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Ultrasonography of the rumen in 30 Saanen goats

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Summary

This study describes the results of ultrasonographic examination of the rumen in 30 healthy Saanen goats. A linear or convex transducer with a variable frequency of 5 to 13 MHz was used to scan standing, non-sedated goats. The location and size of the rumen, the distance between the wall of the rumen and abdominal wall and the appearance and size of the gas, fibre mat and fluid layers of the ruminal contents were assessed. The rumen was seen as a large organ medial to the left abdominal wall. The wall of the rumen appeared as a thick echogenic line. The longitudinal groove was seen as an echogenic notch, which divided the rumen into the dorsal and ventral sacs. The rumen could be visualized from the 9th to 12th intercostal space (ICS) and flank on the left side in all the goats. The rumen was largest in the 12th ICS at 41.6 ± 5.13 cm and smallest in the 8th ICS at 11.3 ± 4.29 cm. The dorsal sac of the rumen was largest in the left cranial flank (17.4 ± 4.43 cm) and the ventral sac was largest in the 12th ICS on the left (29.1 ± 6.03 cm). In the cranial left flank, the rumen was situated immediately adjacent to the abdominal wall in all the goats. The spleen was located between the rumen and abdominal wall in the 8th to 12 th ICS in many of the goats. The gas, fibre mat and fluid layers of the ruminal contents could be visualized in all the goats. The gas layer was 9.9 ± 3.05 cm, the fibre mat layer 16.0 ± 4.55 cm and the fluid layer 12.2 ± 5.57 cm.

Keywords: goat, ultrasonography, rumen, normal findings

Sonographische Untersuchung des Pansens bei 30 Saanenziegen

Bei 30 Ziegen wurden die ultrasonographischen Befunde am Pansen beschrieben. Die Ziegen wurden stehend mit Linear- oder Convex-Schallköpfen, deren Frequenzen zwischen 5 und 13.0 MHz eingestellt werden konnten, untersucht. Bestimmt wurden die Lage und Ausdehnung des Pansens, der Abstand des Pansens von der Bauchwand sowie die Darstellbarkeit und Ausdehnung von Gas-, Futter- und Flüssigphase des Pansens. Der Pansen stellte sich als grosses Organ medial der linken Bauchwand dar. Die Pansenwand war als dicke echogene Linie zu erkennen. Die seitliche Pansenfurche war als echogene Einkerbung zu sehen, welche den Pansen in den dorsalen und ventralen Pansensack unterteilte. In den Interkostalräumen 9 bis 12 sowie in der Flanke konnte der Pansen auf der linken Seite bei allen Ziegen dargestellt werden. Die Ausdehnung des Pansens war im 12. Interkostalraum mit 41.6 ± 5.13 cm am grössten und im 8. Interkostalraum mit 11.3 ± 4.29 cm am kleinsten. Der dorsale Pansensack war in der kranialen Flanke mit 17.4 ± 4.43 cm am grössten, während der ventrale Pansensack im 12. Interkostalraum mit 29.1 ± 6.03 cm die grösste Ausdehnung aufwies. In der kranialen Flanke lag der Pansen der Bauchwand bei allen Ziegen direkt an. In den Interkostalräumen 8 bis 12 lag bei vielen Ziegen die Milz zwischen Bauchwand und Pansen. Die Gas-, Futter- und Flüssigphase konnte bei allen 30 Ziegen erkannt werden. Die Gasphase erstreckte sich über 9.9 ± 3.05 cm, die Futterphase über 16.0 ± 4.55 cm und die Flüssigphase über 12.2 ± 5.57 cm der Pansenausdehnung.

