Practical Use of Ultrasound Scan in Small Ruminant Medicine and Surgery

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KEYWORDS

• Ultrasound diagnosis • Sheep • Respiratory disease • Urolithiasis

KEY POINTS

- Ultrasound examination of particular organs takes no more than 5 minutes with the results available immediately.
- 5 MHz linear array scanners can be used for most organs except the heart and right kidney.
- Transthoracic ultrasonography is particularly useful for critical evaluation of lung and pleural pathologies.
- Transabdominal ultrasonographic examination can readily identify distended urinary bladder and advanced hydronephrosis.

Videos of ultrasound examples accompany this article at http://www.vetfood.theclinics.com/

INTRODUCTION

Many veterinarians in food animal practice routinely use transrectal ultrasonographic examination for the early detection, and possibly sexing, of bovine embryos using 5-MHz linear array scanners. This equipment can also be used in adult sheep to provide diagnostic quality ultrasound images except for the kidney and heart; a 5- to 6.5-MHz sector scanner is often necessary in sheep less than 30 kg.

Transthoracic ultrasonography is particularly useful for critical evaluation of the lungs because auscultated adventitious sounds do not correlate well with lesion distribution in ovine pulmonary adenocarcinoma (OPA) and other respiratory tract pathologies.[1,2]

Transabdominal ultrasonography has been used successfully in commercial flocks for the past 30 years to determine fetal number and gestation length permitting more precise feeding and management during late gestation.[3–5] Ultrasonographic

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examination has yielded important clinical information regarding size of the abomasum to determine colostrum ingestion,[6] respiratory system,[7] joints,[8] bladder and kidney,[9] uterus,[10] peritoneum, and liver.[11] Ultrasound examination of vaginal prolapse has guided a more effective method for replacement when the urinary bladder is identified within the prolapsed tissues.[12] On-farm identification of distended bladder caused by urinary tract obstruction[9] enables immediate action without recourse to laboratory testing and further delays that adversely influence prognosis.

ULTRASONOGRAPHIC EXAMINATION—EQUIPMENT

A 5.0-MHz linear transducer connected to a real-time, B-mode ultrasound machine can be used for all ultrasonographic examinations in adult sheep except examination of the right kidney and heart, where a 5- to 6.5-MHz sector transducer is necessary to ensure good contact between the concave flank of the right sublumbar fossa and access to the fourth and fifth rib spaces, respectively. A field setting of 7 to 9 cm on the linear scanner is appropriate for most abdominal examinations; occasionally the 20-cm field depth afforded by certain 5.0- to 6.5-MHz sector scanners more accurately determines the extent of fluid accumulation and bladder diameter, but this does not significantly alter the clinical diagnosis. Transrectal examination of the bladder and rectum has been reported in both rams and ewes,[13,14] but this examination has not proved necessary to determine obstructive urolithiasis in clinical practice.

SITES FOR ULTRASONOGRAPHIC EXAMINATION

Chest

A 5- to 6.5-MHz sector transducer connected to a real-time, B-mode ultrasound machine is preferred for ultrasonographic examination of the chest. An initial field setting of 6 to 7 cm allows detailed examination of the pleurae and superficial lung parenchyma and can be subsequently increased to examine the full extent of any lesions (up to 12–16 cm). A 5-cm-wide strip of skin is quickly shaved from both sides of the thorax extending vertically from the point of the elbow; in many breeds the ventral margin of this area of skin has only fine hairs and no fleece. The skin is soaked with warm tap water then ultrasound gel liberally applied to the wet skin to ensure good contact. The transducer head is firmly held against the skin overlying the intercostal muscles of the fifth to seventh intercostal spaces, and the thorax examined in both longitudinal and transverse planes. The dorsal lung field is selected at the start of all ultrasound examinations in an attempt to visualize normal lung tissue, as this area is much less commonly affected in ovine respiratory disease.

Liver

The liver can be imaged from the seventh to eleventh intercostal spaces halfway down the right chest wall with the 5- to 6.5-MHz sector probe head pointed toward the contralateral shoulder.[11]

Bladder, Uterus, Vagina, and Ventral Abdomen

The absence of fleece in the ventral midline and inguinal area expedites preparation when examining the ventral and caudal abdomen in sheep. Ultrasonographic examination of the bladder and caudal abdomen are undertaken in the standing animal using either 5- to 6.5-MHz linear array or sector scanners. The caudal abdomen is examined for the bladder and gravid uterus. The right inguinal region is chosen because the left side of the abdomen is largely occupied by the rumen. The transducer head is firmly

held at right angles against the abdominal wall. Because of the bladder's cylindrical rather than spherical shape when distended, an estimate of its size can be obtained by moving a 5.0-MHz linear scanner (field depth of 10 cm) cranially along the ventral midline from the level of the pubic symphysis. The posterior reproductive tract can be imaged by directing the sector transducer toward the tail head from its midline position immediately cranial to the pubic symphysis.

Right Kidney

Examination of the right kidney necessitates shaving the fleece from an area of the right sublumbar fossa immediately caudal to the last rib. The sector transducer head is firmly held against the skin to ensure good visualization of the right kidney juxtaposed the caudal lobe of the liver.

Abomasal Diameter of Neonatal Lambs

The abomasal diameter of neonatal lambs can be measured using a 5- to 6.5-MHz sector scanner applied at right angles to the abdominal wall at the umbilicus. The abomasum can be clearly identified as a hypoechoic area delineated by a hyperechoic wall. The vertical distance is measured between the probe head and the far abomasal wall.

Vaginal Prolapse

The contents of the vaginal prolapse can be readily determined using either linear array or sector scanners.

Scrotum

Sequential examination of the pampiniform plexus, testicle, and tail of the epididymis is undertaken as the linear or sector scanner is moved distally over the lateral aspect of each spermatic cord, testicle, and tail of the epididymis.

Joints

Ultrasonography using a 7.5-MHz linear array scanner with a stand-off can provide some additional useful information regarding the thickness of the joint capsule and extent and nature of any joint effusion. However, such information can more readily be obtained by careful palpation; arthrocentesis often fails because of the presence of a pannus.

ULTRASONOGRAPHIC FINDINGS

Chest

The surface of normal aerated lung (visceral or pulmonary pleura) is characterized by the uppermost white linear echo with equally spaced reverberation artifacts below this line (**Figs. 1** and **2**; Video 1). The chest wall is approximately 1 cm thick in 20- to 40-kg lambs extending up to 3 cm in adult sheep in good body condition with subcutaneous fat and skeletal muscle (80–100 kg; body condition score 3 or greater, scale 1–5). The visceral pleura can be observed moving 2 to 5 mm in a vertical plane during respiration. There is no detectable pleural fluid in normal sheep.

Lung Consolidation

Superficial areas of consolidated lung parenchyma transmit sound waves and appear more hypoechoic than surrounding lung tissue (**Fig. 3**; Video 2). Airways within consolidated lung appear as 3- to 10-mm hyperechoic areas within the hypoechoic lung parenchyma.

