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Ultrasonography of the penile urethra of healthy Dorper × Santa Ines lambs between 2 and 5 months of age

Ultrassonografia da uretra peniana de cordeiros Dorper × Santa Inês hígidos entre 2 e 5 meses de idade

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Highlights

Ultrasound examination of the penile urethra is feasible in Dorper × Santa Ines lambs.
The examination can be performed using a linear probe for rectal use in large animals.
Urethral lumen width greater than 3 mm using the rectal probe indicates dilation.

Abstract

The objectives of this study were to establish, by ultrasonography, values of the width of the penile urethral lumen of Dorper × Santa Ines lambs, verify the effects of age and Dorper cross degree, and compare two types of linear probes. Forty healthy, uncastrated lambs (18 ½ Dorper and 22 ¾ Dorper) kept confined for fattening were studied. Ultrasonographic examinations were performed at 60 (beginning of confinement period), 120, and 150 days of age (end of confinement period). The penile urethra was examined at four sites: the proximal urethra (perineal region), sigmoid flexure (caudal aspect of the base of the scrotum), distal to the sigmoid flexure (cranial aspect of the base of the scrotum), and distal urethra (half the distance between the glans and the base of the scrotum). Images were acquired in B-mode with transcutaneous cross sections using two types of linear probes: for external use (13 MHz) and for transrectal use in large animals (10 MHz). The urethral lumen width was measured at each anatomical site. Data were analyzed using two-way repeated measures ANOVA. Genetic factors did not influence

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the results. The image definition was lower for the probe for rectal use. The urethra was identified as a circular or elliptical structure with an anechoic lumen and slightly hyperechoic wall. Urethral width increased with age in the proximal urethra (P = 0.038), distal to the sigmoid flexure (P = 0.013), and in the distal urethra (P < 0.001), but not in the sigmoid flexure (P = 0.056). The effect of the type of probe used was confirmed at the four anatomical sites examined (P < 0.001), with higher values measured using the probe for rectal use. With the probe for external use, the lumen width ranged 0.5-2.0 mm in the proximal urethra, 0.6-1.9 mm in the sigmoid flexure, 0.7-2.0 mm distal to the sigmoid flexure, and 0.7-2.1 mm in the distal urethra. With the probe for rectal use, the values were 0.6-2.3, 0.8-2.2, 0.7-2.1, and 0.8-2.5 mm, respectively. Ultrasound examination of the penile urethra of Dorper × Santa Ines lambs is feasible, and the values obtained for lumen width can be accepted as a parameter for comparison. This examination can be performed using a linear probe for rectal use in large animals.
Key words: Sheep. Ultrasound examination. Urethral lumen width. Urinary tract.

Resumo

Os objetivos deste estudo foram estabelecer, por ultrassonografia, valores da largura do lúmen da uretra peniana de cordeiros Dorper × Santa Inês, verificando os efeitos da idade e do grau de sangue Dorper e comparando dois tipos de transdutores lineares. Foram estudados 40 cordeiros (18 ½ Dorper e 22 ¾ Dorper) sadios, não castrados, e mantidos confinados para engorda. Os exames ultrassonográficos foram realizados aos 60 (início do período de confinamento), 120 e 150 dias de idade (final do período de confinamento). A uretra peniana foi examinada em quatro locais: uretra proximal (região perineal), flexura sigmoide (aspecto caudal da base do escroto), distal à flexura sigmoide (aspecto cranial da base do escroto) e uretra distal (½ da distância entre a glande e a base do escroto). As imagens foram realizadas em modo B com cortes transversais transcutâneos utilizando-se dois tipos de transdutores lineares: para uso externo (13 MHz) e para uso transretal em animais de grande porte (10 MHz). A largura do lúmen da uretra foi mensurada em cada local anatômico. Os dados foram analisados por meio da análise de variâncias de medidas repetidas bifatorial. O fator genético não influenciou os resultados. A definição das imagens foi inferior com o transdutor para uso retal. A uretra foi identificada como uma estrutura de formato circular ou elíptico com lúmen anecoico e parede ligeiramente hiperecoica. A largura da uretra aumentou com o avançar da idade na uretra proximal (P = 0,038), distal à flexura sigmoide (P = 0,013) e na uretra distal (P < 0,001), mas não na flexura sigmoide (P = 0,056). O efeito do tipo de transdutor utilizado foi confirmado nos quatro locais anatômicos examinados (P < 0,001) sendo os valores mensurados com o transdutor para uso retal maiores. Com o transdutor para uso externo, a largura do lúmen variou de 0,5-2,0 mm na uretra proximal, 0,6-1,9 mm na flexura sigmoide, 0,7-2,0 mm distal à flexura sigmoide e 0,7-2,1 mm na uretra distal. Com o transdutor para uso retal estes valores foram, respectivamente, 0,6-2,3, 0,8-2,2, 0,7-2,1 e 0,8-2,5 mm. O exame ultrassonográfico da uretra peniana de cordeiros Dorper × Santa Inês é viável e os valores obtidos da largura do seu lúmen podem ser admitidos como parâmetro para comparação. O exame pode ser realizado com o transdutor linear para uso retal em grandes animais..
Palavras-chave: Exame ultrassonográfico. Largura do lúmen da uretra. Ovino. Trato urinário.