Schlüsselwörter: Ziege, Sonographie, Pansen, Normalbefunde

Introduction

The rumen is by far the largest of the forestomachs. It is an enormous, flat-sided, sac-like organ occupying most of the left side of the abdominal cavity (Cegarra et al., 1977). The shape of the rumen is identical in sheep and goats. Compared with cattle, the rumen of small ruminants is relatively longer and the ventral sac is more distinctly developed (Barone, 1997). In small ruminants, the ventral sac of the rumen is always larger than the dorsal sac (König and Liebich, 2002). The capacity of the caprine rumen ranges from 10 to 28 litres (Smith and Sherman, 1994) and may be as high as 30 liters (Barone, 1997). The contents of the rumen in healthy goats are layered and include a dorsal gas cap, a middle layer consisting of a fibre mat and a ventral layer of fluid. Evaluation of the rumen, particularly its contents and wall, is limited to physical examination. Ultrasonography has been used to evaluate the rumen in cattle (Braun, 2009), and the dorsal sac of the rumen, longitudinal groove and ventral sac of the rumen have been described in three cows (Tschuor and Clauss, 2008). The wall of the rumen was echogenic, and reverberation artifacts, which ran parallel to the ruminal wall, were seen in the region of the dorsal gas cap (Tschuor and Clauss, 2008). The fibre mat in the middle appeared as an echogenic mass with gas inclusions, and the ventral fluid layer was hypoechogenic. To the authors' knowledge, there are no studies on the ultrasonographic appearance of the caprine rumen. Ultrasonography is an important tool in the diagnosis of diseases in goats, and thus the goal of the present study was to describe the ultrasonographic findings of the rumen in 30 healthy Saanen goats.

Animals, Material and Methods

Animals

Thirty clinically healthy, non-lactating female Saanen goats, which were 2.5 to 6.5 years (mean ± sd = 4.9 ± 1.10 years) old, were used. The goats originated from two farms and had been sold for slaughter. They were fed hay ad libitum and housed in two large pens, which were bedded with straw daily. After purchase, all of the goats were deemed healthy based on the results of a thorough clinical examination, a complete blood cell count, biochemical profile, urinalysis, and examination of rumen juice and faeces. The results of these examinations have been described in detail (Becker-Birck, 2009).

Ultrasonographic examination of the rumen

Ultrasonographic examinations were carried out on both sides of standing, non-sedated animals using a linear or convex transducer with a frequency of 5 to 13.0 MHz. The penetration depth of the transducers ranged from 3 to 10 cm depending on the frequency setting. The 8th to 12th intercostal spaces (ICSs) and flank were examined on the left side and the 12th ICS and flank on the right. First the location for visualisation of the rumen and its neighbouring organs was determined from the left side of the goats. The dorsal and ventral margins of the rumen were determined by measuring the distance from each margin to the midline of the back (Fig. 1), in a fashion similar to the methods used for calculating the margins of the lungs (Braun et al., 1996), spleen (Braun and Sicher, 2006) and omasum (Braun and Blessing, 2006) in cattle. The size of the rumen was then determined by subtracting the dorsal margin of the rumen from the ventral margin. The location of the longitudinal groove was also determined by measuring the distance from the groove to the dorsal midline of the back. The dorsal sac of the rumen extended from the dorsal margin of the rumen to the longitudinal groove, and the ventral sac extended from the longitudinal groove to the ventral margin of the rumen. The distance from the rumen to the abdominal wall was determined electronically by using the electronic calipers on the monitor. The gas, fibre mat and fluid layers of the rumen were evaluated on the left side of the goats immediately caudal to the last rib using a 13 MHz transducer setting. The flank was scanned from dorsal