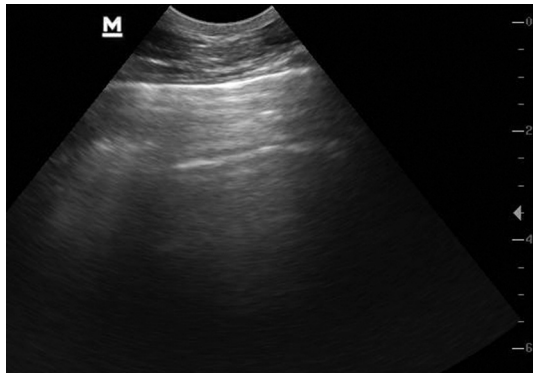

Fig. 1. The surface of normal aerated lung (visceral or pulmonary pleura) is characterized by the uppermost white linear echo with a reverberation artifact below this line. Using a 5-MHz sector scanner, the probe head is at the top of the image, dorsal is to the left, and centimeter markers in the right hand margin.

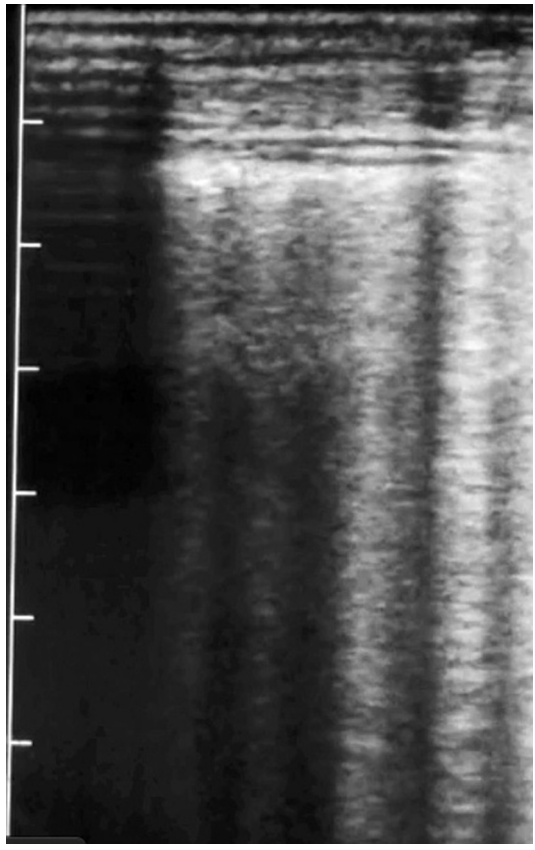

Fig. 2. The surface of normal aerated lung (visceral or pulmonary pleura) is characterized by the uppermost white linear echo. Using a 5-MHz sector scanner, the probe head is at the top of the image, dorsal is to the left, and centimeter markers in the left hand margin.

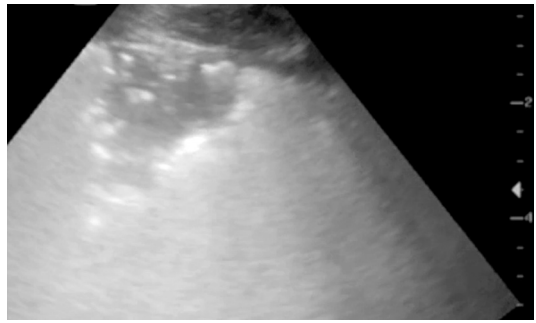

Fig. 3. Using a 5-MHz sector scanner, abrupt loss of the bright linear echo formed by normal aerated lung tissue (visceral or pulmonary pleura) can be seen replaced by a triangular-shaped hypoechoic area representing an OPA lesion.

Pleural Effusion

Pleural effusion transmits sound waves readily and appears as an anechoic area that increases in depth as the probe head travels ventrally down the chest wall, but such pathology is rare in sheep.

Pleural/Lung Abscesses

The white linear echo of the normal visceral pleura is lost with the pleural abscess, appearing as an uniform anechoic area containing many hyperechoic dots caused by gas echoes bordered by a broad hyperechoic line representing the abscess capsule (**Figs. 4** and **5**; Videos 3 and 4). With extensive pleural abscessation/pyothorax, where the abscess extends to occupy most of one side of the chest and

Fig. 4. Using a 5-MHz linear scanner, the 2.5-cm-diameter pleural abscess appears as an anechoic area containing many hyperechoic dots caused by gas echoes bordered by a broad hyperechoic line representing the abscess capsule. Shadowing on either side of the image is caused by the adjacent ribs.

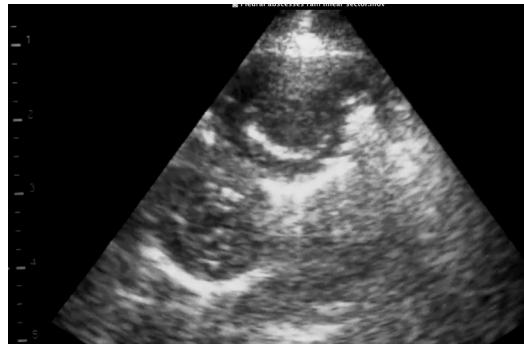

Fig. 5. Using a 5-MHz sector scanner, two pleural/lung abscesses appear as anechoic areas containing many hyperechoic dots caused by gas echoes bordered by broad hyperechoic lines representing the abscess capsule.

contains up to 3 L of pus, auscultation of the lung field may only reveal transmitted gut sounds, particularly rumen contraction sounds when the abscess occupies the left thorax.

Fibrinous Pleurisy

Exudate within the pleural space (**Fig. 6**; Video 5) appears as an anechoic area containing numerous hyperechoic strands (fibrin). There is consolidation of the ventral margin of the lung. In severe cases, unilateral pleurisy may extend for up to 10 cm from the chest wall with a hyperechoic lattice work appearance containing numerous anechoic pockets (**Fig. 7**; Video 6). There is attenuation of lung and heart sounds upon auscultation of the affected side in animals with extensive unilateral lesions. Fibrinous pleurisy may prevent movement of the underlying lung surface during respiratory excursions.

Ovine Pulmonary Adenocarcinoma

The first indication of changes in the superficial lung parenchyma caused by OPA is the abrupt loss of the bright linear echo formed by normal aerated lung tissue (visceral or pulmonary pleura) to be replaced by a large hypoechoic area in the

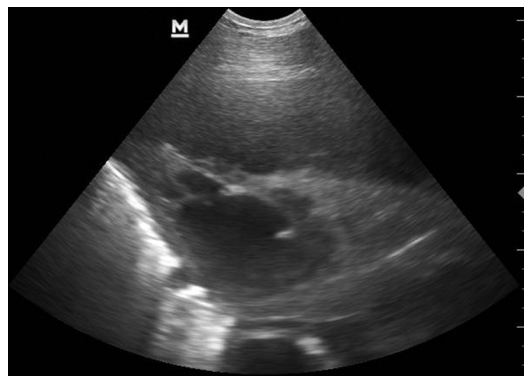

Fig. 6. Using a 5-MHz sector scanner, up to 8 cm of exudate appears as a hypoechoic area between the parietal pleura and bright linear echo, which represents the aerated lung surface (visceral pleura).

