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Anatomy and Physiology of Reproductive System of Bovine Species: A Review

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ABSTRACT

The primary organ of reproduction in the bull are the ***testicles****. Other secondary sex organs include three accessory sex glands comprising the seminal vesicles, prostrate and bulbourethral gland (Cowper's gland) and the reproductive male tracts. The reproductive tracts are the epididymis, the vas deferens and the penile urethra. In the male, the organs that are involved in spermatozoa production, transport and coitus are: testicles, epididymis, vas deferens or ductus deferens, prostate gland, seminal vesicles and penis.*

All reproductive organs work in concert for formation, maturation and transport of spermatozoa, which are eventually deposited in the female reproductive tract

This paper reviewed the anatomy and physiology of bovine reproductive system from literature published in peer reviewed journals.

Key words: *Review, Anatomy and Physiology, Bovine, Sex organs*

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INTRODUCTION

Attaining Puberty and Sexual Maturity in the Bull

Male puberty is said to occur when the first ejaculate consist of at least 50 million spermatozoa with 10% minimal progressive motility [1], that is, when rapid testicular growth occurs, changes in the secretion of hormones and result to the onset of spermatogenesis [2]. Breeds differ in age and weight relative to puberty. Nellore bulls reach puberty by age 15 months [3], while bulls of European breeds reach puberty at 10 months of age [4]. Feeding and thermal stress can contribute to the schematic representation of the hypothalamic-pituitary-gonadal axis in these characteristics [5].

After puberty, the testicles of the bulls continue to grow and the number of spermatozoa in the ejaculate increases until 24 months of age, when they reach sexual maturity. At this time, there is an increase in seminal volume, progressive sperm motility, vigour and total sperm concentration, and a decrease in some sperm diseases [6].

Descent of the Testicles

Testicular development includes its descent from the abdominal cavity to the scrotal pocket through the inguinal ring. The descent of the testicles to the scrotum is preceded by the formation of the vaginal process from the peritoneum that internally coats the scrotum. At 140 days of gestation, the testicles of the bovine foetus are already housed inside the scrotum and completing the cellular differentiation [7].

Reproductive Anatomy and Physiology of the Bull

The primary organ of reproduction in the bull are the **testicles**. Other secondary sex organs include three accessory sex glands comprising the seminal vesicles, prostate and bulbourethral gland (Cowper's gland) and the reproductive male tracts. The reproductive tracts are the epididymis, the vas deferens and the penile urethra. In the male, the organs that are involved in spermatozoa production, transport and coitus are: testicles, epididymis, penis, vas deferens or ductus deferens, prostate gland, seminal vesicles and penis (Figure I). All reproductive organs work in concert for formation, maturation and transport of spermatozoa, which are eventually deposited in the female reproductive tract.