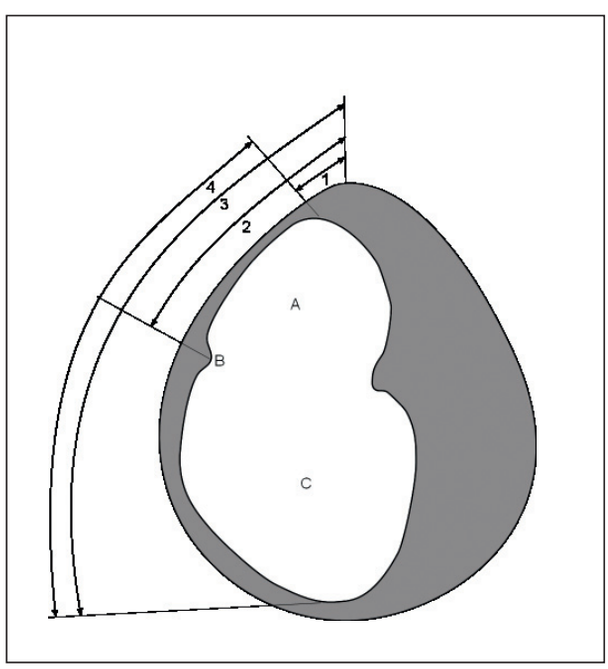

Figure 1: Schematic representation showing how rumen measurements were made in the goats. A Dorsal sac of rumen, B Longitudinal groove, C Ventral sac of rumen, 1 Distance between the midline of the back and the dorsal margin of the rumen, 2 Distance between the midline of the back and the longitudinal groove, 3 Distance between the midline of the back and the ventral margin of the rumen, 4 Size of the rumen.

to ventral, and the borders between the individual layers were measured from the midline of the back using a measuring tape. This allowed calculation of the size of each layer by simple subtraction. Rumen motility was assessed from the left flank. Identification of organs located immediately adjacent to the rumen was also done on the right side.

Postmortem examination

After examination, the goats were slaughtered (n = 14) or euthanized (n = 16). A macroscopic postmortem examination of the rumen was carried out in the slaughtered goats. The euthanized 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 rumen was examined on these sections.

Statistics

The statistical software program StatView 5.1 (SAS Institute, Cary, USA) was used for analysis of the data. Frequencies, means and standard deviations were calculated.

Approval of the study by an ethical committee

The study was approved by an ethical committee of the canton of Zurich, Switzerland.

Results

Ultrasonographic appearance

The rumen was situated to a large extent directly next to the abdominal wall on the left side. This large organ extended medially from the left abdominal wall, and its wall was seen as a thick echogenic line. Differentiation of the various compartments varied: in all the goats, the dorsal and ventral sacs of the rumen could be differentiated caudally because of the prominent longitudinal groove, which appeared as an echogenic notch (Fig. 2). Visualization of the anterior dorsal blind sac of the rumen was possible in only three goats, and the caudal dorsal blind sac could not be differentiated from the dorsal sac because it is not as well developed as in cattle (Vollmerhaus and Roos, 1999).

Rumen motility

Ruminal contractions could not be directly observed in any of the goats. However, changes in the layering of the ruminal contents could be seen during contractions; the gas layer became smaller and the fibre mat larger. The layers then returned to their pre-contraction size once the contraction was finished.

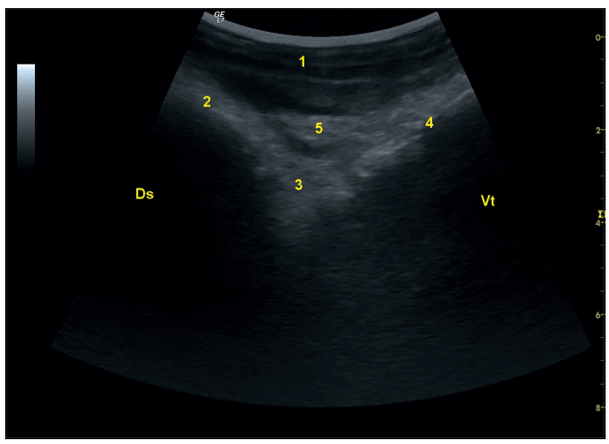

Figure 2: Ultrasonogram of the rumen of a three-year-old Saanen goat showing the longitudinal groove. This view was from the 12th ICS using a 5.0 MHz convex transducer. 1 Lateral abdominal wall, 2 Dorsal sac of rumen, 3 Longitudinal groove, 4 Ventral sac of rumen, 5 Insertion of the greater omentum, Ds Dorsal, Vt Ventral.