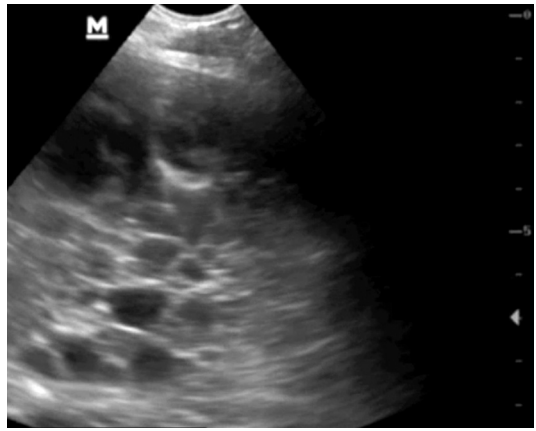

Fig. 7. Using a 5-MHz sector scanner, unilateral pleurisy is seen extending for up to 8 cm from the chest wall with a hyperechoic lattice work appearance containing numerous anechoic pockets.

ventral margins of the lung lobes at the fifth or sixth intercostal spaces (**Figs. 8–10**; Videos 7–9). The hypoechoic areas visualized during ultrasonography, corresponding to lung tissue invaded by tumor cells causing consolidation (**Fig. 11**), allow the extent and distribution of the OPA lesions to be accurately defined during the ultrasonographic examination. Direct comparison of the echogenic appearance of affected right lung with adjacent liver shows the extent of cellular proliferation within the OPA mass (see Video 9). This video is achieved by scanning through affected

Fig. 8. Using a 5-MHz linear scanner, the sharply demarcated hypoechoic area ventrally corresponds to the distinct OPA tumor.

Fig. 9. Using a 5-MHz linear scanner, the large and sharply demarcated (>6 cm deep) hypoechoic area corresponds to consolidated lung tissue invaded by OPA tumor.

lung then diaphragm into the liver. Small focal hyperechoic areas clearly identified within the more cellularly dense OPA areas probably represent large airways. Hyperechoic circular areas measuring 1 to 2 cm in diameter within an OPA mass with distal shadowing probably represent either an abscess or necrotic center (Figs. 12–14).

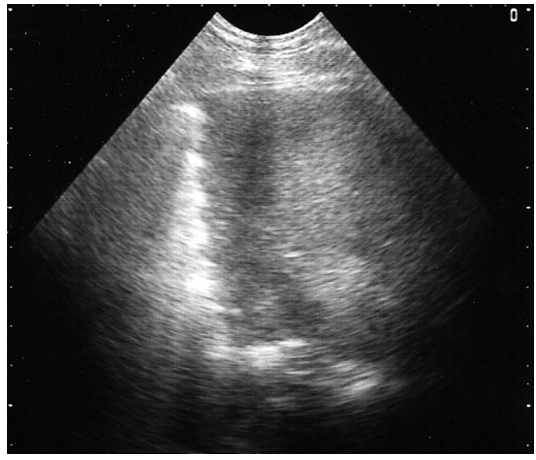

Fig. 10. Using a 5-MHz sector scanner, a vertical hyperechoic line can be seen that represents the distinct separation of the normal hyperechoic visceral pleura dorsally from the hypoechoic mass of the OPA lesion ventrally.

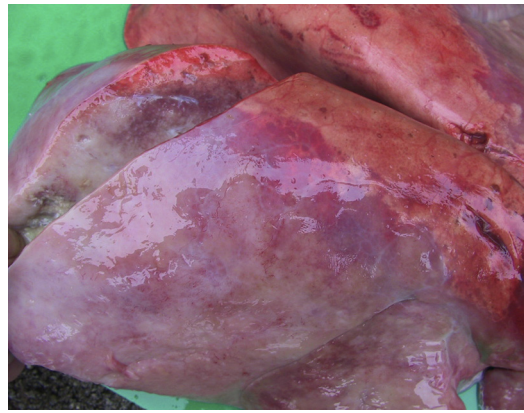

Fig. 11. Necropsy reveals the sharp delineation of normal lung dorsally from the OPA tumour ventrally (see **Figs. 8–10**). Note the sharp demarcation on both the lung surface and on cut section.

Case reports show where the diagnosis of OPA is made using linear and sectors scanners; the sharp demarcation between tumor-affected lung ventrally and normal lung is clearly shown (Videos 10–13).

Fibrinous pleurisy causing adhesions between OPA-affected lung and the pericardial sac is seen ultrasonographically and at necropsy in Video 13; the left lung shows 3 to 4 abscesses measuring 1 to 4 cm in diameter within OPA-affected lung and at necropsy. It proved difficult to separate the pleurae on the left side, and the abscesses are better shown involving the lung once it had been removed from the chest cavity.

HEART

Congenital Cardiac Defects

Congenital cardiac defects[15] and tumors[16] in lambs are rare such that single cases are often reported in the literature.

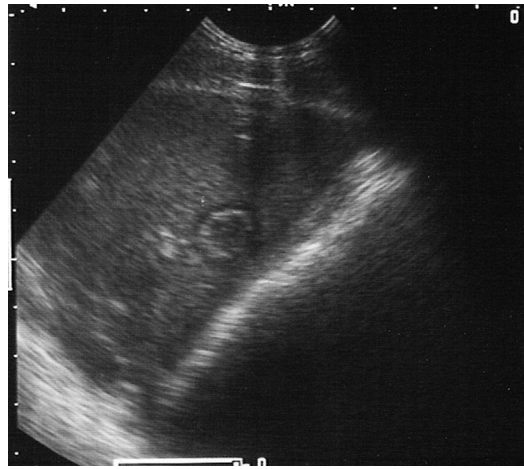

Fig. 12. Using a 5-MHz sector scanner, a 1.5-cm abscess with a distinct capsule within the OPA mass can be seen.

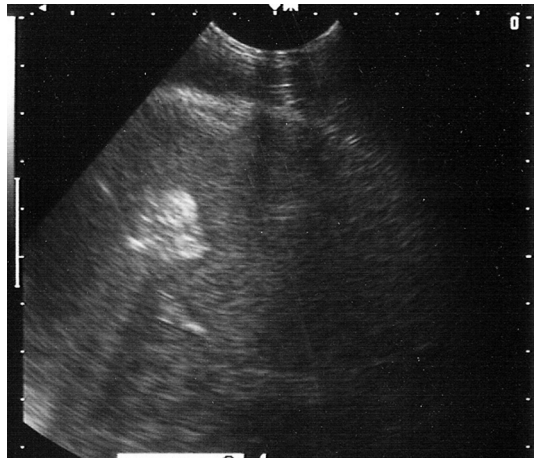

Fig. 13. Using a 5-MHz sector scanner, a 2-cm-diameter hyperechoic lesion with distant shadowing can be seen, which represents a necrotic center within the OPA mass.