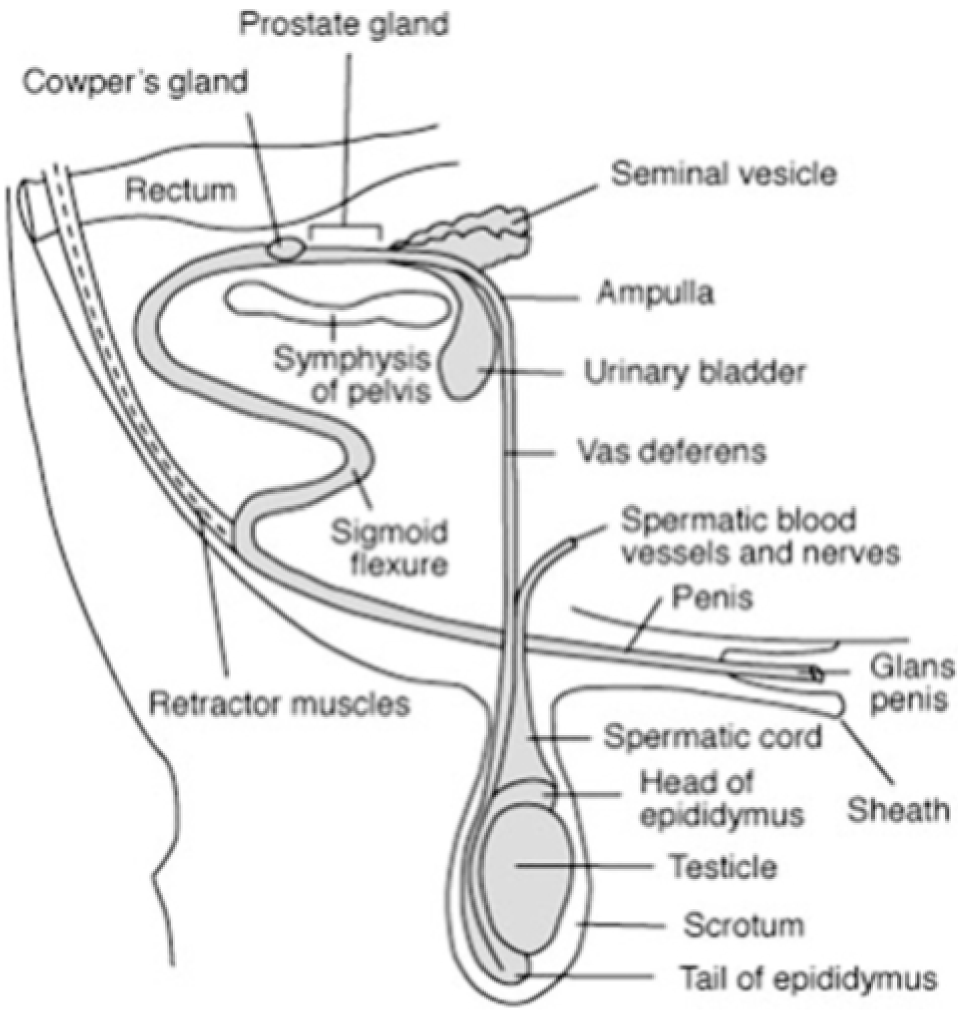

Figure I: Reproductive anatomy of the bull (Setchel, 1992**)**

The penis of the bull can be divided into a root, body, and glans penis. The root of the penis can be defined as the origin of the erectile tissue (*Corpus carvenosum* and *Corpus spongiosum*) that comprises the penis as well as the origin of the skeletal muscles of the penis [8]. The erectile tissue that makes up the bulk of the penis is the corpus cavernosum. The paired *corpora cavernosa* originate separately on each side of the ischiatic arch medial to the ischiatic tuberosity. These individual limbs are termed the crura of the penis. The crura pass ventromedially until they join to form the body of the penis. The *corpus spongiosum* is the erectile tissue that surrounds the urethra. The origin of the *corpus spongiosum*, called the bulb of the penis, originates between the crura along the midline of the ischiatic arch. Therefore the root of the penis is composed of the crura (corpus cavernosum) and the bulb (corpus spongiosum) [9].

The erectile tissue is enclosed in the dense outer covering of the tunica albuginea. The tunica albuginea consist of an inner circular layer and outer longitudinal layer of fibers. The inner circular layer sends trabecular scaffolds throughout the *corpus cavernosum* for the attachment of the cavernous endothelium. Located caudal to the root of the penis are the skeletal muscles of the penis: the ischiocavernosus, bulbospongiosus, and retractor penis muscles. The paired ischiocavernosus muscles originate on the medial surfaces of the ischiatic tuberosities overlying the crura. The muscle fibers pass ventromedially in a "V" fashion until ending a short distance on the body of the penis [8]. During erection the ischiocavernosus muscle contracts pushing blood from the cavernous spaces of the crura into the body of the penis [10].The bulbospongiosus muscle lies caudal to the bulb of the penis, originating along the ischiatic arch and continuing until the junction of the crura [8]. The bulbospongiosus muscle fibers run transversely across the bulb of the penis and the contraction of this muscle results in propulsion of the ejaculate through the urethra [10]. The retractor penis muscle extends from the caudal vertebrae and internal anal sphincter to insert distal to the penile sigmoid flexure [9]. These paired muscles relax during erection allowing the penis to extend from the prepuce and contract during quiescence, retracting the penis into the sheath [9]. The body of the penis begins where the two crura meet distally to the ischiatic arch. It bend in an "S" shape called the sigmoid flexure. The proximal bend of the sigmoid flexure opens caudally and is located near the scrotum. The distal bend is opened cranially and the short suspensory ligaments of the penis attach the penis to the ventral surface of the ischiatic arch. Craniad and at the mid ventral abdomen, it extend along the ventral body wall to become the free part of the penis. The glans penis is a small restricted region at the tip of the free part of the penis [9]. The free part of the penis is the distal extent from the attachment of the internal lamina of the prepuce to the glans penis [9]. It is twisted in a counter clockwise direction as viewed from the right side, illustrated by the oblique direction of the raphe of prepuce continued as the raphe of the penis to the urethral process. The twist of the free end of the penis is due to the attachment of the apical ligament. The apical ligament of the penis is formed by the longitudinal fibers of the tunica albuginea leaving the body of the penis just distal to the sigmoid flexure and reattaching near the apex of the penis [11]. The prepuce of the penis is composed of an external and internal fold or lamina [9]. The external lamina is the haired outer fold of skin attached to the ventral abdomen. The haired skin terminates at the preputial orifice where the external fold turns inward to line the preputial cavity as the internal lamina. The internal lamina serves to attach the external lamina to the penile epithelium. At birth the penis is attached by connective tissue and small blood vessels, along its entire length to the sheath. As the calf approaches puberty these connections are terminated; one remnant of the connections may remain at puberty as the frenulum. The frenulum attaches the glans to the prepuce and might be thickened and vascular [11].