Size of the rumen in individual intercostal spaces on the left

The rumen could be seen from the 9th to 12th ICS and from the flank on the left side in all 30 goats (Tab. 1). It could be visualized from the 8th ICS in only 17 goats. The dorsal margin of the rumen ran parallel to the margin of the lungs from cranioventral to caudodorsal (Fig. 3). Because of superimposition of the lungs, the greatest distance between the visible dorsal margin of the rumen and the midline of the back was 21.4 ± 2.57 cm seen from the 8th ICS (Tab. 1). The distance between the visible dorsal rumen margin and midline of the back became progressively smaller caudally because superimposition of the lungs gradually decreased. It was smallest at 9.6 ± 1.80 cm in the

Figure 3: The lines drawn on this Saanen goat show the location of the dorsal margin of the rumen (purple) and longitudinal groove (green) between the 8th intercostal space and the caudal flank. The ventral margin of the rumen is not shown because it is located too far ventrally. The locations shown represent the average values of 30 goats.

cranial flank region. The ventral margin of the rumen ran cranioventrally. Its distance from the midline of the back was 32.7 ± 3.89 cm in the 8th ICS and became progressively larger caudally and reached a maximum of 51.7 ± 5.08 cm in the 12th ICS. The size of the visible rumen was largest in the 12th ICS at 41.6 ± 5.13 cm. It became slightly smaller further caudally and was 35.3 ± 8.35 cm in the caudal flank. The size of the visible rumen became markedly smaller further cranially because of superimposition of the lungs; it was 11.3 ± 4.29 cm in the 8th ICS.

The longitudinal groove of the rumen could be seen in all the goats. It was furthest from the midline of the back in the 8th ICS (28.3 ± 2.31 cm) and closest in the 12th ICS (22.3 ± 2.68 cm) (Tab. 1).

The dorsal sac of the rumen was largest in the cranial flank (17.4 ± 4.43 cm) and smallest in the 8th ICS (6.8 ± 2.02 cm) (Tab. 1). It could be seen from the 8th ICS in only three goats and from the 9th ICS in 19. The ventral sac of the rumen was largest in the 12th ICS at 29.1 ± 6.03 cm, and decreased in size cranially and caudally. It was smallest in the 8th ICS (2.7 ± 1.16 cm) from which it could be visualised in only three goats (Tab. 1).

Distance between the rumen and left abdominal wall

The rumen was situated 0.01 ± 0.03 cm from the cranial left flank in all the goats (Tab. 1). In the 8th to 12th ICS, the spleen was seen dorsolateral to the rumen in 10 to 20 goats (Fig 4). This resulted in an increase in the average distance between the rumen and abdominal wall, which varied from 1.27 ± 1.28 to 2.85 ± 0.84 cm.

Gas, fibre mat and fluid layers

The gas, fibre mat and fluid layers in the rumen could be seen from the cranial left flank in all the goats. The degree to which the various layers could be differentiated varied.

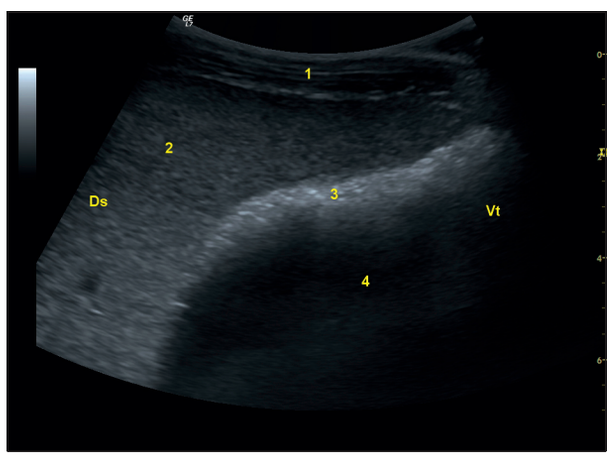

Figure 4: Ultrasonogram of the rumen and spleen in a three-year-old Saanen goat viewed from the 11th intercostal space using a 5.0 MHz convex transducer. 1 Abdominal wall, 2 Spleen, 3 Rumen wall, 4 Rumen, Ds Dorsal, Vt Ventral.

