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DIAGNOSTIC ULTRASOUND IMAGING OF VEGETATIVE VALVULAR ENDOCARDITIS IN CATTLE

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Bovine vegetative valvular endocarditis in 5 cases was examined using echocardiography to determine its diagnostic capacities, and in addition, observations on the abnormality of the liver associated with heart failure were performed by ultrasonography. In 4 out of 5 cases, the vegetations revealed echogenic or "shaggy" masses of various sizes, and one of them also contained the cystic pattern. In the remaining one case, a vegetation demonstrated the pattern of acoustic reverberation reflecting microbubbles. The smallest vegetation which was detectable in this study was 0.5×1 cm in size. Due to its technical facility, two-dimensional echocardiography was more beneficial for detecting vegetations as compared with the M-mode technique, and it allowed easy estimation of the size, shape, attached portion and mobility of the vegetation. In addition, ventricular hyperkinesis and eccentric hypertrophy of the ventricle on the side with affected valve were recognized in the indirect echocardiographic findings in this disease. In Cases 1 and 2, the congested and enlarged liver with notably dilated hepatic veins was visualized in a wider area than in normal cattle. Ultrasonographically, the lower margin of the liver, whose parenchyma revealed a tightly packed and high-level echo pattern, was wide angled and somewhat roundish.

Key words : echocardiography, ultrasonography, vegetative valvular endocarditis, liver, cattle

INTRODUCTION

Vegetative valvular endocarditis is a relatively common heart disease in cattle. The right side of the bovine heart is usually affected and cardiac valve function is compromised due to vegetations on the valve leaflets.^{1,16,17)} Until now, the diagnosis of vegetative valvular endocarditis has been based on clinical signs, physical findings and laboratory findings.^{1,16,17)}

In recent years, echocardiography has provided a useful means by which the cardiac chambers and valves in cattle can be imaged.^{14,26)} The M-mode technique

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holds potential value for the diagnosis of vegetative endocarditis in domestic animals.^{2,9,10,13,15,23,28)}

Studies on two-dimensional echocardiographic diagnosis of vegetative valvular endocarditis have also been reported recently in dogs¹⁹⁾ and cattle.^{5,21)} However, there have been no detailed descriptions of the echocardiographic properties of vegetations and other cardiac findings associated with vegetative endocarditis. In addition, ultrasonographic observations of the liver have been limited to a short description of chronic passive congestion of the liver.²²⁾ This report describes the echocardiographic features and the diagnostic role of echocardiography in addition to some ultrasonographic observations of the liver in vegetative valvular endocarditis in cattle.

MATERIALS AND METHODS

Five Holstein cattle, including 4 cows and 1 heifer, suspected of having a heart disorder, were referred to the Veterinary Teaching Hospital of Hokkaido University. Each animal was examined both echocardiographically and ultrasonographically. Moreover, clinical laboratory examinations, electrocardiography and phonocardiography were performed. Thereafter, all patients were euthanatized and necropsies and histopathological examinations were made.

The imaging techniques and instruments (an electronic linear-array scanner equipped with a 3.5 MHz transducer and an M-mode echocardiographic apparatus with a 2.25 MHz probe) used in the recording echograms were described in the previous papers.^{25,26)} The real-time scans were recorded on a 3/4 inch videotape. All ultrasonographic studies were performed under almost the same time-gain-compensation settings. Echograms were analyzed for the purpose of examining the abnormal features associated with this disease. Echogram analysis was done on the basis of information gained from our clinical and laboratory data on dogs, cats, horses and cattle, and from reports on ultrasound imaging in man.^{3,4,6-8,11,12,18,20,24-27,29)} In addition, echocardiographic data from 5 normal Holstein heifers (body weight of approximately 250 kg) were collected to be compared with Case 2.

RESULTS

Clinical findings (TAB. 1): The earliest signs included fluctuating fever, tachycardia, pounding heartbeat, distension and pulsation of the jugular vein, mild inappetence, moderate reduction in milk production in cows and lameness or arthritis. Moreover, cardiac murmur, hyperpnea, weight loss and mastitis were noticed in some cases. Auscultation revealed pounding heart sounds in all cases and systolic murmurs in 2 cases.

