Ultrasound anatomy of the penis in normal *Bos taurus* bulls

Amy E. Schkeeper, Robert C. Cole, William R. Brawner, Julie A. Gard, Herris S. Maxwell, Misty A. Edmondson

Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Auburn, AL

Abstract

The bull penis is subject to various medical conditions that have the potential to cause permanent damage to the penile tract, and thus devastating financial loss to the owner. Such conditions include: trauma with hematoma formation, abscess formation, vascular shunting, urethral obstruction, and fistula formation. The purpose of this study is to examine and document the sonographic appearance of the penis in a subset of normal *Bos taurus* bulls extending from the distal bend of the sigmoid flexure through the glans. A second purpose is to provide an anatomical reference correlating ultrasound, computed tomography, magnetic resonance imaging, and gross images. Four locations in the bull penis were chosen: the distal bend of the sigmoid flexure (S), the glans (G), and two equidistant locations in between (A and B). Bulls presenting for breeding soundness examination were recruited and were divided into three age groups: 15-18 months, 22-24 months, and 36 months and older. The hypothesis was that no significant differences ($p < 0.5$; with a confidence interval of 95%) in the penile measurements of bulls in and between the different age groups, including the measurements between locations A, B, and S, would be found. Following numerous measurements of the bull penis from bulls in three different age groups and at three different locations A, B, and S no significant differences in measurements were found supporting our hypothesis. The data were analyzed using the general linear model (GLM) for analysis of variance (ANOVA) and Scheffe's test for multiple comparisons. A p value of < 0.05 is considered significant.

Keywords: Fibroelastic, urethra, comparison, correlative, CT, MRI

Introduction

A bull's usefulness is primarily related to the viability of his reproductive tract. Swelling of the preputial region is a common presenting complaint that, when associated with penile injury and dysfunction, can lead to devastating economic and genetic losses to the cattle producer.[1-3] Causes of penile dysfunction and/or preputial swelling include penile hematomas, abscesses, urinary obstruction or fistula formation due to urethral calculi, hair rings, papillomas and vascular shunting. Hematomas can form in bulls from various causes including premature separation of the interdigitating attachment (joins the epithelium of the free portion of the penis with the integumentary epithelium of the penile portion of the internal lamina of the prepuce), rupture of the tunica albuginea ("broken" or "fractured" penis) and less commonly, rupture of superficial vessels of the prepuce.[1,2] Hematomas often resolve on their own without notice, but have the potential to serve as a nidus for infection, resulting in an abscess; which can lead to phimosis.[2] Abscesses may also occur secondary to lacerations or foreign body penetration.[2] Accurate and rapid diagnosis is crucial since the course of treatment of these conditions can be vastly different. While diagnosis can be suggested via location and symmetry of the swelling, the convenience, portability, and availability of base line descriptions of cross-sectional imaging via ultrasound has potential for aiding in the diagnosis of penile abnormalities.

Ultrasound is a developing, minimally invasive imaging modality, that practitioners are finding invaluable for the examination of food animals, particularly for reproductive assessments.[4] Ultrasound of the testes and epididymis as well as the accessory sex glands including the prostate, the bulbourethral gland, the ampullae, and vesicular glands, has been described in the literature and is typically done with little or no sedation.[5-11] The only reports of ultrasonic evaluation of the bull penis include two single transverse images of a normal penis, two penile abscesses, two penile hematomas, and one method for injecting contrast medium into the crus penis.[7,8,12,13] Although, the penis has been mentioned as part of an ultrasound examination of the reproductive tract, the sonographic appearance of the penis in the normal bull has not yet been thoroughly documented. Once normal findings are completely documented, the use

of ultrasound for diagnosing bovine penile problems can progress beyond detection of large abscesses and hematomas. In human medicine, ultrasound is commonly used in diagnosis of causes of impotence including vascular shunting.[14] These sometimes subtle changes could not be accurately identified if the normal ultrasonographic appearance was not established first.

Bulls have a fibroelastic penis which is firm at all times and forms a sigmoidal flexure in the non-aroused state (the distal curve of the "S" shape opens cranially).[15] The penis has a cylindrical shape with a urethral groove. The penis consists of a root, body and glans penis. The root consists of the origin of the erectile tissue (corpus cavernosum and corpus spongiosum) and the muscles of the penis. The paired corpus cavernosa (crura) make up the majority of the penis and arise alongside the ischiatic arch, medial to the ischiatic tuberosity, and course ventromedially to form the body of the penis.[16] The corpus spongiosum (bulb of the penis) surrounds the urethra, originating along the midline of the ischiatic arch, between the crura.[16] The thick tunica albuginea surrounds the erectile tissues and has an outer layer of longitudinal fibers and an inner circular layer. The inner layer is filled with a dense system of trabeculae that form a central axial column of fibrous tissue and radiate towards the tunica.[15] Between the fibrous tissues are small cavernous blood spaces along the length of the penis, representing the corpus cavernosum penis.[15] The paired retractor penis muscles originate from the first and second coccygeal vertebra and pass along the ventral caudal surface of the penis to attach to the ventrolateral surface of the penis at the distal bend of the sigmoid flexure – these retract the penis and prepuce into the sheath after erection.[17] The free part of the penis has a counterclockwise twist when viewed from behind, making the urethral orifice lie along the right side of the penis.[15] The glans is not well developed and is made up of loose connective tissue encompassing a thin layer of plexiform veins.[15]

The objectives of this study were to determine the normal ultrasonographic appearance of the penis in normal bulls and to provide a cross-sectional atlas of the penis correlating gross anatomy with ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) and to determine if variations occur in penile measurements at various sites of the penis and if the differences are determined to be significantly between the age groups sampled.

Methods
Animals
Bos taurus bulls presenting for breeding soundness examination (BSE) between November 2015 through February 2016 were recruited for this study on a voluntary basis with informed client consent. Exclusion criteria included any history of reproductive or urinary tract injuries or medical problems related to the penis or urethra (including penile trauma, penile hematomas, retropreputial abscesses, penile vascular shunting, urethral calculi, stranguria, or hematuria). This study was approved by and in accordance with requirements of our institutional animal care and use committee. Animals were grouped based on age: Group 1 (15-18 months), Group 2 (20-24 months), and Group 3 (36 months and older).

Ultrasound examination
Ultrasound examination was performed (A.E.S) after a BSE was performed with the bull restrained in a squeeze chute with a mechanical headgate. A wooden bar was placed behind the pelvic limbs so as to confine the bull to the front portion of the chute, limit back and forth motion, and prevent or slow kicking. Semen was collected from all bulls for the BSEs using electroejaculation. The results of the BSEs were not included in this study. No sedation was given to any bull prior to or during the ultrasound examination. If a bull was not cooperative for the ultrasound examination, the examination was terminated and bull was excluded from this study. An 8L (4-12MHz) wide band linear probe with a portable ultrasound machine (GE Logiq E, Carlsbad, CA) was used to obtain transverse images of the penis from the level of the distal bend of the sigmoid flexure and extending distally. Images at the distal bend of the sigmoid flexure were obtained caudal to the scrotum from behind the patient. These images were both obtained from above and below the crossbar in the chute, depending on ease of examination and positioning of the patient. The remainder of the images were obtained cranial to the scrotum alongside the patient (either the left or right of the patient). Isopropyl alcohol was applied generously to

the skin of the sheath as the coupling agent. The hair was not clipped in any patient. The majority of the images were scanned at 10 MHz. Subjective assessment of ease of examination and cooperation of the bull was recorded as good (bull remained stationary or displayed minimal swaying or shifting feet) or fair (bull swayed left and right, moved forwards and backwards, and lifted back feet). Images were recorded both with and without pressure specifically to assess the corpus spongiosum and urethra. Pressure involved the amount of contact force required with the probe. This could not be objectively measured, but degree of pressure used was considered adequate when the entire corpus cavernosum could be visualized. The images were labeled at four locations during the examination: S – the distal bend, G – the glans, and at two equidistant locations between the distal bend and the glans – A and B with A being more proximal. Image analysis and review were not performed (A.E.S) until after the examination to limit the time required for the bull to be restrained. Images were oriented with the left side of the patient being on the left side of the screen.

