Urine Concentration and Dilution

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Learning Objectives

• At the end of the session, the students should be able to:

• Discuss the urine concentrating mechanisms.

• Explain the countercurrent multiplier mechanism for creating hyperosmotic medullary interstitium.

• Discuss the countercurrent exchange mechanism.

• Discuss urea recycling.
Review
Review

• ADH-Osmoreceptor feed back mechanism

• Thirst mechanism

• Factors increasing or decreasing ADH release

• Factors affecting thirst

• Urine dilution mechanism
Urine Concentrating Mechanism
• Usually the urine osmolarity is < 300 mOsm/L

• To conserve water the kidney can concentrate the urine to upto 1200-1400 mOsm/L
Requirement to excrete concentrated urine

- ADH
- Hyperosmotic medullary interstitium
The Effects of ADH on the distal collecting duct and Collecting Ducts

(a) Absence of ADH

Large volume of dilute urine

(b) Presence of ADH

Small volume of concentrated urine
Hyperosmotic Gradient in the Renal Medulla Interstitium
• Once the high solute concentration in the medulla is achieved, it is maintained by a balanced inflow and outflow of solutes and water in the medulla.
Countercurrent Multiplier Mechanism

• The countercurrent multiplier mechanism depends on the special anatomical arrangement of the loops of Henle and the vasa recta, the specialized peritubular capillaries of the renal medulla.

• Countercurrent multiplier mechanism produces a hyperosmotic renal medullary interstitium
<table>
<thead>
<tr>
<th>Tubule Type</th>
<th>Active NaCl Transport</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H₂O</td>
</tr>
<tr>
<td>Proximal tubule</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Thin descending limb</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Thin ascending limb</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thick ascending limb</td>
<td>++</td>
<td>0</td>
</tr>
<tr>
<td>Distal tubule</td>
<td>+</td>
<td>+ADH</td>
</tr>
<tr>
<td>Cortical collecting tubule</td>
<td>+</td>
<td>+ADH</td>
</tr>
<tr>
<td>Inner medullary collecting duct</td>
<td>+</td>
<td>+ADH</td>
</tr>
</tbody>
</table>

ADH, antidiuretic hormone; NaCl, sodium chloride; 0, minimal level of active transport or permeability; +, moderate level of active transport or permeability; ++, high level of active transport or permeability; +ADH, permeability to water or urea is increased by ADH.
Figure 28–3

Countercurrent multiplier system in the loop of Henle for producing a hyperosmotic renal medulla. (Numerical values are in milliosmoles per liter.)
This process gradually traps solutes in the medulla and multiplies the concentration gradient established by the active pumping of ions out of the thick ascending loop of Henle, eventually raising the interstitial fluid osmolarity to 1200 to 1400 mOsm/L.
Countercurrent Multiplier

The repetitive reabsorption of sodium chloride by the thick ascending loop of Henle and continued inflow of new sodium chloride from the proximal tubule into the loop of Henle is called the countercurrent multiplier. The sodium chloride reabsorbed from the ascending loop of Henle keeps adding to the newly arrived sodium chloride, thus “multiplying” its concentration in the medullary interstitium.
Role of ADH and Distal Tubule

(a) Absence of ADH

Large volume of dilute urine

(b) Presence of ADH

Small volume of concentrated urine

Cortex

Medulla

DCT

Collecting duct

Solute

Very dilute

Very concentrated
Role of Urea: Urea Recycling
(c) The permeability characteristics of both the loop and the collecting duct tend to concentrate urea in the tubular fluid and in the medulla. The loop of Henle, DCT, and collecting duct are impermeable to urea. As water reabsorption occurs, the urea concentration rises. The papillary ducts’ permeability to urea accounts for roughly one-third of the solutes in the deepest portions of the medulla.
Hyperosmotic Gradient in the Renal Medulla Interstitium
Major factors that contribute to the buildup of solute concentration into the renal medulla:

1. Active transport of sodium ions and cotransport of potassium, chloride, and other ions out of the thick portion of the ascending limb of the loop of Henle into the medullary interstitium

2. Active transport of ions from the collecting ducts into the medullary interstitium

3. Facilitated diffusion of urea from the inner medullary collecting ducts into the medullary interstitium

4. Diffusion of only small amounts of water from the medullary tubules into the medullary interstitium—far less than the reabsorption of solutes into the medullary interstitium
Medullary Interstitium is now hyperosmotic. How will it be preserved?
Renal Medullary Blood flow

• Is < 5% of total renal blood supply so is very sluggish.

• Vasa recta serve as countercurrent exchanger.
Countercurrent Exchange in Vasa Recta

Figure 29-7. Countercurrent exchange in the vasa recta. Plasma flowing down the descending limb of the vasa recta becomes more hyperosmotic because of diffusion of water out of the blood and diffusion of solutes from the renal interstitial fluid into the blood. In the ascending limb of the vasa recta, solutes diffuse back into the interstitial fluid and water diffuses back into the vasa recta. Large amounts of solutes would be lost from the renal medulla without the U shape of the vasa recta capillaries. (Numerical values are in milliosmoles per liter.)
• The vasa recta do not create the medullary hyperosmolarity, but they do prevent it from being dissipated.

• Countercurrent exchange mechanism preserves the hyperosmolarity of medullary interstitium.