Echocardiography of the normal bovine heart: technique and ultrasonographic appearance

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Fifty-one clinically healthy cows were examined ultrasonographically from the third and fourth intercostal spaces on both sides of the thorax. A 3·0 MHz transducer was used and the heart was examined in the caudal long, caudal short and cranial long axes on the right side, and in the caudal and cranial long axes on the left side. In each position the optimal transducer orientation and the images of the structures were recorded. In the caudal long axis view of the heart on the right (transducer positioned at the fourth intercostal space), all four chambers were visible with the transducer positioned 8 to 10 cm dorsal to the level of the olecranon. The left ventricular outflow tract, consisting of the aortic valve and ascending aorta, were visible in the same position with the transducer rotated 10 to 40° clockwise. In the caudal short axis view of the heart on the right, the left and right ventricles were visible in cross-section with the transducer held at right angles to the ribs in the fourth intercostal space, 3 to 6 cm dorsal to the olecranon and tipped slightly dorsally. In the cranial long axis view of the heart on the right, the right ventricular outflow tract, consisting of the pulmonary valve and pulmonary artery, was visible in the third intercostal space, 8 to 10 cm dorsal to the olecranon with the transducer angled craniodorsally and rotated 10 to 20° clockwise. In the caudal long axis view of the heart on the left, the left and right ventricles and the left ventricular outflow tract were visible with the transducer placed in the fourth intercostal space. In the cranial long axis view on the left, the right ventricular outflow tract was visible.

ECHOCARDIOGRAPHY has not been studied as extensively in cattle as in small animals and horses. Fundamental studies have been made in calves (Amory and Lekeux 1991, Amory and others 1991, 1992), but there have been few studies in healthy adult cattle (Pipers and others 1978a, Yamaga and Too 1986). Echocardiographic examinations have been made of cows with endocarditis (Pipers and others 1978b, Lacuata and others 1980, Yamaga and Too 1987), pericarditis (Yamaga and Too 1986, Möller 1997), cardiomyopathy (Yamaga and Too 1986), leukosis (Yamaga and Too 1986) and congenital anomalies (Pipers and others 1985, Hagio and others 1987, 1989). Pipers and others (1978a) examined 15 healthy cows by A and M mode echocardiography and Yamaga and Too (1986) used M mode to examine 15 healthy cows for comparative purposes. The goal of this paper is to describe a method for the ultrasonographic imaging of the bovine heart and to illustrate the appearance of the images obtained by using different transducer positions and orientations.

MATERIALS AND METHODS

Animals

Fifty-one clinically healthy adult cows were used. There were 25 Swiss braunvieh, 21 Simmental and five Holstein cows. Their ages ranged from two to 10 years and they weighed between 390 and 746 kg.

Echocardiography

The ultrasonographic examinations were made while the cows were standing, by the method described by Schweizer (1998), using a 3·0 MHz phased array transducer (Ultramark 9; Advanced Technology Laboratories) in 2-D mode. An area of hair, 15 cm x 15 cm, over the third, fourth and fifth intercostal spaces in the cardiac region was clipped on both sides of the thorax. The region was cleaned with 70 per cent alcohol and covered with contact gel. The heart was then examined ultrasonographically on the right and then the left side with the transducer in five of the eight positions described for the horse (Carlsten 1987, Stadler and others 1988). These positions were the caudal long, caudal short and cranial long axes on the right side, and the caudal long and cranial long axes on the left side. The caudal and cranial axes were examined from the fourth and third intercostal spaces, respectively. At each examination site a record was made of the transducer position and orientation, the structures imaged were identified, and all the images were recorded on video.

Postmortem examination

All the cows were slaughtered at the end of the study and their hearts were examined macroscopically.

RESULTS

It was possible to examine the heart of each of the 51 cows with the transducer in all five positions.

Caudal long cardiac axis (right side)

In the caudal long axis on the right side, the four chambers of the heart (four-chamber view) and the left ventricular outflow tract (ascending aorta and aortic valve) could be imaged from the fourth intercostal space.