Laboratory findings (TAB. 2): Mild anemia was noted in a few cases. Two cases had absolute leukocytosis and neutrophilia with a shift to the left. High total serum

TABLE 1 Clinical findings

	No. of case				
	1	2	3	4	5
Age	6 y, cow	15m, heifer	9 y, cow	9 y, cow	10y, cow
Lameness or arthritis	++	++	++	+	++
Distension and pulsation of jugular vein	+++	+	+	+	++
Cardiac murmur	-	-	+	+	-
Pounding heart sounds	++	++	++	++	++
Hyperpnea	+	+++	++	-	-
Weight loss	+++	+	++	+	+++
Mastitis	+	-	-	+	+

y = years; m = months;

-, +, ++, +++ = not seen, mild, moderate, severe.

protein value, hyperglobulinemia and severe decrease of A/G ratio were recognized in all cases. Elevated plasma fibrinogen value was evident, except in one case. The blood biochemical examinations revealed elevated serum gamma glutamyl transferase (GGT) in Case 1, elevated creatine phosphokinase (CPK) in Case 4 and elevated glutamic oxaloacetic transaminase (GOT) in Case 5. Blood cultures were not performed.

Electro-and phonocardiographic findings (TAB. 3): Electrocardiograms with the A-B lead showed slightly to severely elevated voltages of QRS complexes in all cases and ventricular premature contractions in 3 cases. In the phonocardiogram, the systolic murmur was recorded in 2 cases and a fourth heart sound was recognized occasionally in 2 cases.

TABLE 2 Laboratory data

Item		No. of case				
		1	2	3	4	5
RBC	(X10 ⁴ /ul)	517	558	469	458	488
PCV	(%)	25	25	30	24	30
Hemoglobin	(g/dl)	6.8	—	10.3	7.2	—
WBC	(/ul)	8600	22900	7400	4100	19100
Band neutrophils	(%)	4.0	12.5	1.3	3.0	11.5
Neutrophils	(%)	43.0	39.0	84.8	34.5	75.5
Lymphocytes	(%)	50.0	34.5	11.8	57.0	9.5
Monocytes	(%)	—	14.0	1.8	2.5	2.0
Eosinophils	(%)	3.0	—	0.3	3.0	1.5
Serum protein	(g/dl)	8.0	6.8	8.4	7.6	8.6
Fibrinogen	(mg/dl)	400	800	1200	900	1600
Electrophoresis						
Albumin	(%)	21.6	19.8	25.8	23.3	19.2
Globulin	α (%)	17.0	21.0	19.8	16.5	18.3
	β (%)	6.5	18.5	6.9	8.5	8.9
	γ (%)	52.6	40.5	47.2	51.8	53.4
A/G ratio		0.28	0.25	0.35	0.35	0.24
GOT	(KU)	80	41	58	62	174
LDH	(WU)	2300	1596	1971	2241	3106
GDH	(IU/L)	15	5	3	—	13
GGT	(IU/L)	65	32	27	26	5
ALP	(KAU)	5	7	4	15	8
CPK	(IU/L)	17	15	26	108	—

Echocardiographic findings (TAB. 4):

Case 1: When the transducer was placed in the left and right intercostal spaces, an echogenic mass, including the cystic pattern, was seen in the right ventricular cavity (FIGS. 1 & 2). An enormous mass occupied the larger part of the right ventricle. Pleural effusion was also noted (FIG. 1). The M-mode echocardiographic measurements revealed dilatation of the right ventricle, thickening of the right ventricular wall, increase of the left ventricular wall velocity (LVWV), the mean velocity

TABLE 3 Electro- and phonocardiographic findings

No. of case	Electrocardiogram (A-B lead)	Phonocardiogram
1	QRS: 22 mV ventricular extrasystole	4th heart sound
2	QRS: 11 mV	
3	QRS: 14 mV P wave: low voltage	ejection murmurs
4	QRS: 14 mV broad P wave ventricular extrasystole	regurgitant murmurs 4th heart sound
5	QRS: 13 mV sinus tachycardia ventricular extrasystole	

of circumferential fiber shortening (mVcf) and the early diastolic closing velocity of the mitral valve (E-F slope), and shortening of the ejection time (ET).

