Renal and Urinary A & P review
Advanced Pathophysiology

A&P Starting points

1. maintain homeostasis of internal environment for optimal cell and tissue metabolism
2. Life sustaining balance of solutes and H20, excreting metabolic wastes, conserving nutrients, and regulating acid/base balances
3. Also has endocrine function
4. renin (Regulation of BP), erythropoietin (erythrocyte production) vit d3- 1,25 (calcium metabolism)
5. Also perform gluconeogenesis in times of fasting
6. Formation of urine through filtration, reabsorption, and secretion by glomuli and tubules

Structure/function renal

- Paired structures lying B/L between 12 thoracic and 3rd lumbar spaces
- Outer cortex
- Inner medulla
- Nephron-urine forming unit
- Glomerulus – capillaries serve as filtration units
- Juxtaglomerular cells- secrete renin

NEPHRON

- Each kidney contains 1.3 million nephrons
- 3 types of nephrons
- Superficial, mid-cortical, and juxtamedullary
- Proximal tubule- microvilli to enhance reabsorption
- Loops of Henle- transport solutes and H2O
- Distal tubule- adjust acid base balance
- Collecting duct- primary place to reabsorb NA+/H20 & excrete K+

Renal blood flow

- 1000-2000ml/min
- 20-25% of CO
- Blood flow in the glomerulus is maintained at constant flow despite many factors (autoregulation)
- Exercise, body position (stimulate mild vasoconstriction) and hypoxia (stimulates carotid and aortic bodies to vasoconstrict vis sympathetic) also influence RBF
- GFR is filtration of plasma per unit /per min **** directly r/t perf pressure *****

Autoregulation & innervation

- maintained by sympathetic neural regulation
- vasoconstriction to maintain constant GFR
- sympathetic noradrenergic nerves that regulate vasoconstriction
- Myogenic =
- Tubulo-glomerular feedback
- neural regulation
  - Norepinephrine
  - Dopamine
- hormonal
  - RAS
  - ANG1, ANG2 and ACE
  - ANP, BNP
- Histamine, bradykinin, NO, prostaglandins
- Adenosine

- if systemic BP goes up
  - afferent arterioles constrict so the increasing blood flow does not impact the kidneys
- arterial pressure decreases
  - stimulates sympathetic nerve activity (carotid sinus and baroreceptors)
  - Inc vasoconstriction and dec RBF and GFR
  - diminishes secretion of NA+ and H_2O
  - promoting the blood volume and thus increase to systemic blood volume and pressure

Tubular reabsorption and tubular secretion

- Proximal tubule
  - Reabsorbs >> NACL, GLU, K+, HCO_3, PO_4, protein, urea, H20
  - Secretes >> H+, foreign substances, organic anion and cations
- Loop of Henle
  - Concentrates urine , h20 reabsorption in descending loop NACL diffuses in, NA+ reabsorbed in ascending loop h20 stays in, urea secretion
- Distal tubule
  - Reabsorbs >>NACL, h20 (ADH required) HCO_3
  - Secretes >> K+, H+, NH_3, urea, some drugs
- Collecting tubule
  - Reabsorption >> h20 (ADH required)
  - Secretion ⍰ NA+, K+, H+,NH_3+

Renal hormones

- Vitamin D
  - Inactive and requires 2 step hydroxylation to establish metabolically active form
  - Decreased levels of phosphate stimulate active VIT D formation and increased levels inhibit renal system matters in homeostasis of calcium phosphate and VIT D deficiency
- Erythropoietin
  - Produced by fetal liver and in the adult kidney
  - EPO stimulates the bone marrow to produce RBCs in response to tissue hypoxia, when the kidneys are receiving less oxygen via the blood, erythropoietin is stimulated
  - Also affects angiogenesis, mitogenesis, and anti-apoptosis

Vitamin D synthesis

- Vitamin D2 (ergocalciferol)
- Vitamin D3 (cholecalciferol)

- Vitamin D promotes Calcium absorption in the GUT and maintains adequate serum calcium and phosphate for bone health

Vitamin D synthesis

- Vitamin D (biologically inert) obtained from the sun/food intake/supplementation must undergo 2 hydroxylation's to become active
- 1st step In the liver = converts Vitamin D 25-hydroxyvitamin {25 (OH)D} also known as calcidiol
- 2nd step occurs in the kidney=forms the physiologically active 1,25 dihydroxyvitamin D {1,25(OH)2D} also known as calcitriol
- serum ca+ <10 stimulates PTH secretion, then stimulates a series of event s to help restore Calcium levels (CA+ mobilization form bones, absorption of CA+ and phosphate from intestine by stimulating renal activation of vitD increased renal CA+ and PO4 uptake and decreased secretion)

Urinary structures

Ureters

Bladder
detrusor and trigone muscles
innervated w/ parasympathetic fibers

Urethra

Renal system Workup and common complaints

Common Symptoms of the Renal System

- Hematuria/dysuria/incontinence

- Edema

- HTN

- Uremia s/sx
    - weakness and easy fatigability, anorexia, vomiting, ALOC, and seizures

- Evaluation
    - Stepwise approach
        - Nephrotoxins
        - Cause of pre-renal azotemia

- Initial testing
    - UA w/ micro, BUN/creat, GFR
    - urine protein or albumin (by random [or "spot"] protein-to-creatinine ratio or albumin-to-creatinine ratio)
    - renal ultrasound (if calculi suspect then CT abd/pelvis)
    - serum and urine protein electrophoresis (SPEP and UPEP) at the time of the initial evaluation and
    - if these are abnormal, a free light chain assay.