Four-chamber view For the image of the four cardiac chambers (Fig 1), the transducer was placed in the fourth intercostal space, 8 to 10 cm dorsal to the level of the olecranon, held parallel to the ribs and directed slightly craniodorsally. In this position, the right ventricle was visible in all of the cows, the tricuspid valve in 43 and the right atrium in 39 (Table 1). The interventricular septum was medial to the right ventricle. The left ventricle was visible in all of the cows, the mitral valve in 43 and the transition to the left atrium in 35.

Left ventricular outflow tract To image the left ventricular outflow tract, the transducer was originally positioned as for the four-chamber view, but was then turned slightly cranially and rotated 10 to 40° clockwise. From lateral to medial, the thoracic wall and right ventricle were visible in 50 cows, the tricuspid valve in 43, the interventricular septum and left ventricle in 51, and the aortic valve and ascending aorta in 42 of the cows (Fig 2, Table 1).

Caudal short axis view of the heart (right side)

In the caudal short axis of the heart on the right side, the right and left ventricles were visible in cross-section. The transducer

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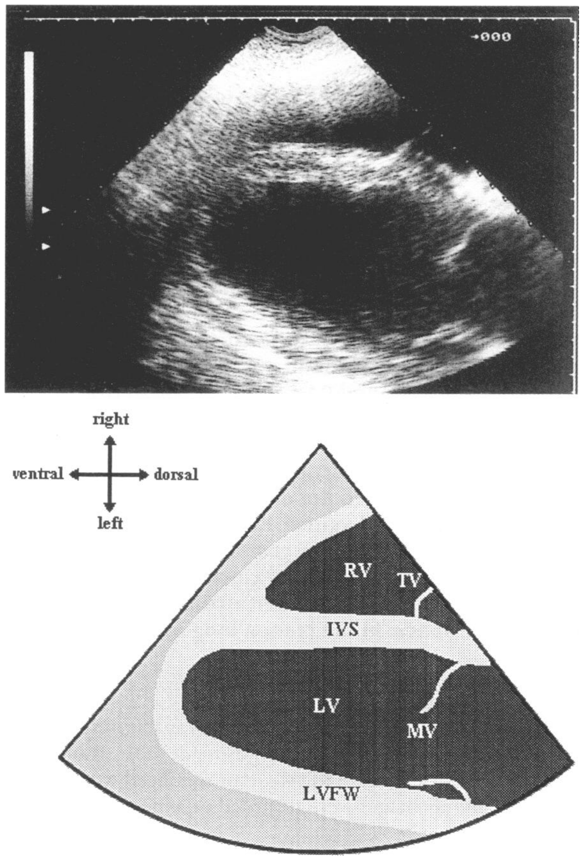


FIG 1: 2-D echocardiogram and schematic representation of the four chambers of the heart during diastole in a cow; caudal long axis of the heart, right side. The transducer was directed craniodorsally and held in the fourth intercostal space on the right side, 8 cm dorsal to the olecranon. The tricuspid and mitral valves are open. RV Right ventricle, TV Tricuspid valve, IVS Interventricular septum, LV Left ventricle, MV Mitral valve, LVFW Left ventricular free wall

