Cardiovascular Ultrasonography in Cattle

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KEYWORDS

• Echocardiography • Pericarditis • Endocarditis
• Ventricular septal defects • Vascular ultrasound

Diagnosing heart disease in cattle is challenging because clinical signs can be hidden until signs of congestive heart failure occur. An early diagnosis is of primary importance because the prognosis of the most common heart disorders ranges from guarded to poor.[1] Ancillary tests, such as complete cell blood count and serum biochemistry panel, may lack the sensitivity or specificity to detect heart disease.[1,2] By contrast, the main diseases of superficial vessels may be detected with a precautionary clinical examination; however, a precise diagnosis requires medical imaging to observe the suspected vessel and its content.[3] Medical imaging is also required for the assessment of deep vessels that cannot be clinically assessed. For all these reasons, cardiovascular ultrasonography may be valuable in the management of suspected cardiovascular disease. With the improvement of ultrasound equipment quality and portability, this ancillary test can be used in a farm setting or in hospital. This article reviews the diagnostic and prognostic applications of ultrasound concerning bovine heart disease and vascular disease.

ULTRASONOGRAPHY OF THE HEART: TECHNIQUE AND NORMAL FINDINGS

Echocardiography can be performed in the field as well as in hospital. The equipment required consists of a low-frequency probe (2.5–3.5 MHz) in adults[4–7] or a higher-frequency probe (3.75–5 MHz) in calves.[8–10] The narrow intercostal space, the cranial position of the heart in the chest, and the shape of the probe may be limiting factors for performing all the scanning views of the heart. A small, phased array (pencil-like) probe is preferred, if available (**Fig. 1**). However, a large sectorial probe may be sufficient to allow the diagnosis of bacterial endocarditis, pericarditis, and ventricular septal defects, the most common cardiac diseases in cattle.[1,11]

Echocardiograms are usually performed on standing animals.[4–11] For calves, the examination can also be performed with the animal restrained in right lateral

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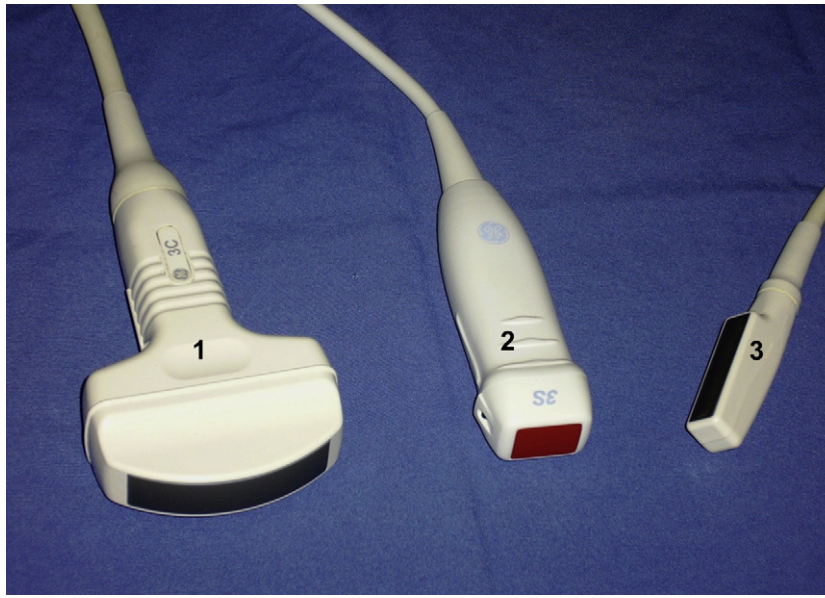

Fig. 1. Different probes may be used to perform echocardiography. Low-frequency probes, such as sectorial probes used to monitor pregnancy in small ruminants, (1) or, if available, a small, phased array probe (2), can be used in cattle. High-frequency linear probes (3) used in reproductive monitoring do not allow good penetration for adults but can sometimes be used in calves. The linear probes' major inconvenience is lack of dexterity in the intercostal space.

recumbency on a table with the standard imaging opening for small animals.[12] The area from the third to the fifth intercostal space in the cardiac region is clipped on both sides of the thorax. The skin is then rinsed with warm water or alcohol, and transmission gel is applied. The thoracic limbs can be moved cranially (**Fig. 2**)[11] or gently abducted[7] to facilitate better contact between the probe and the intercostal space.

Right Parasternal Ultrasonograms

The echocardiogram performed in the right side of the thorax allows to distinguish three long-axis and one short-axis view of the heart.[6,7,11] When the probe is applied parallel to the fourth intercostal space, the long-axis four-chambers view of the ventricles, atria, and the interventricular septum is observed (**Fig. 3**). The operator needs to remember that the moderator band (trabeculae septomarginalis) that connects the anterior and posterior walls of the right ventricle, frequently observed with this view (see **Fig. 3**), is thick in cattle and should not be misinterpreted as mural endocarditis. Placing the probe slightly more cranially with a slight clockwise rotation, the left ventricular outflow tract (LVOT) is observed—the left ventricle, left atria, aortic valve, and the aortic root (**Fig. 4**). The right ventricle and right atria are also observed with this view. A slight clockwise rotation in the same intercostal space or probe placement in the third intercostal space allows the visualization of the right ventricular outflow tract (RVOT) in which the right ventricle and atrium and the pulmonary valve and pulmonary trunk are observed (**Fig. 5**). The short-axis view of the heart is obtained by placing the probe perpendicular to the ribs in the fourth intercostal space to observe a transverse section of both ventricles (**Fig. 6**). The short-axis view may be

Fig. 2. Practical realization of echocardiography via the right side of the thorax in an on-farm setting. If needed, the right forelimb (1) can be moved cranially by a helper (2) so that the region of interest (3) can be examined. The ultrasound device is placed in a safe location (4) to avoid problems with other herdmates.

difficult to obtain because of symmetric images and interferences with the pleural surface.[7] As in small animals, other views may be obtained from the right side of the thorax;[12,13] however, their usefulness in clinical situations remains to be determined.

Left Parasternal Ultrasonograms

Echocardiography on the left side is especially useful when suspecting left heart disease. Preparation for an ultrasonographic examination of the cow is the same as for the right thorax. The caudal long-axis view of the heart is obtained by placing the probe on the fourth or the fifth intercostal space dorsally to the level of the olecranum directed slightly caudodorsally, allowing a view of the ventricles, atria, and the atrioventricular valves (**Fig. 7**). The probe is then turned slightly more cranially and rotated slightly counterclockwise to observe the LVOT (**Fig. 8**). The left parasternal cranial long-axis view of the RVOT (**Fig. 9**) is seen from the third[6,7] or fourth intercostal space.[7] Different echocardiographic measurements have been made in adult cows[5,7] or calves.[8–10] However, the usefulness of measured echocardiographic parameters in cattle in a clinical setting remains to be determined. The cardiac chamber dimensions may be an objective tool when suspecting heart dilation secondary to heart disease.[12,14] The left ventricular fractional shortening (FS) can also be measured using M-mode analysis of the right parasternal short- or long-axis view.[12,14,15] The FS represents the percentage of change of the left ventricular diameter between the diastole (end diastolic diameter of the left ventricle [LVd]) and the systole (end systolic diameter of the left ventricle [LVs]) by the formula FS (%)=100×(LVd−LVs)/LVd. In healthy

