

## 4. Results

### 4.1 Auscultation

All 96 patients underwent a careful auscultation. In 61 animals the examination was performed without any sedation and in other 35 animals the examination was done under sedative medication. In the non sedation groups, 34 (55.74%) were male and 27 (44.26%) were female. The average age was 29.85 month (range 4-96 months) and the body weight was 1.15 kg in average (range 0.5-2.3 kg). In the sedation group, 21 (60%) were male and 14 (40%) were female. The average age was 40.66 month (range 12-108 months) and the body weight was 1.13 kg in average (range 0.5-2.3 kg).

In the non sedated groups (n=61), 47 animals (47/61, 77.05%) had normal heart sounds. Heart murmurs were noted in 14 animals (14/61, 22.95%) grading from 1/5 to 4/5. Five animals (5/61, 35.71%) had a first grade, six animals (6/61, 42.86%) had second, one (1/61, 7.14%) had third grade, and 2 animals (2/61, 14.29%) had fourth grade systolic murmur. Most of the murmurs were detected loudest on the left side of the thoracic wall. An arrhythmia was recorded in twelve animals (12/61, 19.67%) and gallop rhythm was found in one case (1/61, 1.64%). One case (1.64%) had muffled heart sounds concurrently with arrhythmia. Four cases (4/61, 6.56%) had abnormal lung sounds during examination and ten animals (10/61, 16.39%) were dyspneic.

In the sedated groups (n=35), heart murmurs were detected in thirteen animals (13/35, 37.14%). First, second, third and fourth degree heart murmurs were noted in three (3/13, 23.08%, 1°), seven (7/13, 53.85%, 2°), two (2/13, 15.38%, 3°) and one (1/13, 7.69%, 4°) animals respectively. Heart murmurs were detected in animals aged between 12-108 months (median 60 month). A systolic click was detected in one case (1/35, 12.86%).

## Results

### 4.2 Electrocardiography

Based on the clinical examination and anesthetic status, 29 cases belong to group A (NSN group), 32 cases in group B (NSD group), 11 cases in group C (SN group) and 24 in group D (SD group)

#### Group A (non sedated-normal group, NSN group)

The electrocardiographic mean values in lead II reveal the P amplitude was 0.08 mV, P duration was 0.02 sec. The R amplitude was 1.52 mV. QRS duration was 0.03 sec. Five cases showed S waves in lead II with a mean amplitude 0.03 mV. Twenty three cases had positive T waves and five cases showed negative T waves in lead II. The mean amplitude of T was 0.14 mV. The mean values of PR interval and QT interval were 0.05 and 0.1 sec respectively (See Figure 26 and Table 4 for details).

Table 4: Electrocardiographic values from group A (NSN group).

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	29	360	190	260.69	250	51.96
P amplitude (mV)	29	0.20	0.05	0.08	0.10	0.041
P duration (sec)	29	0.04	0.02	0.02	0.02	0.005
PR interval (sec)	29	0.08	0.03	0.05	0.06	0.012
QRS duration (sec)	29	0.04	0.02	0.03	0.04	0.010
R amplitude (mV)	29	2.70	0.50	1.52	1.50	0.593
S amplitude (mV)	29	0.40	0.00	0.03	0.00	0.089
QT interval (sec)	29	0.12	0.08	0.10	0.10	0.014
T amplitude (mV)	29	0.60	-0.20	0.14	0.10	0.188

#### Group B (non sedated-disease group, NSD group)

The electrocardiographic mean values showed the mean P amplitude was 0.10 mV, P duration was 0.03 sec. The R amplitude was 1.87 mV. Mean QRS duration was 0.03 sec. thirteen from thirty two cases showed S waves in lead II with a mean amplitude 0.1 mV. Five cases from thirty two cases showed negative T waves in lead II. The mean amplitude of the T wave was 0.12 mV. The mean value of PR interval and QT interval was 0.06 sec and 0.1 sec respectively. (See Table 5 for details)

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Table 5: Electrocardiographic values from group B (NSD group).