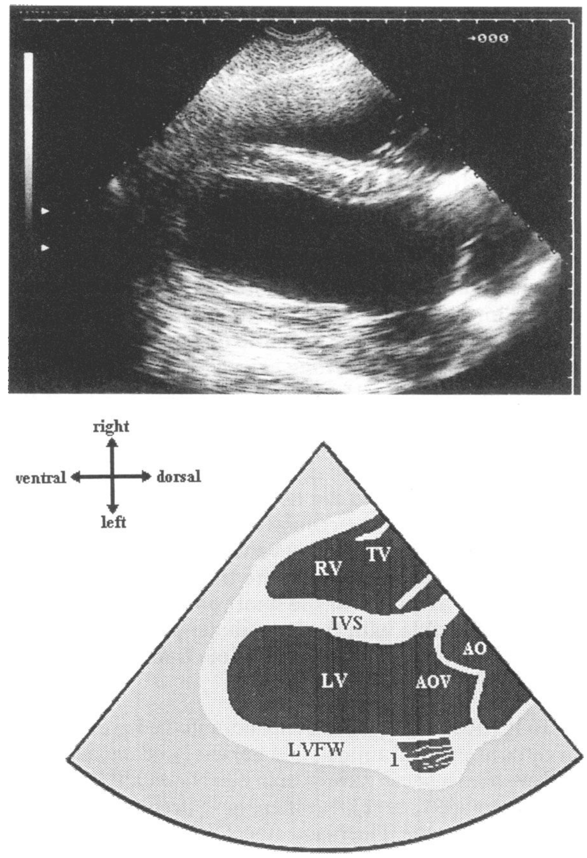


FIG 2: 2-D echocardiogram and schematic representation of the left ventricular outflow tract during diastole in a cow; caudal long axis of the heart, right side. The transducer was directed cranially, rotated 20° clockwise, and held in the fourth intercostal space, 8 cm dorsal to the olecranon on the right side. The tricuspid valve is open and the aortic valve is closed. RV Right ventricle, TV Tricuspid valve, IVS Interventricular septum, LV Left ventricle, AOV Aortic valve, AO Aorta, LVFW Left ventricular free wall, 1 Papillary muscles

was placed in the fourth intercostal space, 3 to 6 cm dorsal to the level of the olecranon, and held at right angles to the ribs and tipped slightly dorsally. In all of the cows, the right ventricle, interventricular septum and left ventricle with its papillary muscle were visible from lateral to medial (Fig 3, Table 1).

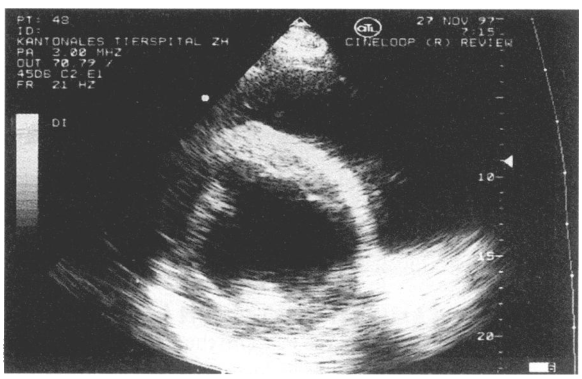
Cranial long axis view of the heart (right side)

To image the right ventricular outflow tract, consisting of the pulmonary artery and valve, from the right side, the transducer was held parallel to the ribs in the third intercostal space, 8 to 10 cm dorsal to the level of the olecranon. The transducer was angled craniodorsally and then rotated clockwise 10 to 20°. The right atrium, tricuspid valve, right ventricle and right ventricular outflow tract were visible in 17, 38, 41 and 37 of the cows, respectively (Fig 4, Table 1).

Caudal long axis view of the heart (left side)

The ultrasonographic examination of the caudal long axis of the heart from the left side revealed the left and right ventricles and the left ventricular outflow tract.

Two chamber view To image the left and right ventricles, the transducer was held parallel to the ribs in the fourth intercostal space, 5 to 10 cm dorsal to the level of the olecranon, and turned slightly caudodorsally. Immediately adjacent to the wall of the thorax, the left ventricle, the mitral valve and a small part of the left atrium were imaged in 47, 42 and 33 of the cows, respectively (Fig 5, Table 1). Further medially, the interventricular septum and right ventricle, the tricuspid