Measurements (table and appendix)

Image analysis and review was performed using either the built in software (GE, Carlsbad, CA) on the ultrasound machine for the ultrasound images or a DICOM viewing software (Osirix, Switzerland) for the CT and MR images. Various measurements of the penile structures were made at the four previously described locations: skin thickness (A,B,G); both layers of the ventral and dorsal aspect of the tunica albuginea individually and as a whole (S,A,B,G); the height, width, circumference, and area of the corpus cavernosum (S,A,B,G); the height of both parts of the corpus spongiosum together and separately, in both the ventral and dorsal aspects, with and without pressure (S,A,B,G); the height, circumference, and area of the corpus spongiosum as a whole, with and without pressure (S,A,B,G); the height of the urethra with and without pressure (S,A,B,G); the height of one of the ventral vascular channels of the penis (S,A,B); the height of the largest preputial vessel in the field of view (S,A,B); the height of the ventral aspect of the fibrofatty tissue in the glans (G); the height and width of the fibrofatty tissue of the glans (G); and the height of the retractor penis muscles (S). Note, the tunica was measured at the level of one of the ventral vascular channels. Pressure was not applied at location G as the penis is very movable at this location. The number of preputial vessels in the field of view was recorded (S,A,B,G). Subjective assessment of the quality of images was recorded as excellent (visualization of the penile structures from the ventral skin through the dorsal tunica with clear distinction of the dorsal margin of the dorsal tunica), good (visualization through the corpus cavernosum with clear distinction of the dorsal aspect of the corpus cavernosum), fair (visualization through the mid corpus cavernosum with difficult distinction of the dorsal aspect of the corpus cavernosum), and poor (visualization through the ventral aspect of the corpus cavernosum with difficult distinction of the dorsal aspect of the corpus spongiosum) (S,A,B,G). The echogenicity and echotexture of all measured structures were observed and recorded.

Gross, computed tomography, and magnetic resonance imaging

The penile tract of a 2y old 727kg Angus bull was removed from a patient euthanized for reasons unrelated to the reproductive or urinary tract. This bull had no history of reproductive or urinary tract trauma or other reproductive/urinary medical problems. The penile tract was removed proximal to the proximal bend of the sigmoid flexure. Ultrasound of this penile tract was not performed. The cross sectional imaging was obtained for representative purposes to compare against live animal imaging. Helical transverse CT images of the removed penile tract were obtained with 5.0 mm thickness slices and reconstructed into 0.6 mm thickness slices with a 64 slice CT scanner (100 kVp, 80 mA, 1s tube rotation, 0.984:1 pitch, FOV 24 x 24 cm, matrix 512 x 512; GE Light-speed; GE Medical Systems, Milwaukee, WI). T1-weighed transverse MR images (TR 400.0 ms, TE 11.5 ms, 5.0 mm, FOV 25 x 25 cm) were also obtained using a 1.5 T scanner and a spine coil (Infinion, Philips Medical Systems, Andover, MA). The penile tract was positioned to be in a retracted state for both the MR and CT scans. The same measurements and observations were obtained at the previously described four locations, excluding measurements of the skin and assessment of the preputial vessels. In addition, Hounsfield Units (HU)

were measured at each location and averaged. Cuts through the penile tract at the four measured locations were made using a 10 scalpel blade.

Statistics
Data were analyzed using the general linear model (GLM) for analysis of variance (ANOVA) and Scheffe's test for multiple comparisons. A p value of < 0.05 was considered significant.

Results
Examination
Thirty-four bulls were recruited: 15 in group 1 (15-16 months of age), 4 in group 2 (22-24 months of age), and 15 in group 3 (36-75 months of age). *Bos taurus* bulls of the representative breeds; Angus, Hereford, Simmental, Simmental-Angus, and Red Angus, were utilized in this study in all three age groups. The bulls were in good body condition having a score between 6-7 on a 1-9 point scale. Additionally, all bulls included in the study were determined to have passed the Society for Theriogenology guidelines for breeding soundness examination. Withers height and weight were not included as parameters in this study since, aside from appropriate body condition score, are not included in breeding soundness evaluation. All bulls displayed good cooperation for the ultrasound examination cranial to the scrotum. Approximately half of the bulls in each group held their penis in a mildly retracted state with the glans located in the distal third between the termination of the sheath and the scrotum, while the remainder of the bulls held their penis in a very retracted state with the glans located in the proximal third of the sheath. With the bulls in the more retracted state, only locations G and B were able to be imaged cranial to the scrotum while locations A and S were both imaged caudal to the scrotum. Approximately, a third of the bulls in each group displayed fair cooperation for the examination caudal to the scrotum. All images were considered diagnostic with the majority being classified as good to excellent quality in each group at locations A, B, and G, and considered fair in the majority of bulls in each group at location S.

Sonographic appearance locations A and B (Fig. 1A)
Locations A and B were indistinguishable sonographically. The corpus cavernosum (CCP) was bilobed and had a fine, mildly hyperechoic texture when enough pressure was applied and when the ultrasound probe was held perpendicular to the axis of the penis. If the pressure was lessened or if the probe was not perpendicular, the central portion of each crus became hypoechoic with distal acoustic shadowing and the remainder of the CCP became mildly heterogeneous. A ventral vascular channel in the most ventral portion of each crus was anechoic with a hyperechoic dorsal and ventral rim and with variable distal acoustic enhancement. This channel occasionally narrowed or collapsed with pressure. The corpus spongiosum (CSP) and urethra varied in appearance depending on the amount of pressure. Without pressure, the CSP was egg-shaped and had a large coarse hypoechoic outer layer with a smaller inner layer that was mildly hypoechoic with a fine echotexture. With pressure, the outer layer of the CSP decreased in size, became circular to ovoid in shape, and became hyperechoic with a fine echotexture. This layer of the CSP was not always distinguishable from the surrounding tunica without manipulation of pressure. The inner layer of the CSP became somewhat smaller in size with pressure, and maintained a hypoechoic fine texture. The urethra was anechoic and collapsed in the majority of patients with or without pressure, though the location was always visible. The tunica that surrounds the CCP and CSP could be easily distinguished into its longitudinal and circumferential parts. The circumferential fibers of the tunica that surrounds the CCP was homogenously hypoechoic, and not always visible along the dorsal aspect. This hypoechoic part of the tunica maintained the same width surrounding the CCP though became slightly thicker at the ventral junction of the crus. The longitudinal fibers of the tunica that surround both the CCP and CSP were hyperechoic with a fine echotexture. The skin surrounding the penis was hypoechoic, thin, and maintained the same width around the penis. In some bulls, air (hyperechoic reverberating shadows) was seen between the penile skin and the prepuce, which, if in enough quantity, would hinder visualization of the penis. The air dissipated enough to adequately assess

the penis within a few minutes. The number of preputial vessels seen on the images obtained varied from 1 unilaterally to 6 bilaterally, and varied vastly in size. All vessels were anechoic with a hyperechoic ventral and dorsal rim and had variable distal acoustic enhancement.

Sonographic appearance location G (Fig. 2A)

At location G, the penis had already begun its counterclockwise rotation (as seen from behind), with the CSP and urethra noted on the left of the patient. The urethra was no longer visible at this location. The two layers of the CSP became indistinguishable and the CSP appeared as an ill-defined, slightly heterogeneous hyperechoic circular structure. The CSP was often only visible if followed from proximal to the glans. The CCP extended distally as a small process being homogenously mildly hyperechoic with a circular cross-section. Ventral vascular channels were no longer visible. The tunica could still be differentiated into the longitudinal and circular layers with the entire tunica being easily visualized. The fibrofatty portion of the glans surrounded the tunica and was primarily hypoechoic with radiating hypo and hyperechoic bands coursing towards the axis of the penis. This fibrofatty tissue had a slightly hyperechoic rim, which was adjacent to the penile skin.

