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Comparative morphological features of male genitalia of cattle and buffalo bull

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Abstract
Since males are responsible for 90% of a herd's genetics, choosing more fertile and precocious bulls is highly important. The basic criterion in assessing normality of the reproductive tract follows a rigorous evaluation of the reproductive organs regarding their position, shape, dimensions, symmetry, consistency, and relation with other organs. Aspects intrinsic to the animal, such as breed and age, are important during the assessment, besides environmental factors such as nutritional and sanitary management. Thus, knowing the morphological aspects of the genital system enables one to identify the organic changes and their relations with subfertility and infertility, as well as adopting therapeutic measures aiming at increasing animal reproductive efficiency in case the pathology is treatable and reversible.

Keywords: Hernia, buffalo bull, umbilical, herniorrhaphy

Introduction
Morphology, in biology, is the study of the size, shape, and structure of animals, plants, and microorganisms and of the relationships of their constituent parts. The term refers to the general aspects of biological form and arrangement of the parts of a plant or an animal. In order to safely perform the breeding soundness evaluation in bulls, it is crucial to know the anatomic-physiologic characteristics of the male reproductive system. Such information allows the veterinarian to understand the interrelations of the organs and to differentiate physiologic conditions from possible pathology onset. Externally, the male reproductive system is made up of the scrotal sac, testicles, epididymis, part of the spermatic ducts, foreskin, and penis, while inside the abdominal cavity and the pelvis are the accessory sex glands (ampullae of the deferent ducts, seminal vesicles, prostate, and bulbourethral glands), which are crucial for seminal fluid production. All reproductive organs work in concert for formation, maturation and transport of spermatozoa, which are eventually deposited in the female reproductive tract.

Spermatic Cord
The spermatic cord, also called spermatic funiculus, is formed by the set of tubular structures grouped in a cord-like shape that come from the abdomen and reach the testicles. The spermatic cord is formed by the deferent ducts, arteries, pampiniform plexus, lymph vessels, nerves, and cremaster muscle. All these elements are surrounded by the tunica vaginalis, cross the inguinal canal, and reach the testicles to perform circulatory and thermoregulatory roles, conduct nerve impulses, and transport gametes.

Inguinal Canal
The inguinal canal is a muscular aponeurotic structure that forms an oblique passage from the caudal portion of the abdominal wall that begins at the deep inguinal ring and ends at the superficial inguinal ring. The inguinal canal allows the testis, epididymis, and spermatic cords to pass from the abdominal cavity into the scrotal sac. The deep inguinal ring is formed from the free caudal edge of the internal oblique muscle and by the inguinal ligament and interconnects the inguinal canal to the abdominal wall. The superficial inguinal ring is formed from the slit in the aponeurosis of the external oblique muscle located near the pubis and interconnects the inguinal canal to the subcutaneous groin tissue. The active mechanism works through the contraction of the internal and transverse oblique muscles that occlude the canal opening, which remains virtually shut (Dyce *et al.*, 2004) [13].

Scrotal Sac
The scrotal sac, also known as scrotum, is a sac-like structure partially divided by a septum,

which forms the right and left scrotal compartments. Each compartment holds the set of organs made up of the testis, epididymis, spermatic cord, and part of the deferent ducts. The muscle-skin part of the scrotum favors the thermal exchange mechanisms allowing testicular temperature to be maintained up to 6°C below the body's internal temperature for spermatogenesis to take place normally (Garcia *et al.*, 2006) [15]. The scrotum has lean skin, with little subcutaneous fat, has sweat glands and little hair. Its muscle portion is called tunica dartos which, along with the cremaster muscle, promotes contraction and relaxation of the scrotal sac. The tunica dartos connects to the common tunica vaginalis and to other fixation structures to originate the proper ligament of the testis and the ligament of epididymis, which bind these organs to the inner portion of the scrotal sac. In buffaloes, the scrotal sac is positioned closer to the inguinal region and is smaller and less pendulous than in bovines (Fig. 1) due to the slight funneling in the region corresponding to the spermatic cord (Bhattacharya *et al.*, 1974) [10]. As in cattle, the testis and epididymis can be palpated through the scrotal wall, while the prostate, seminal vesicles and ampullae of the ductus deferens can be palpated per rectum (Ahmad and Noakes, 2009). The scrotum of the river buffalo is 20–25 cm in length, has a distinct neck and is pendulous. The scrotum of the swamp buffalo is about 10 cm in length (fully extended) and the neck is not distinct (MacGregor, 1941). The testes of the swamp buffalo descend into the scrotum at 2–4 or 6 months of age, while they may be present in the scrotum at birth in the river type. In one study on Murrah buffalo bulls, the scrotum was oblong in 69.77% of bulls whereas it was square in 20.93% and overlapping in 9.30% of buffalo bulls studied (Somasekharam *et al.*, 1986) [28].