Table 1: Results of ultrasonographic examination of the rumen in 30 Saanen goats (mean ± sd, range, all variables in cm).

Organ Structure	Intercostal space					Flank	
	8	9	10	11	12	Cranial	Caudal
Dorsal margin of the rumen[1]	21.4 ± 2.57 18.0–25.5 n = 17	18.5 ± 2.48 12.0–22.0 n = 30	15.3 ± 2.44 10.5–20.0 n = 30	12.9 ± 1.85 9.5–17.0 n = 30	10.0 ± 1.44 7.5–13.0 n = 30	9.6 ± 1.80 7.0–14.0 n = 30	12.6 ± 4.14 8.0–26.0 n = 30
Ventral margin of the rumen[1]	32.7 ± 3.89 27.0–41.5 n = 17	37.3 ± 6.43 26.5 – 49.5 n = 30	43.7 ± 7.47 31.0–57.5 n = 30	48.0 ± 6.61 33.0–57.5 n = 30	51.7 ± 5.72 37.0–60.0 n = 30	51.2 ± 5.08 40.5–58.0 n = 30	47.9 ± 6.27 33.0–61.0 n = 30
Size of the rumen	11.3 ± 4.29 5.0–22.0 n = 17	18.9 ± 7.49 6.5–32.0 n = 30	28.4 ± 7.72 15.0–41.0 n = 30	35.2 ± 6.79 18.5–45.5 n = 30	41.6 ± 5.13 29.0–50.0 n = 30	40.9 ± 7.41 10.5–50.0 n = 30	35.3 ± 8.35 16.0–46.5 n = 30
Longitudinal groove of the rumen[1]	28.3 ± 2.31 27.0–31.0 n = 3	27.6 ± 2.90 23.0–33.0 n = 17	26.3 ± 3.65 21.0–35.0 n = 29	24.1 ± 3.02 19.0–30.5 n = 30	22.3 ± 2.68 17.0–26.5 n = 30	27.4 ± 4.63 18.5–38.0 n = 30	27.7 ± 3.35 22.0–35.0 n = 30
Size of the dorsal ruminal sac	6.8 ± 2.02 5.0–9.0 n = 3	9.9 ± 2.32 7.0–15.0 n = 19	11.1 ± 3.37 6.0–18.5 n = 29	11.2 ± 2.69 5.0–17.5 n = 30	12.2 ± 2.27 7.0–16.0 n = 30	17.4 ± 4.43 9.5–25.0 n = 30	15.1 ± 3.98 7.5–25.0 n = 30
Size of the ventral ruminal sac	2.7 ± 1.16 2.0–4.0 n = 3	10.9 ± 7.04 1.0–24.0 n = 19	17.8 ± 8.01 4.5–29.5 n = 29	24.2 ± 7.29 8.0–34.5 n = 30	29.1 ± 6.03 16.5–39.0 n = 30	24.2 ± 5.03 13.5–35.0 n = 30	20.5 ± 7.08 7.0–32.0 n = 30
Distance from the abdominal wall	1.27 ± 1.28 0.0–3.4 n = 11	2.36 ± 1.23 0.0–4.0 n = 23	2.85 ± 0.84 1.4–4.8 n = 23	2.53 ± 0.75 1.3–3.8 n = 23	1.95 ± 0.77 0.0–2.9 n = 23	0.01 ± 0.03 0.0–0.2 n = 30	0.04 ± 0.10 0.0–0.5 n = 30