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	32	400	160	262.50	260	52.92
P amplitude (mV)	32	0.30	0.05	0.10	0.10	0.063
P duration (sec)	32	0.07	0.02	0.03	0.02	0.011
PR interval (sec)	32	0.08	0.03	0.06	0.06	0.013
QRS duration (sec)	32	0.08	0.02	0.03	0.02	0.014
R amplitude (mV)	32	4.00	0.60	1.87	1.90	0.794
S amplitude (mV)	32	0.80	0.00	0.10	0.00	0.184
QT interval (sec)	32	0.12	0.06	0.10	0.10	0.020
T amplitude (mV)	32	0.4	-0.2	0.12	0.10	0.162

### Group C (sedated-normal group, SN group)

Eleven cases belong to this group. The ECG mean values in lead II reveal a P amplitude of 0.07 mV, P duration was 0.02 sec. The R amplitude was 2.07 mV. The QRS duration was 0.03 sec. Four cases showed S waves in lead II with a mean amplitude of 0.09 mV. Ten cases had positive T wave and one case showed a negative T waves in lead II. The mean amplitude was 0.19 mV. The mean value of the PR interval was 0.06 sec and for the QT interval was 0.11 sec respectively. (See Table 6 for details)

Table 6: Electrocardiographic values from group C (SN group).

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	11	310	160	221.82	220	43.55
P amplitude (mV)	11	0.10	0.05	0.07	0.05	0.025
P duration (sec)	11	0.04	0.02	0.02	0.02	0.006
PR interval (sec)	11	0.08	0.04	0.06	0.06	0.015
QRS duration (sec)	11	0.04	0.02	0.03	0.04	0.010
R amplitude (mV)	11	2.50	1.00	2.07	2.00	0.417
S amplitude (mV)	11	0.60	0.00	0.09	0.00	0.180
QT interval (sec)	11	0.12	0.08	0.11	0.12	0.013
T amplitude (mV)	11	0.40	-0.20	0.19	0.25	0.175

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Group D (sedated-disease group, SD group)

Twenty four cases were defined as group D. The electrocardiographic mean values in lead II showed a P amplitude of 0.13 mV. The P duration was 0.03 sec. The R amplitude was 2.19 mV. The mean QRS duration was 0.03 sec. The sum of the QRS complexes was always positive because of the dominating R wave. Five cases showed S waves in lead II with mean amplitude 0.08 mV. All cases presented positive T waves with a mean amplitude 0.28 mV. The mean values of PR interval and QT interval were 0.06 sec and 0.12 sec respectively. (See Table 7 for details)

Table 7: Electrocardiographic values from group D (SD group).

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	24	360	70	225	240	66.14
P amplitude (mV)	24	0.25	0.10	0.13	0.10	0.066
P duration (sec)	24	0.04	0.02	0.03	0.02	0.009
PR interval (sec)	24	0.08	0.04	0.06	0.06	0.013
QRS duration (sec)	24	0.09	0.02	0.03	0.04	0.017
R amplitude (mV)	24	4.00	0.70	2.19	2.15	0.881
S amplitude (mV)	24	1.40	0.00	0.08	0.00	0.029
QT interval (sec)	24	0.16	0.08	0.12	0.12	0.025
T amplitude (mV)	24	1.00	0.05	0.28	0.20	0.226

In order to compare all ECG values from normal animals with values from animals with heart disease those ECG measurements are summarized in Table 8 and 9.

Normal groups (group A, NSN and group C, SN)

The total number in the normal groups were 40 animals. The ECG showed a mean P amplitude of 0.08 mV and a mean P duration of 0.02 sec. The average R amplitude was 1.68 mV. QRS duration was 0.03 sec in average. Nine cases showed S waves in lead II with a mean amplitude of 0.05 mV. Six cases had negative T waves and thirty four cases showed positive T waves in lead II. The mean amplitude was 0.15 mV. The mean value for the PR interval and QT interval was 0.05 sec and 0.10 sec respectively. (See Table 8 for details)

## Results

Table 8: Electrocardiographic values from normal groups.

