What are the components of the male reproductive system?

CNS, pituitary, testis, epididymis, prostate, seminal vesicles, scrotum, penis

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The male reproductive system consists of several organs acting together to produce functional spermatozoa, and to deliver these spermatozoa to the female reproductive tract. The system is summarized in Figure 1. Spermatozoa, the haploid germ cells, are produced in the testis and undergo maturational changes as they transit the epididymis. The vas deferens transports the spermatozoa from the epididymis to the ejaculatory duct in the prostate. The spermatozoa and secretions of the seminal vesicles empty together, with secretions from the prostate, into the prostatic urethra. Secretions from the bulbourethral gland contribute to the ejaculate as the mixture exits the body through the penile urethra. The entire system is dependent on testosterone, also produced in the testis, and its regulation by the pituitary and hypothalamus. Knowledge of the anatomy and embryological origins of the components of the male reproductive tract is important in developing a basic and thorough understanding of the system as a whole.

Testis

The testis is the site of germ cell development (spermatogenesis) and thus the primary tissue of the male reproductive system. It is also the site of androgen synthesis and secretion. Spermatogenesis occurs within the seminiferous tubules of the testis; the process whereby germ cells progress from haploid cells (spermatogonia) to meiotic cells (spermatocytes) to haploid cells (spermatids). The epithelial cells of the seminiferous tubules, the Sertoli cells, facilitate this process. Leydig cells, that populate the interstitial space between the seminiferous tubules, produce testosterone.

The testis arises from the primitive gonad in which primitive germ cells migrate to the undifferentiated gonad from the yolk sac, causing the coelomic epithelial cells to proliferate and form the sex cords. Formation of the sex cords gives this region a raised contour that is called the genital ridge. During the fourth month of embryogenesis, the sex cords become U-shaped and their ends anastomose to form the rete testis. At this point, the primordial sex cells are referred to as pre-spermatogonia and the epithelial cells of the sex cords as Sertoli cells. The sex cords will become the seminiferous tubules.

The rete testis extends into the mesonephric tissue and will anastomose with some of the mesonephric tubules forming the efferent ducts that communicate with the epididymis (discussed below). The mesenchymal tissue in the interstitial space between the tubules gives rise to the Leydig cells, the site of androgen production.

Scrotum

The function of the scrotum is to house and protect the testis, and to help maintain the temperature of the testis optimal for spermatogenesis. The testis develops on the posterior abdominal wall and descends into the scrotum late in development. Successful descent of the testis into the scrotum is essential for fertility. The scrotum is formed as the coelomic epithelium penetrates the abdominal wall and protrudes into the genital swelling as the processus vaginalis. An outgrowth of most layers of the abdominal wall is carried with this epithelium, giving rise to the fascial layers of the scrotum. The testes then descends behind the processus vaginalis into the scrotum. The cremasteric and Dartos layers of scrotal fascia contribute to the important temperature regulatory function of the scrotum.

Epididymis

The epididymis is a single, highly convoluted tubule connected to the testis by a series of efferent ducts. The function of the epididymis is to bring testicular spermatozoa, that are non-motile and incapable of fertilization, to functional maturity. How this maturation process is accomplished by the epididymis is not fully understood. The epididymis secretes proteins and other molecules that comprise the fluid in the epididymal lumen that bath the sperm. The components of this fluid work together to modify the sperm and bring it to maturity.

The epididymis, vas deferens and seminal vesicles have a common origin from the mesonephric (Wolffian) duct. Initially formed as the early embryonic excretory system, the mesonephric system is comprised of a longitudinal duct and a series of tubules that branch from the duct toward the developing gonad. Although most will degenerate, several of these tubules persist and anastomose with the confluence of the seminiferous tubules (rete testis), to form the efferent ducts through which spermatozoa exit the testis. The portion of the mesonephric duct closest to the efferent ducts elongates, becomes extensively convoluted, and forms the epididymis. The epididymis remains in close contact with the testis and descends with the testis into the scrotum.

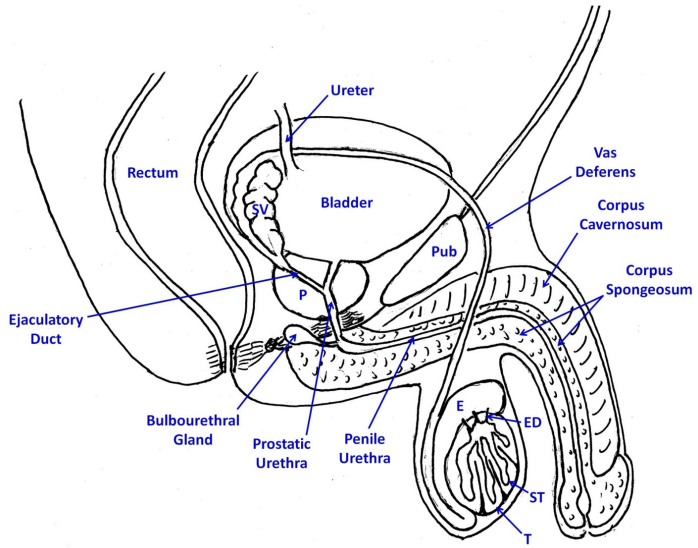

FIG. 1. Overview of the anatomy of the male reproductive track. E, epididymis; ED, efferent duct; P, prostate; SV, seminal vesicle; ST, seminiferous tubule; T, testis.