Sonographic appearance location S (Fig. 3A)

Location S was the most difficult location to image primarily due to the thickness of the tissues caudal to the penis resulting in additional pressure needed to visualize the entire CCP. The CCP and CSP were similar in appearance to locations A and B though the center of each crus of the CCP was almost always hypoechoic with distal acoustic shadowing. The urethra dilated as it coursed proximal to the distal bend of the sigmoid flexure and the CCP and CSP became somewhat distorted due to the angle of the probe with respect to the cranial course/bend of the penis. The appearance to the ventral vascular channels and preputial vessels was similar as locations A and B.

Computed tomography (Fig. 1B,2B,3B)

Locations A, B, and S had a similar appearance. When describing CT images, terms including hyper, hypo and isoattenuating are used. Similar to radiography, CT is a measure of the attenuation of x-rays. Structures that appear white are hyperattenuating, while structures that appear black are hypoattenuating. The CCP was again noted to be bilobed. The core of the crus of the CCP were slightly hyperattenuating with an average HU of 115. The outer portion of the CCP was slightly hypoattenuating with an average HU of 75. The ventral vascular channels were easily seen as symmetric hypoattenuating circular tubes coursing through the ventral aspect of the CCP. The CSP was ovoid and homogenously hypoattenuating with an average HU of 55. The urethra was only seen as a small amount of gas in the central portion of the CSP in the proximal bend of the sigmoid flexure. The tunica appeared homogenously hyperattenuating with an average HU of 100. The distinction between longitudinal and circumferential fibers was not evident. The skin could not be distinguished from the tunica. The retractor penis muscles were seen as symmetric crescent hypoattenuating shapes along the ventral aspect of the penis with an average HU of 42. At location G, the CCP was seen as a small, homogenous, mildly hypoattenuating cylindrical extension with an average HU of 75. The CSP and urethra could not be identified. The tunica was seen as a hyperechoic rim surrounding the CCP with an average HU of 100. The fibrofatty tissue surrounding the tunica was symmetric and mildly hypoattenuating with an average HU of 24. The skin was seen as a hyperechoic rim surrounding the fibrofatty tissue with an average HU of 80. Measurements of the visualized structures were obtained and were within the ranges of the respective ultrasonographic measurements.

Magnetic resonance imaging (Fig. 1C,2C,3C)

Locations A, B, and S had a similar appearance. The MR image is based on signal intensity. When describing MR images, the terms hyper, hypo, and isointense are utilized. Structures that appear bright (white) on MR are said to be hyperintense while structures that are dark (black) are said to be hypointense. The CCP was again noted to be bilobed. The core of the crus of the CCP was hypointense

with the outer portion being well-defined and hyperintense. The ventral vascular channels were seen as small symmetric ovoid regions of hyperintensity – these were hyperintense with respect to the outer portion of the CCP. The CSP was homogeneously hyperintense, being isointense to the ventral vascular channels. The urethra was only seen as a small amount of gas (signal void) in the central portion of the CSP in the proximal bend of the sigmoid flexure. The distinction between longitudinal and circumferential fibers was easily seen with the circumferential fibers being hypointense (isointense to the core of the CCP), and with the longitudinal fibers being mildly hypointense (hypointense with respect to the outer portion of the CCP). The skin was seen as a thin hypointense band encircling the tunica. The retractor penis muscles were seen as symmetric crescent hyperintense shapes along the ventral aspect of the penis – these were hyperintense with respect to the CSP. At location G, the CCP was seen as a very small, hypointense center with a hyperintense rim. The hypointense longitudinal fibers of the tunica surrounded the CCP, though the circumferential fibers could not be distinguished. The fibrofatty tissue was very hyperintense surrounding the tunica and was mildly asymmetric with the portion incorporating the CSP being thicker. The CSP could not be distinguished from the fibrofatty tissue. The skin was not visible. Measurements of the visualized structures were obtained and were within the ranges of the respective ultrasonographic measurements.

Gross anatomy (Fig. 1D,2D,3D)

The architecture of the penis was similar at locations A, B, and S. The CCP was seen to be made up of radiating fibers directed towards the central portion of each crus. The core of each crus was dense and very firm with the outer portion being less dense and thus, less firm. The ventral vascular channels were easily seen and gas filled. The CSP was palpably soft with a denser central portion and a less dense, more cavitary outer portion. The circumferential fibers of the tunica were palpably very firm while the longitudinal fibers were less firm. The skin was seen as a very thin layer surrounding the tunica. The retractor penis muscles were both soft. At location G, the CCP was somewhat soft with a firm tunica surrounding it. The CSP was also soft. The fibrofatty tissue in the glans was palpably spongy.

Measurements

A detailed chart of all measurements is below (Table and appendix.). There were no significant differences found between any recorded measurements within the different age groups (p < 0.5). Hence, these findings support our hypothesis that no statistical differences would be found when comparing measurements taken at specific locations on the penis; A, B, and S in the groups evaluated. The thickness of the penile skin averaged 0.1 cm for locations A, B, and S, and 0.05 cm for location G, with overlap of the ranges of each group. The dorsal aspect of the tunica was only visible in approximately half of the patients at locations A and B, and in only one patient at location S. The height of the circumferential fibers of the tunica was similar between all locations, ventrally and dorsally with an average of 0.1 cm. The height of the longitudinal fibers and the height of the tunica as a whole had similar averages between the dorsal and ventral aspects at locations A, B, and S with an average of 0.27 cm for the longitudinal fibers and 0.36 cm for the whole tunica. Although the high end of the range for the ventral aspect of both the longitudinal fibers and whole tunica exceeded that of the dorsal aspect. The longitudinal fibers and the whole tunica were smaller at location G compared to the other three locations with an average of 0.15 cm and 0.19 cm, respectively. The measurements for the CCP tended to increase from the youngest to oldest age groups at locations A and B, and tended to increase from location B to A to S. There was overlap in the ranges and no significant difference in the averages (p<0.05). The average height of the CCP at locations A, B, and S was 1.26 cm and at location G was 0.25 cm. The CSP height as a whole was similar between locations A, B, and S, and increased when pressure was released with an average of 0.40 cm with pressure and 0.61 cm without pressure. The height of the CSP at location G averaged 0.24 cm. The average urethral height was similar amongst locations A, B, and S at 0.02 cm, and was not visualized at location G. The height of the ventral vascular channel with pressure was similar between locations A, B, and S with an average of 0.1 cm. The average height increased without pressure at locations A and B (0.17 cm), and there was overlap of the ranges. The average height of the ventral vascular channel did not

differ at location S with or without pressure. The diameter of the largest preputial vessel was similar between locations A, B, and S with pressure, but increased to a greater extent at locations A and S without pressure. The largest diameter in any location was 0.37 cm. The average height of the retractor penis muscle was 0.40 cm.

Conclusions

Ultrasound is a fast and non-invasive method of evaluating the bull penis. All bulls in this study were cooperative for the scans of the distal penis cranial to the scrotum, though scanning the distal bend of the sigmoid flexure caudal to the scrotum proved more difficult, yet feasible. The images obtained for this study were all deemed diagnostic with good to excellent quality in the portion of the penis cranial to the scrotum, and fair caudal to the scrotum. The hair did not need to be clipped in any patient, thus decreasing the time needed to remain in the chute. In our experience, a bull can be scanned when confined between two swing gates. However, the use of squeeze chute and head catch with a wooden bar behind the pelvic limbs limited the back and forth motion of the bull thus facilitating the exam.