Introduction

Ultrasound examination of the urinary tract of sheep is used to diagnose diseases such as pyelonephritis, hydronephrosis, renal abscess, hydroureter, cystitis, urinary bladder rupture, obstructive urolithiasis, and urethral rupture (P. Scott, 2016; Stieger-Vanegas & McKenzie, 2021). Among these, obstructive urolithiasis stands out (Videla & van Amstel, 2016; Cook, 2023), especially in male lambs confined for fattening and receiving a diet rich in grains with high energy and protein content and a reduced calcium:phosphorus ratio (Riet-Correa et al., 2008; Antonelli et al., 2012; Guimarães et al., 2012; Ferreira et al., 2015; Morais et al., 2016).

Transabdominal ultrasonography can easily visualize the right and left kidneys and the urinary bladder (Braun et al., 1992; P. Scott, 2013; Ferreira et al., 2014; Stieger-Vanegas & McKenzie, 2021). The ureters are visualized along their entire length in cases of hydroureter (P. R. Scott, 2012) and, when not dilated with retained urine, they can be visualized in their proximal portion (Stieger-Vanegas & McKenzie, 2021). The pelvic urethra can be identified in its initial portion very close to the urinary bladder by transrectal ultrasonography (Braun et al., 1992). Visualization of the penile urethra is considered difficult in healthy sheep because of the reduced lumen width (Stieger-Vanegas & McKenzie, 2021). However, one study confirmed the feasibility of this examination in crossbred Lacaune lambs aged 3 weeks and 4 months (AlLugami et al., 2017). In cases of obstructive urolithiasis, dilation of the penile urethra with retained urine makes it easier to visualize this structure (Stieger-Vanegas & McKenzie, 2021).

Few studies have described the dimensions of the anatomical structures of the sheep urinary system by using ultrasonography. Braun et al. (1992) measured the dimensions of the kidneys, urinary bladder, and the beginning of the pelvic urethra at its exit from the bladder, in healthy adult sheep and those affected by obstructive urolithiasis. Information on the width of the penile urethral lumen in healthy lambs is available in a unique study, and the measurements were performed at the perineal region, base of the scrotum, and preputial region (AlLugami et al., 2017). It is important to know the dimensions of the lumen of the penile urethra in healthy lambs because these values serve as objective physiological parameters for the correct interpretation of urethral dilation due to the accumulation of retained urine. Therefore, this method may aid in the diagnosis of obstructive urolithiasis.

Because of the lack of information on this subject, this study aimed to measure, by ultrasound examination, the width of the lumen of the penile urethra in healthy uncastrated Dorper × Santa Inês lambs between 2 and 5 months of age kept confined for fattening, and to verify the effects of the Dorper cross degree, age, and type of linear transducer used.

Material and Methods

1. Ethical approval. This longitudinal observational study was performed between May 2023 and August 2024 and was previously approved by the Ethics Committee on the Use of Animals of the Universidade Estadual de Londrina (CEUA-UEL) under protocol number 022.2022.