Case 2: A large mass with acoustic reverberation was recognized in the right atrium by intercostal scanning (FIG. 3). Additionally, the ventricular wall motion was hyperkinesis in real-time, two-dimensional echocardiography. The echocardiographic measurements of the right ventricular dimension (RVD), right ventricular wall thickness (RVWT), mVcf and E-F slope were increased.

Case 3: A large echogenic mass exhibiting a cauliflower-like image was visualized on the pulmonary valve and there was dilatation of the right ventricular outflow tract and the pulmonary trunk (FIG. 4). Altering subtly the direction of the ultrasound beam, the mass was observed as if it obstructed the pulmonary orifice. Pericardial effusion was also noted. The M-mode echocardiographic values showed dilatation of the RVD, thickening of the RVWT, shortening of the ET and decrease of the fractional shortening (FS).

Case 4: An echogenic mass on the mitral valve representing the nodular image was recognized in the two-dimensional echocardiogram obtained from the left hemithorax (FIG. 5). The M-mode technique clearly revealed "shaggy" or multiple echoes on the mitral valve in the diastole (FIG. 5) and dilatation of the left atrium. Additionally, the echocardiographic values showed dilatation of the left ventricular

TABLE 4 M-mode echocardiographic measurements

Parameters	Normal cattle				No. of case				
	Cows		Heifers		1	2	3	4	5
	n=15, (*)		n=5						
Mean	SD	Mean	SD						
HR (beats/min)	58.3	6.9	70.1	9.5	93	71	82	87	135
BW (kg)	589.4	62.9	250.0	51.5	500	250	590	550	481
LVDd (mm)	97.1	7.1	66.8	2.3	82	60	99	109	80
LVDs (mm)	57.0	5.8	38.2	1.6	52	32	69	62	52
LVWTd (mm)	21.3	1.5	13.4	1.2	20	15	24	23	27
LVWTs (mm)	36.6	2.3	26.5	1.4	34	23	39	39	36
LVWE (mm)	27.0	2.6	18.9	1.9	29	19	21	19	17
LVWV (mm/sec)	68.4	7.5	55.3	8.8	124	57	71	66	78
IVST (mm)	20.7	1.6	12.7	0.8	19	14	22	29	24
RVD (mm)	31.8	6.2	27.0	5.3	55	66	54	26	30
RVWT (mm)	9.3	0.9	6.8	0.4	15	10	13	12	11
AoD (mm)	69.8	3.3	50.2	2.5	62	51	82	71	80
LAD (mm)	56.4	5.0	38.8	1.0	50	44	61	—	61
LA/Ao	0.81	0.054	0.78	0.021	0.80	0.86	0.74	—	0.75
ET (msec)	396	26.4	344	23.7	234	336	303	288	215
FS	0.41	0.035	0.43	0.026	0.37	0.47	0.30	0.43	0.34
mVcf (circ/sec)	1.05	0.075	1.24	0.108	1.57	1.38	0.99	1.50	1.60
E-F slope (mm/sec)	112.3	20.9	117.8	10.9	262	182	123	250	307

*: previous data²⁷⁾; HR=heart rate; BW=body weight; LVDd (s)=left ventricular dimension at end-diastole (systole); LVWTd (s)=left ventricular wall thickness at end-diastole (systole); LVWE=left ventricular wall excursion; LVWV=left ventricular wall velocity; IVST=interventricular septal thickness at end-diastole; RVD=right ventricular dimension; RVWT=right ventricular wall thickness at end-diastole; AoD=aortic dimension; LAD=left atrial dimension; LA/Ao=left atrial/aortic root ratio; ET=ejection time; FS=fractional shortening; mVcf=mean velocity of circumferential fiber shortening; E-F slope=early diastolic closing velocity of mitral valve.

dimensions, shortening of the ET and increase of the mVcf and the E-F slope.

Case 5: Two-dimensional echocardiography from the left intercostal approach demonstrated a small echogenic mass on the mitral valve (FIG. 6) and M-mode echocardiography showed a mass of "shaggy" echoes on the mitral valve. A small mass on the septal semilunar cusp of the aortic valve was also detected using two-dimensional echocardiography (FIG. 7). Two-dimensional echocardiography by right intercostal scanning revealed small to large echogenic masses on the tricuspid valve that extended into the right ventricle and were mobile in real time. The echocardiographic measurements revealed notable shortening of the ET and marked increase of the mVcf and the E-F slope.

