The Reproductive System: Male, Ch 20

Outline of class lecture

After studying the male reproductive system you should be able to:

1. Define the purpose of reproduction and identify the general organs of the reproductive system.
2. Describe the general organs of the male reproductive system.
3. Describe the functions of the scrotum.
4. Describe the structure and functions of the testes.
5. Explain the process of spermatogenesis and spermiogenesis.
6. Describe the functions of the male duct system, including the testis, epididymis, vas deferens, and urethra.
7. Explain the functions of the male accessory glands – seminal vesicles, prostate gland, and bulbourethral (Cowper’s) glands.
8. Discuss the components of semen.
9. Describe the structure and function of the penis and include a description of how an erection is formed.
10. Discuss the Clinical Applications from the study guide and be able to describe the disorders from the Applications to Health located at the end of this chapter.

Reproductive System

- Purpose
- General Structures
- Male
  - Structures
  - Functions
- Female Anatomy
  - Structures
  - Functions
- Clinical Applications

General Information

- Purpose: To produce offspring and transfer genetic material from generation to generation.
- Includes:
  - Gonads (Testes and Ovaries):
  - Ducts: Receive, store and transport gametes
  - Accessory sex glands: Produce substances that protect, support and facilitate the movement of gametes
  - Supporting structures: Facilitate the delivery and joining of gametes.
    - In females, also house the developing fetus

Male Reproductive System

- General Organs:
  - Testes:
    - Genital ducts: Epididymus, ductus (vas) deferens and portions of the urethra
    - Accessory glands: Seminal vesicle, prostate gland, bulbourethral gland
      - Produce secretions that mix with sperm to form semen
    - Supporting structures: Penis
      - Delivers semen to the female reproductive tract
Scrotum

- **Functions:**
  - Musculature contractions help regulate temperature of testes.
  - Provides an environment ~3°C cooler than core body temperature needed for proper sperm development

Testes (Testicles)

- **General Information**
  - Develop in the abdominal cavity and later (7 month of fetal development) descend through the inguinal canals into the scrotum.

Cryptorchidism

- **Cryptorchidism:** One or both testes have not descended into the scrotum by the time of birth
  - 80% of time, testes will descend spontaneously within 3 months after birth.
  - Generally corrected surgically (orchidopexy) before 6 months of age.
  - Untreated, results in sterility because higher temperatures destroy sperm producing cells.
  - Chance of testicular cancer is

Functions of Testes

- **Exocrine:**
  - **Endocrine:** Produce **testosterone**
    - Regulates development of spermatozoa
    - Regulates development and maintenance of accessory glands.
Structures of Testes
- Each testis has 200 to 300 pyramid shaped lobules each containing 1-3 seminiferous tubules.
- Seminiferous Tubules
  - Function:
    - Lining consists of 2 basic cell types: Spermatogenic cells and Sustentacular (Sertoli) cells.
- Spermatogenic cells:

Spermatogenesis
- Spermatogenesis:
- Spermatogonia: Stem cells; Diploid (2n=46 chromosomes) cells located in the outermost region of the seminiferous epithelium.
  - Starting at puberty will
    - One daughter cell remains as a stem cell and the other differentiates into a primary spermatocyte (2n) and is pushed towards the lumen.
- Spermatocytes:
  - Primary spermatocyte (2n): Undergo meiosis I (reduction division) which results in the formation of 2 haploid (n) secondary spermatocytes.
    - Will have DNA
  - Reduction division is where the tetrads separate (homologous chromosomes) reducing the chromosome number by half.
- Secondary spermatocyte (n): Undergo meiosis II, which results in the formation of haploid spermatids that lie close to the lumen.
  - During meiosis II the chromatids separate.
    - Will have 4 spermatids when complete
- Spermatids (n)
  - Haploid cells with half (23 chromosomes) the chromosome content
  - To become mature
Spermiogenesis

- **Spermiogenesis**: Process where spermatids are transformed into mature sperm and released into the lumen of seminiferous tubules.
  - Entire process, from spermatogonia to maturation, takes ~74 days.
  - Each sperm develops:
    - **Head**: Contains the nucleus with a haploid number of chromosomes (23).
    - **Acrosome**: Caplike vesicle filled with enzymes that help the sperm penetrate into the ovum
    - **Midpiece**: Contains numerous mitochondria that provide ATP for locomotion.
    - **Tail**: Flagellum that propels the sperm at

- Sperm are released into the lumen of the seminiferous tubules, migrate to the epididymis where they complete their maturation (10 to 14 days after arriving).

- Sperm
  - Are reabsorbed if not ejaculated
  - Can be stored in an inactive state in the epididymis and vas deferens for ~ a month
  - Life expectancy of ~48 hours within the female reproductive tract.

- **Sustentacular (Sertoli) cells**:
  - Located between spermatogenic cells and forms a continuous layer around each tubule.
  - **Function**:
    - Forms blood-testis barrier: Prevents immune system from attacking sperm and allow selected substances to pass from the blood to sperm
    - Support, protect, and nourish the spermatogenic cells and produce chemical stimuli that promote their development.
    - Phagocytose excess
    - **Regulates sperm production**:
      - Secrete androgen-binding protein (ABP) into the seminiferous tubules.
        - **ABP** binds to testosterone and
        - Secretes inhibin, a hormone that inhibits the synthesis and release of follicle stimulating hormone (FSH) by the anterior pituitary.
        - FSH increases sperm production.