Fig 1: The scrotum and testis of a buffalo bull and cow bull.

In buffalo bull, the scrotal sac is positioned closer to the inguinal region and is smaller and less pendulous than in bovines.

Testis

Testicles are the organs hosting male gametogenesis and, therefore, are the most important ones in the reproductive context. Compared to taurine bovines, testicular development is slower in buffalo bulls since the former can have scrotal circumference of 30 to 33 cm between 12 and 24 months of age. This value is only found in buffaloes over 30 months old that are kept under appropriate nutritional and sanitary conditions (Ahmad *et al.*, 1984; Brito *et al.*, 2002; Anurag *et al.*, 2004; Vale *et al.*, 2008) [4, 11, 6, 31]. Testis in buffalo are ovoid in shape and turgid on palpation, with a marked resonance. The testes are of unequal size, with the left usually bigger. Buffaloes with body weight between 400 and 600 kg have an average testicle weight of 108.7 g, while in bovines of similar bodyweight, gonads weigh approximately 160 gm (Moura *et al.*, 2002) [19]. In young buffaloes, the right testicle measures on an average 8.83 x 4.64 cm (length x width) while the left testicle measures 8.77 x 4.58 cm (Sousa *et al.*, 1980) [30]. In buffaloes, the seminiferous tubules take up 82% of the testicular space (Pawar *et al.*, 1991) [23]. In buffaloes, the testicular artery may have a varied number of ramifications, but, overall, the artery is split at the cranial and caudal branches, which also ramify, with either branch taking equal part in testicle vascularization (Passipieri *et al.*, 1986). Testicle development in buffaloes is slow and gradual until 14 months of age. Nevertheless, spermatogenic activity may begin between 18 and 24 months of age and, when well-managed, bubaline males may have reproductive activity at 24 months of age, with gamete production stabilizing at 36 months. It is common for bubaline bulls to stabilize their body and testicular growths at 36-48 months of age when they reach 650-750 kg, an indication of maturity (Ahmad *et al.*, 2010) [5].

Table 1: Testicular dimensions and sperm production parameter of cow and buffalo bull

	Cow bull	**Buffalo bull**
Scrotum	Between the thighs	Between the thighs
Testis		
Size (cm)	1 4 x 7 x 7	8.77 x 4.62 x 4.62
Shape	Oval	Oval
Long axis	Vertical	Vertical
Weight(gm)	300	168
Length of seminiferous tubule (m)	5000	3000
Length of epididymis (m)	30	-
Epididymal journey of spermatozoa	10	9.3
Sperm production (in billion)	12	6-8
Total duration of spermatogenesis	61	38.5
Overall rate of spermatogenesis (no. of sperms from one type A spermatogonium)	64	74
Sperm production per gram of testicle (in millions)	12-17	13.26

Epididymis

The epididymis is a tubular-shaped organ located medially to the testicle and is formed by three regions, namely the caput, corpus, and cauda. The epididymis is the organ responsible for nutrition, maturation, selection, transport, and storage of spermatozoa. Along the epididymal transit, the male gamete acquires motility ability and undergoes morphological, molecular, and metabolic changes needed for it to have fertilizing potential. The epididymis in adult bulls is 13 cm long and weighs on average 18 g (Sousa *et al.*, 1980) [30]. Whereas in bubaline bulls, epididymis weighs around 16 gm and caput to cauda length is 15 cm (Silvana *et al.*, 2010).

Vas deferens

The two-ductus deferens or vas deferens extend from cauda epididymis to the pelvic urethra. The ducts are firm with thick muscular walls and lumen quite small. The ducts are convoluted near the cauda epididymis and then run parallel to the corpus epididymis. Later, these pass through the inguinal canal into the abdominal cavity along with other components of the spermatic card. On reaching the abdominal cavity, the vas deferens separates from the spermatic card, passes upward and backward to open into the pelvic urethra. The vas deferens is about 3 mm thick in cow bull.

