Ultrasonography of the bull genital system

Harry Momont
School of Veterinary Medicine, University of Wisconsin-Madison, Madison, WI

Abstract

Ultrasonography has become a mainstay of reproductive medicine. It is used less frequently for examination of male cattle than females. This paper describes the technical aspects of diagnostic ultrasonography of the bull genital system, provides examples of normal findings, and discusses commonly encountered abnormalities.

Keywords: Cattle, bull, ultrasonography, reproductive organs, testis

Introduction

Ultrasound refers to any sound waves with frequencies above the threshold of human hearing (> 20 kHz). Medical applications of ultrasound can be either diagnostic or therapeutic. The author is not aware of any reports on the use of therapeutic ultrasonography for the bull reproductive system, so the focus will be on diagnostic applications. Diagnostic ultrasonography produces images of internal tissues and relies on ultrasound frequencies, typically, in 1 - 15 MHz range. Higher frequencies are correlated with shorter wavelengths that allows for finer image detail. Lower frequency ultrasound has longer wavelengths that suffer less from attenuation as they pass through tissue, allowing for imaging of deeper structures. Best image is generally obtained by using the highest frequency transducer that will penetrate to the depth of the structure that one wishes to examine. The viewed image is the result of coherent echoes returned to the transducer by reflection that occurs when the transmitted ultrasound beam encounters tissues with differing acoustic impedance properties.

Major advantages of diagnostic ultrasonography are, it is noninvasive, produces images in real time, and can be packaged in a portable system that allows for point-of-care use in large animal facilities. Additionally, unlike radiography, it does not use ionizing radiation and is generally regarded as safe.

The production of image artifacts is a significant issue when interpreting ultrasonographic studies and they are a part of almost every imaging session. Common artifacts (e.g., reverberation, distal enhancement, attenuation, speed propagation error, reflection, refraction, and beam width artifact) can be attributed to equipment or operator limitations (e.g., selection of an inappropriate transducer frequency, incorrect instrument settings, patient movement, and poor patient preparation) or tissue interactions with the sound beam that cannot be anticipated or properly compensated for by the imaging software. A basic understanding of ultrasonographic principles and common artifacts is crucial to interpreting images. There are texts[1-3] available that cover these basics and it is highly recommended to have 1 of them as a reference material.

A detailed knowledge of normal anatomy is crucial for the correct interpretation of ultrasound studies. An excellent bovine reproductive anatomy guide can be obtained from the National Association of Animal Breeders.[4] Recommended reading materials include general reviews of male genital pathology[5,6] and bull genital ultrasonography.[7,8] A mental and digital library of normal sonograms can be obtained by repeatedly examining the reproductive tracts of normal bulls.

B-Mode ultrasonography

Brightness or B-mode is the system that produces the classic gray-scale images in real time that most of us associate with ultrasonography. First report on B-mode ultrasonography for examination of the bull scrotum was published in 1987.[9] A number of subsequent studies failed to confirm additional substantial benefit when ultrasonography was used as an adjunct to the standard bull breeding soundness examination (BSE).[10-12] Consequently, ultrasonography is not a basic component of a standard bull BSE as recommended by the Society for Theriogenology.[13,14] The major advantage of ultrasonography is its ability to confirm, localize, and monitor the progression of gross morphological lesions of the reproductive tract. It is recommended for prepurchase examinations of older bulls, for all cases of infertility or subfertility in valuable animals, and for bulls with palpable or visible scrotal lesions. Additionally, abnormal seminal parameters (e.g., low semen volume, pyospermia, teratospermia, hemospermia, azoospermia, and oligospermia) call for an ultrasound examination.

Safety of everyone involved in the examination should be a priority when working with bulls. Mature bulls can be unpredictably aggressive, and their large size increases the danger. Whereas younger bulls are generally less aggressive, in author's experience they are more prone to kicking than mature bulls. A good stock or chute with a squeeze and well-trained handlers make the job much easier. Sedation is generally not required; however, it can be used for fractious animals.