Pertinent Labs

- Serum creatinine

- GFR

- BUN

- Cr Cl (creatinine clearance)

- Urinalysis w/ micro
    - Color
    - WBCS
    - pH
    - Sp. gravity
    - Urine sediment
    - Casts

Crystals=

RBCs=

Fluids and Electrolytes

Distribution of body fluids

- Intracellular (2/3) and extracellular (1/3)
- =total body water (TBW)
- Approximately 60%
- Amount of fluid is relatively constant
- Exchange happens between compartments to maintain cellular compartment integrity
- Percentage depends on age and fat composition
- FAT is hydrophobic very little in adipose tissues, therefore, obese or overweight individuals are more prone to dehydration due to proportionally less TBW

Aging and distribution

- Newborn 75-80% body water
- Infant 67%
- Childhood 60-65%
- >adolescents 42-70%
- Based on lean muscle mass and BMI level
- Water movement
- Osmosis
- Lipid bilayer and aquaporins
- TBW is normally at equilibrium
- Na+ most abundant ECF and responsible for osmol balance in ECF
- K+ maintains intracellular balance

https://youtu.be/rPWf43lYcBU

Starling hypothesis

- Net filtration=forces favoring filtration –forces opposing filtration
- Capillary hydrostatic pressure (BP)
- Capillary oncotic (plasma) pressure
- Interstitial hydrostatic pressure
- Interstitial oncotic pressure

Edema

- homeostatic mechanisms that serve to maintain this balance, and these must be overwhelmed before fluid buildup becomes evident as peripheral edema
- symptom of nephrotic syndrome is diffuse peripheral and periorbital edema
- Severe protein-wasting renal disease or acute renal failure with volume overload
- diffuse or bilateral edema, the diagnostic focus is on determining which organ system is in dysfunction
- Excess accumulation of fluid in interstitial space
- A problem with fluid distribution not necessarily fluid excess
- An increase in the forces favoring fluid filtration from the capillaries/lymphatics to the tissue

- Caused by 4 processes

    - An increase in hydrostatic pressure

    - Venous obstruction

    - Loss or diminished production of plasma proteins

    - Increases in capillary permeability

Edema Mechanisms

- Venous obstruction
    - Can increase the the hydrostatic pressure of fluid within the capillaries enough to cause fluid to escape into the interstitial spaces
    - Tight fitting clothes, thrombophlebitis, hepatic obstruction, & prolonged standing
    - CHF, RF, and cirrhosis
    - Na+/h20 retention
    - Causes volume overload, increased venous pressures, and create edema
- Losses/diminished production of albumin
    - Decrease in plasma oncotic pressure
    - Causes fluid to shift into the interstitial spaces
    - Can occur with malnutrition and liver disease, also kidney and open wounds, hemorrhage, and cirrhosis.
- Increases in capillary permeability
    - Plasm proteins escape, normally lymphatic system absorbs small proteins that cross capillary membrane, when these are blocked or surgically removed then allow proteins and fluid to accumulate into the interstitial fluid

- Trauma, burns, crushing injuries, neoplastic disease, and allergic reactions

- Clinical manifestations
  - Localized or generalized
  - Weight gain, swelling, puffiness, tight fitting clothing/shoes , limited movement in affected area
  - Increases the distance nutrients, oxygen, and wastes have to go between capillaries and tissues.
  - Wounds heal more slowly, increased risk of infection and pressure sores
  - Life-threatening in organs- brain, larynx, and lung

Na+/Cl-/h20 balance

- Sodium regulated by:
  - Renal effects of aldosterone from adrenal cortex
  - Naturetics peptides
- Water regulated by:
  - ADH (vasopressin) from posterior pituitary
  - Follows osmotic gradients by Na+ concentrations

Na+

- 90% ECF cations
- Regulates extracellular osmotic forces
- Work in conjunction with K+ and CA+ for neuromuscular irritability
- Regulation of acid base balance
- Participation in cellular chemical reactions
- Membrane transport
- Maintained within narrow range of 135-145 meq/l
- Kidney regulates by renal tubular absorption
  - In response to excess or deficit of Na+, neural and hormonal signals help to synergistically control the balance
  - Hormone-aldosterone
  - Enzyme-renin
    - Angiotensin I—angiotensin II
    - Natriuretic peptides =ANP and BNP

Cl-

- Major anion in extracellular fluid
- Provides electroneutrality (particularly in relationship to Na+)
- Follows active transport with Na+

- Increases and decreases with cl- are proportional to na+
- Inversely related to bicarb concentration (another main anion in ECF)

Water balance

- Water secreted =water ingested /generated by metabolism
- ADH and perception of thirst are primary factors in reg. of water balance
- Triggered when 2% drop In body weight OR increased osmol
- Dry mouth/thirst, inc osmol and volume depletion (plasma) activate osmoreceptors →cause thirst → increases plasma volume and dilutes ECF osmol
- ADH secreted by increased in plasma osmol or dec circ blood volume/low Bp
- Action to increase permeability of renal tubular cells to h20 → h20 then reabsorbed and decrease plasm osmol

Balance

- Integration of renal, hormonal, and neural functions
- Changes in composition of electrolytes
- Affect electrical potentials
- Cause shifts of fluids in compartments
- Alterations of pH
- Ph must be maintained within a tight range 7.35-7.45

- How does the body put up with this, how does it handle it--? Co2 into aqueous solution>> reacts to form carbonic acid>> bicarbonate
- 5-10% can just dissolve, another 5-10% can attach to hemoglobin; the other must be transported in these forms primarily from bicarbonate
- These reactions are a buffer system, reduced the acidosis
- If you would dump hydrogen ions into the blood, you would have acidosis, vice versa alkalosis if you dump some base instead of just making you pH go up

References

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