Penis

The penis is the copulatory organ and is of fibroelastic nature in cows and buffaloes. The penis of the bull is about 90 cm in length from its root to the tip of the glans. The diameter is about 4 to 5 cm on erection. The glans penis is 7.5 to 12.5 cm long and is rather pointed. The penis in buffaloes is shorter, compared to cattle bulls, contains very little erectile tissue and is cylindrical in shape with a tapering end. As a consequence, even in the non-erectile state, the penis is firm in consistency, and the organ does not enlarge too much during erection. In adult buffalo bulls, the average penis length is 83.51 cm and 56.72 cm in the swamp type (Joshi *et al.*, 1967), measured from the beginning of the sigmoid flexure to the free end, while the average thickness is 1.95 cm (Vale *et al.*, 2008).

The penis has a cylindrical shape and is anatomically divided into three regions: crura (or root), body, and glans. The crura and the base of the penile body make up the intrapelvic penis, while the body and the free end, which contains the glans, make up the extrapelvic penis (Cavaliere *et al.*, 1997). In river buffalo, the penis hangs clear of the abdomen by 15–30 cm, being attached thereto by a triangular fold of skin running backwards from the umbilicus. In swamp type buffalo, the sheath of the penis adheres closely to the abdomen except for the last 2–3 cm (MacGregor, 1941). The penis in the river buffalo contain great amounts of elastic fibres (65.41% for corpus spongiosum and 51.12% for corpus cavernosum) suggest that these fibres have an important role in penile erection in the buffalo (Pereira *et al.*, 2008) [24].

Foreskin

The foreskin, also called preputial sheath, consists of the outer penile cover of cutaneous and muscular origin with a shape corresponding to the penis and located in the ventral region, between the scrotal sac and the navel. It is responsible for the mechanical protection of the male sexual organ. The prepuce in the bull is about 35 cm long and 4 cm in diameter. The preputial orifice is 5 to 7 cm behind umbilicus and is surrounded by tuft of hair (Fig. 2).

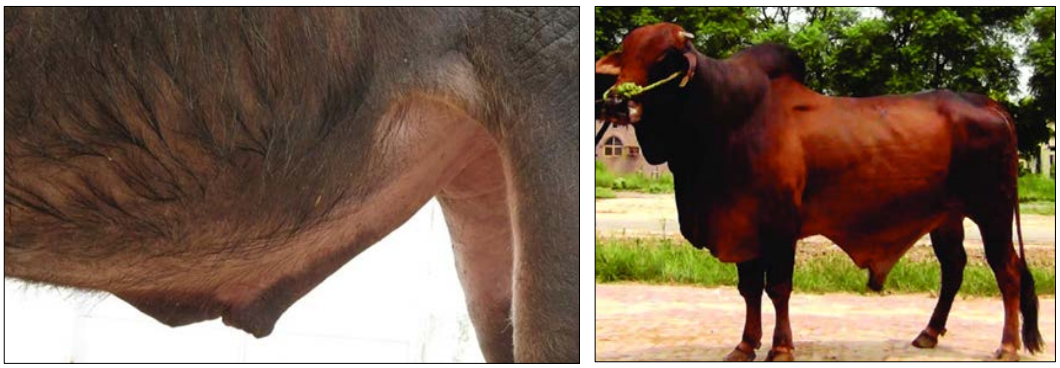

Fig 2: The prepuce of a buffalo bull and cow bull. In buffalo bull, the prepuce is positioned closer to the inguinal region and is smaller and less pendulous than in bovines

In the bulls of Indian breeds, the prepuce is in the form of pendulous sheath. The preputial cavity in buffalo is only 30 to 35 cm deep compared to the average length of 40 cm in European breeds (Kunavongkrit & Koonjaenak, 2006) [17]. The hair within the prepuce is absent or scanty and very short. The prepuce itself is tightly and closely adherent to the ventral part of the abdominal wall. It ends few centimeters caudal to the umbilicus where it hangs freely.