Acquiring an image requires that the transducer be coupled to smooth scrotal skin. This will require stretching the scrotal skin by pulling down on the testis, along with the application of a coupling agent. Author prefers to cover the transducer for all examinations by inserting a small amount of coupling gel in a disposable sleeve or glove. Scrotal contents (spermatic cord, vascular cone, epididymis, and testis) are examined in sagittal and transverse planes. Representative images should be labeled, measured, and preserved. The probe may be applied to the caudal, lateral, or cranial surface of the scrotum to obtain the best image of the target tissues. Author prefers a linear transducer that will cover most of the testis of a mature bull in the sagittal view. The linear transrectal probe used for routine examination of female cattle is nearly ideal for this purpose. A transducer frequency of 5 - 8 MHz provides a good image with adequate depth. A higher-frequency transducer may be required for detailed imaging of epididymis; however, the cost of an additional ultrasound probe can be substantial. One should purchase a system that gives the best image after testing image quality and durability under field conditions.

Normal testis (Figure 1) has a relatively homogeneous parenchyma with a stippled, medium echogenicity. The parenchyma surrounds a centrally located and more hyperechoic (whiter) mediastinum testis. The width of the mediastinum testis is about 5 - 10 mm and increases with age. A second age-related ultrasonographic correlation is the gradual increase in echogenicity that accompanies the onset of puberty.[11,15]

When examining peripubertal bulls the author has commonly observed an aberrant feature (Figure 2). Small, scattered hyperechoic foci may be randomly distributed in the parenchyma or concentrated in 1 area of the testis and can vary widely in number. Less commonly they encircle the mediastinum testis, suggesting involvement of the straight tubules. Similar lesions appeared in human males[16] and are classified as microlithiasis, small foci of mineralization of unknown etiology and significance. Histological basis for this lesion in the bull has not been established and its impact on fertility is likewise unknown; however, it does not appear to be a substantial factor in bull infertility.

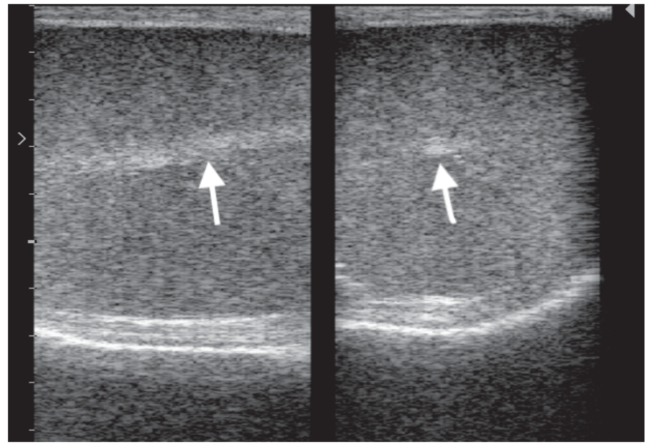

Figure 1. Ultrasonogram of a normal testis of a yearling Holstein. Note mediastinum testis (arrows) appearing as a linear structure in sagittal view on the left and appearing in cross section in transverse view on the right. Mediastinum testis is more hyperechoic than surrounding parenchyma. Images were obtained with a 5 MHz linear transducer placed on the caudal aspect of scrotum using alcohol as a coupling agent. Scale for the left image is cm.