The intracorpus blood pressure during an erection is 800 to 24,000 mm Hg. Hence, damage to the tunica albuginea surrounding the penis results in significant hemorrhage. The blood supply to the penis is provided by the internal pudendal artery. Sensory innervation of the penis is provided by branches of the dorsal nerve of the penis, which is a branch of the pudendal. The retractor penis is controlled by nerves from the pudendal and hemorrhoidal nerves. Autonomic innervation is provided by nerves from the pelvic plexus [9].

Sheath and Prepuce

The penis lies in the prepuce or sheath in the non-erect state. During erection, the penis is exteriorized through the preputial orifice. The prepuce has three basic components: the exterior portion, the skin, and the interior lining.

The lining is a loose movable structure that extends from the glans to the preputial orifice. The pouch formed when the preputial lining is reflected to attach to the glans is called the fornix. Blood supply is from the external pudendal artery. The prepuce is innervated by fibers from the iliohypogastric and ilioinguinal nerves [11].

The scrotum and testicles

The scrotum is composed of an outer layer of thick skin and three underlying layers, the tunica dartos, the scrotal fascia, and the parietal vaginal tunica. The scrotal skin is extensively populated with numerous large adrenergic sweat and sebaceous glands that are highly endowed with thermal receptors and nerve fibers. Neural stimulation from the thermal receptors enables the tunica dartos, which consists of smooth muscle fibers and lies just beneath the scrotal skin, to contract and relax in response to changes in temperature gradients and facilitates the cooling of the scrotal surface via scrotal glandular sweating [12]. Thus the scrotum plays an important role not only in housing and protecting the testicles but also has a role in thermoregulation of the testes. The spermatic cord connects the testicles to the body and provides access to and from the body cavity for vascular, neural, and lymphatic systems that support the testicles. In addition, the spermatic cord accommodates the cremaster muscle, the primary muscle supporting the testicles, and the pampiniform plexus, a complex and specialized venous network that wraps around the convoluted testicular artery [13]. This vascular arrangement is very important in temperature regulation of the testicular environment. The plexus consists of a coil of testicular veins that provide a counter-current temperature exchange system: this is an effective mechanism whereby warm arterial blood entering the testicles from the abdomen is cooled by the venous blood leaving the testicles. Testicular arteries originate from the abdominal aorta and elongate as the testicles migrates into the scrotum [13]. In cattle and other large domestic ruminants these arteries are highly coiled, reducing several meters of vessel into as little as 10 cm of spermatic cord [13]. The arterial coils and venous plexus are complex structures that form during fetal life in cattle [14]. Because of the pendulous nature of the bovine scrotum, testicular cooling is facilitated by the contraction and relaxation of the cremaster muscle, which draws the testicles closer to the abdominal wall during cooler ambient temperatures and vice versa during warmer temperatures. Scrotal and testicular thermoregulation is a complex process involving a number of local mechanisms that strive to maintain the testicles at environmental and physiological conditions conducive for normal spermatogenesis.