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	40	360	160	250	240	52.28
P amplitude (mV)	40	0.20	0.05	0.08	0.05	0.037
P duration (sec)	40	0.04	0.02	0.02	0.02	0.006
PR interval (sec)	40	0.08	0.03	0.05	0.06	0.013
QRS duration (sec)	40	0.04	0.02	0.03	0.04	0.009
R amplitude (mV)	40	2.70	0.50	1.68	1.80	0.599
S amplitude (mV)	40	0.60	0.00	0.05	0.00	0.121
QT interval (sec)	40	0.12	0.08	0.10	0.10	0.016
T amplitude (mV)	40	0.60	-0.20	0.15	0.10	0.183

Disease groups (group B, NSD and group D, SD)

A total of fifty six cases were grouped in the cardiac disease groups. The mean ECG values showed P amplitudes of 0.11mV, P duration was 0.02 sec. The mean R amplitude was 2.01 mV and the QRS duration was 0.03 sec. Eighteen cases showed S waves in lead II with mean amplitude 0.05 mV. Fifty one cases had a positive T wave and five cases showed a negative T wave in lead II. The mean amplitude was 0.18 mV. The mean value for the PR interval and QT interval was 0.06 sec and 0.11 sec respectively. (See Table 9 for details)

Table 9: Electrocardiographic values from disease groups.

ECG Measurement	Total cases	Max	Min	Mean	Median	SD
Heart rate (bpm)	56	400	70	246.43	250	61.30
P amplitude (mV)	56	0.30	0.05	0.11	0.10	0.065
P duration (sec)	56	0.07	0.02	0.02	0.02	0.010
PR interval (sec)	56	0.08	0.03	0.06	0.06	0.013
QRS duration (sec)	56	0.09	0.02	0.03	0.03	0.015
R amplitude (mV)	56	4.00	0.60	2.01	2.00	0.840
S amplitude (mV)	56	1.40	0.00	0.05	0.00	0.231
QT interval (sec)	56	0.16	0.06	0.11	0.10	0.023
T amplitude (mV)	56	1.00	-0.20	0.18	0.20	0.203

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### Abnormalities of wave form

Two abnormalities of P waves could be detected in the study. It composed of P pulmonale and P mitrale. P pulmonale (P amplitude more than 0.1 mV) was identified in 17 tracings (Figure 27) and 15 tracings showed P mitrale (P duration was longer than 0.02 second). Six ECG tracings showed R amplitude higher than 3 mV (Figure 27). ST segment depression was rare but also detected in this study (Figure 28). T waves that were higher than 25% of R wave in lead II were detected in five ECG registrations (Figure 33).

