Ultrasonography of the urinary tract in 29 female Saanen goats

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Ultrasonography of the urinary tract in 29 female Saanen goats

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Summary

The left and right kidneys, ureters, urinary bladder and urethra of 29 female clinically healthy Saanen goats were examined via transcutaneous and transrectal ultrasonography. In order to establish reference values the examinations were performed using a 5.0 MHz linear transducer to scan the right caudal costal part of the abdominal wall, right and left dorsal flanks and right and left inguinal regions of standing goats. A 5.0 MHz intracavity probe was used for transrectal ultrasonographic examination of the urinary bladder and urethra. The kidneys were examined in longitudinal and cross section and assessed subjectively. They could usually be seen from the 12th intercostal space on the right side and dorsal right flank. The right kidney was 8.0 ± 0.67 cm long and the left was 8.4 ± 0.64 cm long. The ureters could not be visualized in any of the goats. The length of the urinary bladder was 5.1 ± 1.38 cm, and its largest cross-sectional diameter was 2.6 ± 1.01 cm. The urethra was seen in 23 goats and appeared as echogenic lines with no visible lumen. The transition from the neck of the bladder to the internal urethral orifice extended beyond the brim of the pelvis in only one goat.

Keywords: goat, ultrasonography, urinary tract, kidney, urinary bladder

Ultrasonographische Untersuchung des Harnapparats bei 29 Saanenziegen

Zusammenfassung

In der vorliegenden Arbeit wird die Untersuchung der linken und der rechte Niere, der Harnleiter, der Harnröhre und der Harnblase mittels transkutaner und transrektaler Sonographie bei 29 weiblichen, klinisch gesunden Saanenziegen beschrieben. Um Referenzwerte festzulegen wurde die Untersuchungen am stehenden Tier mit einem 5.0

MHz-Linearschallkopf im Bereich der rechten kaudalen rippengestützten Bauchwand, im Bereich der linken und rechten dorsalen Flanke und im Bereich der rechten und linken Leistengegend durchgeführt. Die Harnblase und Urethra wurden zusätzlich transrektal mit einer 5.0 MHz-Stabsonde untersucht. Zuerst wurden beide Nieren in Längs- und Querschnitten untersucht und subjektiv beurteilt. Die Nieren konnten rechts meist im Bereich des 12. Interkostalraums und in der dorsalen Flanke dargestellt werden. Die Länge der rechten Niere betrug 8.0 ± 0.67 cm, die der linken 8.4 ± 0.64 cm. Die Darstellung der Ureteren gelang bei keiner der untersuchten Ziegen. Die bei der transrektalen Untersuchung ermittelte Länge der Harnblase betrug 5.1 ± 1.38 cm. Der grösste Querdurchmesser lag bei 2.6 ± 1.01 cm. Die Urethra konnte bei 23 Tieren als echogene Linie dargestellt werden. Bei keiner Ziege war ein Lumen zu erkennen. Der Übergang zwischen dem Harnblasenhals und dem Ostium urethrae internum überragte den Beckenkamm (Pecten ossis pubis) nur in einem Fall.

Schlüsselwörter: Ziege, Sonographie, Harnapparat, Niere, Harnblase

Introduction

Ultrasonography has been a useful aid in the diagnosis of urinary tract disorders of ruminants for many years. In cattle, a number of reports have described the ultrasonographic findings in pyelonephritis (Hayashi et al., 1994; Flock, 2007; Braun et al., 2008), renal cysts and tumours (Braun, 1997), rupture of the urinary bladder (Smith et al., 1983; Carr et al., 1993; Braun et al., 2007), rupture of persistent urachus (Braun et al., 2006), malignant lymphoma at the junction between the ureter and urinary bladder (Braun et al., 2004) and purulent necrotising cystitis (Braun et al., 2007). In sheep, the ultrasonographic findings in hypervitaminosis D (Franz et al., 2007) and obstructive urolithiasis in rams (Braun et al., 1992; Braun, 1997; Streeter and Step, 2007) have been reported, and obstructive uropathy has been described in female goats (Morin and Badertscher, 1990). Studies on the ultrasonographic appearance of the urinary tract in healthy female cattle (Braun, 1991; Braun, 1993), healthy female sheep (Schefer, 1991) and healthy male sheep (Braun et al., 1992a; Braun et al., 1992b) served as references.
To view the right kidney in cattle, the transducer is placed in the right craniodorsal flank region or in the last intercostal space on the right (Braun, 1991; Braun, 1993). In contrast, the left kidney can usually only be seen via transrectal ultrasonography. In rare cases, the left kidney is situated far enough to the right that it can be imaged from the right flank. Only in rare instances the left kidney can be visualized from the left flank because of the presence of the rumen. In sheep, the left kidney is caudal to the right kidney and can be seen from the right flank, but it is sometimes obscured by the gas-filled large intestine (Schefer, 1991; Braun et al., 1992b).
The ureters can only be imaged if obstructed. Transrectal ultrasonography allows visualisation of the urethra and urinary bladder in cattle and sheep. The urinary bladder can also be seen from the left or right inguinal region in sheep but not cattle. To the authors' knowledge, ultrasonographic studies of the urinary tract in goats have not been published. The goal of the present study was to provide a reference range of normal values for the ultrasonographic appearance, dimensions and location of the kidney, ureter, urinary bladder and urethra in healthy female goats.