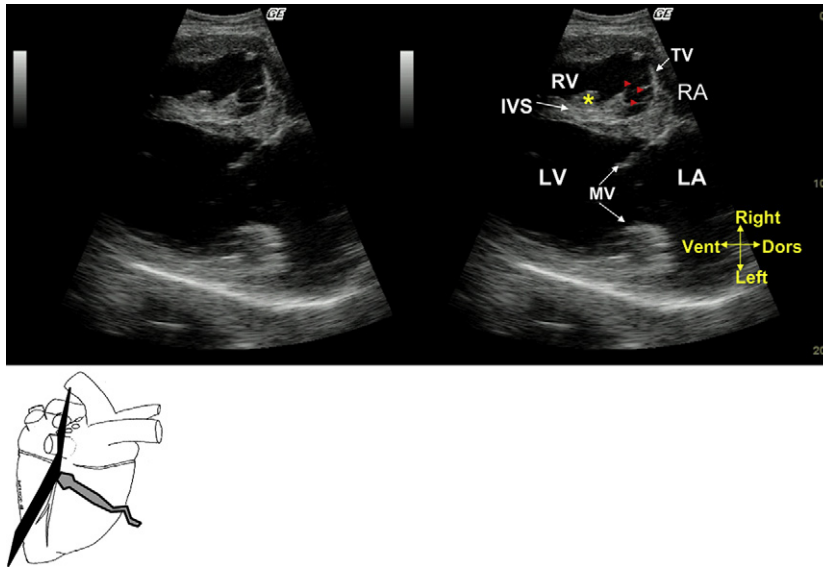

Fig. 3. Right long-axis view of the heart (four-chambers view). The tendinous chordae of the tricuspid valve are also seen as echoic lines (*arrowhead*). The moderator band (*) is also partially observed emerging from the posterior wall of the right ventricle. Ds, dorsal; IVS, interventricular septum; LA, left atrium; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

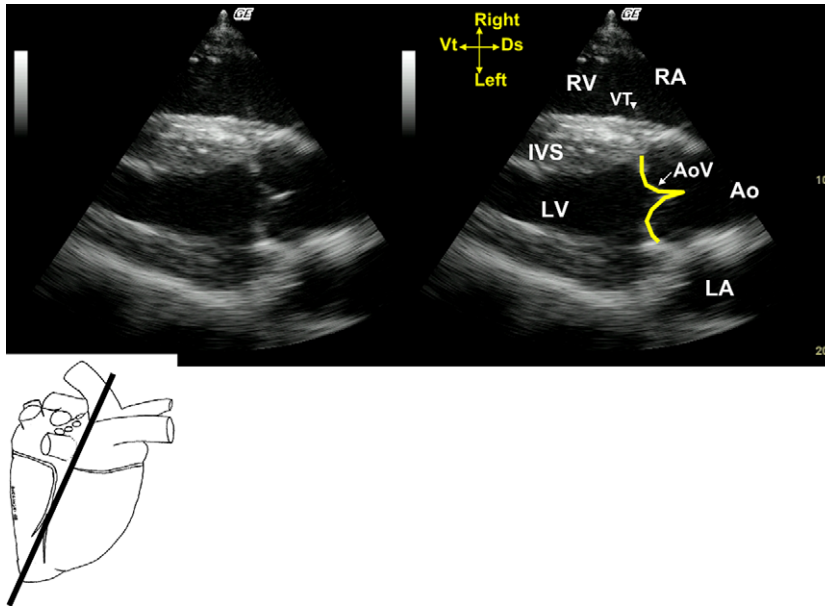

Fig. 4. Right long-axis view of the LVOT. The aortic valve is also observed and represented as a yellow line. Ao, aorta; AoV, aortic valve.

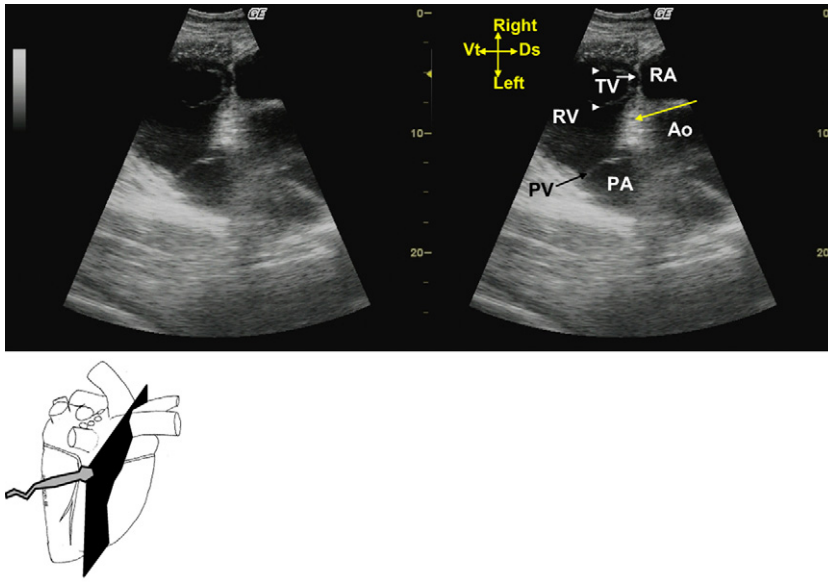

Fig. 5. Right parasternal cranial long-axis view of the right ventricular outflow on the third intercostal space. A small anechoic circular structure (*yellow arrow*), which is the coronary artery, is observed between the aorta and the right ventricle. The tendinous chordae of the tricuspid valve are also observed (*arrowheads*). Ao, aorta; Ds, dorsal; PA, pulmonary artery; PV, pulmonary valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

Holstein and Jersey cows, the normal FS range varies between 28% and 55%.[7] In other species, the FS can be used as a rough method for assessing the global inotropism and the left systolic function that can be affected by various cardiac or noncardiac diseases.[12,14–16] This calculation is useful when suspecting myocardial disease in horses.[3,14] The main echocardiographic measurements of other cardiac structures are indicated in **Table 1**.[5,7] To date, the data are currently lacking in cattle concerning the prognostic values of echocardiographic measurements or calculated parameters.

PRACTICAL APPLICATION OF ECHOCARDIOGRAPHY IN BOVINE MEDICINE

Although the clinical manifestations of heart disease may be indicative of most cardiac disorders,[1] the definitive diagnosis requires ancillary tests, such as serum biochemistry panel, complete cell blood count, blood culture, pericardiocentesis, electrocardiography, and echocardiography.[1–3] Echocardiography is a noninvasive diagnostic imaging technique that permits cowside diagnosis, which can be useful in a field setting when clinical signs are not obvious or with commercial animals to allow rapid culling or euthanasia if the diagnosis and the associated prognosis are not compatible with financial restraints or animal welfare.

The echocardiographic findings in cases of suspected heart disease include specific cardiac findings and nonspecific findings that appear secondary to congestive heart failure (eg, pleural effusion, compression of the lung).[17] The most common cardiac diseases—pericarditis, infectious endocarditis, and ventricular septal defects[1]—can be suspected on the basis of clinical findings and echocardiographic findings.