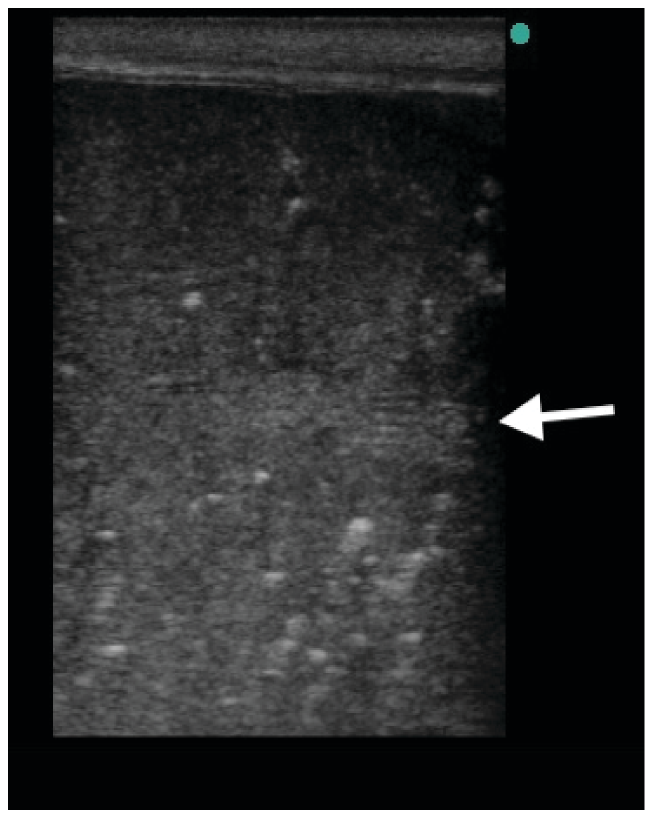

Figure 2. Sagittal view of a testis of a mature bull with scattered hyperechoic foci distributed throughout the parenchyma. Note normal mediastinum testis (arrow).

There is another common abnormality (Figure 3) encountered when examining bovine testis. These larger hyperechoic foci have been identified as fibrotic in nature[17] and may progress in time to mineralization. Unlike smaller lesions noted above, they are often accompanied by acoustic shadowing. Lesions may be more focal in nature or radiate outward from the mediastinum testis in a pattern, suggesting involvement of individual seminiferous tubules.[18] These lesions may represent a discrete local degeneration of the germinal tubules; however, care should be exercised in attaching significance to them as they are often noticed in bulls with normal spermiograms.[17] A reduction in sperm production capacity is expected in bulls with large amounts of fibrotic tissue in the parenchyma.

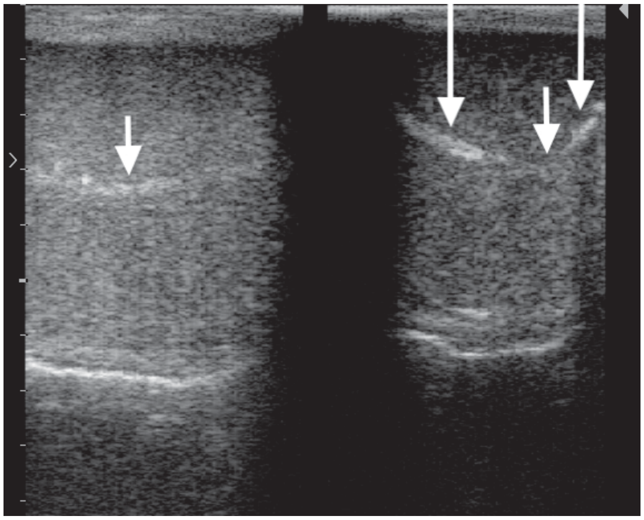

Figure 3. Sagittal (left) and transverse (right) views of a yearling dairy bull testis with mild testicular fibrosis. Normal mediastinum (short white arrows) is in longitudinal section (left) and in cross-section in transverse view (right). Fibrosis (longer arrows on right) appears to radiate from the mediastinum suggesting involvement of discrete seminiferous tubules. Note acoustic shadowing is below the fibrotic tissue on the extreme right of the image.

Whereas the precise pathogenesis of these fibrotic lesions is not clearly defined, some suggested etiologies include infectious or inflammatory conditions, developmental defects of the seminiferous tubules or their connecting ducts, autoimmunity, obesity, and aging.[18] When *Trueperella pyogenes* was injected into the testis of rams, the initial hypoechoic response attributable to inflammation and edema was followed by the development of hyperechoic lesions that were confirmed to be fibrotic tissue.[19] Furthermore, an outbreak of bovine respiratory syncytial virus in a group of bulls was associated with an increased prevalence of fibrotic lesions; however, a cause-and-effect relationship could not be confirmed.[17] In theory, the pathological mechanism of obesity is a disruption of scrotal thermoregulation. However, scrotal insulation that resulted in a dramatic decrease in semen quality had no fibrotic lesions of the testis in a follow up (4 - 6 months) examination.[20,21] Trauma and age are also considered as factors for progressive fibrosis of the ventral testicular parenchyma; however, it has also been described as a normal feature of aging.[22]

Hypoechoic lesions are less commonly encountered. They may represent delayed sexual development, degeneration, or tumors. Lesions with mixed echogenicity are also less common and the author has observed them with tumors, inflammation, or abscesses.

