Urinary System

And Adrenal Function
Overview

- Kidney anatomy and physiology
- Urine
- Ureters, Bladder and Urethra
- Adrenal Function
Functions of the Kidney

- Filter fluids from the blood
- Regulate volume and composition of blood
- Gluconeogenesis
- Produce hormones renin and erythropoietin
- Metabolize vitamin D to active form
- Create urine
Kidney Anatomy

4.5 x 2.5 x 1"
Surrounded by fat
Kidney Anatomy

- Approx 8 lobes
- Pelvis is continuous with ureter
- Calyces collect urine from papillae
- Walls of calyces, pelvis and ureter have smooth muscle that moves urine via peristalsis
Kidney Blood Supply

- ¼ of cardiac output each minute!
- 90%+ of blood perfuses the cortex
Nephron Anatomy

- Over 1 million!
- Each about 1.2” long
- 2 capillary beds
  - Glomerulus
    - Produce filtrate
  - Peritubular capillaries
    - Reclaim filtrate
**Kidney Physiology**

3 processes:
- Glomerular filtration
- Tubular reabsorption
- Tubular secretion

- Entire plasma is filtered 60x/day! (total – 47 gal)
- Kidneys consume 20-25% of all O used at rest
Glomerular Filtration

- Note large afferent arteriole compared with the smaller efferent arteriole creating relatively high glomerular BP.
- Blood colloid osmotic pressure due to the inability of proteins to pass through the membrane.
- Capsular hydrostatic pressure due to the material in the capsule.
- Net filtration pressure = 10mm Hg

2 million of these! – about SA of skin

Net outward pressure
Glomerular Filtration

- Substances that pass
  - Water
  - Glucose
  - Ions
  - Amino acids
  - Nitrogenous waste
  - Molecules < 3nm

- What does not pass
  - Blood cells
  - Plasma proteins
GFR regulation
Sodium reabsorption via Na/K pump (80% of active transport)
Water follows via osmosis (passive)
  - Aquaporins – water channel proteins; obligatory water reabsorption; constant component of PCT
  - Solutes follow solvent – lipid-soluble substances, ions, urea
Secondary active transport
  - electrochemical gradient (opens some channels)
  - facilitated diffusion
  - glucose, amino acids, lactate, vitamins
Tubular reabsorption

- **Loop of Henle**
  - Adjusts concentration of water in the urine
  - Water can leave the descending limb (but solutes cannot)
  - Water cannot leave the ascending limb (but solutes can)
    - no aquaporins here
GFR regulation
Tubular reabsorption

- Distal Convoluted tubule and collecting ducts
  - Adjusts concentration of water in the urine
  - Water can leave the descending limb (but solutes cannot)
  - Water cannot leave the ascending limb (but solutes can)
    - no aquaporins here
PCT is main site; also DCT and CD

- Important for substances not filtered out at glomerulus
  - Metabolites and drugs bound to proteins
  - Eliminate reabsorbed substances (urea, uric acid)
  - Remove excess K+ (nearly all K+ in urine is due to secretion)
- Control blood pH
  - If pH drops – secrete H+ into urine
  - (If pH rises – Cl- is reabsorbed by body instead of HCO3-. (this is not secretion!))
Urine Concentration and Volume

Osmolality = number of solute particles dissolved in 1kg water

(1 osmol = 1 mole/1 kg water; 1000 milliosmol = 1 osmol)

300 mOsm = body solute load

Kidneys maintain this osmolality with a countercurrent mechanism
Urine Concentration and Volume

Loop of Henle
Urine Concentration and Volume

Collecting Duct
Regulation of Urine Concentration

ADH – anti-diuretic hormone (vasopressin)
- Released by the pituitary (posterior lobe)
  - In response to blood osmolality
  - Release inhibited by alcohol
- Inhibits urine output
  - Up to 99% of water can be reabsorbed
- Causes aquaporins to be inserted into the walls of the collecting duct (more ADH = more aquaporins)
  - Controls water reabsorption
Diuretics

ACETAZOLAMIDE
- A carbonic anhydrase inhibitor that inhibits the reabsorption of $\text{HCO}_3^-$ in the proximal convoluted tubule.
- Weak diuretic properties.

Diamox

THIAZIDES
- Inhibit reabsorption of $\text{Na}^+$ and $\text{Cl}^-$ in the distal convoluted tubule, resulting in retention of water.
- Most commonly used diuretics.

Lasix

Aldactone dyrenium

BUMETANIDE, FUROSEMIDE, TORSEMIDE, ETHACRYNIC ACID
- The loop diuretics inhibit the $\text{Na}^+$/K$^+$/2Cl$^-$ cotransport in the ascending loop of Henle, resulting in retention of $\text{Na}^+$, $\text{Cl}^-$, and water in the tubule.
- These drugs are the most efficacious of the diuretics.

SPIRONOLACTONE, AMILORIDE, TRIAMTERENE
- Spironolactone, an aldosterone antagonist, inhibits the aldosterone-mediated reabsorption of $\text{Na}^+$ and secretion of $\text{K}^+$.
- Amiloride and triamterene block Na$^+$ channels.
- These agents can prevent loss of $\text{K}^+$ that occurs with thiazide or loop diuretics.