- **Interstitial cells of Leydig**
  - Located within the loose CT of lobule between seminiferous tubules.
  - **Function**:
    - Begin secretion during puberty
Hormonal Control of Spermatogenesis

- **Gonadotropic Hormones (FSH and LH)** regulate the growth, development, and functions of the gonads.
  - Consist of two types:
    - **Follicle stimulating hormone (FSH)**
      - **Females**: Stimulates the development of the ovarian follicles and ova (egg).
      - **Males**: Stimulates the testes to produce sperm and stimulates
    - **Luteinizing hormone (LH)**
      - **Females**: Induces ovulation and formation of corpus luteum, which is an endocrine structure that secretes estrogen and progesterone
      - **Males**: Stimulates interstitial cells in testes to produce androgens – the most important of which is testosterone
        - **Testosterone** helps stimulate spermatogenesis

Reproductive Ducts in Males

- Functions to transport sperm from the body.
- Ducts system includes the:
  - Seminiferous tubules
  - Epididymus
  - Ductus deferens
  - Urethra.

Epididymis

- Coiled tube (~20 ft in length) located on the exterior of the testis
- **Function**:
  - In 10 to 14 days their motility increases
  - Can store for at least a month; if not ejaculated they are reabsorbed.

Ductus (vas) Deferens

- **Function**: Transports sperm from
  - **Peristaltic contractions**: Propel sperm toward the urethra during ejaculation

Urethra

- Passage way for semen and urine out of the body
Accessory Sex Glands in Males
- **Accessory sex glands** secrete most of the liquid portion of semen and consist of:
  - Seminal vesicles.
  - Prostate gland
  - Bulbourethral glands

**Seminal Vesicles**
- Located near base of urinary bladder.
- **Secretory products:**
  - Yellowish alkaline viscous fluid that contains fructose (energy source for sperm), prostaglandins (sperm viability and reverse peristaltic contractions of Fallopian tubes), and clotting proteins (fibrinogen)

**Prostate Gland**
- Donut shaped gland that surrounds the urethra at the base of the urinary bladder
  - ~ the size of a golf ball
- **Secretory products:**
  - Milky, slightly acidic (pH ~6.5) fluid that contains:
    - **Citric acid**
    - **Clotting enzymes** to activate fibrinogen from seminal vesicles to become fibrin.
    - **Proteolytic enzymes:** Liquefy coagulated semen.
      - Include: Prostate specific antigen (PSA), profibrinolysin, lysozyme, amylase, and hyaluronidase.
  - Fluid constitutes ~25% of semen volume

**Bulbourethral (Cowper’s) Glands**
- Paired pea size structures, located inferior to the prostate on either side of the membranous urethra within the urogenital diaphragm.
- **Secretory Products**
  - Clear, viscous, alkaline fluid
  - Secreted during sexual arousal prior to ejaculation to protect sperm by lubricating and neutralizing the acid environment of the urethra.

**Semen**
- **Semen** is a mixture of sperm and secretions of the accessory glands
  - pH = 7.2 to 7.7
- Average volume of ejaculation is 2.5 to 5 ml.
- Below 20 million sperm/ml is likely to be infertile.
- Ejaculated semen coagulates within 5 minutes due to the presence of clotting proteins from seminal vesicles – functions to hold semen next to cervix; 5 to 20 minutes later the semen liquefies due to proteolytic enzymes (fibrinolysin) produced by the prostate gland.
Capacitation of Spermatozoa

- Capacitation is
  - Contact with fluids of female genital tract activates (capacitates) the sperm (requires 1-5 hours)
  - Capacitation includes:
    - Uterine and fallopian tubes fluids wash away the inhibitory factors that suppress sperm activity in the male genital ducts
    - Acrosomal membrane of sperm head becomes thinner
    - Sperm membrane becomes permeable to Ca²⁺ ions and Ca ions enter and activate the flagellum to whip about more powerfully

Why does only one sperm enter the Oocyte?

- A few minutes after a sperm penetrates the zona pellucida of the ovum, Ca²⁺ ions diffuse into the oocyte and cause multiple cortical granules to be released by exocytosis form the oocyte.
- The granules contain substances that change the configuration of the zona pellucida and prevent binding of additional sperm as well as cause sperm that have already began to bind to fall off.

Penis

- Penis consists 3 cylindrical masses of erectile tissue.
  - Single ventral corpus spongiosum that expands distally to form the glans penis.

Erectile Tissue

Erectile tissue: Consists of numerous blood sinuses (vascular spaces) lined by endothelial cells and surrounded by smooth muscle and elastic CT that forms the trabeculae
NO and Vasodilatation of Penal Arteries

- Stimulation of parasympathetic neurons relax smooth muscle of penal arteries by the production of nitric oxide (NO).
  - A small population of parasympathetic neurons can make and release NO directly.
  - Most parasympathetic neurons innervating the penis release acetylcholine (ACh) which stimulates endothelial cells in the area to make and release NO.
- NO causes vasodilatation.
- Vasodilatation of arteries supplying the penis causes them to distend and compress the penal veins which inhibits the outflow of venous blood, resulting in an erection.
- Ejaculation is a sympathetic reflex causing the peristaltic waves of contraction of smooth muscle to propel semen out of the urethra.
- Penis returns to flaccid state when the arteries constrict and pressure on the vein is relieved.

Erectile Dysfunction

- Erectile Dysfunction (ED) or impotence: Consistent inability to ejaculate or to attain or hold an erection long enough for sexual intercourse.
- Causes include:
  - Diabetes mellitus; vascular disturbances; neurological disturbances, drugs (alcohol, antihypertensives), anxiety, and fear.
  - Insufficient release of nitric oxide, which relaxes the smooth muscle of the penile arterioles and erectile tissue. Most frequent.
- Viagra (sildenafil) enhances the effects of nitric oxide by inhibiting the enzyme (a type of phosphodiesterase) that stops the action of nitric oxide.
  - This allows the arteries supplying the penis to dilate more effectively and produce an erection.