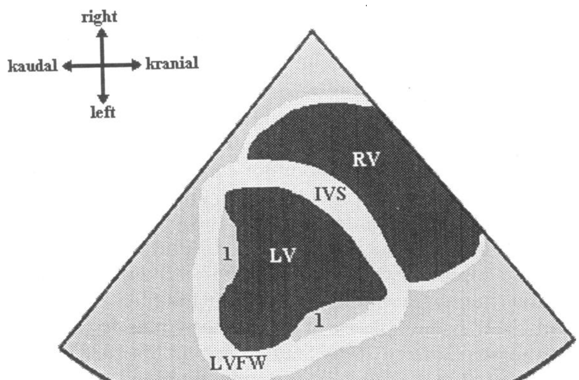


FIG 3: 2-D echocardiogram and schematic representation of the right and left ventricles during diastole in a cow; caudal short axis of the heart, right side. The transducer was directed slightly dorsally, rotated 90° clockwise, and held in the fourth intercostal space, 4 cm dorsal to the olecranon on the right side. RV Right ventricle, IVS Interventricular septum, LV Left ventricle, LVFW Left ventricular free wall, 1 Papillary muscles

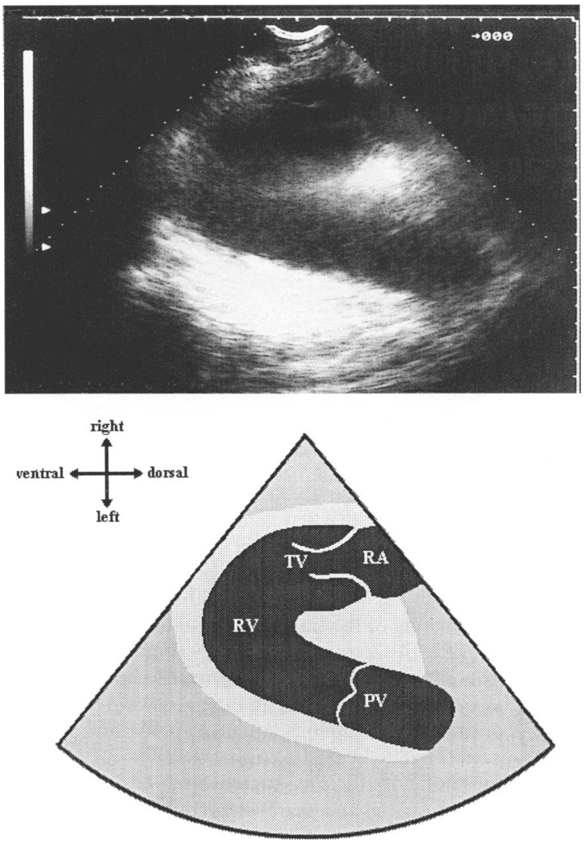


FIG 4: 2-D echocardiogram and schematic representation of the right ventricular outflow tract during diastole in a cow; cranial long axis of the heart, right side. The transducer was directed craniodorsally, rotated 10° clockwise, and held in the third intercostal space, 9 cm dorsal to the olecranon on the right side. The tricuspid valve is open and the pulmonary valve is closed. RA Right atrium, TV Tricuspid valve, RV Right ventricle, PV Pulmonary valve