Internal Organs

The internal male reproductive system is made up of accessory sexual glands that comprise the seminal vesicles, the ampullae of the deferent ducts, the prostate, and the bulbourethral gland (Fig. 4). In buffaloes, the accessory glands are smaller than in bovines of similar age, however, physiologically their roles are identical (Vale *et al.*, 1981) [33]. The secretions of the accessory sexual glands, allied to those from the epididymis and the testis, make up the seminal plasma.

They contain several substances such as fructose, citric acid, potassium, zinc, acid phosphatase, free amino acids, and prostaglandins, which are added to the semen at the moment of ejaculation (Setchell *et al.*, 2006) [27]. Besides neutralizing vaginal pH, the primary roles of the seminal plasma are assuring organic and inorganic molecular support to the spermatozoa for energy production, maintaining the medium osmolarity, protecting against reactive oxygen species (ROS), modulating sperm motility, and acquiring the ability of performing spermatic capacitation and the acrosome reaction (Jobim *et al.*, 2004; Roldan *et al.*, 2007) [16, 25].

Table 2: Dimensions of accessory sex glands in cow and buffalo bull (Bagshaw *et al.*, 1974 and Sarangi *et al.*, 2020)

	Cow bull	Buffalo bull
Ampulla (cm)	10-12 x 1-1.5	9.2-9.4 x 0.64-0.66
Seminal vesicle dimensions (cm)	13 x 3 x 1.42	6-7 x 2.1-2.2 x 0.4
Seminal vesicle weight (gm)	35	20
Prostate gland		
Pars propria (cm)	3 x 1 x 1	1.57 x 1.48 x 1
Pars disseminate (cm)	12 x 1.5 x 1.0	6.7 x 2.9 - 3.9 x 2.4
Bulbourethral gland dimensions (cm)	2.9 × 1.9 x 1.8	1.3 x 1.1 x 1.1
Bulbourethral gland weight (gm)	4.6	-

Ampullae of the Deferent Ducts

The deferent ducts are canals that are tubular, long, and thin, of firm consistency and have thick muscle walls. Their role is to bring the spermatozoa from the epididymis to the urethra. The pelvic terminal portion of each deferent duct has a dilation called ampulla of the deferent ducts. The deferent ducts, along with the ducts of the seminal vesicles, pass under the body of the prostate and reach a protuberant structure called seminal colliculus (*colliculus seminalis*), which is a component of the pelvic urethra. The ampulla in bulls' measures about 10 to 12 cm in length and 1.0 to 1.5 cm in diameter.

Urethra

The urethra in males is the common passage for the excretion of urine as well as for the transportation of semen. The urethra has three distinct parts (pelvic part, bulb of urethra and the penile part). In bull, the pelvic part of urethra is about 20 cm in length and is situated on pelvic floor. The pelvic urethra is enclosed by heavy urethral muscle. The bulb of urethra is extra pelvic part situated at ischial arch and is bending ventral to the pelvis. The penile urethra runs inside the penis proper.

Seminal Vesicle

The seminal vesicles, also called vesicular glands, are multilobulated organs of firm consistency located dorsal to the urinary bladder, lateral to the ureter and the ampullae of the deferent ducts, and cranial to the prostate. In buffalo bull, the seminal gland is comparatively smaller in comparison to the bulls. In adult bubaline bulls, the vesicles are half the size of the organ in bovines, with less evident lobulations (Vale *et al.*, 1980 & Sousa *et al.*, 1980) [32, 30]. They are covered in a capsule of fibrous connective tissue that contains smooth muscle cells and fibroblasts, which extends trabeculae that split the gland into lobes and lobules. In buffaloes, these glands are tubulo-alveolar, with a columnar-type secreting epithelium with a few scattered rounded basal cells. The epithelium of the seminal vesicles is responsive to the action of sexual hormones and, thus, is more developed with greater secreting activity in sexually mature animals. The mature seminal glands is straight, tube-liked structure, large in size, hard, tough and firm in texture, pale-yellow in color, multilobulated; large lobules on its outer surface giving the cluster of grapes-like appearance of the gland (Fig 3 B) present on dorsal aspect of pelvic urethra near the neck of the urinary bladder (Fig 3 A).