Animals, Material and Methods

Animals

Twenty-nine, clinically healthy, female, Saanen goats, 2.5 to 6.5 (mean ± SD, 4.1 ± 1.04) years of age and weighing 42 to 86 (62.6 ± 8.99) kg, were used. The goats originated from two different farms and were destined for slaughter.

Ultrasonographic examination of the urinary tract

A real-time scanner (EUB 8500, Hitachi Medical Systems, Zug) with a 5.0 MHz linear probe (Type EUP-L53) was used for transcutaneous examination of the kidneys, ureters and urinary bladder, and a 5.0 MHz bar-shaped intracavity probe (Type EUP-U33) was used transrectally for visualisation of the urinary bladder and urethra. The ultrasonographic examinations were carried out on standing, non-sedated goats as described previously for cattle (Braun, 1991; Braun, 1993), sheep (Schefer, 1991; Braun et al., 1992b) and goats (Steininger, 2009). The 10^{th} to 12^{th} intercostal spaces on the right and both flanks were clipped before scanning the intercostal spaces from cranial to caudal with the transducer held parallel to the ribs and the flanks from dorsal to ventral with the transducer held perpendicular to the longitudinal axis of the body.

Examination from the flanks

The right flank was arbitrarily divided into four quadrants to better describe the location of the kidneys (Fig 1). The costal arch represented the cranial border, and the anterior contour (tensor fasciae latae muscle) of the hind limb the caudal border. An imaginary line drawn along the transverse processes of the lumbar vertebrae represented the dorsal border and the linea alba represented the ventral border. The quadrants were created by drawing a perpendicular line from the 5^{th} lumbar vertebra and a horizontal line between the patella and costal arch. Analogous quadrants were used in the left flank.

Ultrasonographic examination of the kidneys

Both kidneys were examined in various longitudinal planes with the transducer held parallel to the longitudinal axis of the organ and then in different cross-sectional planes with the transducer held perpendicular to the longitudinal axis of the kidney. The last two intercostal spaces on the right and the region immediately caudal to the last rib were scanned for the right kidney. The right and left dorsal flanks were scanned to locate the left kidney.

Criteria for kidney evaluation

First the kidneys were evaluated subjectively by noting their location, surface appearance and mobility in relation to adjacent organs. The echogenicity of the renal cortex, medulla and sinus was assessed and compared. The echogenicity of the renal cortex was also compared with that of the liver parenchyma. Finally visualisation of the renal hilus and ureters were evaluated.

The calipers were used to make measurements on frozen longitudinal images taken through the renal hilus and the medullary pyramids in a sagittal plane, and in cross section at the level of the hilus of the kidney. The length of the kidney was measured on longitudinal images through the hilus of the kidney. The thickness of the kidney between the renal capsule and medulla was measured in longitudinal plane in the region of the medullary pyramids. The diameter of the three largest medullary pyramids was also determined. Transverse plane images were used to determine the thickness (distance between the dorsal and ventral aspects) and width (distance between the medial and lateral aspects) of the kidney, and the thickness of the renal tissue (distance between the renal capsule and sinus measured dorsally) and the length of the renal sinus at the level of the transition from the renal pelvis to ureter, perpendicular to the transverse plane.

Ultrasonography of the ureters

The right flank was scanned to determine whether the ureters could be visualised. Transrectal ultrasonography was also carried out to locate the junction of the ureters with the bladder.