Vegetative Endocarditis

Vegetative lesions on the heart valves (vegetative endocarditis) of sheep are generally small and difficult to image, but larger lesions can be imaged with 5- to 6.5-MHz sector scanners (Figs. 15 and 16). Color-coded Doppler sonography may be necessary to detect valvular dysfunction caused by smaller heart valve lesions.

Pericarditis

Septic pericarditis is rare in sheep, and diseases causing significant pericardial effusion/exudate generally cause sudden death (such as clostridial diseases) such that ultrasonographic examination of the pericardium is rarely undertaken.

ABDOMEN

Ascites

The scant peritoneal fluid in normal sheep cannot be visualized during ultrasonographic examination. Ascitic fluid appears as an anechoic area with abdominal

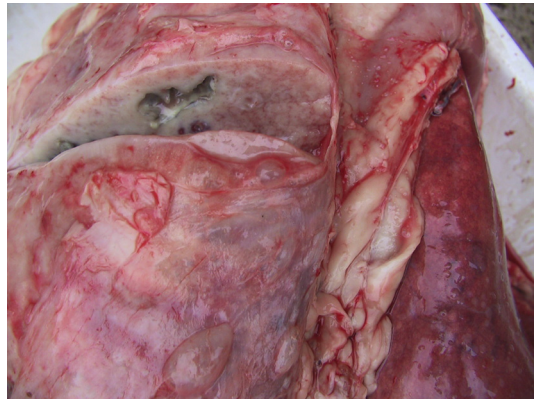

Fig. 14. A 2-cm-diameter necrotic center within the OPA mass as featured in Fig. 13.

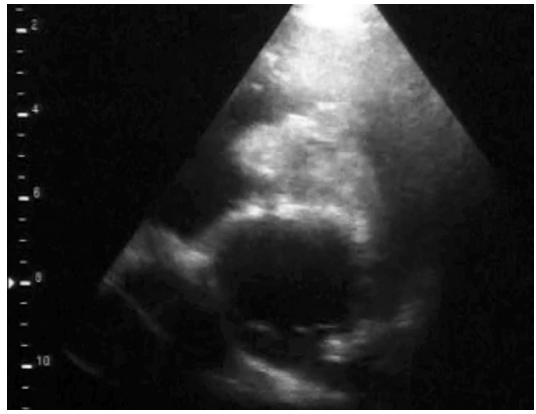

Fig. 15. Using a 5-MHz sector scanner, 2.5-cm-diameter highly irregular hyperechoic mass involving the tricuspid valve is seen. See **Fig. 16**.

viscera displaced dorsally in the standing animal. The intestines are clearly outlined as hyperechoic (bright white) lines/circles containing material of varying echogenicity (**Fig. 17**; Video 14). By maintaining the probe head in the same position for 10 to 20 seconds, digesta can be seen as multiple small dots of varying echogenicity forcibly propelled within the intestines. Accumulation of transudate is seen in sheep with very low serum protein concentrations in diseases such as paratuberculosis but has also been reported in cases of right-sided heart failure caused by bacterial endocarditis. Large amounts of transudate accumulate in sheep with intestinal adenocarcinoma in which transcoelomic spread of the tumor causes impaired lymphatic drainage.

Peritonitis

With the exception of subacute fasciolosis, significant peritoneal exudation is rarely seen in sheep with peritoneal reaction limited by the omentum to focal fibrinous/fibrous adhesions and localized accumulations of peritoneal exudate. Two well-encapsulated

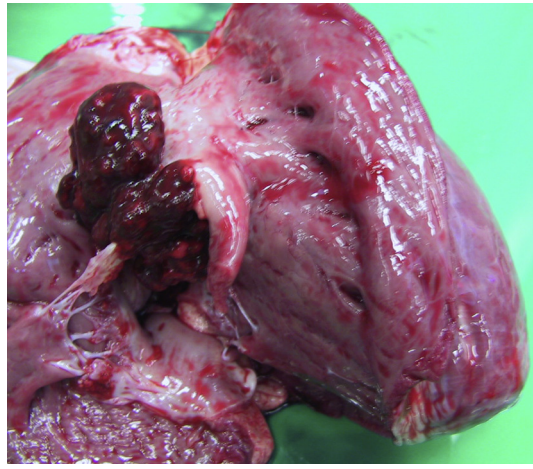

Fig. 16. Irregular vegetative lesion (bacterial endocarditis) on the tricuspid valve.

Fig. 17. Using a 5-MHz sector scanner, ascitic fluid can be seen appearing as an anechoic area with intestines displaced dorsally in the standing animal clearly outlined as 1 to 2 diameter hyperechoic circles and longer cylinders containing digesta of varying echogenicity.

abscesses surrounded by omentum are imaged in **Fig. 18** and are shown at necropsy in Video 15; the cause of these abscesses could not be determined.

Small Intestinal Torsion

Torsion of the small intestine around the root of the mesentery is not uncommon. The intestines involved in the torsion are grossly distended with little propulsion of digesta; an increased amount of peritoneal fluid is also seen (Video 16).

Intra-abdominal Hemorrhage

Intra-abdominal hemorrhage most commonly arises either during late pregnancy associated with vaginal prolapse or during unskilled dystocia correction. Hemorrhage results from rupture of blood vessels in the broad ligament and can be imaged with the probe head positioned immediately cranial to the pubis (**Fig. 19**; Video 17).

Liver

The liver is readily identified in the seventh to eleventh intercostal spaces on the right side.

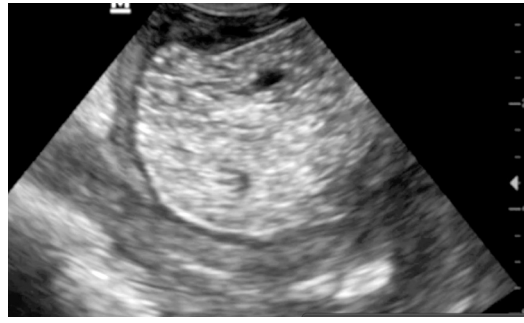

Fig. 18. Using a 5-MHz sector scanner, well-encapsulated 4-cm-diameter abscess can be seen within the abdominal cavity.