[1] Centimetres from midline of the back

The transition from one layer to the next was very distinct in 19 goats but difficult to see in 11 animals. The transition from the fibre mat to fluid layer was sometimes extremely difficult to discern. The gas layer (Fig. 5), which was enveloped by an echogenic wall and characterised by intense reverberation artifacts, was always easy to identify and was 9.9 ± 3.05 cm in height (Tab. 2). The fibre mat layer (Fig. 6), which was echogenic and characterised by a surrounding heterogeneous rumen wall had a height of 16.0 ± 4.55 cm. The fluid layer (Fig. 7), which was hypoechogenic and surrounded by a homogeneous and smooth rumen wall, was 12.2 ± 5.57 cm in height.

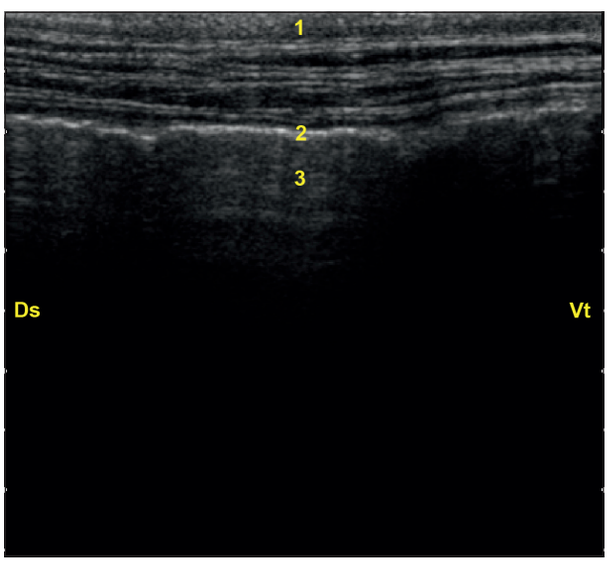

Figure 5: Ultrasonogram of the rumen in the region of the gas cap in a five-year-old Saanen goat viewed from the dorsal left flank using a 5.0 MHz linear transducer. 1 Abdominal wall, 2 Rumen wall, 3 Reverberation artifacts, Ds Dorsal, Vt Ventral.

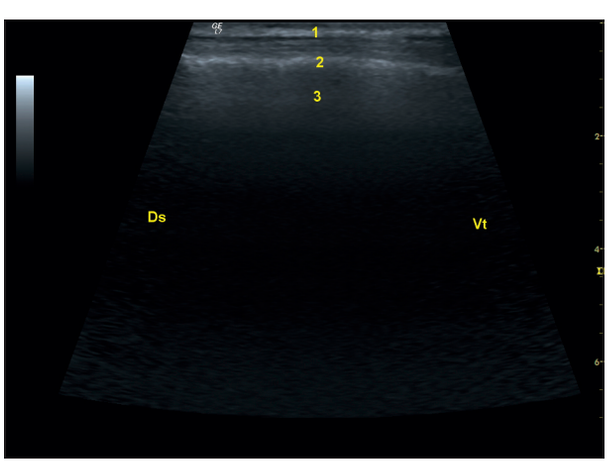

Figure 6: Ultrasonogram of the fibre mat of the rumen of a three-year-old Saanen goat viewed from the mid-region of the left flank using a 5.0 MHz convex transducer. 1 Abdominal wall, 2 Rumen wall, 3 Fibre mat of the ruminal contents, Ds Dorsal, Vt Ventral.

