Unit 1 E
Physiology of the Urinary System

Physiology of the Urinary System

• Functions of the kidney
  • Elimination of excess water
  • Elimination of waste products of metabolism, such as Urea & Creatinine
  • Elimination of foreign substances (such as drugs that have been detoxified by the liver)
  • Retention of substances necessary for normal body function (glucose, electrolytes, minerals, amino acids, etc)

• Functions of the kidney, continued
  • Regulation of electrolyte balance and osmotic pressure of body fluids (BP)
  • Maintenance of body acid/base balance
  • Hormone production
    • Erythropoietin - RBC stimulus
    • Renin - long term regulation and maintenance of blood pressure
Physiology of the Urinary System

- Kidney accomplishes these tasks by:
  - Filtering
  - Reabsorbing
  - Secreting
  - Concentrating
- To accomplish these tasks, needed are:
  - Renal blood flow
  - Glomerular filtration
  - Tubular reabsorption
  - Tubular secretion

Urine Formation

- Glomerular filtration
  - @ 120 ml/minute of renal plasma is filtered through the glomeruli
  - (Glomerular filtration rate / GFR - chemistry test)
  - Blood enters glomerular capillary system
    - Very high pressure created by arterioles
    - Special capillaries allowing filtration
    - Selected components of the blood plasma to pass through the semi-permeable membrane into the capsular space of Bowman’s capsule

Urine Formation - Filtration

- Glomerular filtration continued
  - Ultrafiltrate
    - Composition similar to blood plasma
    - Contains substances up to @ 70,000 daltons.
      - Water, glucose, amino acids, urea, creatinine, ammonia, electrolytes - Na, Cl, etc.
      - NOT blood cells, fats, proteins.
    - Recap:
      - GFR - glomerular filtration rate - @ 120 mL/min, varies with age and sex
      - Used to monitor kidney disease progression
    - Ultrafiltrate:
      - Substances - 70,000 daltons
      - No blood cells, fats, higher mol wt. proteins, etc.
Urine Formation

- **Physiology of the Urinary System**
  - Kidney accomplishes these tasks by:
    - Filtering
    - Reabsorbing
    - Secreting
    - Concentrating

- **Anatomy review**
  - Modified blood leaving through efferent arteriole pass through vessels (peritubular capillaries) that participate in reabsorption process.
  - These vessels eventually become the renal vein.

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Urine Formation - Reabsorption

- **Selected substances removed during ultrafiltration are returned to circulation.**
  - Those things (small enough to filter) that the body cannot afford to lose.
  - Proximal tubules reabsorb water, sodium chloride, bicarbonate, potassium, calcium, amino acids, phosphate, protein, glucose, and other substances.
  - Varying proportions are reabsorbed
    - proteins and glucose almost completely reabsorbed
    - sodium chloride is only partly reabsorbed
    - no reabsorption of creatinine

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Urine Formation - Reabsorption

- **Tubular processing of the glomerular ultrafiltrate**
Urine Formation - Reabsorption

• Both active and passive transport processes are used.

Renal tubular function

• Failure to reabsorb unwanted substances
  • Urea
  • Creatinine
  • phosphates, sulfates, uric acid

• Such substances not actively transported, but some may be passively returned.

Urine Formation - Secretion

• Secretion of unwanted substances
  • drugs, & some waste products

• Acid - base balance through the
  • reabsorption of filtered bicarbonate ion
  • secretion of H+ ions attached to bicarbonate
  • secretion of H+ ions attached to phosphate
  • secretion of H+ ions attached ammonia
Urine Formation - Concentration

- Endocrine influence - hormones affecting excretion/reabsorption of electrolytes and water.

Urine Formation - endocrine influence

- Antidiuretic hormone (ADH) (also known as vasopressin)
  - secreted by the posterior pituitary gland.
  - Controlled by body hydration, ADH regulates absorption of water in the distal portion of the nephron
  - By making the walls of the distal and collecting tubules permeable to water.

Urine Formation - endocrine influence

- Antidiuretic hormone (ADH)
  - insufficient ADH results in diabetes insipidus
    - Effects
      - Excess urine production, increased urine volume
      - Decreased plasma volume
    - Excess results in SIADH
      - Results in
        - high plasma volume
        - low serum osmolarity
        - high urine osmolarity
        - low plasma sodium
        - higher than normal urine sodium.
Urine Formation - Concentration

- Endocrine influence
  - Aldosterone
    - From adrenal cortex
    - Acts on distal and collecting tubules
    - Promotes active reabsorption of sodium from the glomerular filtrate (and concurrent secretion of potassium).
    - Increases water retention
    - Raises blood pressure

Renal Functions

- Hormones produced by the Kidney
  - Erythropoietin / EPO
    - Also called hematopoietin / hemopoietin
    - Produced and released by peritubular capillary endothelial cells in the kidney
    - Stimulates bone marrow to produce and release RBCs

Renal Functions

- Hormones produced by the Kidney
  - Renin
    - Enzyme -like acting substance
    - Released from the juxtaglomerular cells
    - Released in response to decreased blood pressure.
      - Acts on plasma substrate (angiotensinogen) changing it to Angiotensin I. When it passes through the lungs it is then changed into the active form, Angiotension II.
      - Causes dilation of afferent arterioles and vasoconstriction of efferent arteries
      - Promotes reabsorption of sodium in the proximal tubules
      - Promotes secretion of the sodium retaining hormone, aldosterone.
      - (all of which cause increase in BP)
Renal Functions

- Electrolyte balance
  - Sodium & Potassium
    • Renin-angiotensin-aldosterone system (reabsorption of sodium and secretion of potassium)
    • Calcium reabsorbed in proximal tubule under influence of parathyroid hormone (PTH)
    • Magnesium regulation parallels calcium
    • Phosphorus reabsorption in proximal tubule is suppressed by PTH.

- Renal threshold /Threshold substances
  - When plasma concentration of a substance is so high that it can no longer be reabsorbed. The substance will then be detectable in the urine.
    - Glucose - high threshold substance
      • appears in the urine when plasma concentration exceeds about 160 to 180 mg/dl.
    - Other threshold substances:
      • amino acids
      • ascorbic acid
      • creatine
      • potassium
      • sodium chloride
Renal Functions

• **Acid – Base balance**
  • Hydrogen ions are produced as waste from metabolism and are generally secreted.
  • Lungs eliminate volatile respiratory acids
  • Kidneys responsible for non-volatile metabolic acids
    • Keto acids (from ketones)
    • Sulfuric & Uric acid
    • Hydrogen ions
  • Kidneys also capable of removing base substances (bicarbonate), if needed
  • Goal is to maintain overall body pH of 7.40 ± 0.005 (7.35 - 7.45)

• **In metabolic acidosis (↓ pH) blood condition**
  • H+ ions are secreted in exchange for sodium and bicarbonate ions
  • H+ ions are attached to ammonia ions making ammonium (NH3 & NH4+) which is eliminated in exchange for sodium.

• **Alkalosis (↑ pH)**
  • Hydrogen ions conserved
  • Bicarbonate can be excreted, but not often

Exam 1

• Includes identifying anatomy from drawings...