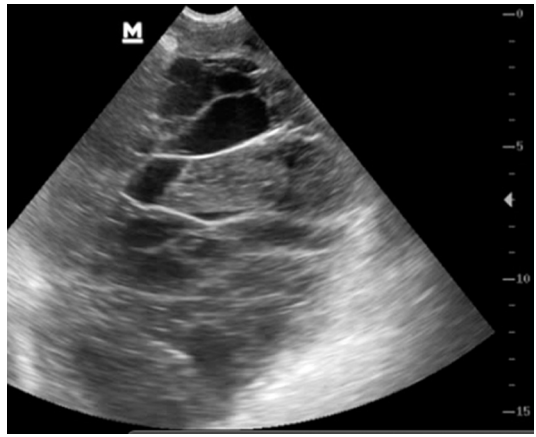

Fig. 19. Intra-abdominal hemorrhage can result from rupture of blood vessels in the broad ligament and is imaged with the probe head positioned immediately cranial to the pubis.

Liver Fluke

The most common liver problem in sheep is liver fluke (predominantly *Fasciola hepatica* infestation). Hepatomegaly and multiple hyperechoic dots within the liver parenchyma (**Fig. 20**; Video 18), representing accumulations of inflammatory cells, are common findings in sheep with subacute fasciolosis.[11] These lesions resolved within 1 month of treatment with triclabendazole.

Loss of normal liver architecture and distension of the gallbladder (Video 19) is commonly seen in chronic liver fluke infestation. Romanski[17] reported gallbladder dimensions measured ultrasonographically in sheep after various intervals during fasting with a doubling of volume after 2 days and suggested that such measurement could provide important clinical information. These data support the necropsy findings of gallbladder distension in cachectic sheep.

Large liver abscesses caused by *Corynebacterium pseudotuberculosis*, the causal agent of caseous lymphadenitis, are not uncommon in many countries including the United States.[18,19] Where infection does cause large liver abscesses, these lesions should be readily identified during ultrasonographic examination.

Ultrasonographic examination of the liver has confirmed the presence of ovine hydatid cysts and the potential use of ultrasonography as a mass screening approach

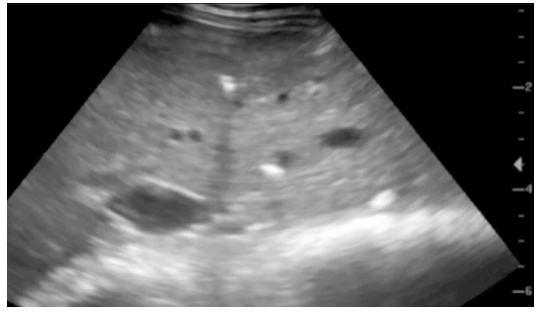

Fig. 20. Using a 5-MHz sector scanner, multiple hyperechoic dots can be seen throughout the liver parenchyma with shadowing that represents accumulations of inflammatory cells in a sheep with subacute fasciolosis.

for cystic echinococcosis.[20,21] Cysts of *Echinococcus granulosus* in the liver of sheep were located by ultrasonography and injected with dipeptide methyl ester and the treatment response monitored ultrasonographically.[22]

Although hepatocellular tumors are not uncommon in old sheep, such lesions are usually only recognized at the slaughter plant in ewes culled for poor condition; however, it was reported that liver tissue obtained via ultrasound-guided percutaneous liver biopsy suggested n diagnosis of adenocarcinoma of the liver, which was later confirmed at necropsy.[23]

URINARY TRACT

Ultrasonographic examination of the bladder and caudal abdomen provides useful information in male sheep with suspected partial or complete urethral obstruction (Video 20), which is a common condition of intensively reared rams.[24] Early recognition of clinical signs by the owner and prompt veterinary treatment are essential because urinary back pressure quickly results in irreversible hydronephrosis. Early diagnosis of urolithiasis allows prompt surgical correction of breeding rams by tube cystotomy[25] (**Fig. 21**; Video 21) and rapid implementation of control measures to prevent further cases.

Examination using a 5.0-MHz linear array scanner readily identifies distended bladder and uroperitoneum if present, but the true size of the bladder may not be measured because it may extend to 20 cm in diameter, thereby exceeding the 10-cm field of many linear array scanners. The distended bladder extends 6 to 8 cm in diameter cranial to the pelvic brim in 20- to 40-kg growing lambs and 12 to 16 cm diameter in mature rams (**Figs. 22** and **23**). The bladder wall appears as a hyperechoic circle; edema of the wall results in widening of this white line. In those rams with uroperitoneum, fibrin tags can sometimes be seen as fine hyperechoic filaments with the anechoic fluid.

Urinary tract infections leading to pyelonephritis are rare in sheep with the exception of those males that have undergone subischial urethrostomy surgery to bypass the site of obstructive urolithiasis. In cases of cystitis, the bladder wall appears much thicker than normal with fibrin tags on the mucosal surface that appear as hyperechoic strands. Large fibrin clots, typically represented by irregularly shaped hypoechoic circles containing hyperechoic dots, are often present within the distended bladder.

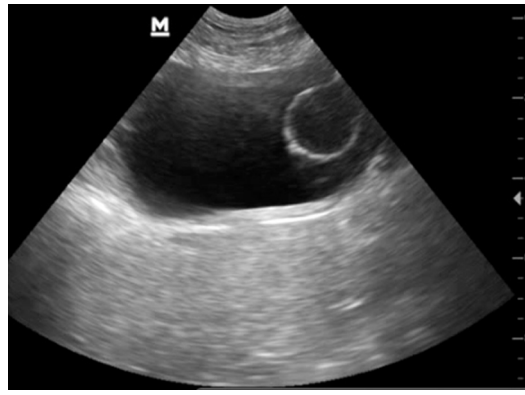

Fig. 21. Tube cystotomy surgery used for the treatment of obstructive urolithiasis in a ram. The inflated cuff of the Foley catheter is visible as a 2-cm-diameter hyperechoic circle within the bladder, which measures approximately 4 cm. A 5-MHz sector scanner was used.

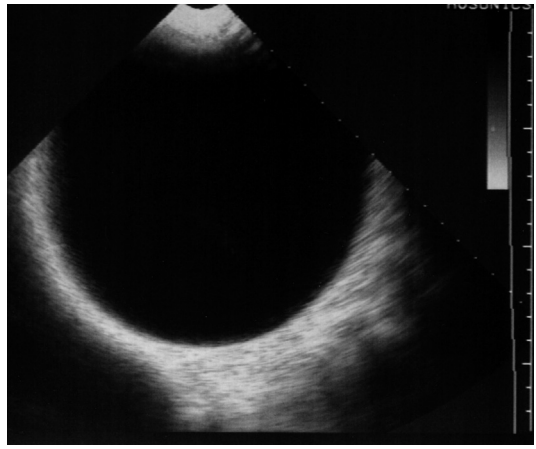

Fig. 22. The distended urinary bladder extends to greater than 12 cm diameter (see **Fig. 23**).

Kidney

Examination of the right kidney is undertaken using a 5.0-MHz sector transducer; the concave nature of the right sublumbar fossae prevents good contact and use of a linear transducer. The right kidney is juxtaposed to the caudal pole of the liver underlying the dorsal aspect of the right sublumbar fossa (**Fig. 24**). Advanced hydronephrosis can be identified by the grossly increased renal pelvis, which is represented by the anechoic (fluid-filled) center of the kidney (**Figs. 25** and **26**; Video 22). It is not always possible to scan the left kidney in sheep via the flank, but such examination is not necessary because the urinary tract obstruction is distal to the ureters; therefore, the condition affects both kidneys equally.