This study provides an anatomical reference for the bull penis from the level of the distal bend to the glans using ultrasound, CT, MRI, and gross images. Although CT and MRI are invaluable cross sectional imaging modalities in people and small animals, due to the size of the bovine patient, it is not possible to use these modalities to evaluate the penis unless it is for gross specimens. This emphasizes the need to understand the ultrasonographic appearance of the penis as this is the only imaging modality capable of providing cross sectional images in a live patient. This information can then be used as the basis for further studies of the bovine penis. With the normal values and appearance of the penis established, alterations in the tunica albuginea and CCP, including vascular shunting in cases of penile trauma or congenital shunting and occlusion of the vascular channels can be studied. The information provided herein will aid in future diagnoses of urinary obstruction, vascular shunting, tearing of the tunica, hematoma, and abscess formation. It may limit the need for more challenging imaging procedures such as cavernosography and urethrography. Limitations of this study are that all bulls had a breeding soundness examination utilizing electroejaculation performed immediately prior to scanning, though as the bull penis is fibroelastic, this is not expected to alter the dimension of the penis. Other potential limitations of the study include the challenges of imaging the penis at the level of the sigmoid flexure. This is an important area to image as it is the most common site of injury with a fractured penis. This was more difficult than areas distal to the scrotum, but with experience and practice, we found that diagnostic images could be obtained in this region. Although not part of this study, light sedation could be given that may potentially make imaging that region easier. Ultrasound examination requires the use of variable pressure with the probe no matter what organ is being imaged. Some patients require more probe pressure than others and certain locations require more pressure than other locations (sigmoid vs the distal penis). As a result, there is no practical way to standardize the amount of pressure required. With practice the clinician will come to understand how pressure (or lack thereof) can affect the image. This was shown when evaluating the CCP and ventral vascular channels, as well as the CSP and urethra. For example, it is possible that if too much pressure is applied, a dilated obstructed urethra could be artifactually collapsed causing the clinician to misdiagnose a urethral obstruction. Furthermore, with experience, we believe the clinician will be able to gauge how much probe pressure is required and will learn to vary the probe pressure when needed as is routinely done with ultrasoungraphy of the ovary when determining follicular diameter. This is a clear limitation of ultrasound as operator variability will have an effect not only on measurement values, but image quality. Despite this limitation, the values that are reported here will serve as a baseline and could be revised as more studies are performed. Only *Bos taurus* bulls of the most common breeds (Angus, Simmental, and Hereford) were utilized in the study to represent the most common subset of the bull population that is seen within the United States. *Bos indicus* breeds were not included in this study due to the possibility of adding confounding variables to the measurements taken. A similar study, assessing *Bos indicus* bulls needs to be preformed which would allow for statistical comparisons within *Bos indicus* bull populations and for valid comparisons to the measurements taken from bulls of *Bos taurus* lineage.

References

1. Barth A: Testicular degeneration In: Hopper RM, editor. Bovine reproduction. Ames(IA): Wiley-Blackwell; 2015. p. 103-108.
2. Maxwell H: Inability to breed due to injury or abnormality of the external genitalia of bulls. In: Hopper RM, editor. Bovine reproduction. Ames(IA): Wiley-Blackwell; 2015. p. 113-130.
3. Simpson KM, Streeter RN: Bovine urolithiasis In: Hopper RM, editor. Bovine reproduction. Ames(IA): Wiley-Blackwell; 2015. p. 172-180.
4. Ginther OJ: How ultrasound technologies have expanded and revolutionized research in reproduction in large animals. Theriogenology 2014;81:112-125.
5. Abou-El-Roos, MEA: Evaluation of buffalo-bulls by using modified serving capacity test and diagnostic ultrasound. J Egypt Vet Med Associ 2004;64:17.
6. Abu-Seida, AM: Ultrasonographic diagnosis of some scrotal swellings in bulls. Pak Vet J 2012;32:378-381.
7. Gnemmi G, Lefebvre RC: Ultrasound imaging of the bull reproductive tract: an important field of expertise for veterinarians. Vet Clin North Am Food Anim Pract 2009;25:767-779.
8. Gnemmi G, Lefebvre RC: Bull anatomy and ultrasonography of the reproductive tract In: DesCôteaux L, Colloton J, Gnemmi G, editors. Practical atlas of ruminant and camelid reproductive ultrasonography. Ames(IA): Wiley-Blackwell; 2010, p. 143-162.
9. Kastelic JP, Brito LFC: Ultrasonography for monitoring reproductive function in the bull. Reprod Domest Anim Suppl 3 2012;47:45-51.
10. Momont H, Checura C: Ultrasound evaluation of the reproduction tract of the bull In: Hopper RM, editor. Bovine reproduction. Ames(IA): Wiley-Blackwell; 2015. p. 79-91.
11. Streeter RN, Step DL: Diagnostic ultrasonography in ruminants. Vet Clin North Am Food Anim Pract 2007;23:541-574.
12. Anderson DE, St-Jean G, Desrochers A, et al: Use of Doppler ultrasonography and positive-contrast corpus cavernosography to evaluate a persistent penile hematoma in a bull. J Am Vet Med Assoc 1996;209:1611-1614.
13. Nöthling JO, Irons PC, Gerber D: Ultrasound-guided injection of contrast medium into the crus penis for diagnosis of erection failure in bulls. Theriogenology 2002;57:1199-1205.
14. Bacar MM, Batislam E, Altinok D, et al: Sildenafil citrate for penile hemodynamic determination: an alternative to intracavernosal agents in Doppler ultrasound evaluation of erectile dysfunction. Urology 2001;57:623-626.
15. Nickel R, Schummer A, Seiferle E: Male genital organs of the ruminants In: Schummer A, Nickel R, Sack O, editors. The viscera of the domestic mammals. 2nd ed. New York: Springer-Verlag; 1979. p. 333-339.
16. Nabors B, Linford R: Anatomy of the reproduction system of the bull In: Hopper RM, editor. Bovine reproduction. Ames(IA): Wiley-Blackwell; 2015. p. 5-10.
17. Beckett SD, Wolfe DF. Anatomy of the penis, prepuce, and sheath: cattle, sheep, and goats In: Wolfe DF, Moll D, editors. Large animal urogenital surgery. Baltimore: Williams-Wilkins; 1998. p. 201-209.

Table. Measurements obtained with ultrasound

Measurements in cm or cm2	Location A	Location B	Location G	Location S
Tunica				
	.34 (0.18-0.45) **N16**	**0.25** (0.21-0.34) **N16**		**0.34** (0.34-0.34) **N1**
Dorsal Aspect of the Tunica				
Ventral Aspect of the Tunica	**.39** (0.27-0.62)	**0.42** (0.27-0.69)	**0.19** (0.12-0.28)	**0.42** (0.15-0.61)
CCP				
Height	**1.28** (0.81-1.77)	**1.17** (0.72-1.52)	**0.25** (0.14-0.43)	**1.33** (0.85-1.74)
Width	**2.45** (1.81-1.77)	**2.42** (2.00 -3.07)		**2.48** (2.07-3.05)
Circumference	**6.93** (4.98-9.24)	**6.63** (5.34-8.29)	**0.99** (0.52-1.54)	**7.16** (6.04-9.00)
CSP with pressure				
Height	**.42** (0.19-0.68)	**0.35** (0.22-0.58)	NA	**0.44** (0.21-0.74)
Circumference	**1.57** (0.89-2.12)	**0.56** (0.43-1.75)	NA	**1.62** (0.89-2.9)
CSP without pressure				
Height	**.62** (0.41-0.87)	**0.56** (0.43-1.00)	**0.24** (0.11-0.42)	**0.65** (0.30-0.92)
Circumference	**2.09** (1.61-2.47)	**1.83** (1.46-2.72)	**0.70** (0.37-1.35)	**2.16** (1.22-2.90)
Urethra				
Height with pressure	**0.04** (0.00-0.09)	**0.02** (0.00-0.15)	Not visible	**0.01** (0.00-0.11)
Height without pressure	**0.17**(0.10-0.29)	**0.02** (0.00-0.19)	Not visible	**0.16** (0.00-0.56)
Ventral Vascular Channel				
Height with pressure	**0.09** (0.01-0.18)	**0.10** (0.05-0.21)	NA	**0.10** (0.03-0.21)
Height without pressure	**0.17** (0.10-0.29)	**0.16** (0.10-0.24)	NA	**0.11** (0.04-0.15)