2. Animals and management. Forty weaned, healthy, uncastrated male Dorper × Santa Inês lambs between 2 and 5 months of age were included. The lambs had a Dorper cross grade of ½ (n=18) or ¾ (n=22). They were raised on a farm located in the municipality of Londrina, Paraná, southern Brazil. They were weaned at 2 months of age and remained confined for fattening until 5 months of age in a shed with a paved floor divided into stalls with an area of 16 m^2 that housed 8-10 lambs of similar age (area of 1.6-2 m^2/head). Each stall contained two feeding troughs (linear area of 30-37 cm/head) and one water trough. The lambs were fed a total mixed ration composed of 85% concentrate (corn grain, soybean meal, and mineral core with monensin) and 15% corn silage, and had free access to water.

3. Weighing, physical examination, and ultrasound evaluation. Maintaining health was an essential inclusion criterion established for the study, and the lambs were frequently monitored. Prior to all ultrasound evaluations, weighing was performed on a conventional scale, and a physical examination was performed, including measurement of heart rate, respiratory rate, rumen movements, body temperature, and assessment of mucous membrane color, hydration status, fecal characteristics, behavior, and attitudes.

Ultrasound examinations of the penile urethra were performed at 60 (± 5) (beginning of the confinement period), 120 (± 5), and 150 (± 5) days of age. The lambs were physically restrained in the right lateral recumbent position. The areas to be evaluated were shaved with the aid of a portable hair trimmer, and a conductive gel was applied between the skin and the acoustic lens of the transducer as an essential element to ensure images with adequate definition.

The penile urethra was examined at four anatomical sites in transcutaneous cross sections. The width of the urethral lumen was measured, regardless of whether it was circular (measured by diameter) or elliptical (measured by the major axis). The urethral wall was not included in these measurements, and only one image per site was obtained and subsequently measured during the examination procedure. The anatomical sites examined were as follows: a) proximal urethra (perineal region 4-5 cm ventral to the anus), b) sigmoid flexure (caudal aspect of the base of the scrotum), c) distal to the sigmoid flexure (cranial aspect of the base of the scrotum), and d) distal urethra (half the distance between the glans and the base of the scrotum) (Figure 1). The ultrasound examinations were performed by the same examiner using a veterinary ultrasound device (MyLabDelta, Esaote Veterinary, Genova, Italy). The measurements were guided in B-mode using two types of linear probes with their highest frequencies: a 13 MHz probe for external use (model SL 1543) and a 10 MHz probe for transrectal use in large animals (model SV 3513).

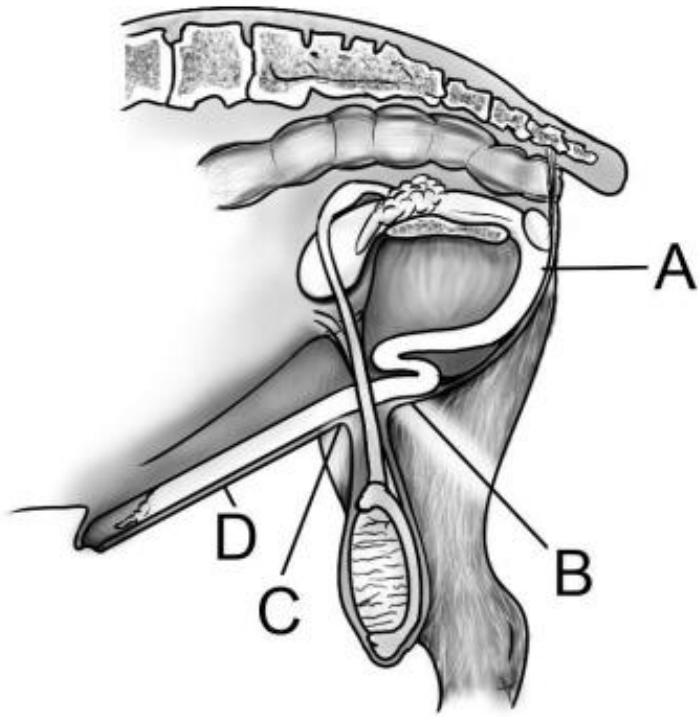

Figure 1. Ultrasonographic assessment sites of the penile urethra of healthy Dorper × Santa Ines lambs aged 2 to 5 months and confined for fattening:
proximal urethra (A), sigmoid flexure (B), distal to the sigmoid flexure (C), and distal urethra (D).