Vas deferens

A portion of the mesonephric duct distal to the forming epididymis becomes thickened and muscular, and forms the vas deferens (or ductus deferens). In its course the vas deferens ascends from the scrotum, with the vessels that vascularize the testis and epididymis, passes through the inguinal canal, crosses behind the bladder to enter the prostate. The ejaculatory duct, also a mesonephric duct derivative, connects the vas deferens to the prostatic urethra. The primary function of the vas deferens and ejaculatory duct is transport of mature spermatozoa and seminal vesicle secretions (discussed below) to the prostatic urethra.

Seminal vesicles

The fully developed seminal vesicle resides immediately above the prostate gland. It develops as an out-pocketing from the mesonephric duct, just proximal to the developing ejaculatory duct. The seminal vesicle is

comprised of a series of tubular alveoli, lined with a very active secretory epithelium. In fact, the seminal vesicle contributes the majority of the fluid volume of the ejaculate (~70%). Seminal vesicle secretions are rich in fructose and prostaglandins. The seminal vesicle also produces several androgen-dependent secretory proteins that are involved in such processes as the clotting of the ejaculate and immunoprotection of the sperm.

Prostate

The prostate gland is located in the space inferior to the bladder. Its location immediately anterior to the rectum allows the prostate to be palpated and biopsied through the rectum. The prostate arises from several distinct sets of tubules that evaginate from the primitive urethra, each developing into a separate lobe. The lobes are composed of alveoli, lined with a secretory epithelium, that drain through a series of converging tubules into the prostatic urethra. The lobes are essentially continuous in the normal adult prostate, with no apparent gross or morphologic distinctions. A more recent and useful subdivision of the prostate distinguishes prostatic zones based on morphologic and functional properties (i.e., central, peripheral and transitional zones).

Prostatic secretions contribute significantly to the fluid volume of the ejaculate (~25%). These secretions are high in zinc, citric acid and choline, as well as several secretory proteins including acid phosphatase, seminin, plasminogen activator and prostate specific antigen (PSA). The exact roles of most prostatic secretions are unknown, although they are presumed important for the function of spermatozoa during and after ejaculation. Many of the proteins are proteases that are involved in the liquification of coagulated ejaculate. Elevated levels of PSA in the blood is often diagnostic of abnormal prostatic growth such as occurs with cancer of the prostate.

Penis

The penis is responsible for the delivery of male germ cells to the female tract during sexual intercourse. It is comprised of two corpus cavernosi and the corpus spongiosum. The corpus cavernosi are erectile tissue which when filled with blood produce the penile erection. The corpus spongiosum, also an erectile tissue, forms the penile urethra and glans penis. The penile urethra is continuous with the prostatic and membranous portions urethra, and provides the remaining conduit for the sperm and ejaculatory fluids as they leave the body. The physiology of penile erection (discussed in a subsequent chapter) is complex and is subject to a number of clinical disorders. The

importance of proper erectile function to sex and reproduction, and the common occurrence of erectile dysfunction (affecting 10-20 million men in the United States), has made erectile dysfunction a primary clinical concern in andrology.

Endocrine and nervous control of the male reproductive tract

The entire male reproductive tract is dependent on hormones for proper function. The pituitary produces the gonadotropins, follicle-stimulating hormone (FSH) and luteinizing hormone (LH), under the control of the hypothalamus. FSH is required for the initiation of spermatogenesis, and LH stimulates androgen production by the testicular Leydig cells. The testis requires high concentrations of testosterone to maintain the process of spermatogenesis and the accessory organs are dependent on androgen for proper secretory function. In addition to hormonal control, the reproductive organs are also subject to sympathetic and parasympathetic nervous control. This is particularly true for the erectile function of the penis, that is under parasympathetic control, and for ejaculation, that is under sympathetic control.

Conclusion

This brief introduction to the male reproductive tract demonstrates the integrated nature of the system. The seminiferous tubules are continuous with the penile urethra via the epididymis and vas deferens, with the accessory organs contributing their secretions along this course. The entire system is maintained by pituitary gonadotropins and androgens secreted by the testis. Understanding the anatomy and embryological development of the components of the male reproductive tract are key to understanding its normal function, as well as the common, and the not-so-common, disorders encountered in the clinic.

Suggested reading

Brooks JD. Anatomy of the Lower Urinary Tract and Male Genitalia. In: Wein AJ, Kavoussi LR, Novik AC, Partin AW, Peters CA, Eds.Campbell-Walsh Urology, 9th Edition. Philadelphia: WB Saunders; 2007; Chapter 2.

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