Ultrasonographic findings of the liver :

In Cases 1 and 2, the liver, with notably dilated hepatic veins, was visualized more dorsally than in normal cattle and at the caudal margin of the right 13th rib. The caudal vena cava was also observed relatively easily (FIG. 8). The lower margin of the liver had a wide angled border and was somewhat roundish (FIG. 9). The parenchyma revealed a tightly packed and high-level echo pattern (Figs. 8 & 9).

Pathological findings :

Heart: Case 1: One enormous vegetation incorporating the tricuspid valve and including the cysts occupied the larger part of the right ventricle, and the other (0.5 cm in diameter) existed on the right semilunar cusp of the pulmonary valve. The right ventricle was dilated and the wall was thickened.

Case 2: A gigantic thrombus was attached to the right atrial wall and contained microbubbles produced by causative bacterias within itself (FIG. 10). Vegetations containing similar components were observed also on the tricuspid valve. There were also notable dilatation of the right ventricle and thickening of the wall.

Case 3: Vegetative endocarditis was found on the pulmonary valve (FIG. 11) and there was a large amount of reddish pericardial effusion. The cauliflower-like vegetation obstructed almost the whole cavity of the pulmonary trunk. The right ventricle was also dilated.

Case 4: Several nodular vegetations (1 to 3 cm) were found on the mitral valve, and the left atrium and ventricle were moderately dilated.

Case 5: Valvular vegetations of about 0.5 to 5 cm existed on the tricuspid, mitral and aortic valves. The smallest of them lay on the septal semilunar cusp of the aortic valve (FIG. 12).

Liver: In necropsy, the liver was congested and enlarged slightly to moderately and the cut-surface showed a nutmeg-like feature. Microscopic examination showed interstitial fibrosis and infiltration of inflammatory cells, peri-acinar fatty change and dilatation of the sinusoid due to congestion. These findings were summarized in Table 5.

TABLE 5 Histopathological findings of the liver

	No. of case				
	1	2	3	4	5
Interstitial fibrosis	++	++	+	+	+
Cellular infiltration	++	++	+	+	+
Periacinar fatty change	-	-	-	+++	-
Congestion	+	+	+	+	+

+: mild, ++: moderate, +++: severe

DISCUSSION

The echocardiographic diagnosis of valvular endocarditis in man depends on the detection of a vegetation which is recognized as an echogenic or "shaggy" mass on the valve leaflets.⁴⁾

In the domestic animals, the application of M-mode echocardiography in the diagnosis of vegetative valvular endocarditis has already been reported.^{2,9,10,13,15,23,28)} In the present observation, vegetations were visualized as "shaggy" or multiple linear echoes in the same echo pattern as those in the above cited papers. More recently, two-dimensional echocardiographic detection of the vegetation has been reported,^{5,19,21)} and the vegetation has been observed as an echogenic or "shaggy" mass as it is in man.⁴⁾

In 4 out of the 5 cases examined, the vegetations revealed echogenic or "shaggy" masses of various sizes, and one vegetation (Case 1) also contained the cystic pattern. In the remaining one case, a vegetation demonstrated the pattern of acoustic reverberation. It was thought that the reverberation reflected microbubbles produced by causative bacterias within the vegetation. Therefore, it seems probable that the vegetation shows various images due to the component of the vegetation.

Because of technical facility, in the present study two-dimensional echocardiography seemed to be useful in detecting the vegetation as compared with the M-mode method, and it allowed easy estimation of the size, shape and attached portion of the vegetation.^{4,19)} When the vegetation was mobile, it could be detected somewhat more easily. By the use of two-dimensional echocardiography, the vegetation (0.5×1 cm) on the septal semilunar cusp of the aortic valve was detectable in Case 5. However, in Case 1, the small vegetation (0.5 cm in diameter) on the right semilunar cusp of the pulmonary valve was not visualized, although the gigantic vegetation was imaged in the right ventricle. In this study, vegetations over 0.5 cm in diameter were most likely

detected, which agreed with the opinion of HAGIO et al.⁵⁾ and YAMADA et al.²²⁾

In cattle, the leaflets of valves which can be observed are limited by linear-array two-dimensional and M-mode echocardiography, which leads to difficulty in observing the whole feature of each valve. In the case with a small vegetation, if the vegetation is attached to a valve which can be visualized normally, it may be possible to detect it. Sector scanning, which was not utilized in the present cases, can image not only the longitudinal view of the heart but also the transverse one, leading to visualization of more valvular leaflets. Therefore, the vegetation on the right semilunar cusp of the pulmonary valve, which was not detected in this observation, might be detectable by the use of sector scanning.