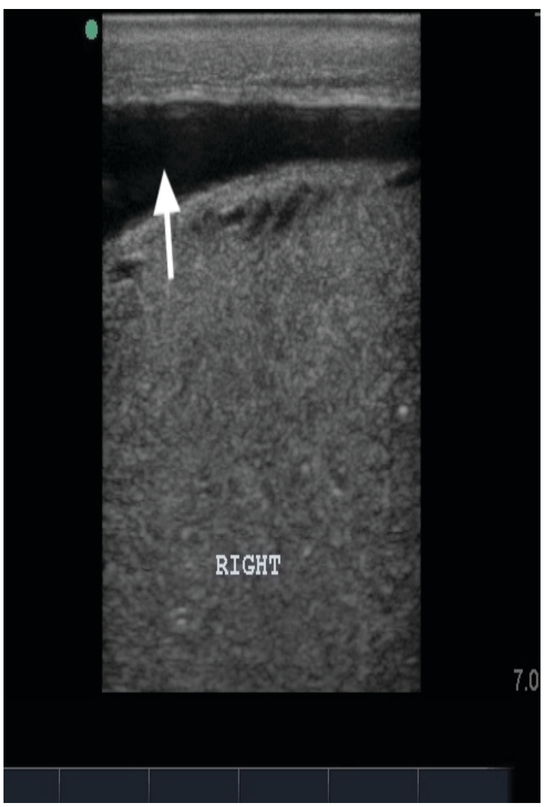

Figure 4. Sagittal view of a yearling bull testis with a history of oligospermia and low semen volume. Note the dilated, hypoechoic rete testis in longitudinal view between 2 arrows.

A specific hypoechoic lesion of the bovine testis is seen in Figure 4. First reported in 1991,[23] fluid distention of the rete testis secondary to outflow obstruction results in the hypoechoic, dilated rete testis. Younger bulls with a history of persistent low semen volume and oligospermia should be monitored for development of this ultrasound finding. A congenital aplasia somewhere along the sperm outflow tract is usually observed in postmortem or after gonadectomy. The lesion may be acquired in older bulls.

A complete scrotal examination should include an assessment of the spermatic cord, vascular cone, scrotal wall, and epididymis. The vascular elements can be assessed by both B-mode and Doppler ultrasonography. Doppler ultrasonography will be discussed later. Lesions associated with the epididymis include cysts, sperm granulomas, and congenital aplasia. Cystic structures in the region of the head of the epididymis may represent proximal mesonephric duct remnants and are generally benign.[5] Other scrotal pathologies encountered in this area include inguinal and scrotal hernias, scrotal hydrocoele (Figure 5), and vascular abnormalities.

Other genital tissues

Ultrasonography of the pelvic accessory sex organs, prepuce, and penis may be accomplished using a the transrectal or transdermal approach. A recent review is available.[8] Alcohol alone may provide adequate coupling to produce a transdermal image; however, dense, long, or matted hair will likely require shaving in addition to using a coupling agent. Special care should be taken when examining the distal penis or the prepuce. Bulls are more likely to object to this manipulation and sedation may be required.