Ultrasonography of the bladder

The bladder was evaluated by scanning the right and left inguinal regions with a 5.0 MHz linear transducer and via transrectal examination using a 5.0 MHz intracavity probe in standing animals. The lumen, luminal contents and bladder wall were assessed subjectively, and the length, largest diameter and wall thickness were determined using the electronic cursors. The transition between the neck of the bladder and urethra was also evaluated.

Ultrasonography of the urethra

A 5.0 MHz intracavity probe was used transrectally to determine whether the urethra could be visualised.

Postmortem examination

After ultrasonographic examination, the goats were slaughtered (n = 13) or euthanased (n = 16). A macroscopic postmortem examination of the urinary tract was carried out in the slaughtered goats. The euthanased goats, which were also used in other studies (Becker-Birck, 2009; Steininger, 2009; Irmer, 2010), were frozen and cut into 1.0 to 1.5 cm-thick transverse sections. The urinary tract was examined on these sections.

Statistical analysis

The software StatView 5.1 (SAS Institut, 8602 Wangen, Switzerland) was used for calculation of mean and standard deviation of continuous data. Correlation coefficients were calculated to examine the relationship between the wall thickness and volume of the urinary bladder.

Results

Location and orientation of the kidneys

The right kidney could only be seen from the right side because of the rumen on the left. It was seen in the 11^{th} and 12^{th} intercostal spaces in eight and 21 goats, respectively, and in the craniodorsal quadrant (Q1) in seven (Tab. 1). In the latter, the right kidney was seen in the 11^{th} and 12^{th} intercostal spaces in four and in the 12^{th} intercostal space and Q1 in three (Tab. 1). The right kidney was positioned with its longitudinal axis parallel to the ribs in 25 goats, parallel to the vertebrae in two, and perpendicular to the ribs in one. In one goat, the orientation of the kidney could not be determined.

The left kidney could be seen from the right side in 27 goats, from the left side in two and could not be seen from either side in another two goats. On the right side, the left kidney could be seen from the 12^{th} intercostal space in one goat, in the craniodorsal quadrant (Q1) in 13 and in the caudodorsal quadrant (Q2) in 21 goats (Tab. 1). In eight goats, the left kidney was visible in the craniodorsal quadrant (Q1) as well as the caudodorsal quadrant (Q2). From the left side, the left kidney was seen in only the craniodorsal quadrant (Q1) in one goat and in Q1 as well as the caudodorsal quadrant (Q2) in one other.

The left kidney was positioned with its longitudinal axis parallel to the vertebrae in 21 goats. In four goats, the cranial pole was tipped ventrally. The orientation of the left kidney could not be determined in one goat, and in another, the left kidney was located beneath the right kidney. In the two goats in which the left kidney could be seen from the left side, its longitudinal axis was parallel to the vertebrae.

Ultrasonographic characteristics of the kidneys

The kidneys had a smooth surface and were mobile, moving in synchrony with respiratory movements. Compared with the echogenicity of the liver parenchyma, the cortical echogenicity of the right kidney was the same in 12 goats, less dense in nine and denser in seven. The cortical echogenicity of the left kidney was the same as that of the liver parenchyma in 14 goats, less dense in eight and denser in five.

The maximum length of the kidney was seen in longitudinal views through the hilus in the sagittal plane (Fig. 2). The kidney had a longitudinal oval shape, and the renal capsule appeared as a fine echogenic line, which was not always distinct, surrounding the renal parenchyma. The renal parenchyma surrounding the renal sinus was homogeneous with fine, evenly distributed echoes. Several medullary pyramids were seen as round to oval indistinct hypoechogenic structures near the renal sinus, which appeared hyperechogenic at its centre.

The kidney also had an oblong oval shape on longitudinal views in the region of the medullary pyramids in the sagittal plane (Fig. 3). The renal cortex could be easily differentiated from the renal medulla and its pyramids; the latter were arranged in the centre and had an echogenic border and hypoechogenic to anechogenic centre surrounded by echogenic renal columns (columnae renales). The interlobar veins and arteries were seen as long hypoechogenic filamentous structures between the medullary pyramids.

The kidneys appeared as oval to round structures with an echogenic capsule in cross section (Fig. 4). The renal sinus appeared as a hyperechogenic band. Within the renal sinus were oblong hypoechogenic structures, which corresponded to the renal artery and vein and the ureter. The renal parenchyma was homogenously echogenic.