Ventricular hyperkinesis and eccentric hypertrophy of the ventricle on the side with affected valves were recognized in the indirect echocardiographic findings in this disease. These findings may also play an auxiliary role in diagnosing.

When elevation of the right heart pressure is present in human patients with heart disease, chronic passive congestion and enlargement of the liver, with dilatation of the inferior vena cava and hepatic veins, are recognized ultrasonographically.^{6,8)}

In Cases 1 and 2 with a large vegetation on the tricupsid valve, the liver, with notably dilated hepatic veins, was visualized in a wider area than that reported on normal cattle in the previous paper.²⁵⁾ The lower margin of the liver was seen to be wide angled and somewhat roundish ultrasonographically. Above mentioned findings were described also by YAMADA et al.²²⁾ According to our experiences, the caudal vena cava has not been imaged together with the liver in normal cows. However, the caudal vena cava could be easily visualized in these two cases. These findings suggested that the liver was markedly congested and enlarged, and they were confirmed by necropsy.

Images of the liver in Cases 1 and 2 showed the "bright liver" echo pattern termed by JOSEPH et al.⁷⁾ In man, recognition of this pattern has always corresponded with liver disease of one of five types: cirrhosis, fatty infiltration, portal tract fibrosis, severe hepatitis or longstanding congestive cardiac failure.⁷⁾ The increased amount of fibrous tissue and/or fatty tissue in the liver is regarded as a possible cause of the brightly reflective echo patterns, but the precise origin of the bright echoes from liver tissue remains unresolved.^{3,7)} In the present study, microscopical examination revealed slight to moderate fibrous proliferation in the liver in all cases, and the liver showed the markedly increased echogenicity in two cases with moderate fibrosis. It is considered that the increased amount of the fibrous tissue in the liver was one of the cause which produced the high-level echo. However, the possibility that the histopathological changes such as congestion, interstitial cellular infiltration and fatty change seen in the liver may also contribute to the increased echogenicity, cannot be neglected.

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EXPLANATION OF PLATES

PLATE I

- Fig. 1 Echocardiograms in Case 1, showing a very large mass occupying the right ventricle.
Right side half of the figure : two-dimensional echocardiogram, left side half : M-mode echocardiogram scanned at the level of the white line on the two-dimensional echocardiogram, Pl : pleural effusion, V : vegetation, LV : left ventricle, RVW : right ventricular wall, IVS : interventricular septum, LVW : left ventricular wall. The next figures follow figure 1.
- Fig. 2 Two-dimensional echocardiogram in Case 1, showing an echogenic mass including the cystic pattern (C) in the right ventricular outflow tract (RVO).
- Fig. 3 Two-dimensional echocardiogram in Case 2, showing a large mass with acoustic reverberation. Ao : aorta, RV : right ventricle.
- Fig. 4 Two-dimensional echocardiogram in Case 3, showing a large "shaggy" mass extending into the pulmonary trunk (PT). SC : supra-ventricular crista.
- Fig. 5 Echocardiograms in Case 4, recorded by left intercostal scanning. Notice the echogenic mass on the mitral valve in the two-dimensional echocardiogram and the "shaggy" echoes on the valve in the M-mode echocardiogram. LVW : left ventricular wall.
- Fig. 6 Two-dimensional echocardiogram in Case 5, showing a small "shaggy" mass on the mitral valve.
- Fig. 7 Two-dimensional echocardiogram in Case 5, showing echogenic masses on the tricuspid valve and the septal semilunar cusp of the aortic valve. RA : right atrium.