N = number of bulls included in the calculation. If no N value is recorded, the structure was measured in all 34 bulls.
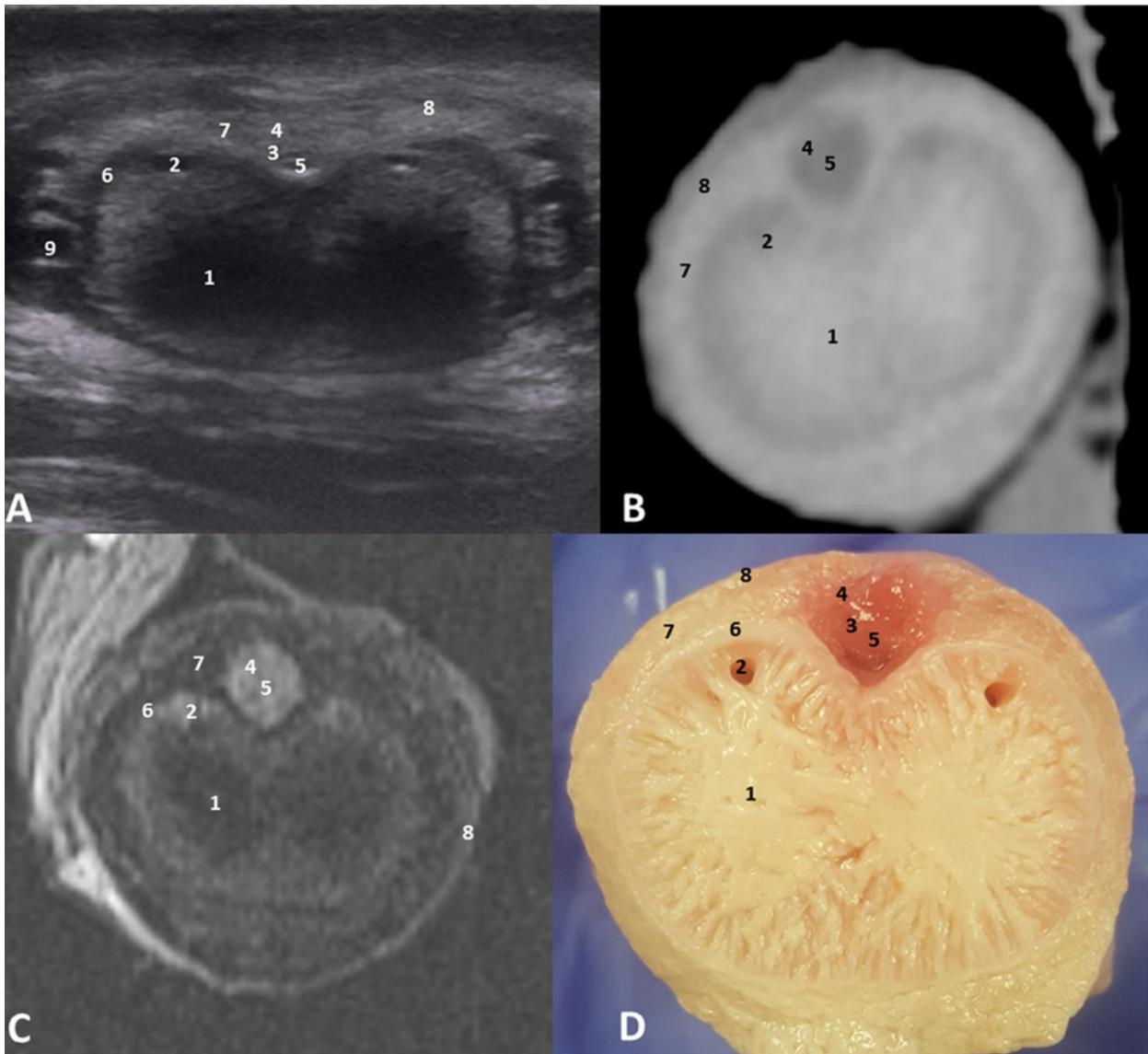
Figure 1. Transverse image through the penis at location A with ultrasound (A), CT (B), MRI (C), and gross (D) images. Ventral is on the top of the image and left is on the left of the image. 1 (CCP), 2 (ventral vascular channels), 3 (CSP dense inner portion), 4 (CSP less dense outer portion), 5 (urethra), 6 (circumferential fibers of the tunica), 7 (longitudinal fibers of the tunica), 8 (skin), 9 (preputial vessel).
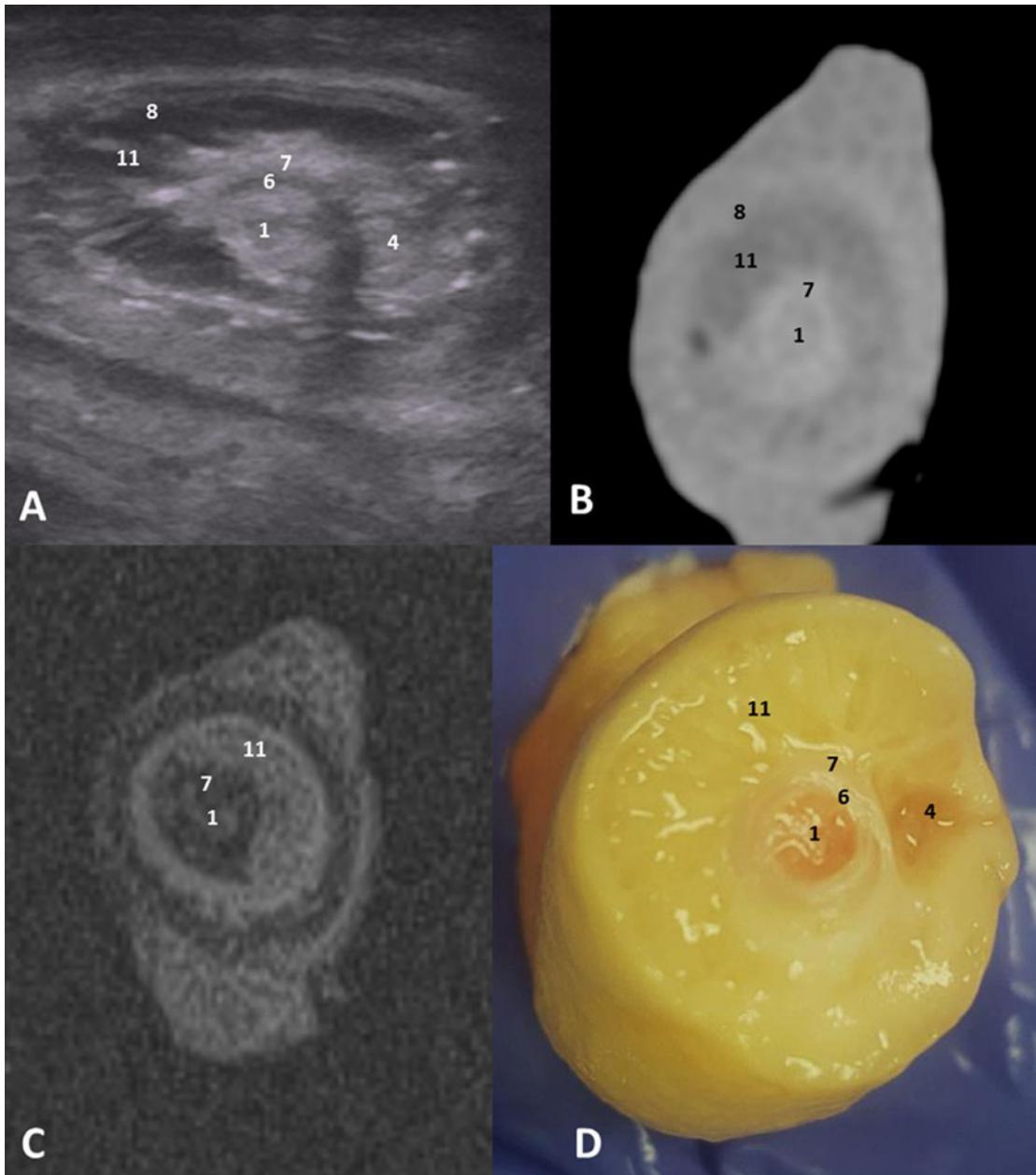
Figure 2. Transverse image through the penis at location G with ultrasound (A), CT (B), MRI (C), and gross (D) images. Ventral is on the top of the image and left is on the left of the image. 1 (CCP), 4 (CSP less dense outer portion), 6 (circumferential fibers of the tunica), 7 (longitudinal fibers of the tunica), 8 (skin), 11 (fibrofatty tissue).
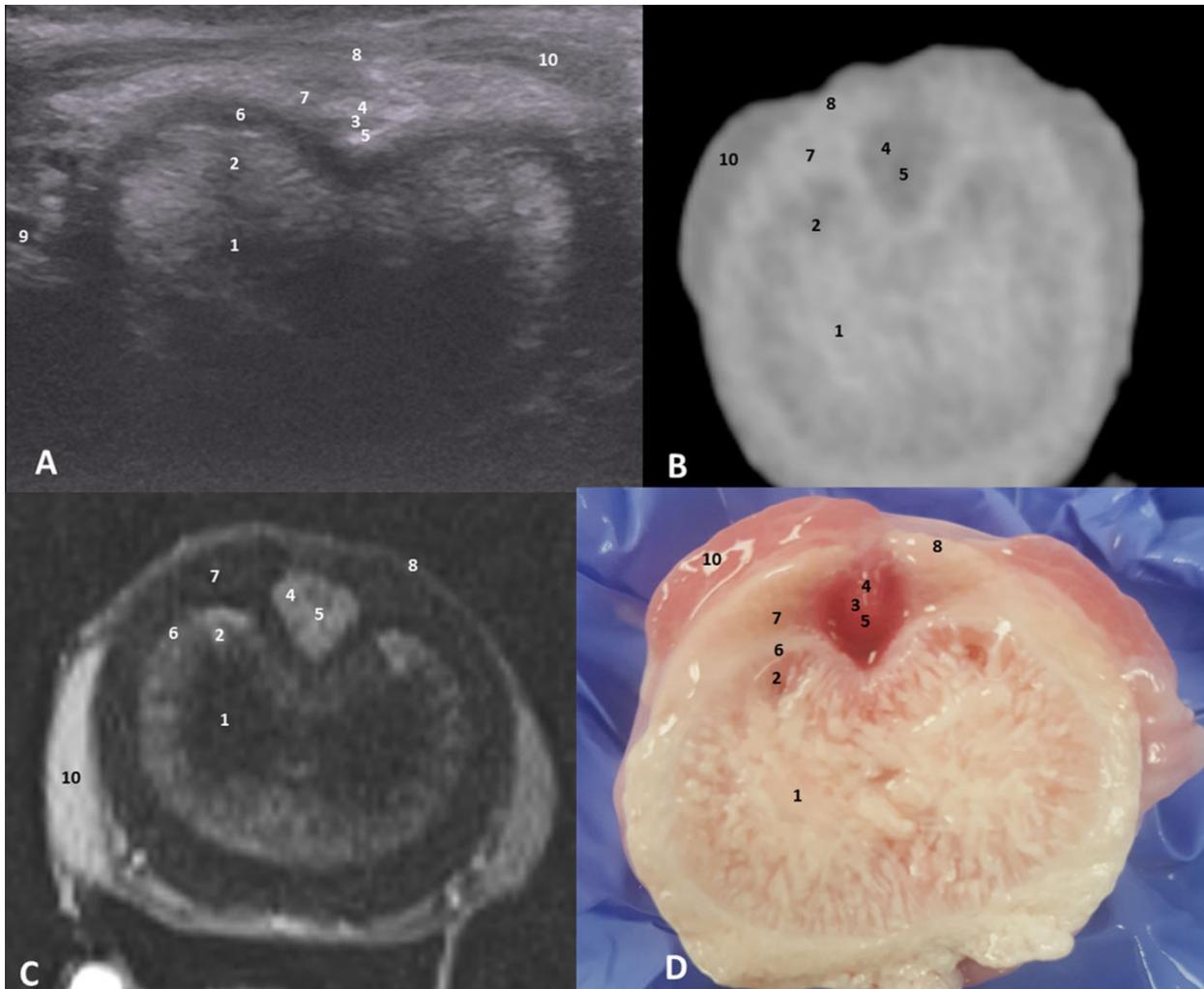
Figure 3. Transverse image through the penis at location S with ultrasound (A), CT (B), MRI (C), and gross (D) images. Ventral is on the top of the image and left is on the left of the image. 1 (CCP), 2 (ventral vascular channels), 3 (CSP dense inner portion), 4 (CSP less dense outer portion), 5 (urethra), 6 (circumferential fibers of the tunica), 7 (longitudinal fibers of the tunica), 8 (skin), 9 (preputial vessel), 10 (retractor penis muscle).

