Renal Secretion & pH Control

Topics for today:

• Renal secretion of potassium
• Examples of solute clearance rates
• Hormones affecting kidney function
• Counter current concentration mechanism
• Renal mechanisms of pH control
• Buffer mechanisms

Active secretion

Various substances are actively transported across the basal surface. Some organic substances are transported via ‘organic anion transporter’ proteins and secreted into the lumen of the tubule.

organic anions secreted (examples):
• penicillin
• creatinine
• diodrast
• phenol red
Active secretion

Other organic substances are transported via ‘organic cation transporter’ proteins and secreted at the apical surface into the lumen of the tubule.

organic cations secreted (examples):
- histamine
- norepinephrine
- quinine

Secretion of potassium ions*
- coupled with active reabsorption of Na
- occurs mainly in distal convoluted tubule

*Prevents disruption of heart EKG rhythm

Renal clearance: some examples

<table>
<thead>
<tr>
<th>Substance</th>
<th>Plasma clearance rates, ml/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>glucose</td>
<td>0</td>
</tr>
<tr>
<td>amino acids</td>
<td>1-4</td>
</tr>
<tr>
<td>Na⁺</td>
<td>0.5</td>
</tr>
<tr>
<td>K⁺</td>
<td>15</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>21</td>
</tr>
<tr>
<td>urea</td>
<td>60</td>
</tr>
<tr>
<td>uric acid</td>
<td>6</td>
</tr>
<tr>
<td>creatinine</td>
<td>150</td>
</tr>
</tbody>
</table>

\[ C_k = \frac{U_x V}{P_x} \]

\[ C_k = \frac{\text{mg/ml}(\text{ml/min})}{\text{mg/ml}} \]

\[ C_k = \text{ml/min} \]
Hormones affecting kidneys

- Bradykinin
- Endothelin
- Renin/angiotensin
- Aldosterone
- Antidiuretic hormone (ADH)
- Atrial natriuretic factor

Renin/Aldosterone system

Water balance and ADH

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>water in beverages</td>
<td>1000 ml</td>
</tr>
<tr>
<td>water in food</td>
<td>1200 ml</td>
</tr>
<tr>
<td>water of oxidation</td>
<td>300 ml</td>
</tr>
<tr>
<td>total</td>
<td>2500 ml</td>
</tr>
</tbody>
</table>

When output exceeds input, plasma osmotic concentration increases
- triggers release of antidiuretic hormone (ADH)
- reabsorption of water increases → urine becomes more concentrated

When input exceeds output, plasma osmotic concentration decreases
- less ADH released
- reabsorption of water decreases → high volume dilute urine (diuresis)
Counter current tubule flow

Renal mechanisms of pH control

- **secretion** of $H^+$ ions into kidney tubule
  ($H^+$ ions excreted in urine)

- **reabsorption** of $HCO_3^-$ ions
  (this raise plasma pH)

- **excretion** of ammonium ions to remove $H^+$
  $H^+ + NH_3 \rightarrow NH_4^-$ (excreted in urine)

Buffers and maintenance of pH

Buffers function to minimize the extent of changes in pH of body fluids.
One particularly important buffer system is the **bicarbonate buffer system**:

$$ CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- $$

$$ K_a = \frac{K_1}{K_2} $$

$$ pH = pK_a + \log \frac{[A^-]}{[HA]} $$

$K_a$ is the pH at which $[A^-] = [HA]$
More on bicarbonate system

\[ \text{pH} = \text{pK}_a + \log \left( \frac{[A^-]}{[HA]} \right) = \text{pK}_a + \log \left( \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} \right) \]

\text{CO}_2 \text{ is equivalent to H}_2\text{CO}_3

\[ \text{pH} = \text{pK}_a + \log \frac{[\text{HCO}_3^-]}{[\text{CO}_2]} \]

\[ \text{pK}_a = 6.1 \]

\[ \text{pH} = 6.1 + \log \left( \frac{20}{1} \right) \]

\[ \therefore \text{pH} = 6.1 + 1.3 = 7.4 \]

The HCO\(_3^-\) / CO\(_2\) ratio in ECF is about 20:1

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

H\(_2\text{CO}_3\) is controlled by kidneys

\[ \text{CO}_2 \text{ is controlled by lungs} \]

\[ 2\text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 + \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \]

\[ \text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

Renal reabsorption of bicarbonate

\[ \text{filtered HCO}_3^- \rightarrow \text{Tubule cell} \rightarrow \text{Tubule lumen} \rightarrow \text{plasma} \]

\[ \text{pH} = \text{pK}_a + \log \left( \frac{[A^-]}{[HA]} \right) \]

\[ \text{Kidney and Lung Control of pH} \]

\[ \text{Topic for Friday:} \]

\[ \text{Kidney and Lung Control of pH} \]

\[ \text{pH} = \text{pK}_a + \log \left( \frac{[A^-]}{[HA]} \right) \]