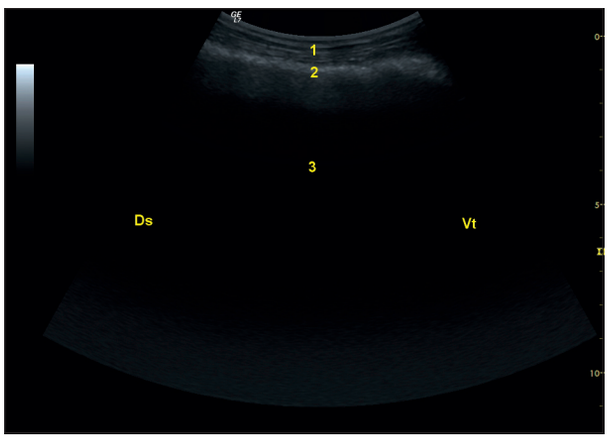

Figure 7: Ultrasonogram of the fluid layer of the rumen of a three-year-old Saanen goat viewed from the ventral region of the left flank using a 5.0 MHz convex transducer. 1 Abdominal wall, 2 Rumen wall, 3 Fluid layer of the ruminal contents, Ds Dorsal, Vt Ventral.

Table 2: Size of gas layer, fibre mat and fluid layer and thickness of rumen wall determined in the cranial flank of 30 Saanen goats.

Layer of the ruminal content	Size (cm) Mean ± sd Range	Thickness of rumen wall (cm) Mean ± sd Range
Gas layer	9.9 ± 3.05 3.0–15.5	0.18 ± 0.06 0.11–0.35
Fibre mat	16.0 ± 4.55 8.0–24.5	0.35 ± 0.13 0.20–0.76
Fluid layer	12.2 ± 5.57 3.5–22.0	0.35 ± 0.15 0.17–0.82

Thickness of rumen wall

The mean thickness of the rumen wall was 0.18 ± 0.06 cm in the region of the gas layer, 0.35 ± 0.13 cm in the area of the fibre mat layer and 0.35 ± 0.15 cm in the region of the fluid layer (Tab. 2).

Neighbouring organs

The spleen was seen dorsolateral to the rumen in the 8th to 12th ICS and cranial left flank. Intestine was always observed ventral to the rumen in the cranial and caudal flank region. The abomasum was seen ventral to the rumen in the cranial abdomen in 18 goats, and the reticulum was seen ventral to the rumen in the 8th ICS in five goats.

Examination of the rumen from the right side

On the right side, the rumen was seen in the caudal flank region in 27 goats, in the cranial flank area in 23 and in the 12th ICS in four. The small and large intestines, left kidney and in two cases the liver were observed adjacent to the rumen.

Discussion

Our study provides novel information on the rumen location and the ultrasonographic appearance of the various layers of the ruminal contents in a large number of goats. The appearance of the gas, fibre mat and fluid layers within the rumen were in agreement with that described for cattle. The transition from the gas to fluid layer was usually easy to identify because of their ultrasonographic appearance. However, the transition from the fibre mat to fluid was often difficult to appreciate. The border between the gas and fibre mat was very distinct because of distinct reverberation artifacts and the prominent echogenic rumen wall at the level of the gas layer. The transition between fibre mat and fluid was indistinct because the layers frequently moved with ruminal contractions. The ruminal wall at the level of the fibre mat appeared heterogeneous and more irregular than at the level of the fluid layer. The fibre mat occupied the most space within the rumen, followed by the fluid and gas layers.

The results of our study showed that the rumen of goats is easily accessible to ultrasonography. The findings serve as a reference for ruminal size and location within the abdominal cavity as well as for the wall and layering of contents when evaluating disorders and diseases of the rumen. Acute ruminal acidosis caused by ingestion of large quantities of rapidly digested carbohydrates is one of the most important diseases affecting the rumen in goats. The result is liquification of the ruminal contents, which is probably easy to document via ultrasonography. Other ruminal changes affecting the layering of the contents, such as an increase in the gas cap attributable to inhibition in eructation, should also be easy to identify via ultrasonography. This imaging tool could also be used to detect an increase in the size of the rumen, especially the ventral sac in cases with anterior functional stenosis. Ultrasonography could also be used to detect inflammatory lesions involving the rumen, such as fibrinous adhesions caused by peritonitis or abscesses, which have been described in cattle with traumatic reticuloperitonitis and