(Editor's Note: Photographs in this manuscript are available in color in the online edition of Clinical Theriogenology.)

Appendix

Location A

| Measurements in cm or cm²		Group 1 avg	Group 2 avg	Group 3 avg	All groups avg
Skin	Ventral height	0.09 (0.06 - 0.13)	0.1 (0.09 - 0.11)	0.1 (0.04 - 0.16)	0.1 (0.04 - 0.16)
Dorsal aspect of the tunica	Whole tunica height	0.26 (0.18 - 0.41)	0.42 (0.42 - 0.42)	0.33 (0.27 - 0.45)	0.34 (0.18 - 0.45)
	Longitudinal fibers height	0.16 (0.09 - 0.33)	0.3 (0.30 - 0.30)	0.23 (0.16 - 0.39)	0.23 (0.09 - 0.39)
	Circumferential fibers height	0.1 (0.07 - 0.12)	0.15 (0.15 - 0.15)	0.1 (0.06 - 0.14)	0.12 (0.06 - 0.15)
Ventral aspect of the tunica	Whole tunica height	0.35 (0.27 - 0.43)	0.4 (0.34 - 0.48)	0.41 (0.29 - 0.62)	0.39 (0.27 - 0.62)
	Longitudinal fibers height	0.26 (0.19 - 0.33)	0.3 (0.25 - 0.39)	0.33 (0.24 - 0.48)	0.3 (0.19 - 0.48)
	Circumferential fibers height	0.09 (0.05 - 0.13)	0.11 (0.09 - 0.17)	0.1 (0.06 - 0.18)	0.1 (0.05 - 0.18)
CCP	Height	1.12 (0.81 - 1.51)	1.35 (1.05 - 1.54)	1.36 (0.89 - 1.77)	1.28 (0.81 - 1.77)
	Width	2.35 (2.09 - 2.59)	2.39 (1.81 - 2.69)	2.63 (1.93 - 3.16)	2.45 (1.81 - 3.16)
	Circumference	6.48 (5.26 - 7.43)	6.97 (5.1 - 8.13)	7.33 (4.98 - 9.24)	6.93 (4.98 - 9.24)
	Area	2.35 (1.4 - 3.29)	2.88 (1.57 - 3.60)	3.22 (1.58 - 4.70)	2.82 (1.40 - 4.70)
CSP with pressure	Denser, inner portion ventral height	0.04 (0.03 - 0.07)	0.06 (0.06 - 0.06)	0.06 (0.03 - 0.12)	0.06 (0.03 - 0.12)
	Less dense, outer portion dorsal height	0.11 (0.06 - 0.15)	0.13 (0.02 - 0.26)	0.13 (0.07 - 0.21)	0.12 (0.02 - 0.26)
	Less dense, outer portion ventral height	0.19 (0.12 - 0.30)	0.3 (0.11 - 0.40)	0.26 (0.11 - 0.43)	0.25 (0.11 - 0.43)
	Whole CSP including urethra	0.32 (0.23 - 0.44)	0.51 (0.33 - 0.68)	0.42 (0.19 - 0.60)	0.42 (0.19 - 0.68)
	Circumference	1.2 (0.89 - 1.62)	1.93 (1.71 - 2.08)	1.59 (0.98 - 2.12)	1.57 (0.89 - 2.12)
	Area	0.11 (0.05 - 0.21)	0.28 (0.23 - 0.32)	0.2 (0.07 - 0.34)	0.2 (0.05 - 0.34)
CSP without pressure	Denser, inner portion ventral height	0.09 (0.06 - 0.16)	0.12 (0.08 - 0.15)	0.11 (0.05 - 0.17)	0.11 (0.05 - 0.17)
	Less dense, outer portion dorsal height	0.2 (0.13 - 0.29)	0.27 (0.21 - 0.32)	0.23 (0.1 - 0.38)	0.23 (0.1 - 0.38)
	Less dense, outer portion ventral height	0.38 (0.29 - 0.50)	0.28 (0.19 - 0.37)	0.38 (0.27 - 0.50)	0.35 (0.19 - 0.50)
	Whole CSP including urethra	0.61 (0.45 - 0.76)	0.60 (0.41 - 0.78)	0.69 (0.58 - 0.87)	0.62 (0.41 - 0.87)
	Circumference	2.00 (1.61 - 2.41)	2.06 (1.71 - 2.41)	2.20 (1.76 - 2.47)	2.09 (1.61 - 2.47)
	Area	0.32 (0.20 - 0.46)	0.33 (0.23 - 0.43)	0.37 (0.23 - 0.47)	0.34 (0.20 - 0.47)