4. Statistical methods. A two-way repeated measures ANOVA was initially used to test the effect of the Dorper cross grade of the lambs (½ × ¾), the effect of age (2 × 4 × 5 months), and the interaction between these two factors. Since the degree of Dorper crossing had no significant effect, animals from both groups were analyzed together (n = 40) to evaluate age variation and differences between the probes. Subsequently, a two-way repeated measures ANOVA was used to test the effects of age (2 × 4 × 5 months), type of linear probe used (external use × rectal use), and the interaction between these two factors. Each anatomical site of the urethra examined was considered separately in these analyses. One-way ANOVA was used to compare the width of the urethral lumen at the four anatomical sites examined using the probe for external use. Pearson's correlation test was used to verify if the width of the urethral lumen correlated with body weight. For these two analyses, the readings of the three ages were considered, totaling 120 measurements at each anatomical site. One-way ANOVA was also used to compare body weight between Dorper crossing grades (½ × ¾), analyzing each age separately. The Tukey's test was used for multiple comparisons, assuming a 5% probability of error. Analyses were performed using the SigmaPlot 13.0 statistical package.

Results

The lambs had the following body weights at 2, 4, and 5 months of age, respectively: 17.20 ± 4.53, 28.40 ± 7.26, and 37.72 ± 8.41 kg. Body weight did not differ between ½ and ¾ Dorper lambs, regardless of age (P = 0.887, 0.154, and 0.414 at 2, 4, and 5 months, respectively).

The images obtained using the 13 MHz linear probe for external use had a higher definition than those obtained using the 10 MHz linear probe for rectal use. The penile urethra had a circular or elliptical structure with a hyperechoic wall and an anechoic lumen (Figure 2). In the images of the proximal urethra, the body of the penis was not always visualized with defined edges (Figure 2A). At the other anatomical sites examined, the penile body was easily identified. The hyperechoic wall of the urethra was not necessarily visualized in its entirety. In the static images, it was possible to perceive the presence of only the ventral (Figure 2B) or dorsal walls (Figure 2C). However, during the examinations, the wall of the urethra was visualized in the greatest extension owing to changes in probe positioning.