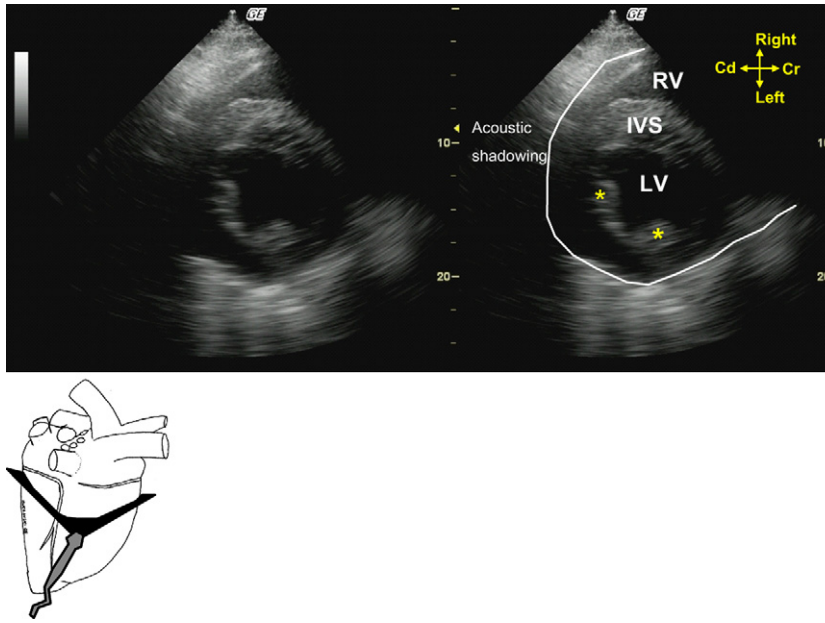

Fig. 6. Right short-axis view of the cardiac ventricles. Both ventricles are seen in transversal section. The papillary muscles of the left ventricle are observed (*), revealing the mushroom shape of the left ventricular lumen. Cd, caudal; Cr, cranial; IVS, interventricular septum; LV, left ventricle; RV, right ventricle.

Pericarditis and Pericardial Effusions

Pericarditis is the most common pericardial disorder in cattle.[1,17] Pericardial effusion is often secondary to hardware diseases and consists of a purulent effusion with varying amounts of fibrin clots.[11,17,18] Recently, idiopathic hemorrhagic pericarditis (IHP) has been mentioned as an uncommon cause of pericardial effusion with a good prognosis in cattle.[19,20] Echocardiography may help distinguish traumatic pericarditis, which has a poor prognosis, from IHP, which can be successfully treated with pericardial drainage.[17,19,20] Pericardial effusion should not be confused with bilateral pleuritis in which anomalies of the pleural space and the lung parenchyma can also be found.[14]

The main ultrasonographic finding of traumatic pericarditis is pericardial effusion, which is normally hypoechogenic to echogenic.[17] Some echoic fibrin clots can also be seen.[11,17,18,21,22] The pericardial layer, which is not seen in healthy animals, is typically seen as a thick echoic membrane surrounding the heart in cases of pericarditis (**Fig. 10**).[17] Hyperechoic points associated with a reverberation artifact can also be observed when free gas is present with septic pericardial effusion. The echocardiographic findings in cases of IHP consist of anechoic[19] to hypoechogenic[20] pericardial effusion with or without echogenic strands of fibrin.[19,20] Therefore, ultrasonographic findings may be useful in the diagnosis of idiopathic pericarditis when anechoic pericardial fluids with no echogenic fibrin clots are observed (**Fig. 11**). However, because IHP and septic pericarditis may have the same ultrasonographic aspects (ie, hypoechogenic fluid and echoic fibrin clots), the definitive diagnosis concerning the origin of pericardial effusion still needs to be confirmed by pericardiocentesis and examination of the pericardial fluid.[2,17–20]

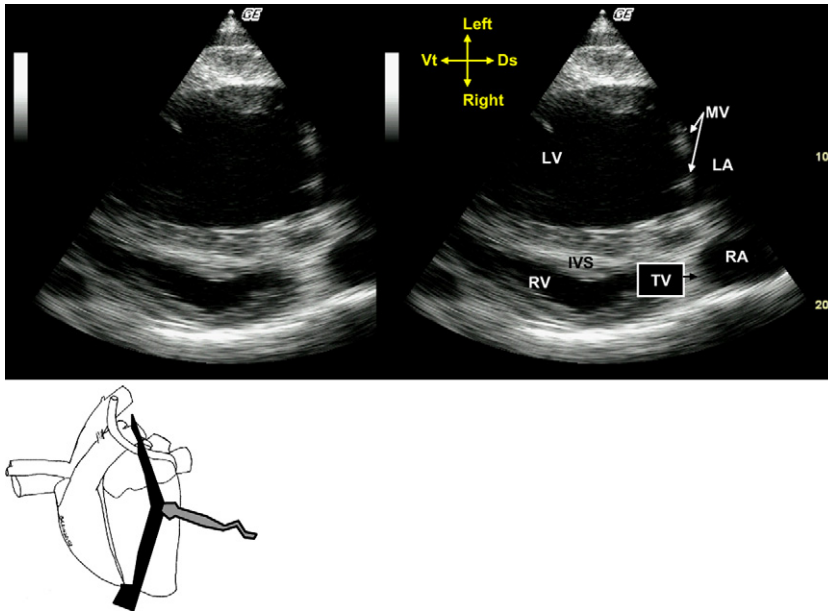

Fig. 7. Left caudal long-axis view of the heart. In this view, the four cardiac chambers are observed as well as the atrioventricular valves. Note that the tricuspid valve falsely appears thickened because the ultrasound beam crosses the valve near its attachment to the myocardium. Ds, dorsal; IVS, interventricular septum; LA, left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

In horses, depending on the clinical and echocardiographic findings, three forms of pericarditis have been described: the effusive form (leading to cardiac tamponade caused by pericardial effusion), the fibrinous form (with accumulation of fibrin in the pericardium), and the constrictive form, in which pericardial thickening reduces the diastolic filling of the heart.[23] In cattle, this classification does not exist. Pericardial effusion typically compresses the right ventricle and atrium[17,20] and the left ventricle.[17,19] This compression is particularly visible during cardiac diastole when measuring the cardiac chamber dimensions. The end diastolic ventricular volume is reduced secondary to the increased pericardial pressure, which leads to a decrease in heart preload and a decreased cardiac output partially compensated by an increased heart rate at rest.[24] Epicardial deposits of echogenic fibrin may also be a limiting factor for ventricular diastole as found in cases of effusive-constrictive pericarditis syndrome in humans.[24]

Pericardial effusion may also be observed with the occurrence of other cardiac and noncardiac diseases.[14] Various heart neoplasms can lead to an anechoic pericardial effusion, discussed below. Anechogenic pericardial effusion can also be seen in cases of hypoproteinemia, right heart failure, or viral disease in horses.[23]

Evidence-based medicine concerning the clinical impact of echocardiographic findings in cattle with pericardial effusion is still lacking. Case series demonstrated that, as in horse,[23] echocardiography can be used to observe the beneficial effects of pericardial drainage and the progression of pericardial fluid accumulation.[19,20] However, for the moment, there are no prognostic echocardiographic factors that can be used by the bovine practitioner. Echocardiography is useful to confirm the suspicion of pericardial effusion, to observe the impact of pericardial effusion on the cardiac chambers or

