Urinary System

A. Functions

1. Maintain blood homeostasis

2. Elimination of waste

B. Structures

1. Kidneys

A) Reddish-brown in color & bean-shaped

B) Lie in superior lumbar region of the posterior abdominal wall (T12 to L3)

C) External Anatomy

1) Renal hilus – indentation located on the medial aspect of the kidney

2) Renal capsule – connective tissue covering surrounding each kidney; several

layers thick

D) Internal Anatomy

1) Renal cortex – outer region of the internal kidney; lies beneath the capsule

2) Renal medulla – inner region of the internal kidney; lies deep to the cortex

a) Renal pyramids – cone-shaped masses in the medulla; contain bundles of the

urine-collecting tubules resulting in a striated appearance; base of each

pyramid faces the cortex; 5-11 per kidney

i) Papilla of the pyramid – the “point” of each pyramid

b) Renal columns – inward extensions of the renal cortex that separate the

pyramids

3) Minor calyces (calyx) – cup-shaped tubes that enclose the papilla of each

pyramid and collect urine from the tubules; 5-11 per kidney

4) Major calyces (calyx) – branching extensions of the renal pelvis; minor calyces

pass urine into them; 2-3 per kidney

5) Renal pelvis – flat, funnel-shaped tube on superior aspect of ureter; major

calyces pass urine into pelvis; 1 per kidney

E) Microscopic Anatomy

1) Nephron – functional unit of the kidney; over 1 million/kidney; produces urine

through the processes of filtration, reabsorption, & secretion

a) Glomerulus – web of capillaries where filtration occurs; filtrate is the result

i) Afferent arteriole – takes blood to the glomerulus

ii) Efferent arteriole – takes blood from the glomerulus

b) Peritubular capillaries – surround the tubular portion of the nephron

c) Bowman’s capsule – cup-shaped, hollow covering that surrounds glomerulus;

collects filtrate from the glomerulus

i) Podocytes – cells in the Bowman’s capsule that wrap around the

glomerulus.

d) Proximal convoluted tubule (PCT) – tubular structure leading from the

Bowman’s capsule; site of most reabsorption

e) Loop of Henle – narrow hairpin loop that connects PCT & DCT

i) Has 2 portions

(a) Descending portion – continuous with PCT

(b) Ascending portion – continuous with DCT

f) Distal convoluted tubule (DCT) – tubular structure that empties into

collecting duct

g) Collecting ducts (tubules) – receive urine from the DCT

i) Receives input from many nephrons (DCTs)

ii) Extends deep into the renal medulla (pyramids)

h) Papillary ducts – created by the junction of adjacent collecting ducts

i) Empty into minor calyces

i) Juxtaglomerular apparatus (JGA)

i) Juxtaglomerular (JG) cells

(a) Monitor BP in the afferent arteriole

(b) Secrete renin

ii) Macula densa cells

(a) Monitor the Na+ content of the filtrate in the DCT

2) Related terms

a) Vascular nephron – refers collectively to the afferent arteriole, glomerulus,

efferent arteriole, and peritubular capillaries

b) Tubular nephron – refers collectively to the Bowman’s capsule, PCT, loop of

Henle, DCT, and collecting ducts

c) Renal corpuscle – refers collectively to the glomerulus & Bowman’s

capsule

2. Ureters

A) Slender tubes that transport urine from the kidneys (renal pelvis) to the urinary

bladder

B) Transport urine via peristaltic action and gravity

3. Urinary bladder

A) Collapsible, muscular sac that stores and expels urine; lined with transitional

epithelium

1) In males – it lies superior to the prostate gland

2) In females – it lies inferior and slightly anterior to the uterus

B) Detrusor muscle – smooth muscle surrounding the bladder squeezes urine from the

bladder

C) Holds max of 800-1000ml

D) Trigone – smooth, triangular portion outlined by the openings of the ureters &

urethra

1) Common site of infections

4. Urethra

A) Thin-walled tube that carries urine from the bladder to the outside of the body