The scrotum receives its blood supply primarily from the external pudendal artery and is innervated by the genital nerve. The genital nerve arises from the second to fourth lumbar nerves and perineal nerve as the genitofemoral nerve. Innervation to the scrotal smooth musculature is from the pelvic plexus. Clinically these innervations are important, because epidural anesthesia does not induce scrotal analgesia [14].

The epididymis

The epididymis is a compact, flat, elongated structure closely attached to one side of the testicle. It is divided into three regions, the head, body and tail. Many tubules entered the head of the epididymis from the testicle and unite to form a single tubule. A bull has approximately 35 meters long epididymis which is convoluted and packed into 18 cm length. Four major functions occur in the epididymis, including the transport of the developing spermatozoa from the testicles to the vas deferens; the concentration of the spermatozoa by absorption of surplus fluids; the maturation of the developing spermatozoa; and the storage of viable spermatozoa in the epididymal tail. If sexual activity is slowed, resorption of spermatozoa from the epididymal tail occurs [9]. The epididymis serves as an outlet for all the spermatozoa produced in the testicles and any blockage of this tube will cause sterility. Temporary blockage due to swelling following an injury or infection (epididymitis) will result in short-term infertility. If the swelling or infection results in formation of scar tissue in the tubule, it may permanently block the passage of spermatozoa. If blockage occurs in both epididymides, the bull will no longer be useful as a breeder. Surgical removal of the tail of the epididymis (epididectomy) is frequently used as a means of sterilization for teaser (Gomer) bulls for estrus detection. Epididectomized bulls will mate cows in the usual manner, because they still produce testosterone form Leydig cells, however will not deposit spermatozoa into the female reproductive tract at coitus [13].

The vas deferens

The vas deferens, also known as ductus deferens, emerges from the tail of the epididymis as a straight tubule and passes as part of the spermatic cord through the inguinal ring into the body cavity [9]. Spermatozoa are transported further along the reproductive tract to the pelvic region through the vas deferens by contraction of the smooth muscle tissue surrounding this tubule during ejaculation. Bulls may also be sterilized by vasectomy in which a section of the vas deferens is removed so that spermatozoa cannot pass to urethra and go outside of the body [13].

Urethra

The two vas deferens eventually unite into a single tube, the urethra, which is the channel passing through the penis. The urethra in the male serves as a common passageway for semen from the reproductive tract and urine from the urinary tract. The pelvic part of the urethra is associated with the accessory genital organs, with the excretory duct of the accessory sex organs entering this part of the urethra. The spongy/penile part is surrounded by corpus spongiosum and is dorsal to bulbospongiosus muscle and ventral to corpus cavernosum [9].

Accessory glands

The accessory genital glands of the bull include the vesicular gland, ampulla of the ductus deferens, and the prostate and bulbourethral glands. The bilateral vesicular gland is the largest accessory gland in the bull and contributes the greatest volume to the ejaculate. It is a lobulated gland of firm consistency. It lies dorsal to the bladder and lateral to the ureter and ampulla of the ductus deferens [8]. The body of the prostate lies dorsal to the urethra between and caudal to the vesicular glands. The disseminate part of the prostate is concealed in the wall of the urethra and covered by the urethral muscle [8]. The ampulla, vesicular glands, and prostate all empty their contents into the urethra through the colliculus seminalis. The bilateral bulbourethral gland lies on each side of the median plane dorsal to the urethra; it is mostly covered by the bulbospongiosus muscle. Its duct opens into the urethral recess. The urethral recess is a blind pouch that exits dorsally into the penile urethra at the level of the ishiatic arch. The presence of this structure makes it difficult to pass a catheter retrograde into the bladder. As mentioned above, the bull has three sets of accessory glands. Semen is made up of the fluids from accessory glands and the mature spermatozoa. The volume of ejaculate is very variable, 1 to 15 ml. The concentration will also vary considerably, however the usual is 1 to 1.8 billion sperm per ml. Since only one spermatozoa is required to fertilize an ovum, considerable dilution of the semen can be done. In addition, the secretions activate the spermatozoa to become motile. The seminal vesicles consist of two lobes about 10 cm long in the bull, each connected to the urethra by a duct, which the main role is the production of nutrients for spermatozoa. The prostate is relatively small in the bull, as compared to other species, and does not produce a very large volume secretion, which is rich in enzymes for spermatozoa metabolism. The clear and buffered secretion that often drips from the penis during sexual excitement prior to service is largely produced by these glands and serves to flush and cleanse the urethra of any urine residue that may be harmful to spermatozoa. The secretion from Cowper's glands assures an optimizer pH for the semen. This is a protection against an eventual low pH of female reproductive tracts and pH decrease due the spermatozoa metabolism. One of the accessory glands may occasionally become infected, resulting in semen samples that are yellow and cloudy and which contain puss cells. It is not uncommon in bulls for the seminal vesicles to be so affected (seminal vesiculitis). Antibiotic treatment is sometimes necessary, but time will generally correct the problem [8].