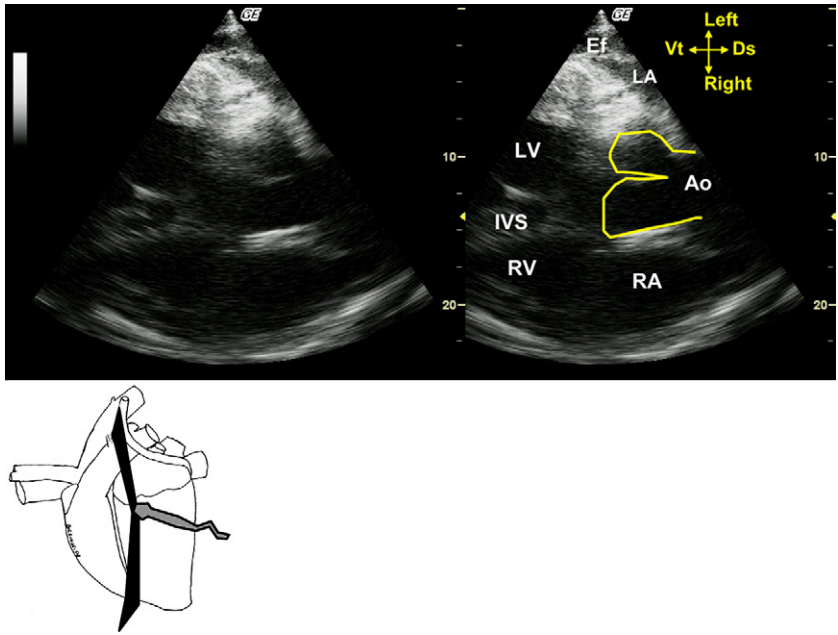

Fig. 8. Left parasternal long-axis view of the LVOT. The left atrium, left ventricle, and aorta are observed. The transversal view of the aortic valve is recognized as a thin echoic line. A small quantity of pleural effusion is also seen. Ao, aorta; Ds, dorsal; Ef, pleural effusion; IVS, interventricular septum; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle; Vt, ventral.

function, to differentiate pericardial and pleural effusion, and to help the clinician choose the optimal site of the pericardiocentesis.[11]

Bacterial Endocarditis and Endocardial Diseases

Bacterial endocarditis is the most common endocardial disease in cattle.[1,25,26] The infection most frequently involves the valvular endocardium, leading to a thickened endocardium and valvular insufficiency.[27] Clinical diagnosis of bacterial endocarditis may be difficult in the absence of heart murmur and clinical signs of heart failure.[25,26] Cardiac auscultation reveals a murmur secondary to valvular insufficiency in 50%[25] to 80%[1] of cases. Clinical signs of heart failure are not definitive in cattle.[25] The auscultation of a cardiac murmur may be heard in cases of congenital heart disease[1,28] and even in healthy cows,[29] in addition to cases of bacterial endocarditis.

Echocardiography is a sensitive diagnostic tool for cases of bovine endocarditis in studies in a hospital setting.[25,26,30,31] The sensitivity for detecting valvular thickening or vegetation in cases of bacterial endocarditis has been reported to be 75% (4 of 6 cases),[26] 95% (21 of 22 cases),[25] and 100% (in 5 cases).[31] The tricuspid valve is the valve most frequently affected by bacterial endocarditis.[25,30] The infection of more than one valve may occur in 13%[25] to 53%[30] of cases. The mural endocardium may rarely be affected.[11,25] A recent German study showed that the sensitivity of echocardiography for detecting bacterial endocarditis depended on the site of the infection.[30] Tricuspid lesions were detected in 13 of 13 cases, mitral lesions in 7 of 8 cases, pulmonary lesions in 6 of 7 cases, and aortic lesions in 2 of 4 cases.[30]

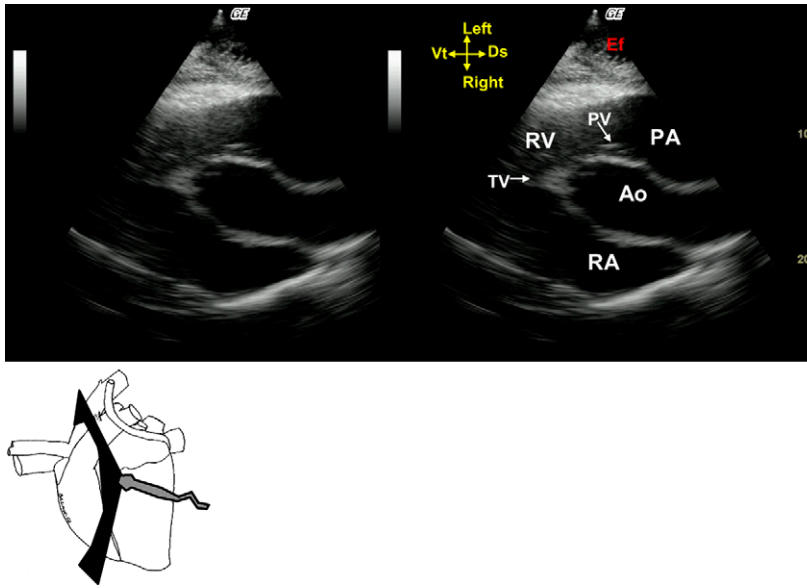

Fig. 9. Left view of the RVOT in a cow. Some pleural effusion is also seen on the left side of the thorax in this case of unilateral pleuritis. Ao, aorta; Ds, dorsal; Ef, pleural effusion; PA, pulmonary artery; PV, pulmonary valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

However, at least one abnormal valve could be diagnosed in all 15 presented cases. The specificity of echocardiographic findings for bacterial endocarditis has not been determined in cattle. This specificity should be good to excellent because of the low incidence of noninfectious valvular anomalies in cattle [32–34] and the clinical presentation of most affected patients in advanced stage of the disease with obvious changes of the affected endocardium.

Typical echocardiographic findings in cases of bacterial endocarditis include a marked irregular thickening of the affected valvular leaflet or of the mural endocardium that can confer a vegetation or a "shaggy" appearance (**Fig. 12**).[21,25,30,35,36] All heart valves should be properly imaged (**Fig. 13**). The infected endocardium is more frequently echogenic[11,21,31,35] than hyperechoic with gaseous content.[11,31] A previous study by Yamaga and Too[31] stated that valvular vegetation with a diameter of less than 5 mm could be missed by echocardiography. Valvular thickening can also occur with ruptured chordae tendineae or flail valvular leaflets in horses,[14] but such conditions are rare in cattle.[3] Valvular blood and serous cysts, which are common in bovine atrioventricular valves,[37] could also theoretically (although not reported) cause a valvular thickening; however, the cysts are small (mean diameter of 2 mm).[37]

For these reasons, when valvular thickening is observed, bacterial endocarditis should be the first diagnosis on the differential list. Secondary to the valvular deformation, regurgitant lesions leading to cardiac chamber dilation may also occur.[11,14,31] The right atrium and right ventricle may enlarge secondary to tricuspid endocarditis (see **Fig. 12**).[31]

Although information is still lacking in cattle, echocardiography has been mentioned as an beneficial ancillary tool to monitor the valvular healing of equine endocarditis.[14,38] During the healing process, the lesions tend to be smaller, smoother, and