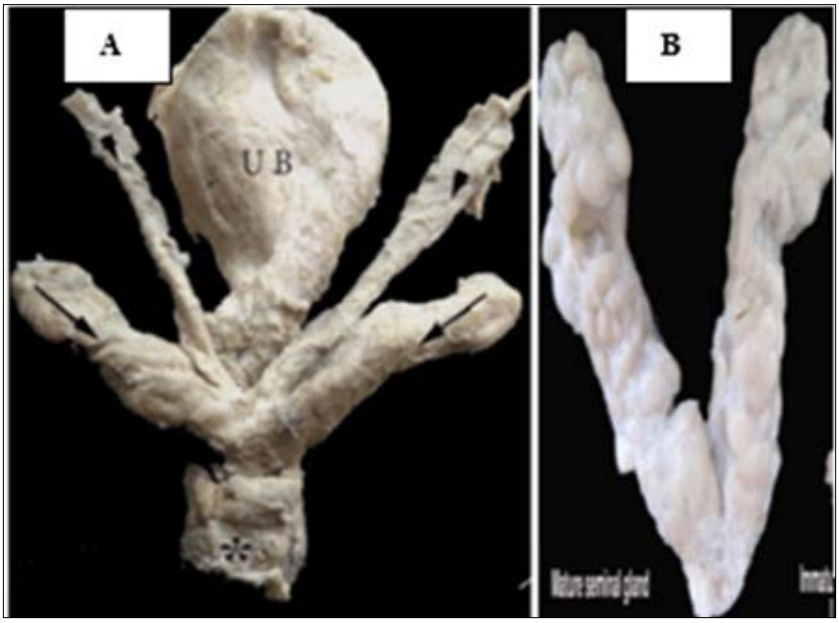

Fig 3: (A) Photograph showing mature seminal gland (arrow), ductus deferens (arrow head), urinary bladder (UB) and urethra (star) of buffalo bull. 3 (B) Photograph showing mature seminal gland of buffalo bull (Bareedy *et al.*, 2014)

The seminal gland was laterally attached to the terminal parts of ductus deferens, where the excretory ducts of the seminal gland opened with the end of ductus deferens forming an ejaculatory duct. The later, opened on the dorsal aspect of pelvic urethra near the neck of urinary bladder.

Prostate

The prostate is a single gland located on the floor of the pelvic cavity between the seminal vesicles. The prostate is divided into two parts: the body and the disseminate part. Just like seminal vesicles the prostate gland is also smaller in size in buffalo bulls, when compared to bovine bulls (Bos Taurus). In buffaloes, the body of the prostate is small and is projected onto the dorsal surface of the urethra between the vesicular glands. The disseminate part of the prostate represents the largest portion of the organ and is concealed in the wall of the urethra and covered ventrally and laterally by the urethral muscle (Mirabella *et al.*, 2003) [18]. The disseminate part is well developed and forms a dense layer of glandular tissue around the prostatic urethra, surrounding it. In cow and

buffalo bulls, the prostate is covered in a thin fibroelastic capsule with trabeculae that segment the prostatic tissue into incomplete lobules (Moussa *et al.*, 1983) [20]. The prostatic liquid is secreted by the prostate and reaches the urethra via the prostatic ducts, or prostatic ductules, which open onto the floor of the prostatic portion of the urethra. In buffaloes, the occurrence of neurotransmitter and neuropeptide-synthesizing enzymes in the prostate tissues, as well as in the ampullae of the deferent ducts, vesicular glands, and vas deferens is much more intense during the mating season than during the non-mating season (Mirabella *et al.*, 2003) [18].

Bulbourethral Glands

The bulbourethral glands, also called Cowper's glands, are small structures of firm consistency and rounded shape. They are located in a caudo-dorsal position in relation to the pelvic urethra so that their ducts converge into the urethral canal. The glands have a thick connective tissue capsule that extends fibroelastic trabeculae and also have smooth muscle cells. The trabeculae segment the organ into lobules and the intralobular stroma is supported by a reticulum rich in thin collagen fibers. The structure of the bulbourethral glands is tubulo-alveolar and their secreting terminations are lined with columnar and cuboidal epithelium, a variation that can be attributed to the differences in the cells' secreting activity (Moussa *et al.*, 1983) [20]. The bulbourethral glands of male bulls are longer and broader than those of buffalo bulls.

Conclusion

In conclusion, the reproductive morpho-functional characteristics in bubaline bulls are similar to those of bovines, although all the component organs are smaller in buffaloes due to the phylogenetic proximity between bovines and buffaloes.

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