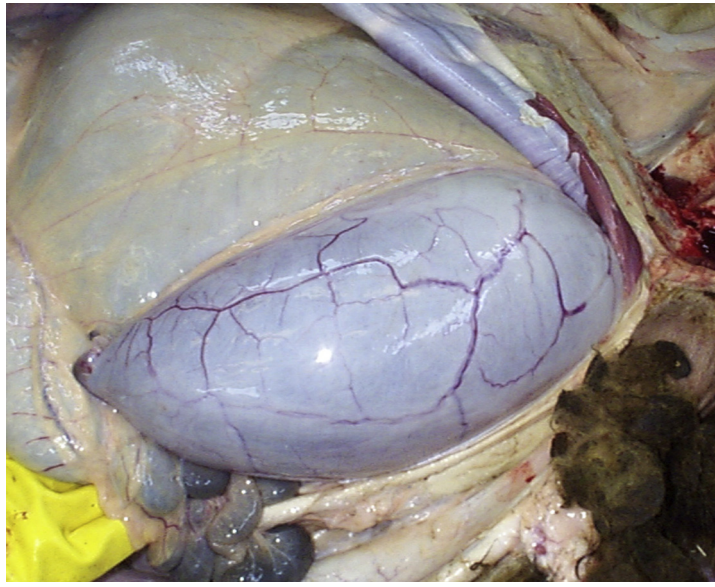

Fig. 23. Necropsy findings of bladder distension imaged in **Fig. 22**.

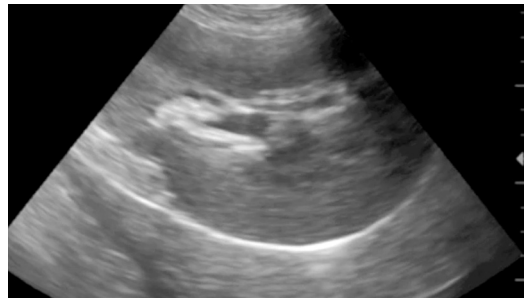

Fig. 24. Ultrasonographic appearance of a normal right kidney. The renal capsule appears as the convex hyperechoic line.

Biricik and colleagues[26] concluded from their studies on young lambs with obstructive urolithiaisis that B-mode and color-coded Doppler sonography might provide useful information for detection of changes in kidneys, like hydronephrosis, renal swelling, and elevated resistance in the renal interlobar artery. A large, greater-than-10-cm diameter renal carcinoma is shown in Video 23 and **Figs. 27** and **28**.

SCROTUM

The normal testicle appears as a uniform hypoechoic area with the hyperechoic mediastinum often visible. The tail of the epididymis is distinct from the testicle and considerably smaller in diameter (2–3 cm compared with >7 cm) with a distinct capsule.

Testicular Atrophy

The testicle(s) is much reduced in size (normal, >7 cm in diameter (**Fig. 29**), frequently 5 cm for atrophy cases (**Fig. 30**)) and appears more hypoechoic than normal and contains many hyperechoic dots. These hyperechoic dots are thought to represent the fibrous supporting architecture now more obvious after atrophy of the seminiferous

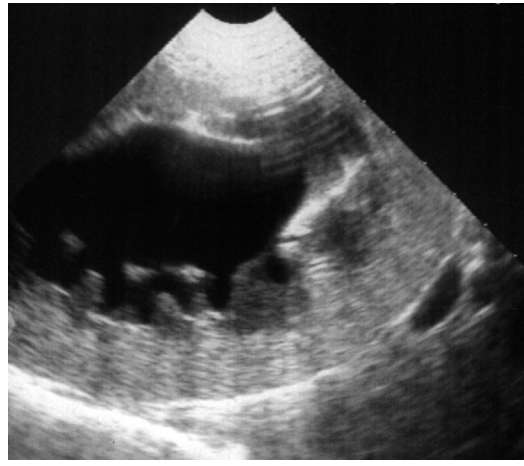

Fig. 25. Advanced hydronephrosis can be identified by the grossly increased renal pelvis which is represented by the enlarged anechoic center of the kidney (see **Fig. 26**).

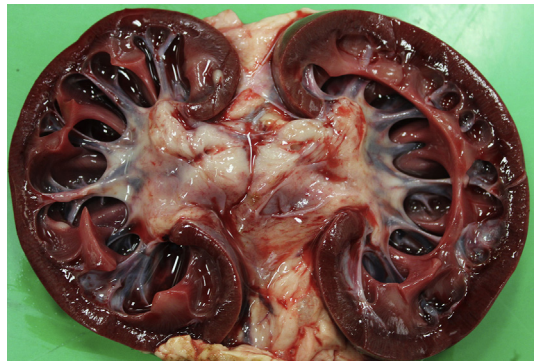

Fig. 26. Necropsy findings of the hydronephrotic kidney featured in Fig. 25.

tubules. Ultrasonography was reported to be useful for the diagnosis of intrascrotal abnormalities after experimental inoculation with *Trueperella pyogenes* into the testicle, especially during investigation of chronic disease after clinical findings had subsided.[27]

Epididymitis

Epididymitis caused by *Brucella ovis* and *Actinobacillus seminis/Histophilus ovis* is a major cause of ram infertility in many countries. Ultrasonographic examination in rams with epididymitis finds a normal pampiniform plexus. Typically, the swollen scrotal contents frequently appear as multiple 1- to 5-cm diameter anechoic areas containing many bright spots surrounded by broad hyperechoic lines (fibrous capsule) extending up to 1 cm in thickness typical of chronic abscesses. The abscesses generally involve the tail of the epididymis but may extend to involve the body and head. The testicle is embedded within fibrous tissue reaction and is much reduced in size. The testicle appears more hypoechoic than normal and contains many hyperechoic spots consistent with testicular atrophy.[28] In unilateral epididymitis cases, the contralateral testicle is much smaller than normal and appears more hypoechoic.

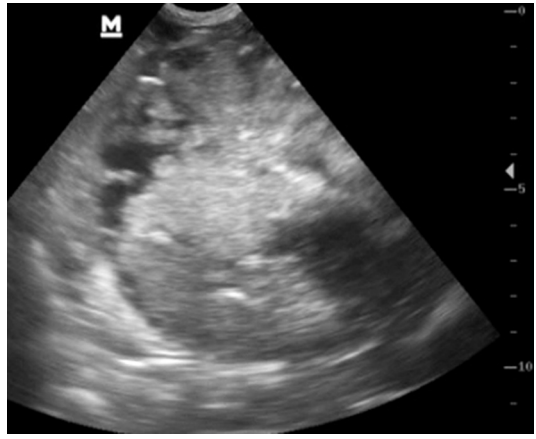

Fig. 27. A renal carcinoma measuring up to 10 cm diameter.