Figure 22.2
Major locations of ion and water exchange in the nephron, showing sites of action of the diuretic drugs.
Angiotensin

Granular cells (along afferent arteriole) release renin (hormone)
Renin causes an increase in angiotensin II (via a metabolic pathway)
  (angiotensinogen -> angiotensin I -> angiotensin II)
Angiotensin II – 5 functions
  - Vasoconstrictor – raises BP
  - Stimulates reabsorption of Na+ (and water) – increases BP due to increased blood volume
    - Directly via nephron tubules
    - Triggers release of aldosterone from adrenal cortex
  - Contracts glomerular cells reducing the GFR
    - Keeps blood in the capillaries (raises blood volume and BP)
  - Contracts efferent arteriole
    - Causes drop in hydrostatic pressure in peritubular capillary bed; allows more fluid to move into the capillaries raising blood volume (and BP)
  - Stimulates release of ADH (anti-diuretic hormone)
    - Increases blood volume (and BP)
Ureters, Bladder and Urethra

**Ureter**
- Peristalsis moves urine to bladder
- Enter bladder at bottom
  - Prevents backflow of urine

**Bladder**
- Highly distensible
- Can hold up to 1 liter
Ureters, Bladder and Urethra

Urethra
- Internal urethral sphincter
  - Involuntary
  - Prevents leaking
  - Contraction opens it (unusual)
- External urethral sphincter
  - At the urogenital diaphragm
  - Voluntary
Adrenal Function

- Surrounded by fat
- Pyramid shaped
- On top of kidneys
- Note that it monitors the blood entering the kidney
Adrenal Function

- Two glands (cortex and medulla)

Adrenal Cortex

- Synthesizes Corticosteroids
  - 2 dozen +; Cholesterol based
  - Mineralocorticoids
    - Regulate electrolyte concentration
      - Primarily Na+ (and therefore water)
      - Important in blood volume and pressure
      - Action potential of neurons and muscles
      - Volume of extracellular fluid
    - Aldosterone (most potent mineralocorticoid)
      - Stimulates Na+ reabsorption at PCT, perspiration, saliva, gastric juice
Note on Aldosterone

- Also secreted by cardiovascular system
- 4 mechanisms regulate aldosterone secretion
  - K+ concentration (increase stimulates secretion)
  - ANP (atrial natriuretic peptide)
    - Secreted by the heart when BP increases
    - Inhibits renin-angiotensin mechanism
      - Blocks renin and aldosterone secretion
  - ACTH (adrenocorticotropic hormone)
    - Under severe stress, increase in ACTH leads to increase in aldosterone
  - Renin-angiotensin mechanism
    - If BP or blood volume decrease kidneys releases renin
Adrenal Function

- **Adrenal Cortex continued**
  - Synthesizes Corticosteroids
    - 2 dozen +; Cholesterol based
    - Glucocorticoids
      - Cortisol (hydrocortisone) (and cortisone)
        - Mobilize fat for energy metabolism
        - Stimulate protein catabolism for repairs and enzyme synthesis
      - Increases vasoconstriction; increases BP
  - Excessive levels
    - Depress cartilage and bone formation
    - Decrease release of inflammatory chemicals
    - Depress immune system
Adrenal Function

- Adrenal Cortex continued
  - Synthesizes Corticosteroids
    - 2 dozen +; Cholesterol based
  - Gonadocorticoids (sex hormones)
    - Androgens
      - Androstenedione, dehydroepiandrosterone (DHEA)
      - Converted to testosterone (males) or estrogens (females)
    - Estradiol and other female hormones
Adrenal Function

- Adrenal Medulla
  - Synthesizes catecholamines
    - Epinephrine (adrenaline) (80%)
    - Norepinephrine (noradrenaline) (20%)
  - Increase heart rate and strength
  - Stimulates release of renin by kidney
  - Dilate blood vessels and bronchioles in lungs; constricts most other blood vessels
  - Relax smooth muscle of digestive and urinary tracts; constricts sphincters
  - Dilates pupils of eyes
  - Inhibits insulin secretion by pancreas
  - Promotes blood clotting
  - Stimulates lipolysis in fat cells
Figure 41.16 Stress and the adrenal gland

<table>
<thead>
<tr>
<th>SHORT-TERM STRESS RESPONSE</th>
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<tbody>
<tr>
<td>1. Glycogen → glucose;</td>
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<tr>
<td>↑ Blood glucose</td>
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<tr>
<td>2. ↑ Blood pressure</td>
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<tr>
<td>3. ↑ Breathing rate</td>
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<tr>
<td>4. ↑ Metabolic rate</td>
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<tr>
<td>5. Change in blood flow patterns</td>
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<table>
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<tr>
<th>LONG-TERM STRESS RESPONSE</th>
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<tr>
<td>1. Conversion of proteins and fats to glucose</td>
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<tr>
<td>2. Immune system suppressed</td>
</tr>
<tr>
<td>2. ↑ Blood volume</td>
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</tbody>
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