Size of kidneys

The length of the right kidney ranged from 6.6 to 9.4 cm, the width from 3.9 to 6.4 cm and the thickness from 3.2 to 5.5 cm (Tab. 2). The thickness of the cortex varied from 0.4 to 1.3 cm. The thickness of the renal parenchyma ranged from 1.0 to 3.6 cm, and the length of the renal sinus at the level of the transition from the renal pelvis to ureter, perpendicular to the cross-sectional plane, ranged from 0.5 to 1.2 cm. The diameter of the medullary pyramids ranged from 0.7 to 2.0 cm. The left and right kidneys had similar dimensions (Tab. 2).

Ureters

The ureters could not be seen from the right flank in any of the goats. The junction of the ureters and bladder could also not be seen via transrectal ultrasonography.

Urinary bladder

The contents of the bladder always appeared anechoic when imaged via transrectal ultrasonography. When imaged from the right or left inguinal region, the bladder contents appeared anechoic in 24 goats and hypoechogenic in five. Concrements were not seen in the bladder of any of the goats. With the exception of one goat, the bladder could be seen from a minimum of one viewing position. The bladder could be seen via transrectal ultrasonography in 25 of the 29 goats (Fig 5). It could be seen from the right inguinal region in 11 goats and from the left in 17. The bladder wall appeared as a smooth echogenic line with a mean thickness of 1.4 ± 0.38 mm (0.8 to 2.3 mm). The length of the bladder determined via transrectal ultrasonography ranged from 2.4 to 7.2 cm. The largest diameter ranged from 1.0 to 4.8 cm. Both variables could not be measured in one goat because the size of the bladder was larger than the screen of the machine. There was no correlation between the degree of fill of the bladder and the thickness of the bladder wall ($P > 0.05$).

Urethra

The urethra could be seen via transrectal ultrasonography in 23 of 29 goats and appeared as two parallel echogenic lines. A lumen could not be observed in any of the goats. The transition from the neck of the bladder to the internal urethral orifice was identified in 10 goats.

Postmortem examination

Postmortem examination of the urinary tract of the goats revealed no abnormal findings.

Discussion

The urinary tract of goats was examined using the methods described for cattle (Braun, 1991; Braun, 1993; Braun, 1997), sheep (Schefer, 1991; Braun et al., 1992a; Braun et al. 1992b) and goats (Steininger, 2009). The ultrasonographic appearance of the caprine kidney was similar to that of sheep, which was not surprising considering that the anatomical features of the kidney are similar in both species. The size of the kidneys as well as other measurements varied little between sheep and goats. The kidneys were most

easily seen from the dorsal flank (quadrants 1 and 2) and the last two intercostal spaces, which was in agreement with findings in sheep (Schefer, 1991; Braun et al., 1992b). Although in the goat the left kidney is situated to the right of the median and caudoventral to the right kidney (Frewein et al., 2004), it could be seen from the left dorsal flank in two animals. This was surprising because the left kidney was not seen from the left in sheep (Schefer, 1991; Braun et al., 1992b) and cattle (Braun, 1993; Braun, 1997). The left kidney is suspended from the fatty mesentery in the abdominal cavity and therefore appears to be relatively mobile. A moderately-filled rumen probably does not push the left kidney to the right and it can be assumed that in those circumstances the left kidney lies dorsal to the rumen. In goats with moderate or poor body condition, the distance between the right and left abdominal walls in the dorsal flank region was so small that the examiner could almost push the two sides together during bilateral palpation. The left kidney could be palpated transabdominally, and the pressure exerted on the transducer resulted in the abdominal wall being pushed against the left kidney on both sides.

The right kidney was usually positioned with its longitudinal axis parallel to the ribs, although in one goat it was parallel to the vertebrae and in one other it was perpendicular to the ribs. The longitudinal axis of the left kidney was usually parallel to the vertebrae; sometimes its cranial pole was tipped slightly ventrally. In one goat, both kidneys were seen one beneath the other, parallel to the ribs. The variations in position and orientation of the kidneys were not associated with pathological changes. Measurements of the right kidney were incomplete in four of the 29 goats because of intestinal gas in one goat, the position of the kidneys deep under the ribs in two goats and inability to see the renal hilus in one other.