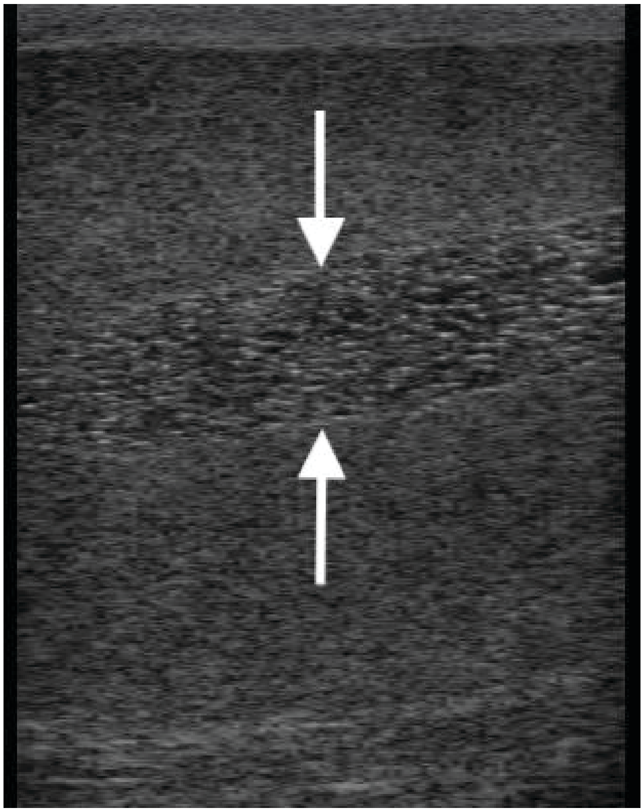

Figure 5. Sagittal view of a mature beef bull testis diagnosed with scrotal hydrocoele. Note the accumulation of hypoechoic fluid in the vaginal process (arrow) contrasts with the more echoic normal testis parenchyma below the fluid and the caudal scrotal wall above it. Small dark areas in the testis periphery are branches of intratesticular artery.

Doppler ultrasonography

A thorough coverage of Doppler ultrasonography will not be attempted here. More detailed information is readily available in recent reviews on the subject.[3,24] Basic function of Doppler ultrasonography is to detect movement within the image. In veterinary medicine, this usually means detecting red blood cells (RBCs) movement through a vessel.

Doppler ultrasonography can be used to detect and evaluate blood flow in the scrotum and testis. Color Doppler is readily available on most mid-range portable systems and not typically in basic machines used for on-farm purposes. In color Doppler mode, the transducer functions in both B-mode and Doppler mode to detect blood flow in tissue and depicts movement as color on the gray scale B-mode image in real time. The color (usually blue or red) indicates movement away from or toward the transducer. Pulsed wave is another Doppler imaging option routinely available with more expensive portable systems. In this mode, the velocity of the moving tissue (RBCs) is displayed as a spectral graph from which peak systolic and end diastolic velocity can be determined and used to calculate various indices of arterial blood flow (e.g., mean velocity, resistive index and pulsatility index).

Doppler ultrasonography has proven useful in human medicine for evaluating circulatory disruption associated with testis torsion, varicosities, and tumors.[25] The resistive index has some correlation with disrupted testes function in bulls.[26] Presently, however, the greatest utility of Doppler ultrasound appears to be the ability to confirm blood flow in tissue using the color Doppler function. Its use as a screening tool for bull infertility requires more detailed study.

Future directions

B-mode ultrasonography will remain the standard for examination of the bull, enhanced by continued improvements in image quality and affordability. Doppler studies will gain acceptance as veterinarians in large animal practice acquire systems with these capabilities. Doppler, contrast-enhanced ultrasonography, and tissue elastography are examples of imaging modalities that are now being used in human medicine.[25]

Conclusion

Ultrasonography is a safe, noninvasive method for obtaining diagnostic and prognostic information about infertile bulls. Competency with both B-mode and Doppler techniques can be readily achieved by repeated imaging the genital tract of normal, fertile bulls. The most frequently encountered lesions are easily detected by instruments with average or better image quality. Author performs ultrasound studies for all cases of infertility involving bulls at collection centers and for valuable natural service sires. Author does not use it for routine screening of young sires in the absence of grossly detectable lesions. It is important to consider that the most frequently detected ultrasonic changes in young bulls are of questionable value to predict future fertility.

Conflict of interest

None to declare.

References

1. Ginther OJ: Ultrasonic Imaging and Animal Reproduction. Fundamentals. Cross Plains, WI; Equiservices Publishing: 1995.
2. Blond L Buczinski S: Basis of ultrasound imaging and the main artifacts in bovine medicine. Vet Clin North Am Food Anim Pract 2009; 25:553-565.
3. Mattoon J, Nyland T: Fundamentals of diagnostic ultrasound. In: Mattoon J, Nyland T: editors. Small Animal Diagnostic Ultrasound. 3rd edition, St. Louis; Elsevier Saunders: 2015. p. 1-49.
4. Mullins K, Saacke R: Illustrated anatomy of the bovine male and female reproductive tracts. From gross to microscopic. Blacksburg, VA: Germinal Dimensions (available from naab-css.org), 2003.
5. McEntee K: Reproductive Pathology of Domestic Animals. San Diego; Academic Press: 1990. p. 224-383.