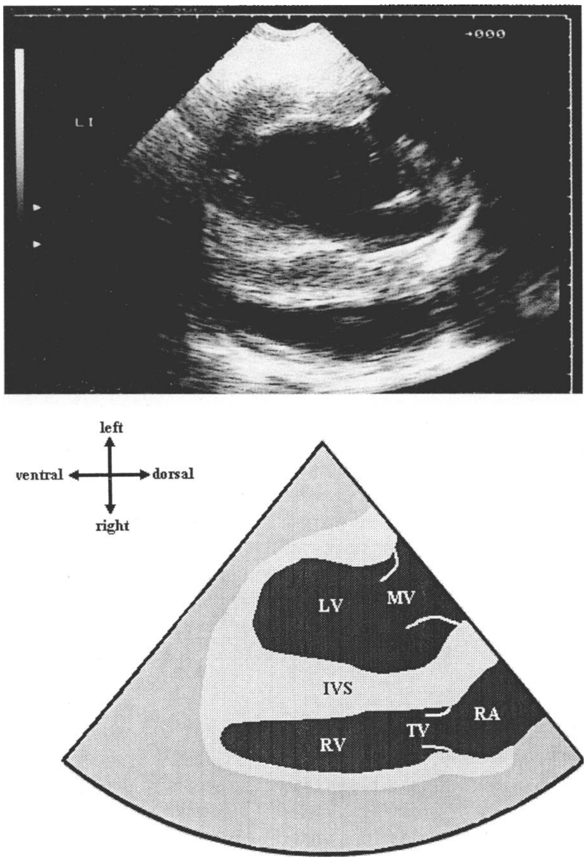


FIG 5: 2-D echocardiogram and schematic representation of the two chamber view during diastole in a cow; caudal long axis of the heart, left side. The transducer was directed slightly caudodorsally while being held in the fourth intercostal space, 7 cm dorsal to the olecranon on the left side. The mitral and tricuspid valves are open. LV Left ventricle, MV Mitral valve, IVS Interventricular septum, RV Right ventricle, TV Tricuspid valve, RA Right atrium

valve and the right atrium were visible in 46, 47, 40 and 33 of the cows, respectively.

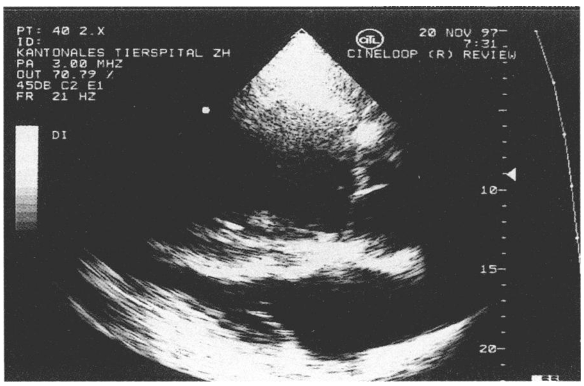
Left ventricular outflow tract To image the left ventricular outflow tract, consisting of the aortic valve and ascending aorta, the transducer was first positioned as described for the view of the left and right ventricles on the left side, but was then turned slightly cranially and rotated 10° anticlockwise. Immediately adjacent to the wall of the thorax, the left ventricle, the aortic valve and the aorta were imaged in 48, 43 and 43 of the cows, respectively. Further medially, the interventricular septum, right ventricle, tricuspid valve and right atrium were visible in 46, 47, 40 and 33 of the cows, respectively (Fig 6, Table 1).

Cranial long axis view of the heart (left side)

In the cranial long axis of the heart, the right ventricular outflow tract, consisting of the pulmonary artery and valve, were imaged. For this, the transducer was held parallel to the ribs in the third intercostal space on the left, 3 to 6 cm dorsal to the level of the olecranon, and turned slightly craniodorsally. Immediately adjacent to the left wall of the thorax, the pulmonary artery and valve were visible in 49 cows (Fig 7, Table 1). Further medially, the right ventricle, tricuspid valve and right atrium were visible in 49, 26 and 15 of the cows, respectively. An oblique section of the aorta was visible in 42 cows.

Postmortem examination

No epicardial, myocardial or endocardial lesions were observed in any of the cows. In one cow there was a cyst, 1·5



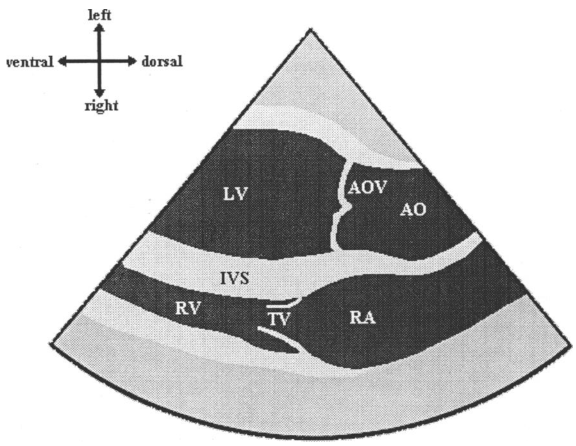


FIG 6: 2-D echocardiogram and schematic representation of the left ventricular outflow tract during diastole in a cow; caudal long axis of the heart, left side. The transducer was directed slightly cranially, rotated 10° anticlockwise, and placed in the fourth intercostal space, 8 cm dorsal to the olecranon on the left side. The aortic valve is closed and the tricuspid valve is open. LV Left ventricle, AOV Aortic valve, AO Aorta, IVS Interventricular septum, RV Right ventricle, TV Tricuspid valve, RA Right atrium

