr>
<tr>
<td>FeNa = Uosm × Prx/Na × Uosm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine/Plasma Creatinine (Ucp/pc)</td>
<td>&gt;40</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

*Muddy Brown Casts*

**Management of ATN**

- Prevention - maintain euvolemia
  - no proven role for diuretics, dopamine or calcium channel blockers
  - alkalinize urine in special cases (myoglobin, urate)

- Established ATN - eliminate hemodynamic and toxic insults
  - no proven role for diuretics, dopamine, or experimental agents such as ANP, growth factors, antioxidants

**Fluid and Electrolyte Abnormalities/Treatment**

- Volume Expansion - restrict Na, diuretics
- Hyponatremia - free water restrict
- Hyperkalemia - restrict, diuretics, kaexylate
- Metabolic Acidosis - bicarbonate
- Hyperphosphatemia - binders
- Hypocalcemia - replace, start Vit. D.
  - Rhabdomyolysis is exception: Rebound hypercalcemia from PTH stimulation

**Complications/Treatment II**

- Hypermagnesemia - restrict (Maalox)
- Hyperuricemia - No treatment
- Nutrition - start TPN/enteral feeds (30-35kcal/kg)
- Anemia/Bleeding - Transfuse, H₂ Blockers, DDAVP, Estrogens
- Drug Dosing - Dose all meds for GFR<10mls/min

**Indications for Dialysis**

- Intractable volume overload
- Refractory Hyperkalemia
- Refractory Acidosis
- Nutritional Requirements (Volume, BUN)
- Uremic Signs/Symptoms:
  - Pericarditis, Encephalopathy

**Renal Replacement**

- CVVH - Continuous venovenous hemofiltration
  - Advantages: hemodynamically better tolerated, precise hour to hour volume control but no evidence of better outcomes (vs IHD)
  - Disadvantages: less efficient than hemodialysis, requires ICU setting and specialized equipment/trained personnel

- Intermittent Hemodialysis
### Stages of Chronic Kidney Disease

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>GFR (mL/min/1.73 m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>≥90</td>
</tr>
<tr>
<td>2</td>
<td>Mild</td>
<td>60-89</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>30-59</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>15-29</td>
</tr>
<tr>
<td>5</td>
<td>Kidney Failure</td>
<td>&lt;15 or Dialysis</td>
</tr>
</tbody>
</table>


### Diabetes Is the Most Common Cause of ESRD

![Chart showing the most common causes of ESRD in 2001 (incident)]

- **Diabetes Mellitus**: 44%
- **Hypertension**: 27%
- **Glomerulonephritis**: 8%
- **Other**: 21%


### eGFR is Best Overall Method of Measuring Kidney Function

- 24-hour urine collection does not give you the best estimation of GFR.
- GFR is the best overall index of kidney function in health and disease.
- eGFR from serum creatinine (Scr) using the Modification of Diet in Renal Disease (MDRD) Study or Cockcroft-Gault equations.
- The MDRD equation is preferred and uses serum creatinine along with age, sex, and race to determine GFR (the new equation: CKD-EPI – will not be in boards!)

### Complications of CKD

- Anemia
- Hypertension
- Bone Disease

### Proteinuria

- áglomerular permeability
- tubular overflow
- átubular absorption
- lower urinary tract disease
- fever, exertion, CHF, trauma

### Proteinuria

- Dip for protein
  - Dip scale:
    - tr 10-20 mg/dl
    - 1+ 30 mg/dl
    - 2+ 100 mg/dl
    - 3+ 300 mg/dl
    - 4+ 1000 mg/dl
  - poor correlation with 24⁵ urine
- Other measures of protein
  - Protein to creatinine ratio
  - Microalbuminuria
Categories of Proteinuria

1. < 1 gm/24°, normal renal function, benign sed
   » orthostatic proteinuria
   » idiopathic transient proteinuria
   » persistent isolated
2. 1 - 3 gm/24°
   » mild glomerular disease
   » tubular dysfunction
3. > 3 gm/24°
   » glomerular disease
   » possibly severe tubular dysfunction