Transport and the tubular transport system

Spermatozoa are transported from the testicles through a tubular system consisting of the convoluted seminiferous tubules, straight seminiferous tubules, rete testis, efferent ductules, epididymis, ductus deferens, and urethra. The tubular system allows for maturation and storage of spermatozoa and provides fluid to ease movement of the spermatozoa [8].

The convoluted seminiferous tubules are the location of the spermatogenic process: the development of spermatogonia to primary spermatocytes, to spermatids, and finally to spermatozoa. This process occurs within the wall of the seminiferous tubule. Specific regions of the tubule are devoted to a particular stage of development, so that each stage can be identified by specific histological techniques. Upon the completion of spermiogenesis, the spermatozoa are released into the lumen of the convoluted seminiferous tubule to begin transit through the straight seminiferous tubule. The straight seminiferous tubule is simply the connection between the convoluted seminiferous tubule and the rete testis. The rete testis is a “network of irregular labyrinth spaces and interconnected tubules. The rete testes are located within the mediastinum testis connecting the seminiferous tubules to the efferent ducts that exit the testicle at the extremitas capitata (head). The efferent tubular system continues as the epididymis on the external surface of the testis. The epididymis is divided into a head, a body located on the medial surface, and a tail located at the distal extremitas caudate.

The ductus deferens is attached to the medial side of the testicle by the mesoductus. The ductus deferens is the continuation of the tail of the epididymis. The ductus deferens enters the abdominal cavity through the inguinal canal, crosses the lateral ligament of the bladder, and before it ends at the colliculus seminalis in the urethra it widens into the ampulla.

Testicular Thermoregulation

For a testicular function to be satisfactory, the temperature of the testicles in the scrotum should be maintained at 2 to 6°C below body temperature [16]. The maintenance of physiological testicular temperature depends on factors that involve the scrotum, pampiniform plexus, spermatic cord and internal vascularization [16].

The counter current mechanism refers to the loss of temperature of the testicular artery by lowering blood pressure as it enters the testicular parenchyma [15]. This occurs by testicular veins that surround the arterial branches helping the temperature drop. Failures in testicular thermoregulation favour testicular degeneration, leading to increased morphological defects of spermatozoa, reduced seminal quality and fertility [17].

REPRODUCTIVE BHAVIOUR OF THE BULL

Libido and mating behaviour

Libido is primarily dependent upon androgenic steroid hormones, which allow mating and aggressive behaviour to occur, as well as maintaining the function of all parts of the male reproductive system. Libido is seldom expressed in animals that are castrated before puberty, if a mature animal that has learnt to copulate is castrated, erection and copulation may persist for long periods or, occasionally, indefinitely. Despite the dependency of male behaviour upon androgen, there has been much debate over the relationship between absolute concentrations of androgen and libido [18]; [19]. Some have argued a permissive role of androgen, while others have demonstrated positive correlations between testosterone concentrations and measures of libido. Breeds of bull that are aggressive and respond quickly to the presence of an oestrous female tend to have higher testosterone concentrations than the more phlegmatic breeds, but whether this is a causal relationship remains unclear.

The males of those domestic species that are naturally herd animals spend a great deal of time detecting oestrous [20].

CONCLUSION

The primary organ of reproduction in the bull are the **testicles**. Other secondary sex organs include three accessory sex glands comprising the seminal vesicles, prostrate and bulbourethral gland (Cowper's gland) and the reproductive male tracts. The reproductive tracts are the epididymis, vas deferens and the penile urethra. In the male, the organs that are involved in spermatozoa production, transport and coitus are: testicles, epididymis, vas deferens or ductus deferens, prostate gland, seminal vesicles and penis. All reproductive organs work in concert for formation, maturation and transport of spermatozoa.

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