Table 1
Echocardiographic dimensions in healthy adult cattle

	Jersey Cows (n = 10)[7]	Holstein Cows (n = 12)[7]	Swiss Braunvieh (n = 25), Simmental (n = 21), and Holstein Cows (n = 5), Total of 51 cows[5]
Parameter	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**
RVd (cm)	2.45±0.53	2.27±0.76	4.1±1.02
RVs (cm)	1.32±0.63	1.14±0.43	3.6±0.98
IVSd (cm)	2±0.4	2.2±0.51	2.4±0.33
IVSs (cm)	3.6±0.5	3.4±0.5	3.1±0.38
LVd (cm)	7.7±0.7	8.7±1.0	7.0±0.73
LVs (cm)	4.2±0.53	4.2±0.8	4.5±0.69
LAD (cm)	10.9±0.5	12±1.2	NP
Ao (cm)	5±0.26	6.4±0.62	4.9±0.92
PA (cm)	4.2±0.27	5.5±0.8	5.6±0.82
FS (%)	44.7±8.3	46.5±9.5	43.4±9.33

Ao, end-diastolic aortic diameter; FS, left ventricular fractional shortening; IVSd, end-diastolic interventricular septal thickness; IVSs, end-systolic interventricular septal thickness; LAD, left atrial diameter; LVd, end-diastolic left ventricle diameter; LVs, end-systolic left ventricle diameter; NP, not performed; PA, pulmonary artery diameter in diastole; RVd, end-diastolic right ventricle diameter; RVs, end-systolic right ventricle diameter.

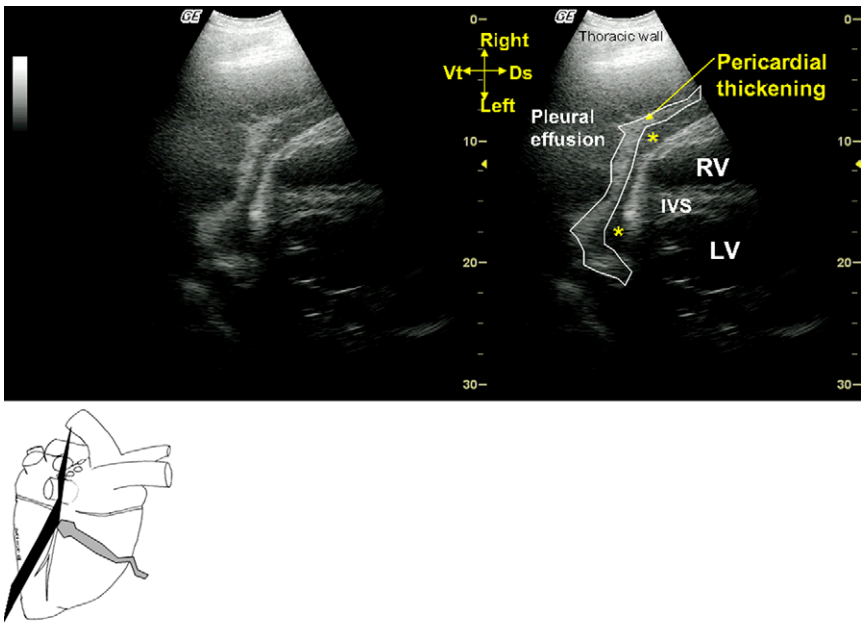

Fig. 10. Right long-axis view of the ventral part of the heart of a cow with pericarditis and pleuritis secondary to hardware disease. Pleural effusion displaced the heart dorsally. A small amount of hypoechoic pericardial effusion is observed (*). Pericardial thickening is demonstrated as an echoic line surrounding the cardiac silhouette. Ds, dorsal; IVS, interventricular septum; LV, left ventricle; RV, right ventricle; Vt, ventral.

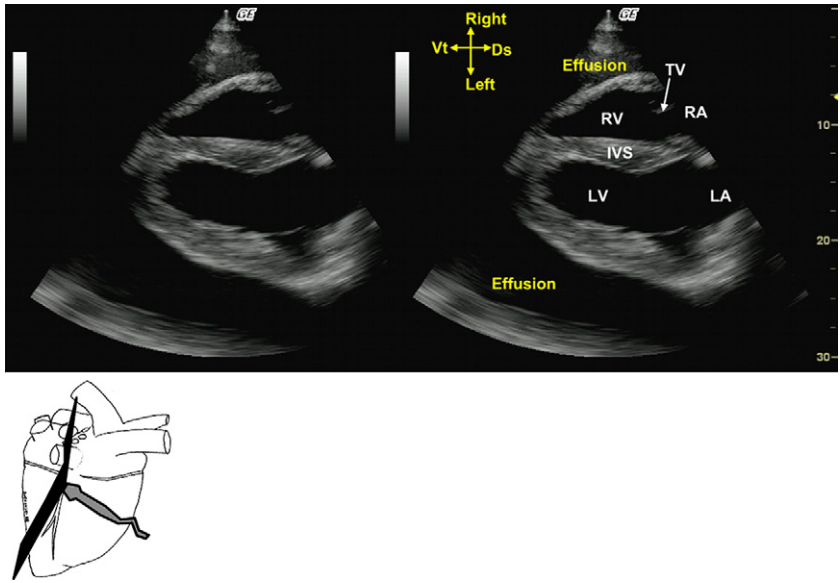

Fig. 11. Right four-chambers long-axis view of a bovine heart with anechoic pericardial effusion. An idiopathic hemorrhagic pericarditis was diagnosed after pericardial fluid analysis, the most important differential diagnosis in an anechoic pericardial effusion secondary to cardiac manifestation of a lymphoma. Ds, dorsal; IVS, interventricular septum; LA, left atrium; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

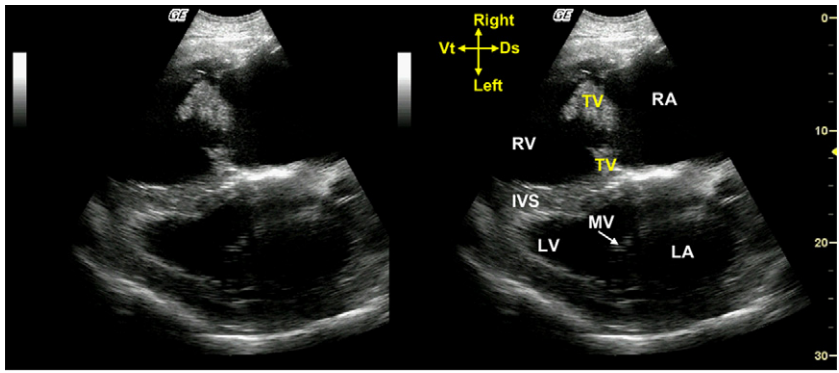

Fig. 12. Right four-chambers long-axis view of a tricuspid endocarditis in a cow. The affected valve is markedly thickened and has a "shaggy" appearance. Tricuspid regurgitation caused by valvular insufficiency led to a secondary right atrial dilation. Ds, dorsal; IVS, interventricular septum; LA, left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Vt, ventral.