1) Internal urethral sphincter

a) Smooth muscle sphincter

b) Located at the junction of the bladder and the urethra

2) External urethral sphincter

a) Skeletal muscle sphincter

b) Surrounds the urethra at the urogenital diaphragm

B) Females

1) External urethral orifice – opening of the urethra; located between the vagina

and the clitoris

C) Males – multiple segments

1) Prostatic urethra – portion running within the prostate gland

2) Membranous urethra – portion running through the urogenital diaphragm

3) Spongy urethra – portion running through the penis (corpus spongiosum)

4) External urethral orifice – opening of the urethra at the end of the penis

5) The male urethra is also the passageway for reproductive secretions

C. Filtering of Blood

1. Blood Pathway

A) Renal artery 🡪 segmental artery 🡪 lobar artery 🡪 interlobar artery 🡪 arcuate

artery 🡪 cortical radiate artery 🡪 afferent arteriole 🡪 glomerulus 🡪 efferent

arteriole 🡪 peritubular capillaries 🡪 cortical radiate vein 🡪 arcuate vein🡪

interlobar vein 🡪 lobar vein 🡪 renal vein

2. Filtration – movement of fluid/substances from the glomerulus into the Bowman’s

capsule

A) Glomerulus

1) Site of filtration

2) Composed of fenestrated capillaries

3) NFP = GBHP - (CHP+GBOP)

B) Bowman’s capsule

1) Filtration slits – gaps between the podocytes that allow fluid to pass through

2) Fluid is referred to as (glomerular) filtrate

3) Glomerular filtration rate (GFR) = volume/time (~180L/day or ~48gal/day)

3. Reabsorption – movement of fluid/substances from the kidney tubules into the

peritubular capillaries

A) Proximal convoluted tubule – site of the greatest amount of reabsorption

1) Na– occurs via both primary active transport & facilitated diffusion

a) The active transport of Na sets up the conditions that allow almost all other

types of reabsorption in the PCT

2) Glucose, amino acids, & vitamins – secondary active transport (cotransport)

with Na+

3) Cations (Ca++, K+, Mg++) via paracellular movement

4) Anions (Cl-, HCO3-) – Cl- via paracellular transport and HCO3- via cotransport

with Na+

5) Water via osmosis

6) Urea & lipid-soluble substances via simple diffusion

B) Loop of Henle

1) Descending portion

a) Water via osmosis

2) Ascending portion

a) Na+, K+ & Cl- via Na+–K+–2Cl- cotransportor and paracellular movement

b) Ca++ and Mg++ via paracellular movement

c) \*NO water\*

C) Distal convoluted tubule

1) Na+ via primary active transport in the presence of aldosterone

2) Ca++ via primary active transport in the presence of parathyroid hormone

3) Cl- via simple diffusion & secondary active transport (cotransport w/ Na+)

4) Water via osmosis in the presence of antidiuretic hormone (ADH)

D) Collecting ducts

1) Na+ via primary active transport in the presence of aldosterone

2) H+, K+, HCO3-, & Cl- via passive processes dependent on the movement

of Na+

3) Water via osmosis in the presence of antidiuretic hormone (ADH)

4. Secretion – movement of fluid/substances from the peritubular capillaries into the

kidney tubules

A) Occurs in all portions of tubule system

B) Important for:

1) Eliminating substances that weren’t filtered (ex. penicillin & aspirin)

2) Eliminating undesirable substances that were passively reabsorbed (ex. urea)

3) Eliminating excess K+

4) Maintaining blood pH (via H+ & HCO3-)

5. Urine

A) Urine Composition

1) 90% water

2) Nitrogenous wastes (urea)

3) Salts

4) Toxins

5) Pigments (from the breakdown of hemoglobin and bile pigments)

6) Hormones

7) If blood, protein, or glucose are detected this is usually an indication of kidney

troubles

8) Pus, mucus, or cloudiness can indicate an infection somewhere in the urinary

tract

B) Urine characteristics

1) Color – clear to deep yellow in color

2) Odor – slightly aromatic when fresh but tends to develop an ammonia odor due

to bacterial metabolism

3) pH – urine is slightly acidic (about pH 6)