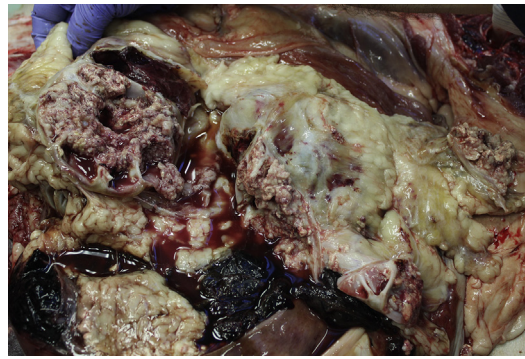

Fig. 28. A renal carcinoma measuring up to 10 cm diameter at necropsy.

PREGNANCY

Real time transrectal ultrasonographic scanning of sheep between days 24 and 34 of gestation offers a safe, accurate, and practical means for diagnosing pregnancy.[29] Accuracies of diagnosis of pregnancy of more than 99%; of differentiation of barren, single-, and multiple-bearing ewes of 98%; and of determination of actual fetal numbers of 97% can be achieved in practice at scanning rates of at least 1 ewe per minute.[4]

Obstetric Problems

Ultrasonographic examination is of particular value where transabdominal ballotment suggests the presence of a fetus in utero after delivery of lamb(s) some 12 to 48 hours previously, but contraction of the cervix prevents further manual examination of the uterus. It can prove difficult to differentiate the contracted uterus from a uterine horn containing a single lamb by transabdominal ballotment alone, but this problem can be easily resolved by ultrasonographic examination of the caudal abdomen (Video 24).

Ultrasonography has been used to monitor uterine involution postpartum, which was delayed in ewes after manual correction of dystocia and cesarean section.[30]

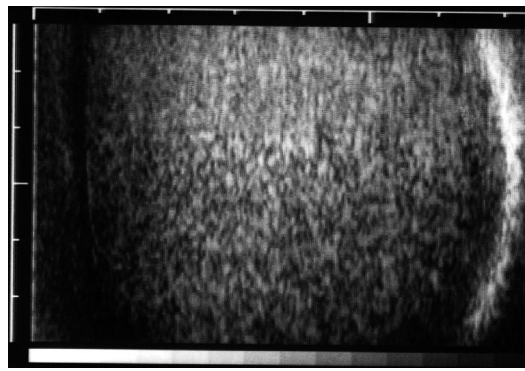

Fig. 29. The normal testicle is greater than 7 cm in diameter at the start of the breeding season in mature rams.

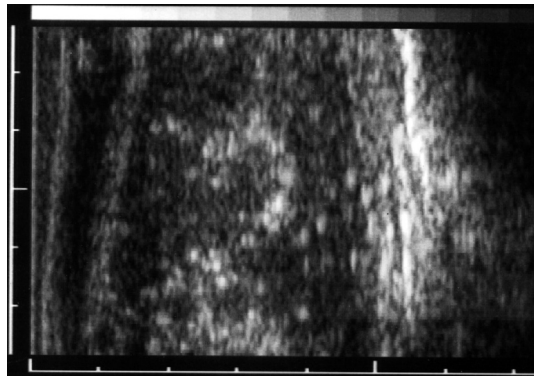

Fig. 30. With atrophy the testicle is often less than 5 cm in diameter and appears more hypoechoic than normal and may contain many hyperechoic dots (see Fig. 29).

Uterine Torsion

Uterine torsion is a problematic diagnosis in sheep because vaginal examination is restricted by the narrow diameter of the reproductive tract and will not identify a torsion involving the body of the uterus cranial to the cervix. A recent article described the application of transabdominal ultrasound examination of the uterine wall as close to the cervix as possible (ventral midline immediately cranial to the pelvic brim with the probe head directed vertically) as a noninvasive means of detecting uterine torsion in sheep.[31] Edema of the uterine wall after torsion resulted in a doubling of the thickness from 5 mm to more than 10 mm. Although a 7.5-MHz scanner was used in this investigation, a 5-MHz linear scanner should provide diagnostic quality sonograms. In the case of uterine torsion seen by this author, the lamb was 1 month overdue based on the single artificial insemination date; the cotyledons were poorly defined and the fetal fluids were not anechoic (Fig. 31). This image looks to be of poor quality but this is because of autolysis (Fig. 32).

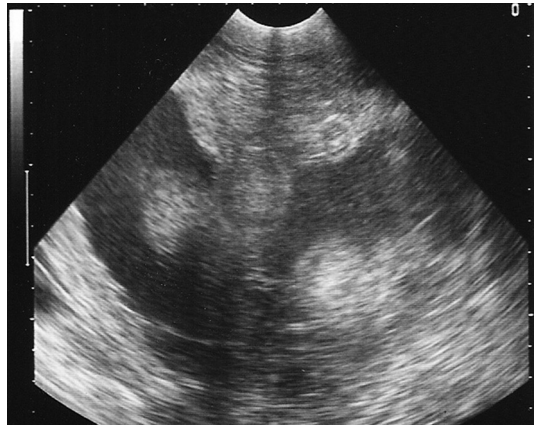

Fig. 31. In this case of a 720° uterine torsion, the cotyledons are very poorly defined, and the fetal fluids are not distinctly anechoic. The quality of this sonogram should be judged alongside the necropsy findings (see Fig. 32) where the uterine wall, placenta, and single lamb are autolytic; the uterine wall is green with widespread fibrin on the serosal surface.

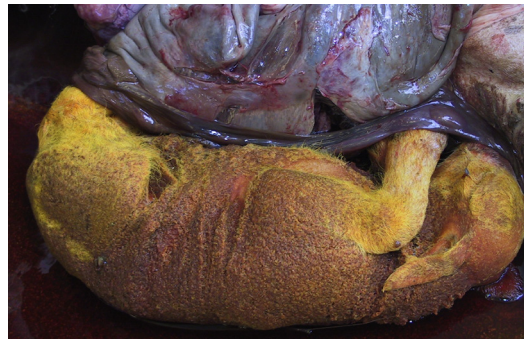

Fig. 32. Necropsy findings of the uterus imaged in Fig. 31; the uterine wall, placenta, and single lamb are autolytic; there is widespread and organized fibrin on the serosal surface of the uterus.

Pyometra is uncommon in sheep but can be identified ultrasonographically with the uterine horns distended 6 to 8 cm with pus (Fig. 33). Uterine tumors are rare in sheep, but cases of leiomyomas have been identified in sheep presenting in poor body condition (Figs. 34 and 35).