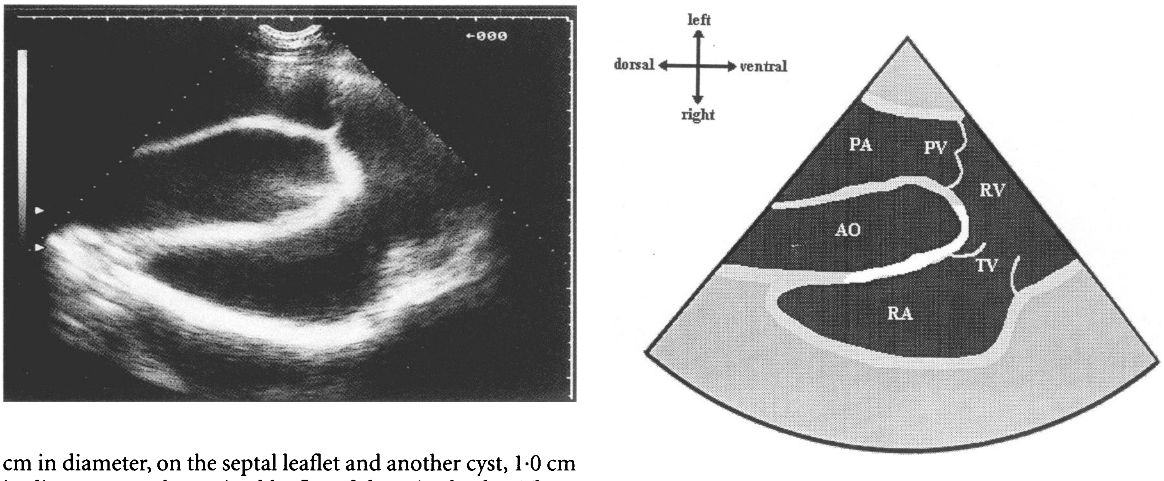


FIG 7: 2-D echocardiogram and schematic representation of the right ventricular outflow tract during diastole in a cow; cranial long axis of the heart, left side. The transducer was directed slightly craniodorsally and held in the third intercostal space, 5 cm dorsal to the olecranon on the left side. The pulmonary valve is closed and the tricuspid valve is open. PA Pulmonary artery, PV Pulmonary valve, RV Right ventricle, TV Tricuspid valve, RA Right atrium, AO Aorta

cm in diameter, on the septal leaflet and another cyst, 1·0 cm in diameter, on the parietal leaflet of the mitral valve. These cysts were not observed during the ultrasonographic examination. However, on a review of the video tape, the cyst on the parietal leaflet was visible in the caudal long axis view on the right side and the cyst on the septal leaflet was observed in the caudal long axis view on the left side. They appeared as hyperechogenic structures with an anechoic content.

DISCUSSION

Although it was possible to image the hearts of all of the cows, the quality of the images varied. This variation was attributable to a variety of factors, including body condition, the width of the intercostal spaces, the demeanour of the cow and the strength of the examiner. Attenuation of the ultrasound beam by reflection and absorption caused significant deterioration of the image in cows with thick thoracic walls. Narrow intercostal spaces resulted in poor contact with the transducer, and rotation or turning of the transducer resulted in reflection of the waves by the ribs, causing further deterioration. It was difficult to obtain consistent images in restless cows. Physical strength was required when examining the cows in both of the cranial positions and sometimes in the caudal position when the transducer had to be pushed under the elbow of cows that would not stand with their leg stretched forward.