4) Specific gravity – 1.005 to 1.035

5) Volume – 1000-2000ml per day

6. Pathway of Urine from Bowman’s capsule

A) Bowman’s capsule 🡪 proximal convoluted tubule 🡪 descending loop of Henle 🡪

ascending loop of Henle 🡪 distal convoluted tubule 🡪 collecting ducts 🡪 papillary

ducts 🡪 minor calyces 🡪 major calyces 🡪renal pelvis 🡪 ureters 🡪 urinary bladder

🡪 urethra 🡪 outside the body

7. Urination (Micturition)

A) Visceral reflex

1) When bladder fills to 200-400ml, stretch receptors in wall fire

2) Impulses travel to micturition center in sacral region of spinal cord

3) Impulses travel back to detrusor muscle and internal urethral sphincter, as well

as to the cerebral cortex

a) The detrusor contracts & the internal urethral sphincter relaxes allowing urine

to travel down the urethra until it reaches the external urethral sphincter

b) The cortex gives us a conscious awareness of the need to urinate

i) Initially we can choose to ignore this and the urge will subside temporarily

4) Under conscious control cerebral cortex fires causing external urethral sphincter

to relax

a) Pressure created by the detrusor muscle and other muscles in the urogenital

region force urine from the body

8. Glomerular Filtration Rate (GFR)

A) Total glomerular filtrate of both kidneys/time

B) Directly proportional to urine production

C) Directly proportional to the NFP

D) Regulation of GFR

1) Autoregulation

a) Myogenic mechanism

i) Triggered by smooth muscle in afferent arteriole

(a) In response to increased systemic BP (stretch)

(i) Causes vasoconstriction of the afferent arteriole to reduce pressure

and protect the glomerulus

(b) In response to decreased systemic BP (stretch)

(i) Causes vasodilation of the afferent arteriole to increase pressure

and maintain a minimal GFR

b) Tubuloglomerular feedback mechanism

i) Triggered by the macula densa cells

(a) In response to increased flow rate and/or osmolarity of the filtrate

(i) Causes vasoconstriction of afferent arteriole to decrease pressure

and protect the glomerulus

(b) In response to decreased flow rate and/or osmolarity of the filtrate

(i) Causes vasodilation of afferent arteriole to increase pressure and

maintain a minimal GFR

2) Hormonal Regulation

a) Renin-angiotensin mechanism

i) JG cells are stimulated to release renin in response to:

(a) Reduced stretch in JGA

(b) Input from macula densa cells

(c) Sympathetic input

ii) Renin converts angiotensinogen to angiotensin I

iii) Angiotensin I is converted to angiotensin II by ACE

iv) Angiotensin II causes:

(a) Vasoconstriction of systemic arterioles

(b) Stimulation of hypothalamic thirst center

(c) The release of ADH & aldosterone

(i) ADH promotes the reabsorption of water in the DCT & CD

(ii) Aldosterone promotes the reabsorption of Na+ in the DCT & CD

b) Atrial natriuretic peptide (ANP)

i) Released from cells in the ventricles

ii) Inhibits release of renin, aldosterone, and ADH

iii) Promotes excretion of Na+ & water from the DCT & CD

3) Neural Regulation (ANS)

a) Sympathetic nervous system

i) No input

ii) Moderate input

iii) Large input – “fight-or-flight”

D. Disorders

1. Pyelitis – infection of the renal pelvis and calyces

2. Pyelonephritis – infection or inflammation of the entire kidney

3. Glomerulonephritis – infection or inflammation of the glomerulus

4. Anuria – low urinary output as a result of injury, transfusion reactions, low blood

pressure, etc

5. Renal calculi – kidney stones

6. Urethritis – inflammation of the urethra

7. Cystitis – inflammation of the bladder

A) Urinary Tract Infection (UTI) – generic term used to refer to urethritis, cystitis, or

both

8. Incontinence – inability to control micturition

9. Vesicoureteral reflux (Kidney reflux) – urine moves backwards up the ureter and into

the kidney; sometimes seen with severe UTI’s

10. Renal Failure – can be caused by:

A) Repeated disorders/infections

B) Physical trauma

C) Chemical poisoning

D) Atherosclerosis