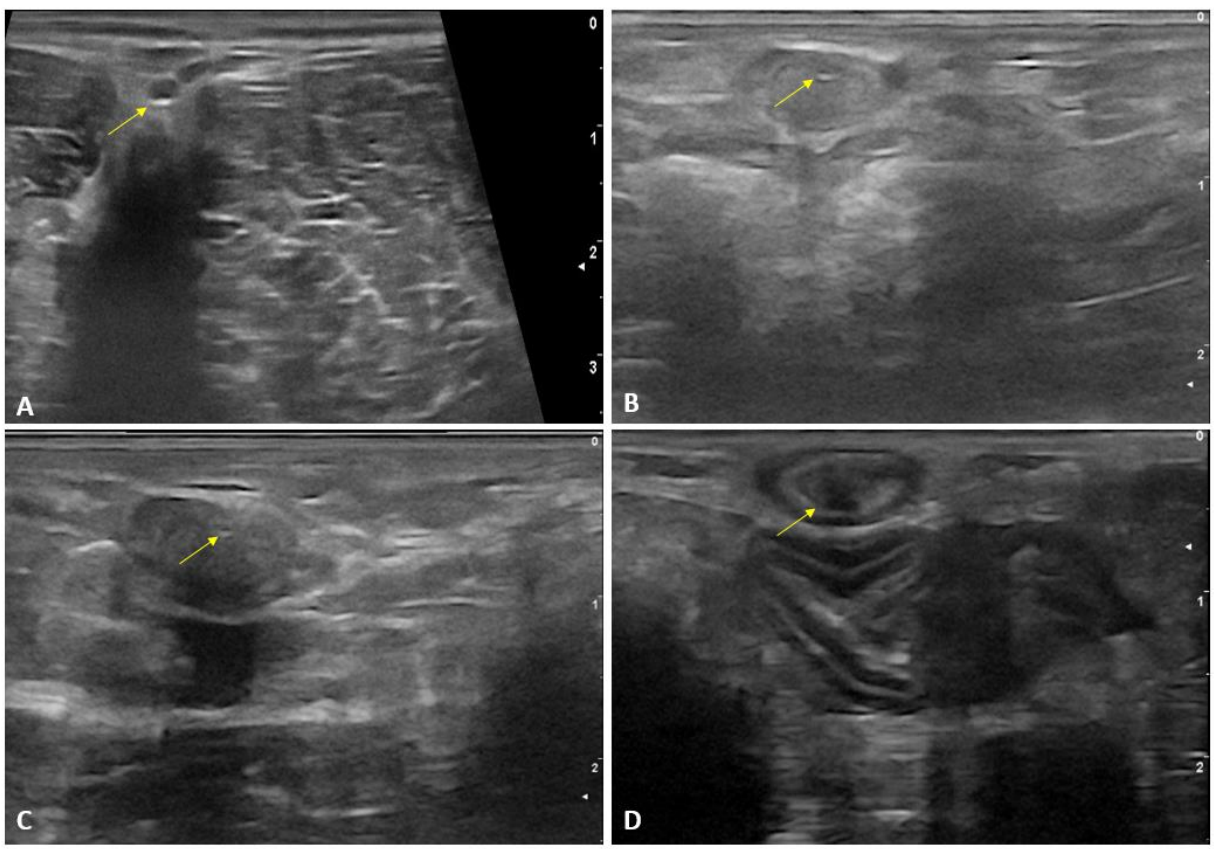

Figure 2. Ultrasound images of the penile urethra (arrow) in healthy uncastrated Dorper × Santa Inês lambs, between 2 and 5 months of age, and confined for fattening. Evaluation using a 13 MHz linear probe for external use, in cross sections at the following locations:
proximal urethra (A), sigmoid flexure (B), distal to the sigmoid flexure (C), and distal urethra (D).

Regardless of the probe used, the elliptical shape was observed more frequently than the circular shape at the four anatomical sites examined. In the images of the proximal urethra, sigmoid flexure, and position distal to the flexure, the elliptical shape was observed in 86.3% of the cases. In the distal urethra, the circular shape was more frequent (39.3% of the cases) than at the other sites.

Measured widths of the penile urethral lumen are listed in Table 1. The degree of Dorper crossing, ½ (n = 18) or ¾ (n = 22), did not influence the results obtained at any of the four anatomical sites examined, either when using the probe for external use (P = 0.485, 0.141, 0.236, and 0.099, respectively) or the probe for rectal use (P = 0.272, 0.531, 0.526, and 0.593, respectively). Therefore, the results obtained from the 40 lambs were analyzed together to evaluate the age variation and differences between the probes.

Table 1
Values (mean ± SD) of the width of the penile urethral lumen (mm) in Dorper × Santa Inês lambs confined for fattening, measured at 2, 4, and 5 months of age at four anatomical sites by ultrasound examination using two types of linear probes. A: effect of age; Pr: effect of probe type; A × Pr: interaction between age and probe