VAGINAL PROLAPSE

Vaginal prolapse may comprise dorsal vaginal wall, urinary bladder, uterine horn(s), or both urinary bladder and uterine horn(s). Urinary bladder is readily identified as an anechoic (black) area on the sonogram usually greater than 8 cm in diameter and compressed dorsoventrally (Fig. 36). A fold in the bladder wall, which presents as a hyperechoic (white) line, can often be visualized in the ventral one-third of the anechoic area. Sections through the tips of uterine horn(s) appear as anechoic circles measuring 3 to 5 cm in diameter bordered by the hyperechoic uterine wall; caruncles are not usually observed.

UDDER

Ultrasonographic examination of an udder with palpable abscesses (Video 25) has limited application in clinical practice. Ultrasonographic measurements of the length

Fig. 33. The imaged uterine horn is distended 6 to 8 cm with pus in this example of pyometra.

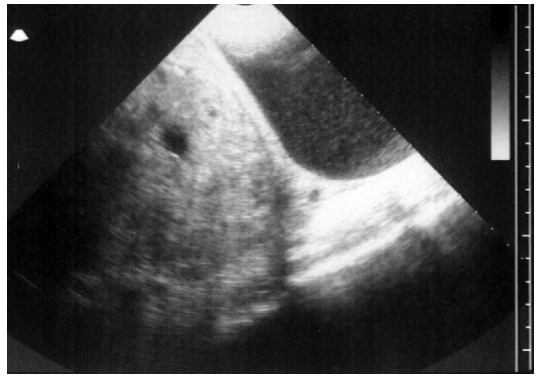

Fig. 34. Leiomyoma measuring up to 16 cm positioned dorsal to the 7 cm diameter urinary bladder (see Fig. 35).

and width of the teat canal in lactating ewes seemed to be positively correlated to the California mastitis test results leading the authors to conclude that ultrasonography holds promise for the future in evaluating the health of the udder of small ruminants.[32,33]

JOINTS

Arthrosonography of sheep with chronic arthritis/synovitis found gross thickening of the joint capsule visible ultrasonographically as a hyperechoic band up to 20 mm thick,[8] but such a condition can readily be determined by careful palpation.

MUSCLE

Ultrasonography could not be used for quantitative assessment of post-injection muscle damage where creatine kinase assay provided a more accurate evaluation of macroscopic muscle damage.[34]

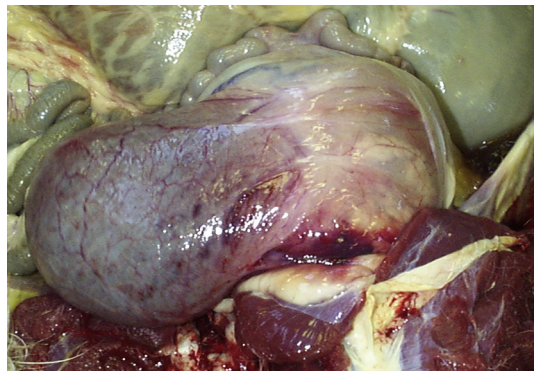

Fig. 35. Necropsy findings of the sonogram featured in Fig. 34. The cadaver is positioned in dorsal recumbency with a ventral midline approach at necropsy; the leiomyoma is dorsal to the urinary bladder.

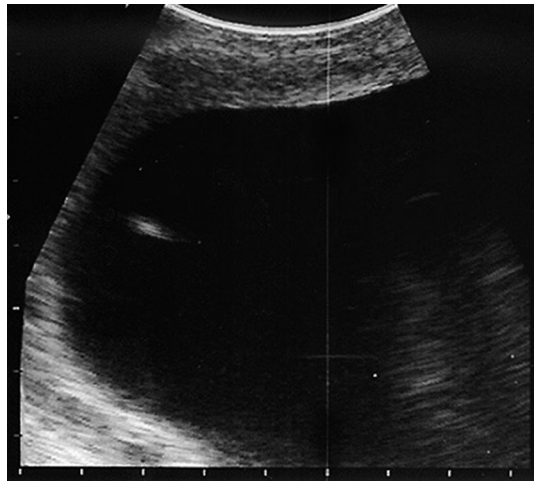

Fig. 36. Urinary bladder in the vaginal prolapse is readily identified as an anechoic (*black*) area usually greater than 8 cm in diameter and compressed dorsoventrally.

ABOMASUM IN NEONATES

Perinatal lamb mortality, defined as losses within the first 3 days of life, is the major cause of lamb deaths with estimates ranging from 10 to 25%.[35–37] Ultrasonographic examination of the abomasum of neonatal lambs provides an immediate indication to the veterinary investigator whether lambs have sucked. The difference in lamb abomasal diameter before and after sucking is so large, 3 cm versus 8 to 10 cm, that minor errors in individual lamb recordings should not affect the collection of meaningful data from 20 or more lambs and their interpretation.

BRAIN

Ultrasound scan has been used as an aid to *Coenurus cerebralis* cyst localization in a lamb.[38]

DISCUSSION

In addition to assisting the veterinarian establish a specific diagnosis at the time of the first ultrasound examination, repeated examinations allow the lesion(s) to be monitored over time. Recording ultrasound findings either as still images or videos also allows full review should treatment prove unsuccessful when it is essential to critically evaluate interpretations of the ultrasound recordings when the pathologic condition is revealed at necropsy. This practice has been adopted in the video recordings in this article where possible.

In the author's experience of farm animal practice, ultrasonography is especially useful in the investigation of respiratory diseases in both cattle and sheep and in obstructive urolithiasis in male sheep.

Respiratory disease is common in sheep, but it proves difficult to diagnose specific diseases/lesions by clinical examination alone because the respiratory rate and intensity of lung sounds are variably affected by gathering, handling stresses, body condition score, and painful lesions. It may prove difficult to distinguish wheezes and crackles, and not all experts agree on what they hear and what pathologic changes

those sounds represent.[2] Indeed, in many respiratory diseases, breath sounds are markedly attenuated or absent. Ultrasonographic examination of the chest allows critical evaluation of the pleurae and establishment of a definitive diagnosis in most cases. The increasing availability of sector scanners in sheep practice offers exciting diagnostic opportunities. Indeed, the clinical application of ultrasound examination of the equine chest was reported almost 25 years ago.[39]

The role of ultrasonography in the logical approach to a novel situation is illustrated in the diagnosis of pelvic nerve paralysis in 2 rams.[40] Marked urinary bladder distension, hydroureters, severe bilateral hydronephrosis, and perirenal fluid accumulation were identified ultrasonographically. Both rams were observed to pass a free flow of urine, but the flow rate was less than normal, and the duration was reduced to around 5 to 10 seconds when around 20 to 30 seconds is considered normal. There was normal tail and rectal muscle tone and normal perineal and pelvic limb reflexes. Detailed dissection at necropsy found no evidence of urethral obstruction. These cases warranted more detailed investigation because the rams passed a free flow of urine and not just occasional drops of urine, which is the classical presentation of urethral obstruction. Without the ultrasound findings at the time of clinical examination, the diagnosis of pelvic nerve paralysis may have been overlooked.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.cvfa.2015.09.008.

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