Urethra	Height with pressure	0.01 (0.00 - 0.09)	0.09 (0.00 - 0.03)	0.01 (0.00 - 0.08)	0.04 (0.00 - 0.09)
	Height without pressure	0.02 (0.00 - 0.07)	0.08 (0.00 - 0.15)	0.05 (0.00 - 0.19)	0.05 (0.00 - 0.19)
Ventral vascular channel	Height with pressure	0.08 (0.04 - 0.18)	0.07 (0.01 - 0.13)	0.11 (0.06 - 0.17)	0.09 (0.01 - 0.18)
	Height without pressure	0.15 (0.11 - 0.22)	0.19 (0.19 - 0.19)	0.18 (0.10 - 0.29)	0.17 (0.10 - 0.29)
Preputial vessel	Largest diameter with pressure	0.21 (0.10 - 0.35)	0.14 (0.06 - 0.23)	0.20 (0.09 - 0.37)	0.18 (0.06 - 0.10)
	Largest diameter without pressure	0.26 (0.15 - 0.33)	0.26 (0.23 - 0.29)	0.26 (0.13 - 0.37)	0.26 (-0.13 - 0.37)
Location B					
Skin	Ventral height	0.09 (0.06 - 0.12)	0.10 (0.06 - 0.15)	0.93 (0.04 - 0.14)	0.10 (0.04 - 0.15)
Dorsal aspect of the tunica	Whole tunica height	0.25 (0.23 - 0.34)	*	0.25 (0.21 - 0.28)	0.25 (0.21 - 0.34)
	Longitudinal fibers height	0.19 (0.14 - 0.29)	*	0.18 (0.13 - 0.23)	0.19 (0.13 - 0.29)
	Circumferential fibers height	0.09 (0.06 - 0.11)	0.18 (0.18 - 0.18)	0.11 (0.09 - 0.13)	0.12 (0.06 - 0.18)
Ventral aspect of the tunica	Whole tunica height	0.34 (0.27 - 0.43)	0.48 (0.35 - 0.69)	0.45 (0.31 - 0.50)	0.42 (0.27 - 0.69)
	Longitudinal fibers height	0.26 (0.19 - 0.33)	0.39 (0.25 - 0.60)	0.35 (0.24 - 0.41)	0.33 (0.19 - 0.60)
	Circumferential fibers height	0.09 (0.06 - 0.12)	0.10 (0.08 - 0.12)	0.11 (0.07 - 0.16)	0.10 (0.06 - 0.16)
CCP	Height	1.04 (0.72 - 1.27)	1.18 (0.85 - 1.49)	1.28 (1.04 - 1.52)	1.17 (0.72 - 1.52)
	Width	2.34 (2.00 - 2.76)	2.39 (2.00 - 2.60)	2.53 (2.12 - 3.07)	2.42 (2.00 - 3.07)
	Circumference	6.25 (5.34 - 7.58)	6.69 (5.40 - 7.58)	6.95 (5.49 - 8.29)	6.63 (5.34 - 8.29)
	Area	2.09 (1.40 - 3.19)	2.55 (1.77 - 3.36)	2.83 (1.82 - 3.95)	2.49 (1.40 - 3.95)
CSP with pressure	Denser, inner portion ventral height	0.04 (0.01 - 0.07)	0.07 (0.04 - 0.10)	0.05 (0.03 - 0.14)	0.06 (0.01 - 0.14)
	Less dense, outer portion dorsal height	0.10 (0.06 - 0.18)	0.14 (0.07 - 0.22)	0.13 (0.08 - 0.22)	0.12 (0.06 - 0.22)
	Less dense, outer portion ventral height	0.21 (0.11 - 0.34)	0.36 (0.23 - 0.42)	0.23 (0.10 - 0.43)	0.27 (0.10 - 0.43)
	Whole CSP including urethra	0.33 (0.22 - 0.54)	0.28 (0.28 - 0.28)	0.41 (0.31 - 0.58)	0.35 (0.22 - 0.58)
	Circumference	1.29 (0.91 - 1.75)	0.43 (0.43 - 0.43)	0.69 (0.46 - 1.00)	0.56 (0.43 - 1.75)
	Area	.013 (0.06 - 0.22)	0.26 (0.14 - 0.34)	0.17 (0.05 - 0.37)	0.19 (0.05 - 0.37)
CSP without pressure	Denser, inner portion	0.10 (0.06 - 0.22)	0.04 (0.04 - 0.04)	0.09 (0.05 - 0.14)	0.08 (0.04 - 0.17)

	Measurement				
	ventral height	...0.17)			
	Less dense, outer portion dorsal height	0.20 (0.16 - 0.27)	0.14 (0.14 - 0.14)	0.23 (0.12 - 0.42)	0.19 (0.12 - 0.42)
	Less dense, outer portion ventral height	0.35 (0.24 - 0.47)	0.28 (0.28 - 0.28)	0.41 (0.31 - 0.58)	0.35 (0.24 - 0.58)
	Whole CSP including urethra	0.56 (0.47 - 0.65)	0.43 (0.43 - 0.43)	0.69 (0.46 - 1.00)	0.56 (0.43 - 1.00)
	Circumference	1.91 (1.6 - 2.12)	1.46 (1.46 - 1.46)	2.11 (1.84 - 2.72)	1.83 (1.46 - 2.72)
	Area	0.29 (0.20 - 0.35)	0.17 (0.17 - 0.17)	0.35 (0.26 - 0.56)	0.27 (0.17 - 0.56)
Urethra	Height with pressure	0.00 (0.00 - 0.05)	0.04 (0.00 - 0.12)	0.02 (0.00 - 0.15)	0.02 (0.00 - 0.15)
	Height without pressure	0.01 (0.00 - 0.03)	0.00 (0.00 - 0.00)	0.48 (0.00 - 0.19)	0.02 (0.00 - 0.19)
Ventral vascular channel	Height with pressure	0.09 (0.05 - 0.15)	0.09 (0.06 - 0.13)	0.11 (0.05 - 0.21)	0.10 (0.05 - 0.21)
	Height without pressure	0.17 (0.12 - 0.24)	*	0.15 (0.10 - 0.19)	0.16 (0.10 - 0.24)
Preputial vessel	Largest diameter with pressure	0.18 (0.08 - 0.30)	0.17 (0.13 - 0.20)	0.20 (0.08 - 0.31)	0.18 (0.08 - 0.31)
	Largest diameter without pressure	0.21 (0.15 - 0.29)	*	0.2 (0.2 - 0.2)	0.21 (0.15 - 0.29)
Location G					
Skin	Ventral height	0.05 (0.03 - 0.08)	0.06 (0.04 - 0.08)	0.05 (0.04 - 0.08)	0.05 (0.03 - 0.08)
Fibrofatty tissue	Ventral height	0.20 (0.07 - 0.29)	0.26 (0.20 - 0.35)	0.20 (0.11 - 0.34)	0.22 (0.07 - 0.35)
	Enitre width	1.92 (1.49 - 2.1)	1.78 (1.53 - 2.06)	1.91 (1.38 - 2.24)	1.87 (1.38 - 2.24)
	Entire height	0.94 (0.29 - 1.61)	1.08 (0.97 - 1.16)	1.01 (0.74 - 1.28)	1.01 (0.29 - 1.61)
	Circumference	4.94 (3.95 - 5.36)	4.61 (4.18 - 4.94)	4.75 (3.87 - 5.20)	4.77 (3.87 - 5.36)
	Area	1.61 (1.14 - 1.97)	1.53 (1.27 - 1.75)	1.51 (0.99 - 1.75)	1.55 (0.99 - 1.97)
Ventral aspect of the tunica	Whole tunica height	0.19 (0.13 - 0.28)	0.17 (0.12 - 0.26)	0.19 (0.13 - 0.24)	0.19 (0.12 - 0.28)
	Longitudinal fibers height	0.14 (0.10 - 0.19)	0.15 (0.11 - 0.23)	0.14 (0.09 - 0.20)	0.15 (0.09 - 0.23)
	Circumferential fibers height	0.06 (0.04 - 0.12)	0.34 (0.03 - 0.05)	0.05 (0.03 - 0.08)	0.05 (0.03 - 0.12)
CCP	Height	0.25 (0.14 - 0.40)	0.27 (0.19 - 0.35)	0.25 (0.16 - 0.43)	0.25 (0.14 - 0.43)
	Circumference	0.97 (0.52 - 1.35)	1.01 (0.80 - 1.24)	0.98 (0.69 - 1.54)	0.99 (0.52 - 1.54)
	Area	0.08 (0.02 - 0.14)	0.08 (0.05 - 0.12)	0.08 (0.04 - 0.18)	0.08 (0.02 - 0.18)