	Probe for external use (13 MHz)	Probe for rectal use (10 MHz)	*P*-value		
			A	Pr	A × Pr
Proximal urethra[1]					
2 months	1.19 ± 0.32 ^{Bb}	1.51 ± 0.42 ^{Aa}	0.038	<0.001	0.008
4 months	1.41 ± 0.42 ^{Ba}	1.61 ± 0.62 ^{Aa}			
5 months	1.51 ± 0.26 ^{Aa}	1.58 ± 0.35 ^{Aa}			
Sigmoid flexure[2]					
2 months	1.21 ± 0.28 ^{Bb}	1.49 ± 0.32 ^{Aa}	0.056	<0.001	0.050
4 months	1.30 ± 0.29 ^{Bab}	1.48 ± 0.39 ^{Aa}			
5 months	1.43 ± 0.24 ^{Aa}	1.53 ± 0.35 ^{Aa}			
Distal to the flexure[3]					
2 months	1.19 ± 0.25 ^{Bb}	1.45 ± 0.36 ^{Aa}	0.013	<0.001	0.005
4 months	1.30 ± 0.33 ^{Bb}	1.45 ± 0.39 ^{Aa}			
5 months	1.49 ± 0.31 ^{Aa}	1.50 ± 0.32 ^{Aa}			
Distal urethra[4]					
2 months	1.22 ± 0.25 ^{Bb}	1.42 ± 0.32 ^{Ab}	<0.001	<0.001	0.010
4 months	1.36 ± 0.40 ^{Bb}	1.54 ± 0.39 ^{Aab}			
5 months	1.64 ± 0.36 ^{Aa}	1.62 ± 0.43 ^{Aa}			

[1] perineum 4-5 cm distal to the anus
[2] caudal to the base of the scrotum
[3] cranial to the base of the scrotum
[4] half the distance between the cranial aspect of the base of the scrotum and the glans
^{A,B} different capital letters represent difference between probes (P < 0.05)
^{a,b} different lowercase letters represent difference between ages (P < 0.05)

The urethral width increased with age. This was well characterized when the examination was performed using the probe for external use but not when the probe for rectal use was used (Table 1). Regardless of the anatomical site examined, the urethral width at 2 and 4 months of age was greater when the probe for rectal use was used. There was no difference between the probes at 5 months.

Considering the results obtained at the three ages together using the probe for external use, it was observed that the width of the lumen of the distal urethra (1.41 ± 0.38 mm) was greater ($P < 0.001$) than that of the sigmoid flexure (1.32 ± 0.28 mm) and of the position distal to the sigmoid flexure (1.33 ± 0.32 mm). The width of the lumen in the proximal urethra was intermediate (1.37 ± 0.36 mm). The width of the lumen correlated weakly with the body weight in the proximal urethra ($r = 0.220$; $P = 0.018$). No correlation was observed for the other anatomical sites examined ($r = 0.095$; $P = 0.920$ in the sigmoid flexure; $r = 0.021$; $P = 0.818$ distal to the flexure; and $r = 0.134$; $P = 0.157$ in the distal urethra).

Failure to visualize the urethra was rare when using the probe for external use (4/480; 0.83%) and infrequent when using the probe for rectal use (12/480; 2.5%).

Discussion

To the best of our knowledge, this is the first study to describe the results of an ultrasonographic evaluation of the penile urethra in beef lambs. The lambs included were the result of crossing two breeds with an aptitude for meat production, with fast growth characteristics, and kept confined for rapid fattening between 2 and 5 months of age, ingesting a diet with a high content of concentrated foods. In other words, the category of sheep subjected to relevant risk factors for obstructive urolithiasis (Riet-Correa et al., 2008; Antonelli et al., 2012; Ferreira et al., 2015; Morais et al., 2016; Videla & van Amstel, 2016; Cook, 2023). The Dorper × Santa Ines crossbreed was chosen because it has been frequently used in Brazilian sheep farming since the last decade (Costa et al., 2012). The only previous study that presented the results of ultrasound examination of the penile urethra used Lacaune crossbred lambs (AlLugami et al., 2017), a breed suitable for milk production (Associação Brasileira de Criadores de Ovinos [A.R.C.O.], 2025). Therefore, the results obtained in the study presented here are relevant for the growing beef lambs.

Based on the concept that the limits of physiological variation are defined by the interval between two standard deviations below and above the mean (Farver, 2008), the obtained urethral lumen width values can be considered a reference interval for Dorper × Santa Ines lambs, 2-5 months old, confined for fattening. Using the probe for external use, the lumen width ranged 0.5-2.0 mm at the proximal urethra, 0.6-1.9 mm at the sigmoid flexure, 0.7-2.0 mm at the position distal to the sigmoid flexure, and 0.7-2.1 mm at the distal urethra. When the probe for rectal use was used, these values were 0.6-2.3, 0.8-2.2, 0.7-2.1, and 0.8-2.5 mm, respectively. Therefore, width values greater than 2.5 mm when using the probe for external use and greater than 3.0 mm when using the probe

for rectal use indicate urethral dilation with retained urine in lambs similar to those used in the present study. This is relevant because it can confirm the diagnosis of obstructive urolithiasis on the basis of objective criteria.