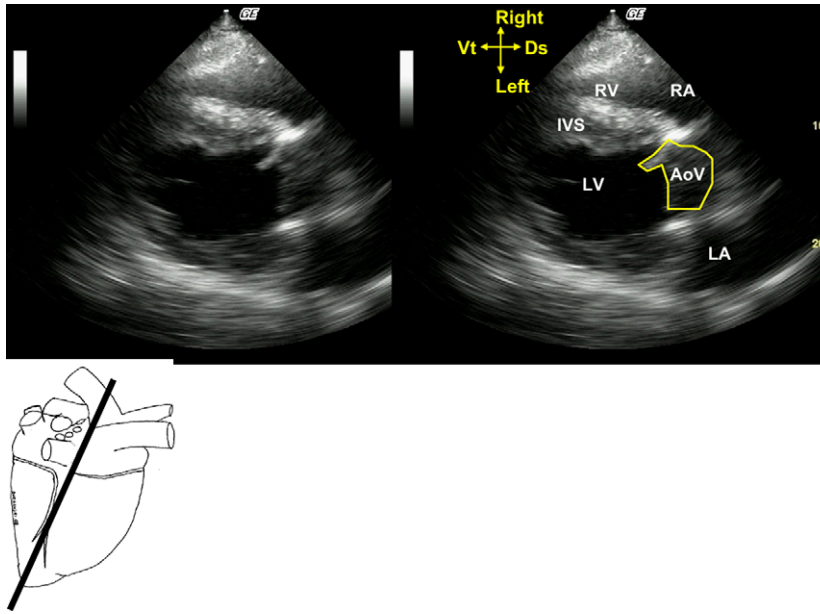

Fig.13. Right long-axis view of the LVOT of a cow with aortic endocarditis. The aortic trunk is totally obstructed by an echogenic heterogenous mass that represents the infectious vegetation. AoV, aortic valve; Ds, dorsal; IVS, interventricular septum; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle; Vt, ventral.

more echoic.[38] Echocardiography could potentially be useful in bovine cases in which therapy is attempted.

Finally, thickening and increased echogenicity of the valves has also been found in cattle as a result of experimental intoxication with *Trisetum flavescens* silage.[39] The echocardiographic findings in these cases had a specificity of 100% for detecting valvular calcifications when compared with histology.

Cardiac Neoplasms

The most common cardiac neoplasm in cattle is cardiac lymphoma in areas where the bovine leukosis virus infection has not been eradicated.[3] The typical signs of enzootic lymphoma (eg, polyadenomegaly, exophthalmos) may [40,41] or may not [42,43] be present concomitant to clinical signs of heart failure. Echocardiographic findings may be helpful in the diagnosis of cardiac lymphoma.[40–44] The nonspecific findings in cases of cardiac lymphoma include varying quantities of anechoic pericardial effusion [40,42,43] with small amounts of echoic fibrin strands.[40,41] The most striking abnormal findings are located in the right atrium, which, as in humans [44] is the most common cardiac site of primary tumor involvement.[40–43] A right atrial dilation can be observed [40,41] or masked by echocardiographic signs of cardiac tamponade due to pericardial effusion.[42] The infiltrated atrial wall, epicardium, or endocardium appears thickened.[40,42] This infiltration may lead to the observation of a luminal echogenic mass with multiple hypoechoic foci.[40,42] Still, the definitive diagnosis must be supported by isolation of neoplastic cells.[3]

Echocardiographic data concerning other types of cardiac neoplasms are scant in ruminants. An echogenic mass at the base of the heart was the main

echocardiographic finding in two cows that each had a tumor of the mediastinal fusiform cells.[26] An echogenic round mass that partially obstructed the right atrium was also found in a case of ovine cardiac fibrosarcoma.[45] In both cases, however, the final diagnosis required histologic analysis of the abnormal mass.[26,45]

Congenital Heart Disease

Congenital heart disease has been estimated to represent 2.7% of congenital problems in calves.[46] The most common bovine congenital heart disease is ventricular septal defect (VSD).[28,47] The echocardiographic findings are compatible with a septal defect in the membranous part of the interventricular septum.[28,48] As in horses, the right long-axis view of the LVOT is best for observing the defect (**Fig. 14**).[14] In cases of a subpulmonic location of the defect, the short-axis view of the interventricular septum between the LVOT and RVOT may also be helpful.[3] Although the size of the defect ($\leq$2.5 cm) and the peak velocity of shunt flow ($\geq$4 m/s) through the VSD (assessed by Doppler ultrasound) have been mentioned as positive prognostic factors in horses with VSD,[49] this information is still lacking in cattle.[28,32] However, the direction of blood flow across the defect is important for suspecting an inversion of the shunt associated with pulmonary hypertension, also called Eisenmenger's complex, which has a poor prognosis.[28,50] The direction of the blood across the defect can be assessed by Doppler ultrasound or by the bubble test.[3,51] The bubble test is simple contrast echocardiography that allows a view of the repartition of a bolus of agitated sterile saline solution injected via the jugular vein during the cardiac cycle.[51] The injected solution increases the echogenicity of the blood in the right heart, which helps to see if the blood in the right heart can be found in the left heart chambers (ie, if an

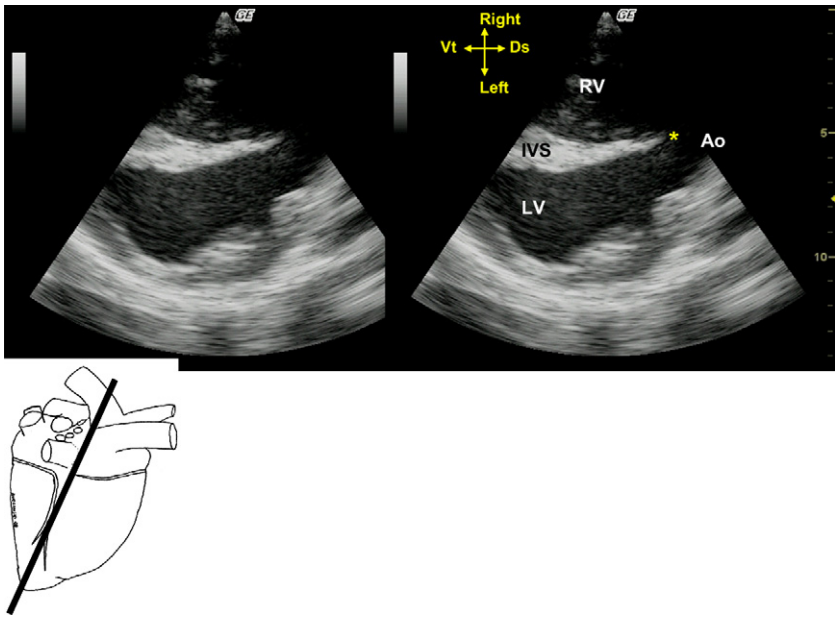

Fig. 14. Right long-axis view of the LVOT in a calf presenting with a pansystolic murmur heard maximally on the right side of the thorax. The membranous part of the interventricular septum is lacking (*), which is diagnostic of VSD. Ao, aorta; Ds, dorsal; IVS, interventricular septum; LV, left ventricle; RV, right ventricle; Vt, ventral.

intracardiac right-to-left shunt is present). Other echocardiographic findings in cases of VSD consist of left atrial, left ventricular, and right ventricular enlargement, and pulmonary artery dilation.[3,28]

Other congenital anomalies have also been diagnosed by echocardiography.[32,34,52–58] The tetralogy of Fallot found in a VSD—dextroposition of the aorta, right ventricular hypertrophy, and pulmonary stenosis—can be imaged with cardiac ultrasonography.[32,52–54] The other, rarer congenital heart diseases may also be imaged; however, their diagnosis may be difficult if not performed by a specialist in echocardiography.[52,55–58]

Cor Pulmonale

Cor pulmonale is represented by right ventricular hypertrophy or right heart failure secondary to pulmonary hypertension that can be caused by high altitude or chronic lung disease.[3,59,60] Echocardiographic findings in two cows were nonspecific.[59] The pulmonary artery was enlarged when compared with the aorta in equine cases of cor pulmonale.[61,62] A pulmonary insufficiency was also noted with Doppler ultrasound.[61,62] Right ventricular and atrial dilation may also be observed, leading to a tricuspid insufficiency.[62] However, information is still lacking concerning the real clinical use of echocardiography in detecting this disease in cattle.