The atria, ventricles and heart valves could be imaged in the majority of the cows. Exceptions included cows in which the lungs extended far cranially and obscured the atria. Imaging

TABLE 1: Optimal position of the transducer for ultrasonographic imaging of the heart in five different axes

Axis	ICS	Transducer position	Transducer direction	Transducer rotation	Definition of area imaged	Structures visualised	Per cent of cows in which visualisation was possible
Right caudal long axis	4	8-10 cm dorsal to olecranon	Slightly cranio-dorsally	0°	Four chamber view	Right ventricle, tricuspid valve, right atrium, left ventricle, mitral valve, left atrium	+++ ++ ++ +++ ++ +
			Slightly cranially	10-40°	Left ventricular outflow tract	Right ventricle, tricuspid valve, left ventricle, aortic valve, aorta	+++ ++ +++ ++ ++
Right caudal short axis	4	3-6 cm dorsal to olecranon	Laterolaterally to slightly dorsal	90°	Right and left ventricles in cross-section	Right ventricle, left ventricle	+++ +++
Right cranial long axis	3	8-10 cm dorsal to olecranon	Craniodorsally	10 to 20°	Right ventricular outflow tract	Right ventricle, pulmonary valve, pulmonary artery, tricuspid valve, right atrium	++ + + + (+)
Left caudal long axis	4	5-10 cm dorsal to olecranon	Slightly caudo-dorsally	0°	Two chamber view	Left ventricle, mitral valve, left atrium, right ventricle, tricuspid valve, right atrium	+++ ++ + +++ ++ +
			Slightly cranially	−10°	Left ventricular outflow tract	Left ventricle, aortic valve, aorta, right ventricle, tricuspid valve, right atrium	+++ ++ ++ +++ ++ +
Left cranial long axis	3	3-6 cm dorsal to olecranon	Slightly cranio-dorsally	0°	Right ventricular outflow tract	Right ventricle, pulmonary valve, pulmonary artery, tricuspid valve	+++ +++ +++ (+)

ICS Intercostal space
+++ 91 to 100 per cent, ++ 76 to 90 per cent, + 50 to 75 per cent, (+) less than 50 per cent

the cardiac structures was difficult in cows with narrow intercostal spaces. This limitation has also been reported in horses (Vörös and others 1991). These findings in the cow were similar to those in horses by Carlsten (1987), who reported that the right side of the heart could be visualised better from the right side than the left side, but that the left side of the heart could be imaged equally well from either side. The only exception was that in the cranial long axis the pulmonary valve was best imaged from the left side. This result agrees with the findings of Yamaga and Too (1984), who also described the imaging of the cardiac valves. Although they described the transducer position and something of the orientation required for optimal imaging, they omitted a description of the angle of rotation of the transducer and the direction in which it should be turned. They also reported that the fourth intercostal space was suitable for imaging the pulmonary valve, whereas in this study it could be imaged only from the third intercostal space.

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First confirmed native case of bovine spongiform encephalopathy in Denmark

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BOVINE spongiform encephalopathy (BSE) is a fatal transmissible neurological disorder of cattle which is associated with accumulation of protease-resistant prion protein (PrP^{res}). The disease was first identified in 1986 in England (Wells and others 1987). The most common cause of infection is considered to be consumption of infectious feedingstuffs due to the presence of ruminant-derived protein originating from diseased animals (Wilesmith and others 1988).

Since BSE was first described, more than 170,000 cases have been diagnosed in the UK, and some countries have reported cases of BSE in cattle imported from the UK. Several native cases have been reported from a number of European countries including the Republic of Ireland, France, Belgium, Switzerland, Liechtenstein, Luxembourg and Portugal (OIE 2000). In 1992, a case of BSE in a cow originally imported from the UK was diagnosed in Denmark. It was established that before export the cow had access to meat and bone meal containing ruminant protein, and it was concluded that the cow was infected before importation to Denmark (Agerholm and others 1993). Since May 1996, all cattle imported from the UK have been incinerated when leaving production. Since April 1997, all animals imported from the UK were, following slaughter, examined for BSE by histopathological examination at the Danish Veterinary Laboratory (DVL), and the carcases incinerated. No further cases have been detected.

BSE has been notifiable in Denmark since May 1990. In 1998 and 1999, 24 and 39 suspect cases, respectively, were submitted for examination at the DVL. All were found to be

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