Examen échographique de la panse chez 30 chèvres de Gessenay

On décrit les constatations échographiques faites sur la panse de 30 chèvres. Ces chèvres ont été examinées debout au moyen de sondes linéaires ou convexes dont la fréquence pouvait être réglée entre 5 et 13 MHz. On a déterminé la situation et l'extension de la panse, sa distance à la paroi abdominale ainsi que la possibilité de visualiser les phases gazeuse, liquide et alimentaire et leurs extensions. La panse se présentait comme un gros organe médialement de la paroi abdominale gauche. Sa paroi pouvait être reconnue comme une ligne échogène épaisse, les sillons du rumen étant visibles comme des encoches échogènes divisant la panse en une partie dorsale et ventrale. La panse pouvait être mise en évidence du 9^{e} au 12^{e} espace intercostal ainsi que par le flanc chez toutes les chèvres. Son extension maximale se situait dans le 12^{e} espace intercostal avec 41.6 ± 5.13 cm et son extension minimale dans le 8^{e} espace intercostal avec 11.3 ± 4.29 cm. Le sac dorsal du rumen avait son extension maximale dans le flanc cranial avec 17.4 ± 4.43 cm et le sac ventral la sienne dans le 12^{e} espace intercostal avec 29.1 ± 6.03 cm. La panse touchait la paroi abdominale dans la partie craniale du flanc chez toutes les chèvres. Dans les espaces intercostaux 8 à 12, la rate se trouvait chez beaucoup de chèvres entre la paroi abdominale et la panse. Les phases gazeuse, liquide et alimentaire ont pu être mise en évidence chez les 30 chèvres. La phase gazeuse s'étendait sur 9.9 ± 3.05 cm, la phase liquide sur 12.2 ± 5.5 cm et la phase alimentaire sur 16. 0 ± 4.55 cm de l'extension totale de la panse.

Esame ecografico del rumine in 30 capre Saanen

In 30 capre, sono stati descritti i risultati ecografici provenienti dal rumine. Le capre sono state esaminate in piedi con trasduttori lineari o convessi con frequenze tra i 5 e i 13.0 MHz. Si è così determinata la posizione e la dilatazione del rumine, la sua distanza dalla parete addominale e infine si è descritta la dilatazione del rumine nella fase gassosa, solida e liquida. Il rumine viene rappresentato come un grande organo mediale alla parete addominale sinistra. La parete ruminale è riconoscibile dalla spessa linea ecogena. Il solco laterale del rumine è visibile come un intaglio ecogeno che divide il rumine in sacco ventrale e dorsale. Negli spazi intercostali 9–12 e nel fianco era visibile il rumine nella parte sinistra in tutte le capre. La dilatazione del rumine nello spazio intercostale 12 era più grande e misurava 41.6 ± 5.13 cm mentre quella dello spazio intercostale 8 misurava 11.3 ± 4.29 cm ed era quindi inferiore. Con 17.4 ± 4.43 cm il sacco dorsale del rumine nel margine craniale era il più grande mentre la maggiore dilatazione di 29.1 ± 6.03 cm veniva riscontrata nel sacco ventrale del rumine nello spazio intercostale 12. Nel margine craniale si posava direttamente il rumine della parete addominale in tutte le capre. In molte capre negli spazi intercostali 8–12 si trovava la milza tra parete addominale e rumine. La fase gassosa, solida e liquida si riscontrava in tutte e 30 le capre. La dilatazione del rumine nella fase gassosa misurava 9 cm ± 3.05, nella fase solida 16.0 ± 4.55 cm e nella fase liquida del 2.12 ± 5.57.

abomasal ulcers (Braun, 2009). The results of the present study provide an additional source of information for diagnosing diseases in goats. Knowledge of the normal ultrasonographic findings is an essential prerequisite for identifying lesions associated with the rumen in goats.

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