Other Cardiac Diseases

Myocarditis and cardiomyopathy can also be encountered in cattle.[3] However, the data are scant concerning their echocardiographic manifestations.[21,41,50,63,64] The echocardiographic findings in cases of dilated cardiomyopathy include a reduced[21,41] to normal[63] FS. The right cardiac chambers are classically enlarged with [41,63] or without[21] left heart dilation. The right heart dilation may lead to tricuspid regurgitation.[63]

The echocardiographic findings in cases of bovine myocarditis have been limited to abscessation of the myocardium.[64] The abscesses were observed as anechoic lesions in the myocardium.[64] The localization of the abscess in the heart is important because they can be missed when performing standard echocardiograms.[50]

PRACTICAL ULTRASONOGRAPHY OF THE VASCULAR SYSTEM

Vascular ultrasonography can be helpful in the noninvasive diagnosis of vascular disease when clinical signs are insufficient to make a diagnosis and also for deep vessel assessment.[3,14,65] The technique for the ultrasonographic examination of the main vessels in cattle has been described, including the jugular,[66,67] mammary,[68] tarsal,[69] caudal vena cava,[70] ovarian and vaginal,[71] and musculophrenic veins.[72] Information is also available for the aorta,[39,73] carotid,[66] uterine,[74] and caudal arteries.[75] The normal findings of venous ultrasonography include a thin echogenic wall with anechoic content (**Fig. 15**).[11,65,66] The superficial vein diameter and appearance can be affected by how much pressure is applied to the probe.[11,65,66] Venous valves can also be observed as thin echoic to hyperechoic lines in the vascular lumen (see **Fig. 15**).[65,68] The ultrasonographic appearance of arteries is grossly the same except for a small variation in diameter between the systolic and diastolic phases of the cardiac cycle—the arterial wall is thicker than the venous wall, arteries are less deformable than the superficial veins, and no valvulae are observed in their lumen.[14,65] If the Doppler function is available, blood flow can be assessed when performing ultrasonography (see **Fig. 15**). The main vascular diseases in cattle include inflammation of the vessel wall, thrombosis, and aneurysm.[3,11,14]

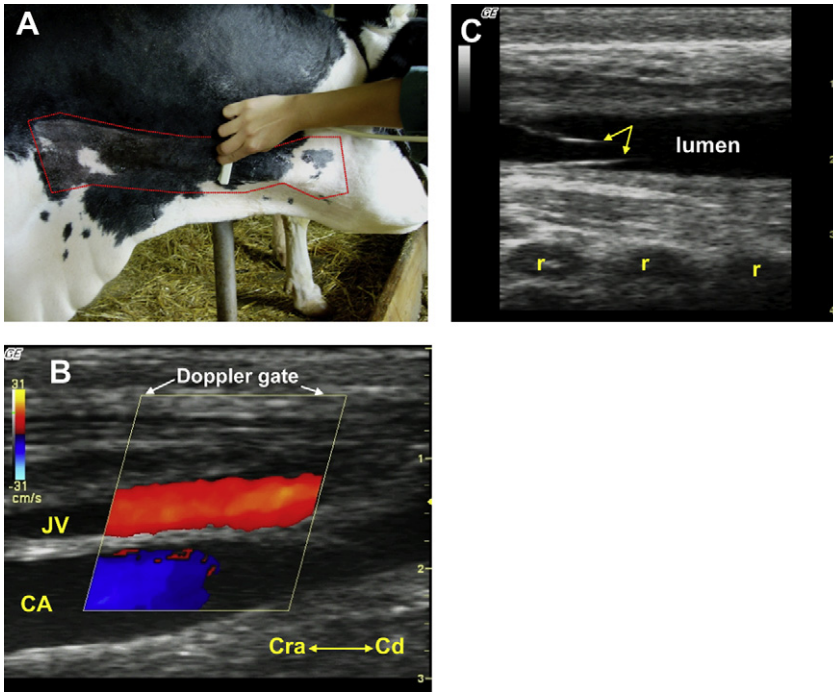

Fig. 15. Ultrasonographic findings of the jugular vein and the carotid artery region in cows. The cow is restrained with a lateral extension of the neck to perform the examination (*A*). If this procedure is performed in a calf, the examination can be performed with the animal in lateral recumbency. Normal findings (*B*) include visualization of the superficial jugular vein and the carotid artery. The jugular vein is a compressible tubular structure with a thin echoic wall and anechoic content; thin echoic lines can be observed in the lumen of the vessel and are compatible with venous valves (*C*; *yellow arrows*). When the color flow Doppler is available (*B*), it shows the opposite laminar blood flow direction in both vessels. CA, carotid artery; Cd, caudal; Cra, cranial; JV, jugular vein, r, tracheal ring.

Phlebitis and Thrombophlebitis

The ultrasonographic appearance of periphlebitis, phlebitis, and thrombophlebitis of the jugular [67,76–78] and limb [69,79,80] vessels have been described in cows. Periphlebitis (inflammation of perivenous tissues) is accompanied by multiple hypoechoic areas compatible with interstitial fluid and necrotic content (**Fig. 16**).[76] In cases of phlebitis, the venous wall is thickened and the echoic intima is difficult to observe. Phlebitis and periphlebitis are often observed together as a consequence of irritant perivascular injections (see **Fig. 16**).[11,14] Thrombosis and thrombophlebitis are characterized by the observation of a luminal hypoechoic to echoic mass that totally or partially occludes the affected vessel (**Fig. 17**). Although most of time the thrombus has a homogeneous echogenicity,[67,77] some anechoic areas can also be seen within the thrombosed area, especially in mature thrombus.[80] A cavitating lesion with anechoic content is a frequent finding in septic thrombophlebitis in horses,[81] but has not been reported in cattle.[67,77,79,80] Transcutaneous ultrasound is a reliable tool to assess the precise extent of the thrombus[69,79,80] as well as recanalization in the healing thrombosed area if Doppler ultrasound is available (see **Fig. 17**).[81] Ultrasound-guided puncture biopsy of the thrombus can also be safely done for diagnostic