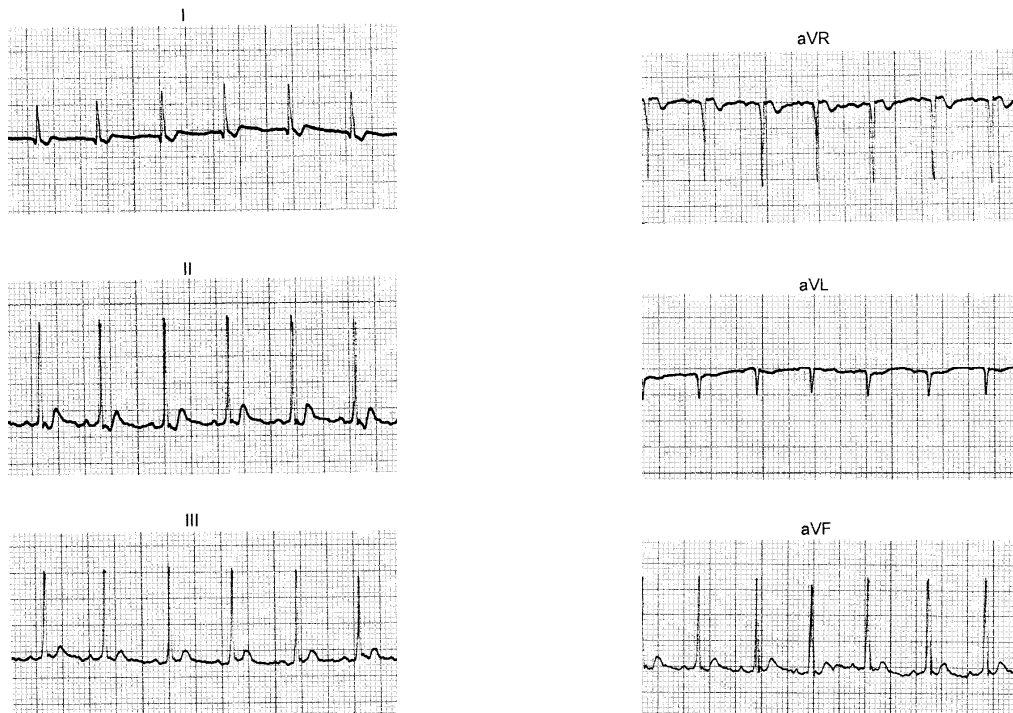
### Heart rate

Heart rate ranged between 190 to 360 bpm (mean 260.96, SD 51.957) in group A (NSN group). In group B (NSD group), the HR ranged from 160 to 400 bpm (mean 262.50, SD 52.915). The HR in group C (SN group) was 160-310 bpm in range (mean 221.82, SD 43.547). In group D (SD group) the HR was 360 bpm maximum and 70 bpm minimum (mean 225, SD 66.136). The mean HR in the non sedated groups (group A and B) were higher than in the sedated groups (group C and D) with a mean of 261.64 bpm and 247.92 bpm respectively.

### Arrhythmia

Arrhythmias were detected in thirty cases. More than one type of arrhythmia could be found in many examples. The arrhythmias that were recognized in this study were ventricular premature complexes, bradycardia, tachycardia, supraventricular premature complexes (Figure 29), atrial fibrillation (Figure 30), atrioventricular block, right bundle branch block and left bundle branch block. The predominant abnormal rhythm was ventricular premature complexes which were found in 17 cases that resulted in 56.67% (17/30) of the arrhythmic cases (Figure 31). Some tracings showed bigeminy and trigeminy VPC rhythm (Figure 32). Atrioventricular block was recorded in nine cases. It contained of two first degree AV blocks, six second degree AV blocks (Figure 33) and one third degree AV blocks (Figure 34). LBBB was found in two cases (Figure 35). Tachycardia, bradycardia, supraventricular premature complexes and RBBB (Figure 36) were rarely recognized and come up to one case each.

## Results



II (Paper speed 25 mm/sec)

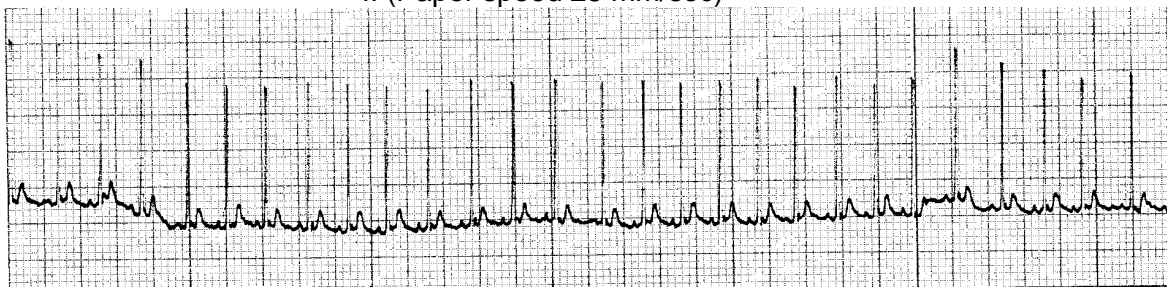


Figure 26: One year old male ferret (Nr.44 NSN group). ECG tracing demonstrates a normal electrocardiogram. Heart rate is 240 bpm with sinus rhythm. In lead II; P = 0.1 mV and 0.02 sec in duration, R = 2 mV, QRS duration = 0.03 sec, PR interval = 0.06 sec, T = 0.3 mV and 0.04 sec in duration. (Paper speed 50 mm/sec, sensitivity 1 cm/ mV)