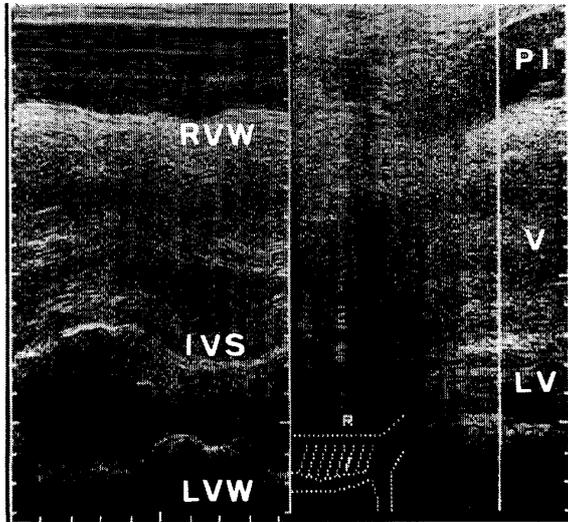


Fig. 1

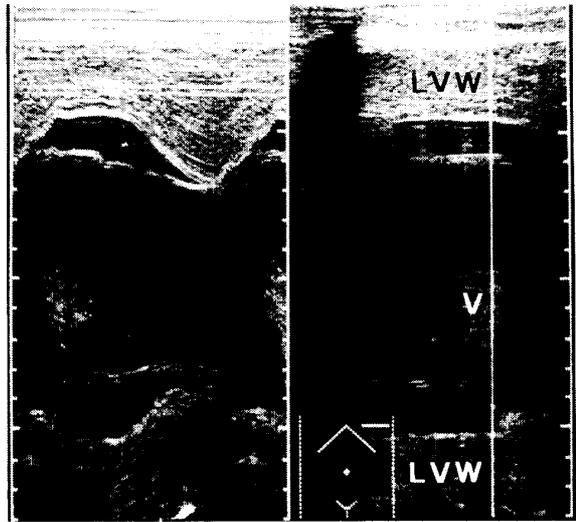


Fig. 5

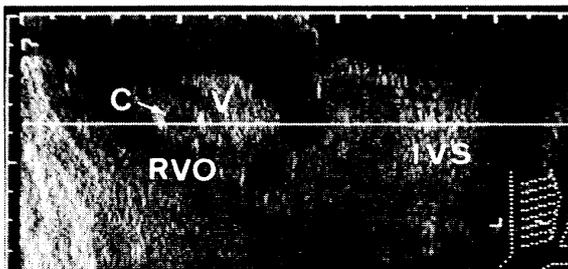


Fig. 2

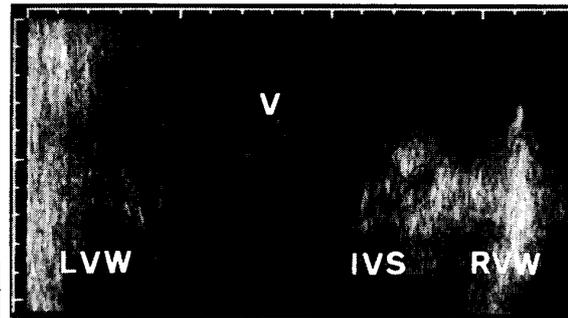


Fig. 6

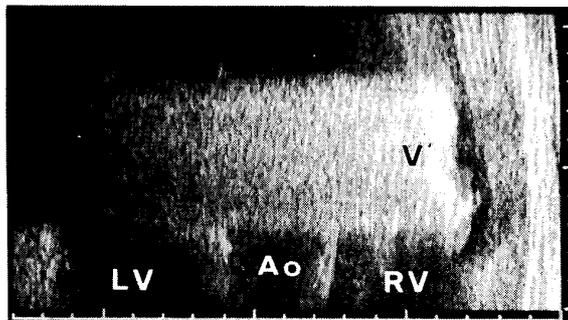


Fig. 3

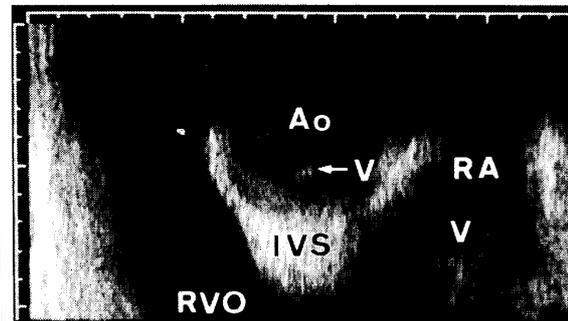


Fig. 7

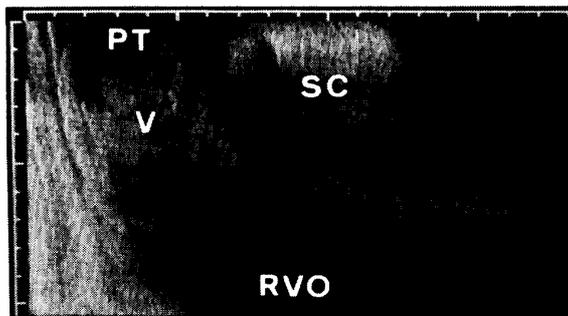


Fig. 4

PLATE II

- Fig. 8 Ultrasonogram of the liver in Case 2 (heifer) with notably dilated hepatic veins (HV). The caudal vena cava (VC) is also observed. L: liver, PV: portal vein.