The mean values observed for the width of the penile urethral lumen in the lambs studied are two to three times greater than those reported in Lacaune crossbred lambs, which ranged 0.47-0.54 mm at 4 months of age (AlLugami et al., 2017). Notably, in both studies, linear probes for external use with very similar frequencies (12 and 13 MHz) were used, and the penile urethra was examined at different anatomical sites that were also similar. The differences between the results could be attributed to the racial factor.

The degree of Dorper crossbreeding did not influence the results in the lambs studied, but age did, demonstrating that the width of the urethral lumen increased in direct proportion to age. This was well characterized in the images obtained using the probe for external use. In contrast, when the probe for rectal use was used, age variation was observed only in the distal urethra. An increase in the width of the urethral lumen with advancing age was also observed in Lacaune crossbred lambs (AlLugami et al., 2017), but the magnitude was smaller than that observed in the present study.

In fact, the penile urethra is a small structure, and its visualization by ultrasonography is generally considered difficult in small ruminants (Stieger-Vanegas & McKenzie, 2021); attempts have been unsuccessful in healthy adult sheep (Braun et al., 1992). According to the results observed in the present study and in a previous study (AlLugami et al., 2017), this is not true for lambs. The failure to visualize the penile urethra in adult sheep is understandable because the examination was performed using a probe with a reduced frequency (5 MHz). In addition, the study by Braun et al. (1992) was performed three decades ago, during which there were notable technological advancements in ultrasound equipment and, consequently, improvements in the quality of image definition.

Systematic examination of the penile urethra at different anatomical locations, as performed in the present study, is justifiable in cases in which obstructive urolithiasis is suspected, as dilation of the urethra with retained urine may indicate the probable site of obstruction. Considering that the sigmoid flexure and urethral process are the two most frequent sites of obstruction with uroliths in sheep (Videla & van Amstel, 2016), the observations should be dilation of only the proximal urethra in the first case and dilation of the urethra as a whole in the second case. It is reasonable to assume that the dilated urethra with urine would be more easily visualized as a circular structure with an anechoic lumen. In a previous study on adult sheep, the width of the pelvic urethral lumen, measured in its initial portion close to the urinary bladder, increased from 1 to3 mm in healthy sheep to 23 mm in obstructed sheep (Braun et al., 1992). In the present study, it was not possible to compare the results of healthy lambs with those of obstructed lambs because no cases of obstructive urolithiasis occurred in confined animals during the study period.

Proof that the linear probe for transrectal use at a frequency of 10 MHz when positioned on the external surface can be used to examine the penile urethra in lambs is a relevant result of the present study. This type of probe is frequently used by veterinarians working with large animals on farms, mainly during routine gynecological examinations. Conversely, these clinicians generally do not have linear probes for external use. The quality and definition of the images obtained using the probe for external use were superior to those using the probe for rectal use, which may be explained by the difference in frequencies (13 MHz vs. 10 MHz). Likewise, it can be assumed that the slightly higher values of the urethral lumen width observed using the probe for rectal use are explained by the lower quality of the image definition, as this may increase the chance of inaccuracy in the measurements. Despite these differences, it is feasible to perform ultrasound examination of the penile urethra in lambs using the linear probe for rectal use.

One limitation of the present study was that it was not possible to compare the results obtained in healthy lambs with the possible changes observed in cases of obstructive urolithiasis.

Conclusions

Ultrasound examination of the penile urethra of Dorper × Santa Ines lambs is feasible, and the values obtained for lumen width can be accepted as a physiological parameter for comparison. This examination can be performed with a linear probe for external use or for rectal use in large animals. Lumen width values greater than 2.5 mm when using the probe for external use and greater than 3.0 mm when using the probe for rectal use can be considered indicative of urethral dilation in lambs with characteristics similar to those in this study.

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Conflict of interest statement

The authors declare that they have no conflicts of interest.

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