Location / Structure	Measurement				
CSP	Whole height	0.23 (0.11 - 0.42)	0.25 (0.15 - 0.34)	0.24 (0.16 - 0.34)	0.24 (0.11 - 0.42)
	Ventral height	0.16 (0.10 - 0.33)	0.17 (0.09 - 0.22)	0.17 (0.13 - 0.25)	0.17 (0.09 - 0.33)
	Circumference	0.68 (0.37 - 1.35)	0.70 (0.41 - 0.89)	0.71 (0.57 - 0.94)	0.70 (0.37 - 1.35)
	Area	0.04 (0.01 - 0.14)	0.04 (0.01 - 0.06)	0.04 (0.02 - 0.07)	0.04 (0.01 - 0.14)
Location S					
Skin	Ventral height	0.07 (0.03 - 0.16)	0.12 (0.10 - 0.15)	0.11 (0.06 - 0.26)	0.10 (0.03 - 0.26)
Dorsal aspect of the tunica	Whole tunica height	*	*	0.34 (0.34 - 0.34)	0.34 (0.34 - 0.34)
	Longitudinal fibers height	*	*	0.27 (0.27 - 0.27)	0.27 (0.27 - 0.27)
	Circumferential fibers height	*	*	0.09 (0.09 - 0.09)	0.09 (0.09 - 0.09)
Ventral aspect of the tunica	Whole tunica height	0.42 (0.28 - 0.61)	0.42 (0.38 - 0.46)	0.42 (0.15 - 0.51)	0.42 (0.15 - 0.61)
	Longitudinal fibers height	0.31 (0.07 - 0.15)	0.31 (0.27 - 0.35)	0.31 (0.08 - 0.40)	0.31 (0.07 - 0.40)
	Circumferential fibers height	0.11 (0.07 - 0.15)	0.12 (0.09 - 0.14)	0.12 (0.08 - 0.18)	0.12 (0.07 - 0.18)
CCP	Height	1.21 (1.00 - 1.50)	1.33 (0.85 - 1.71)	1.45 (1.19 - 1.74)	1.33 (0.85 - 1.74)
	Width	2.26 (2.07 - 2.57)	2.53 (2.13 - 3.05)	2.67 (2.31 - 3.05)	2.48 (2.07 - 3.05)
	Circumference	6.57 (6.04 - 7.45)	7.22 (6.23 - 8.00)	7.69 (6.63 - 9.00)	7.16 (6.04 - 9.00)
	Area	2.54 (2.00 - 3.10)	3.06 (2.30 - 3.93)	3.44 (2.33 - 4.60)	3.01 (2.00 - 4.60)
CSP with pressure	Denser, inner portion ventral height	0.05 (0.03 - 0.13)	0.06 (0.05 - 0.07)	0.06 (0.02 - 0.14)	0.05 (0.02 - 0.14)
	Less dense, outer portion dorsal height	0.13 (0.07 - 0.18)	0.17 (0.14 - 0.20)	0.16 (0.08 - 0.27)	0.15 (0.07 - 0.27)
	Less dense, outer portion ventral height	0.21 (0.10 - 0.39)	0.33 (0.25 - 0.47)	0.26 (0.11 - 0.41)	0.26 (0.10 - 0.47)
	Whole CSP including urethra	0.36 (0.21 - 0.56)	0.52 (0.42 - 0.65)	0.44 (0.22 - 0.74)	0.44 (0.21 - 0.74)
	Circumference	1.38 (0.89 - 1.92)	1.85 (1.33 - 2.32)	1.65 (1.88 - 2.9)	1.62 (0.89 - 2.9)
	Area	0.15 (0.06 - 0.28)	0.27 (0.13 - 0.42)	0.21 (0.07 - 0.45)	0.21 (0.06 - 0.45)
CSP without pressure	Denser, inner portion ventral height	0.06 (0.00 - 0.22)	0.05 (0.00 - 0.01)	0.07 (0.00 - 0.18)	0.06 (0.00 - 0.22)
	Less dense, outer portion dorsal height	0.16 (0.10 - 0.23)	0.18 (0.17 - 0.19)	0.21 (0.16 - 0.41)	0.19 (0.10 - 0.41)
	Less dense, outer portion ventral height	0.28 (0.15 - 0.59)	0.30 (0.18 - 0.42)	0.31 (0.10 - 0.55)	0.30 (0.10 - 0.59)

Structure					
	Whole CSP including urethra	0.60 (0.30 - 0.88)	0.65 (0.62 - 0.67)	0.71 (0.56 - 0.92)	0.65 (0.30 - 0.92)
	Circumference	2.12 (1.22 - 2.80)	2.06 (2.02 - 2.10)	2.30 (1.88 - 2.90)	2.16 (1.22 - 2.90)
	Area	0.36 (0.12 - 0.59)	0.32 (0.32 - 0.32)	0.41 (0.27 - 0.64)	0.37 (0.12 - 0.64)
Urethra	Height with pressure	0.02 (0.00 - 0.11)	0.02 (0.00 - 0.07)	0.01 (0.00 - 0.10)	0.01 (0.00 - 0.11)
	Height without pressure	0.16 (0.00 - 0.46)	0.14 (0.00 - 0.28)	0.18 (0.00 - 0.56)	0.16 (0.00 - 0.56)
Ventral vascular channel	Height with pressure	0.07 (0.03 - 0.12)	0.10 (0.07 - 0.13)	0.13 (0.05 - 0.21)	0.10 (0.03 - 0.21)
	Height without pressure	0.09 (0.04 - 0.15)	0.10 (0.10 - 0.10)	0.14 (0.14 - 0.14)	0.11 (0.04 - 0.15)
Preputial vessel	Largest diameter with pressure	0.18 (0.14 - 0.30)	0.13 (0.09 - 0.17)	0.19 (0.08 - 0.35)	0.17 (0.08 - 0.35)
	Largest diameter without pressure	*	*	0.29 (0.29 - 0.29)	0.29 (0.29 - 0.29)
Retractor penis muscle	Height	0.37 (0.30 - 0.48)	0.39 (0.35 - 0.45)	0.44 (0.30 - 0.55)	0.40 (0.30 - 0.55)

*Not Visible