- Fig. 9 Ultrasonogram of the liver in Case 1. The lower margin of the liver has a wide angled border and is somewhat roundish. The parenchyma shows a tightly packed and high-level echo pattern. GB: gall bladder.
- Fig. 10 Opened right atrium and ventricle in Case 2, showing large and small vegetations attached to the right atrial wall and the tricuspid valve (TV).
- Fig. 11 Pulmonary valve in Case 3 with a large vegetation (arrow).
- Fig. 12 Aortic valve in Case 5 with a small vegetation (arrow) on the septal semilunar cusp.

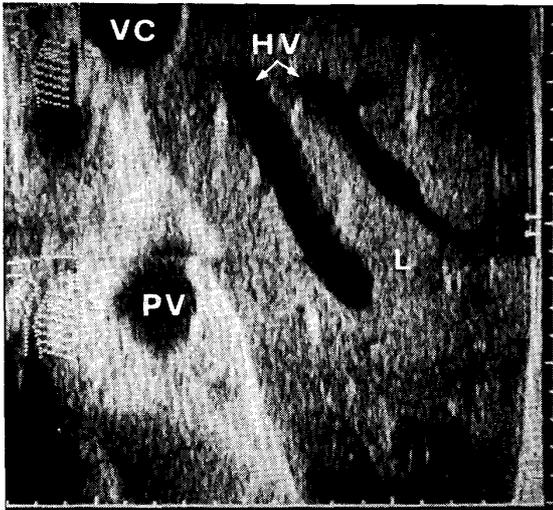


Fig. 8

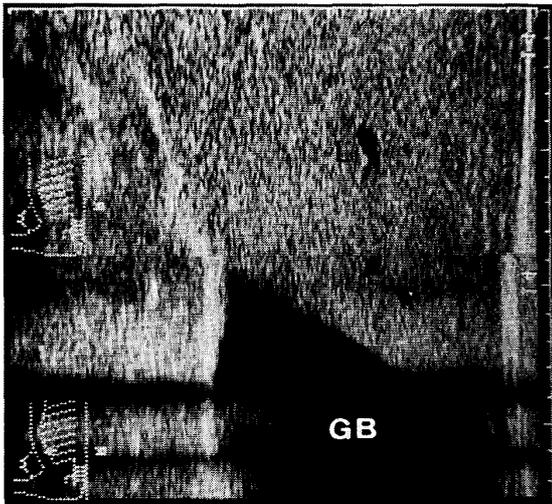


Fig. 9



Fig. 10

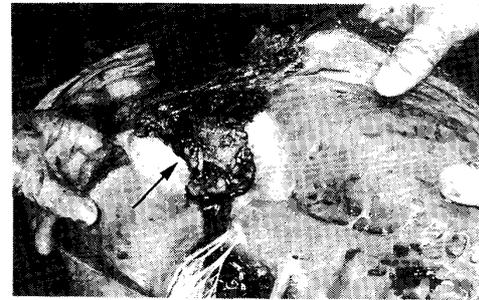


Fig. 11



Fig. 12