Nephrotic Syndrome

1. Proteinuria (> 3.5g/d)
2. Hypoalbuminemia (< 3 g/dL)
3. Hyperlipidemia
4. Lipiduria
5. Edema
6. Bland urine or fatty casts/ free fat / oval fat bodies

Nephrotic Syndrome

Proteinuria (> 3.5g/d)
Hypoalbuminemia (< 3 g/dL)
Hyperlipidemia
Lipiduria
Edema
Bland urine or fatty casts/ free fat / oval fat bodies

NS complications

1. Edema
2. Hypovolemia and ARF
3. Thromboembolic events
4. Infections
5. Fanconi syndrome
6. Atherosclerosis
7. Malnutrition

NS: Etiology

<table>
<thead>
<tr>
<th>Primary Causes</th>
<th>Secondary Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membranous</td>
<td>Medications</td>
</tr>
<tr>
<td>Focal Segmental GS (FSGS)</td>
<td>Gold, NSAIDs, Interferon -alfa,</td>
</tr>
<tr>
<td></td>
<td>Heron, Captopril</td>
</tr>
<tr>
<td>Minimal Change Disease</td>
<td>Allergens</td>
</tr>
<tr>
<td>IgA</td>
<td>Bee Sting, Pollen</td>
</tr>
<tr>
<td>Infections</td>
<td>Bacterial, Viral, Helminth</td>
</tr>
<tr>
<td>Cancer</td>
<td>Solid: Lung, colon, stomach</td>
</tr>
<tr>
<td></td>
<td>Leukemia, Hodgkins</td>
</tr>
<tr>
<td>Autoimmune Diseases</td>
<td>Metabolic Diseases</td>
</tr>
<tr>
<td>Pregnancy</td>
<td></td>
</tr>
</tbody>
</table>

NS w/u - exclude 2°

1. History
   » DM - h/o retinopathy, neuropathy
   » SLE
   » Amyloid - Paraproteinemia, RA, FMF, TB, Osteo
   » Infection - HIV risk factors, hepatitis, syphilis, endocarditis
   » Meds - NSAIDs, Gold, etc
   » Malignancies - Hodgkin’s, Solid tumors
   » Family history
   » Pyelonephritis

NS w/u cont.

1. PE
   » Rashes, joint effusions
   » retinopathy, sensory deficit
   » lymphadenopathy
2. Labs
   » urine sed
   » SMA 20 - BUN, Cr, Alb, glucose, LFT’s
   » 24° urine for protein and cr (15 - 25 mg/Kg/24°)
   » Renal USG
   » ANA, complement, cryoglobulin, HIV, Hep B, Hep C, SIEP, RPR, ANCA, UPEP
Treatment of proteinuria

1. ACE inhibition
   - Use in normotensive patients also.
   - Low salt diet and diuretics improve efficacy.
   - Benefit of adding Angiotensin receptor antagonist?
2. Low protein diet
   - 0.6 to 0.8 mg/kg but evidence is mixed.
3. Blood pressure control
4. NSAIDs
   - Risk of ARF outweighs benefit.
5. Steroids and alkylating agents

Low protein diet

• 0.6 to 0.8 mg/Kg but evidence is mixed.

Blood pressure control

NSAIDs

• Risk of ARF outweighs benefit.

Steroids and alkylating agents

Major Causes of Hematuria in adults

1. Infection
   - Pyelitis, cystitis

2. Malignancy
   - Renal cell Ca
   - Transitional cell Ca
   - Prostatic Ca

3. Metabolic/Other
   - Calculi
   - Hyperparathyroidism
   - Coagulopathy
   - Cytoxan

4. Glomerular
   - GN eg IgA
   - Hereditary
   - Thin basement membrane
   - Alport’s

5. Interstitial
   - AIN
   - PKD
   - Papillary necrosis

6. Vascular
   - Renal vein thrombosis, Atheroemboli, Malignant HTN

Hematuria

H&P, UA, sed

UC

Infection

Antibiotics

H&P c/w GN, dysmorphic RBC

RBC cast

Observe

Renal Biopsy

H&P, UA, sed

H&P c/w GN, dysmorphic RBC

RBC cast

24 h urine Ca, uric acid

CT with contrast

Spiral CT

Urine cytologies x3

Observe

Renal Biopsy