Superimposition of gas-filled loops of small intestine on the kidneys has been reported in humans (Swobodnik et al., 2000), dogs (Knauff, 1987) and horses (Penninck et al., 1986; Kiper et al., 1990). In contrast, this problem was seldom encountered in sheep (Schefer, 1991; Braun et al., 1992b) and was not described in cattle (Braun, 1991; Braun, 1993; Braun, 1997). Thus, it does not appear to play a role in ultrasonographic examination of the kidney in the latter species. Gas in the small intestine is encountered less often in ruminants because carbohydrate metabolism takes place mostly in the rumen and to a lesser extent in the large intestine (Gürtler, 1989). Adequate ruminal fill has been shown to be a critical factor in good visualisation of the kidneys via ultrasonography (Schefer, 1991; Braun et al., 1992b). There were a number of limitations in ultrasonographic examination of the kidneys in goats: it was not possible to see the full length of the kidneys on the

monitor because this variable exceeded the length of the transducer in all the goats. Thus, an exact measurement of kidney length using the electronic cursors was not possible. Two overlapping images were used to determine the length of the kidneys as accurately as possible. The right kidney was seen from the last two intercostal spaces in the majority of goats. To see the kidney in cross section, it was necessary to apply pressure to the transducer, which was positioned caudal to the costal arch and perpendicular to the ribs. This did not always work well and was uncomfortable for some of the goats.

The urinary bladder was always seen via transrectal ultrasonography in female and male sheep, independent of the amount of intraluminal urine (Schefer, 1991; Braun et al., 1992a; Braun et al., 1992b). However, in this study, visualisation of the bladder was associated with the amount of urine in the organ. The bladder could be seen in only 25 of 29 goats via transrectal ultrasonography. Two goats voided urine between transcutaneous and transrectal ultrasonography, which may explain why the bladder could be seen transcutaneously from the inguinal region but not transrectally. Transcutaneous ultrasonography in the inguinal region was resented by most of the goats and for this reason was considered to be difficult and less reliable than other approaches. Evaluation of the urethra from the inguinal region was not possible. Although the size and diameter of the bladder varied among goats, these variables were not associated with the thickness of the bladder wall. This finding is in contrast to reports in cattle (Braun, 1993) and sheep (Schefer, 1991), in which the thickness of the bladder wall progressively decreased as the amount of intraluminal urine increased.

The urethra was seen in 23 goats and appeared as parallel echogenic lines. A lumen could not be seen because none of the goats voided urine and a catheter was not used during the ultrasonographic examination. The bladder extended beyond the pelvic brim even with a small amount of intraluminal urine. The transition from the neck of the bladder to the urethra was in the pelvic cavity in 21 goats and within 4 cm of the brim of the pelvis; the transition could be directly seen in 10 goats. In one goat, the transition was directly over the pelvic brim, and in one other, the bladder was situated so far cranially that the transition was anterior to the pelvic brim.

The present study showed that transcutaneous and transrectal ultrasonography is an ideal method for examination of the urinary tract in goats.

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Figure legends

Figure 1: Division of the flank into quadrants for description of the location of the kidney. Q1 craniodorsal quadrant, Q2 caudodorsal quadrant, Q3 cranioventral quadrant, Q4 caudoventral quadrant

Figure 2: Sonogram of the left kidney in longitudinal section through the hilus in the sagittal plane in a three-year-old female Saanen goat. 1 Lateral abdominal wall, 2 Renal cortex, 3 Medullary pyramids, 4 Renal sinus, 5 Interlobar vessels, Cr Cranial, Cd Caudal, Md Medial

Figure 3: Sonogram of the left kidney in longitudinal section through the region of the medullary pyramides in a three-year-old female Saanen goat. 1 Lateral abdominal wall, 2 Renal cortex, 3 Medullary pyramids, 4 Interlobar vessels, 5 renal capsule, Cr Cranial, Cd Caudal, Md Medial

Figure 4: Sonogram of the left kidney in cross section in a three-year-old female Saanen goat. 1 Lateral abdominal wall, 2 Renal cortex, 3 Renal medulla 4 Arcuate artery and vein, 5 Renal sinus, 6 Renal hilus, Ds Dorsal, Vt Ventral, Md Medial

Figure 5: Sonogram of the urinary bladder and urethra of a three-year-old Saanen goat. 1 Rectal mucosa, 2 Urinary bladder, 3 Neck of bladder, 4 Brim of pelvis, Ds Dorsal, Vt Ventral, Cr Cranial, Cd Caudal

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