6. Foster R: Male genital system. In: Maxie G: editor. Jubb, Kennedy, and Palmer's Pathology of Domestic Animals. Volume 3. 6th edition, St. Louis: Elsevier: 2016. p. 465-510.
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. Momont H, Keeler M, Nicholson M: Ultrasound examination of the reproductive tract. In: Hopper, R: editor. Bovine Reproduction. 2nd edition, Hoboken; Wiley-Blackwell: 2021. p. 120-129.
9. Pechman R, Eilts B: B-mode ultrasonography of the bull testicle. Theriogenology 1987;27:431-441.
10. Eilts BE, Pechman RD: B-mode ultrasound observations of bull testes during breeding soundness examinations. Theriogenology 1988;30:1169-1175.
11. Brito L, Barth A, Wilde R, et al: Testicular ultrasonogram pixel intensity during sexual development and its relationship with semen quality, sperm production, and quantitative testicular histology in beef bulls. Theriogenology 2012;78:69-76.
12. Tomlinson M, Jennings A, Macrae A, et al: The value of trans-scrotal ultrasonography at bull breeding soundness evaluation (BSE): The relationship between testicular parenchymal pixel intensity and semen quality. Theriogenology 2017;89:169-177.
13. Chenowith P, Hopkins F, Spitzer J, et al: Guidelines for using the bull breeding soundness examination form. Clinical Theriogenology 2010;2:43-50.
14. Koziol JH, Armstrong CL: Society for Theriogenology Manual for Breeding Soundness Examination of Bulls. 2nd edition, Society for Theriogenology (therio.org): 2018. p. 123-126.
15. Brito L, Silva A, Unanian M, et al: Sexual development in early and late maturing Bos indicus a Bos indicus × Bos taurus crossbred bulls in Brazil. Theriogenology 2004;16:1198-1217.
16. Balawender K, Orkisz S, Wisz P: Testicular microlithiasis: what urologists should know. A review of the current literature. Cent European J Urol 2018;71:310-314.
17. Barth A, Alisio L, Aviles A, et al: Fibrotic lesions in the testis of bulls and relationship to semen quality. Anim Reprod Sci 2008;106:274-288.
18. Barth A, Kastelic J: Testicular degeneration. In: Hopper, R: editor. Bovine Reproduction. 2nd edition, Hoboken; Wiley-Blackwell: 2021. p. 144-150.
19. Gouletsou P, Fthenakis G, Cripps P, et al: Experimentally induced orchitis associated with Arcanobacter pyogenes: clinical, ultrasonographic, seminological and pathological features. Theriogenology 2004;62:1307-1328.
20. Sidibe M, Franco L, Fredriksson G, et al: Effects on testosterone, LH and cortisol concentrations, and on ultrasonographic appearance of induced testicular degeneration in bulls. Acta Vet Scand 1992;33:191-196.
21. Arteaga A, Barth A, Brito L: Relationship between semen quality and pixel-intensity of testicular ultrasonograms after scrotal insulation in beef bulls. Theriogenology 2005;64:408-415.
22. Humphrey J, Ladds P: A quantitative histological study of changes in the bovine testis and epididymis associated with age. Res Vet Sci 1975;19:135-141.
23. Andersson M, Alanko M: Ultrasonography revealing the accumulation of rete testis fluid in bull testicles. Andrologia 1991;23:75-78.
24. Ginther OJ: Ultrasonic Imaging and Animal Reproduction. Color-Doppler Ultrasonography. Cross Plains, WI; Equiservices Publishing: 2007.
25. Huang D, Sidhu P: Focal testicular lesions: colour Doppler ultrasound, contrast-enhanced ultrasound and tissue elastography as adjuvants to diagnosis. Br J Radiol 2012;85(Spec Iss 1):S41-53.
26. Gloria A, Carluccio A, Wegher L, et al: Pulse wave Doppler ultrasound of testicular arteries and their relationship with semen characteristics in healthy bulls. J Anim Sci Biotechnol 2018;9:14-20.