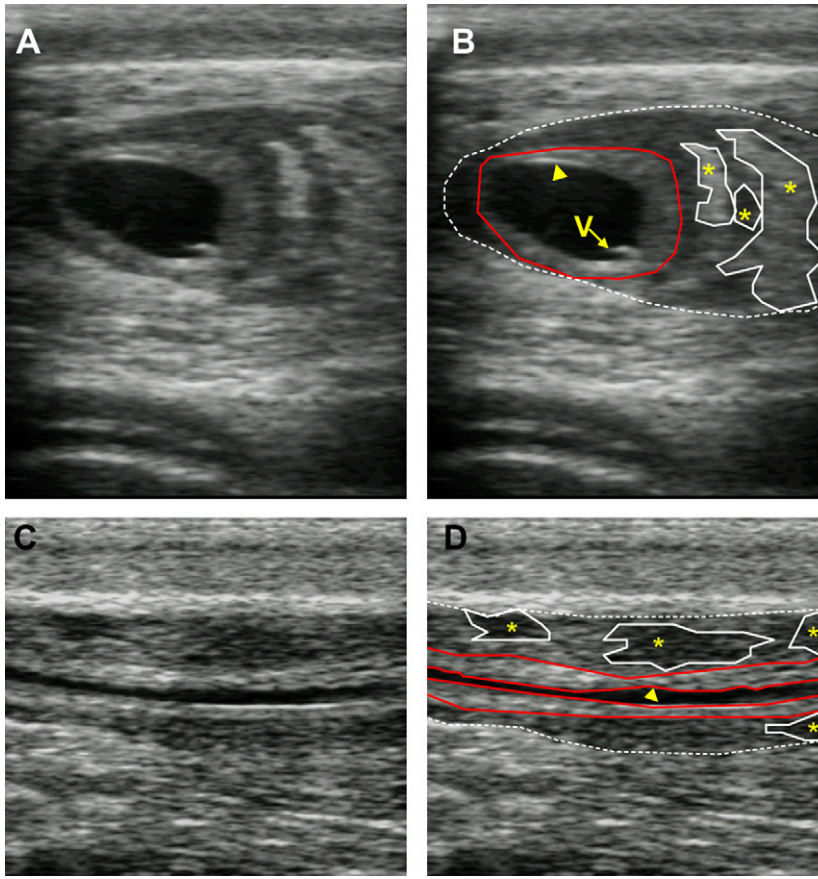

Fig. 16. Transverse (*A*, *B*) and longitudinal (*C*, *D*) ultrasonograms of the jugular vein of a cow with periphlebitis and phlebitis secondary to perivascular dextrose injection by the owner. The anechoic venous lumen is observed with (*A*, *B*) or without (*C*, *D*) distal manual compression. The vascular wall is thickened (*continuous red line*). The thin echoic intima (*arrowhead*) is discontinued. Anechoic or hyperechoic areas (*) are observed in the swollen perivascular tissues (*dotted line*). A venous valve (V) is also observed.

or therapeutic purposes.[81] Thrombi have also been observed in the ovarian and vaginal veins, and in the caudal vena cava[82–84] and the hepatic vein.[84] To date, no information is available concerning the use of ultrasonography other than for diagnostic purposes.

Arterial Thrombosis

Arterial thrombosis is a rare event that can occur as a result of various inflammatory processes (**Fig. 18**).[3] Ultrasonographic findings of arterial thrombosis have been described in distal aortic thrombosis in calves.[73] They are the same as for venous thrombosis, including a hypoechoic to echoic area that partially to totally obstructs blood flow. Ultrasonography can be an interesting tool in monitoring thrombus size reduction.[73] The color-flow Doppler is also an interesting tool for assessing blood flow across the thrombosed area.[73]

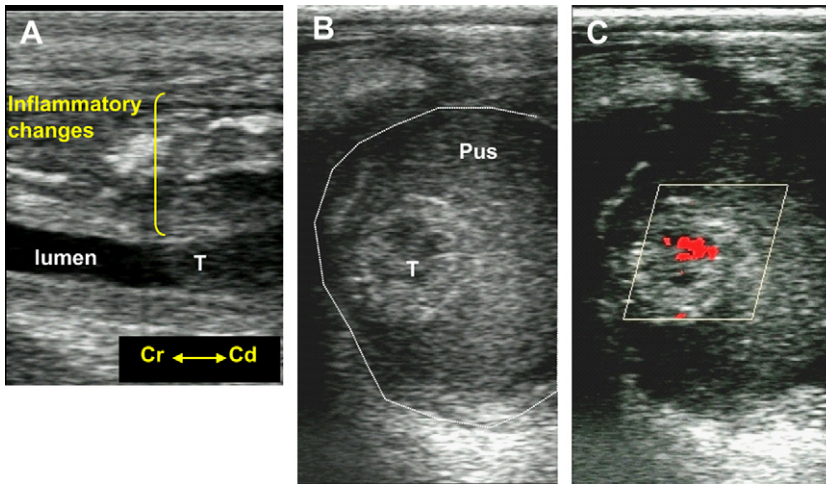

Fig. 17. Ultrasonographic appearance of chronic jugular thrombophlebitis in an adult Holstein cow. (*A*) The longitudinal view of the jugular vein shows a hypoechoic thrombus (T) that totally obstructs the venous lumen. The peripheral venous tissues are swollen with echoic to hyperechoic content. (*B*) As the beam is relocated from the mandible to the thorax and rotated perpendicular to the vessel, a cavitary lesion (*dotted line*) is observed in periphery of the vein. This cavitary lesion has heterogenic content that is similar to pus. (*C*) Doppler interrogation of the thrombosed area shows laminar flow throughout the thrombus (*red area*) compatible with recanalization of the thrombosed area by new vessels.

Other Vascular Diseases

The ultrasonographic findings of other vascular diseases have been described in cases of portacaval shunt in calves,[85] calcification of blood vessels secondary to experimental *Trisetum flavescens* silage feeding in cows,[39] patent ductus venosus,[86] and aneurysm of the ductus arteriosus in a heifer.[87] Although the data are limited to case reports or case-series concerning the use of ultrasonography in cattle, the

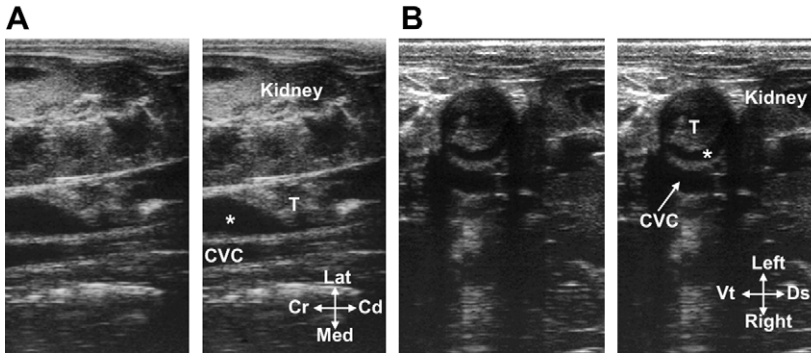

Fig. 18. Transabdominal ultrasonographic findings in a calf with distal aortic thrombosis. The calf was placed in right lateral recumbency. The thrombus is seen in longitudinal (*A*) and transversal (*B*) views and almost totally occupies the aortic lumen (*) near the left kidney. The caudal vena cava is also observed. Cd, caudal; Cr, cranial; CVC, caudal vena cava; Ds, dorsal ; Lat, lateral; Med, medial; T, thrombus; Vt, ventral.

vascular ultrasonography potentially may help in the diagnosis and management of many vascular diseases.[14,65] The Doppler vascular assessment, which is not discussed in this review, has shown promising results in cattle, especially for the genital tract.[74,88–90]

In conclusion, ultrasonography can be of tremendous help in the management of cardiovascular disease in cattle. In most cases, cardiovascular ultrasonography permits an antemortem diagnosis that can be especially useful in cases with a poor prognosis to avoid ineffective treatment. This early diagnosis can also be helpful in highly valuable animals by allowing an earlier therapeutic attempt and for monitoring the healing process.

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