## Results

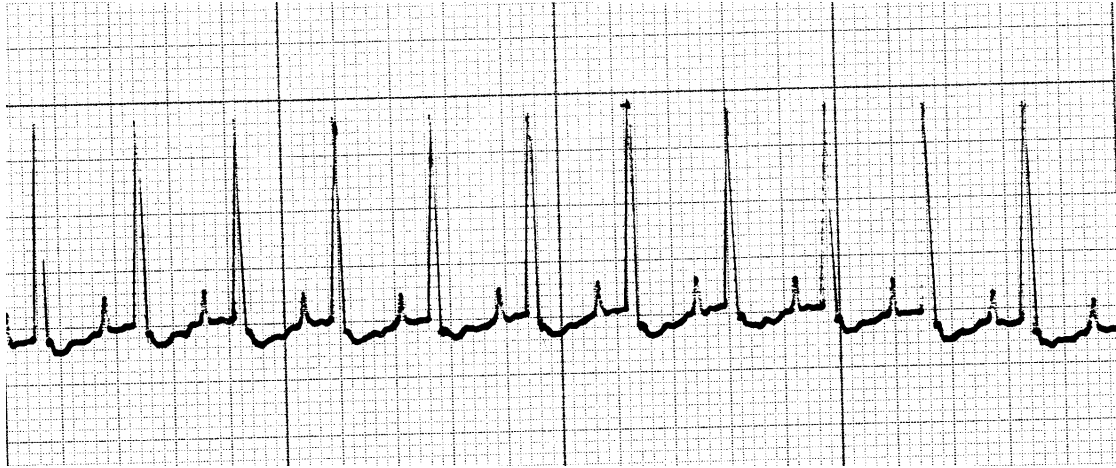


Figure 27: Eight year old male ferret (Nr.10 NSD group) diagnosed as DCMP. Heart rate is 360 bpm; sinus rhythm with constant RR intervals (0.18 sec). R amplitude is 1.8 mV and 0.02 in duration. P wave; P pulmonale with 0.35 mV height. ST segment depression is also present. (Paper speed 50 mm/sec, sensitivity 1 cm/mV)

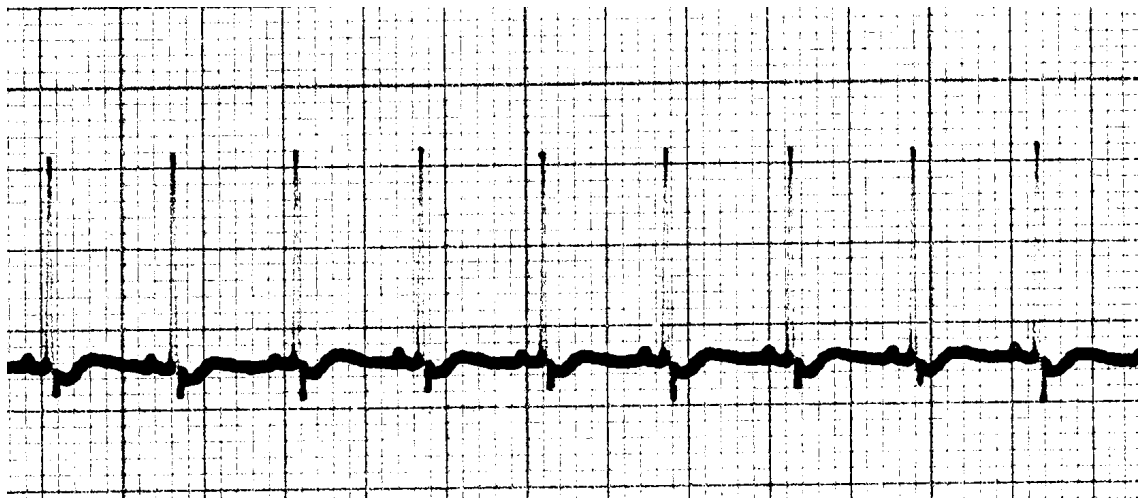


Figure 28: Five year old male ferret (Nr. s13 SD group). The patient suffered from DCMP. ECG demonstrates ST segment depression (0.15 mV). (Paper speed 25 mm/sec, sensitivity 0.5 cm/mV)



## Results

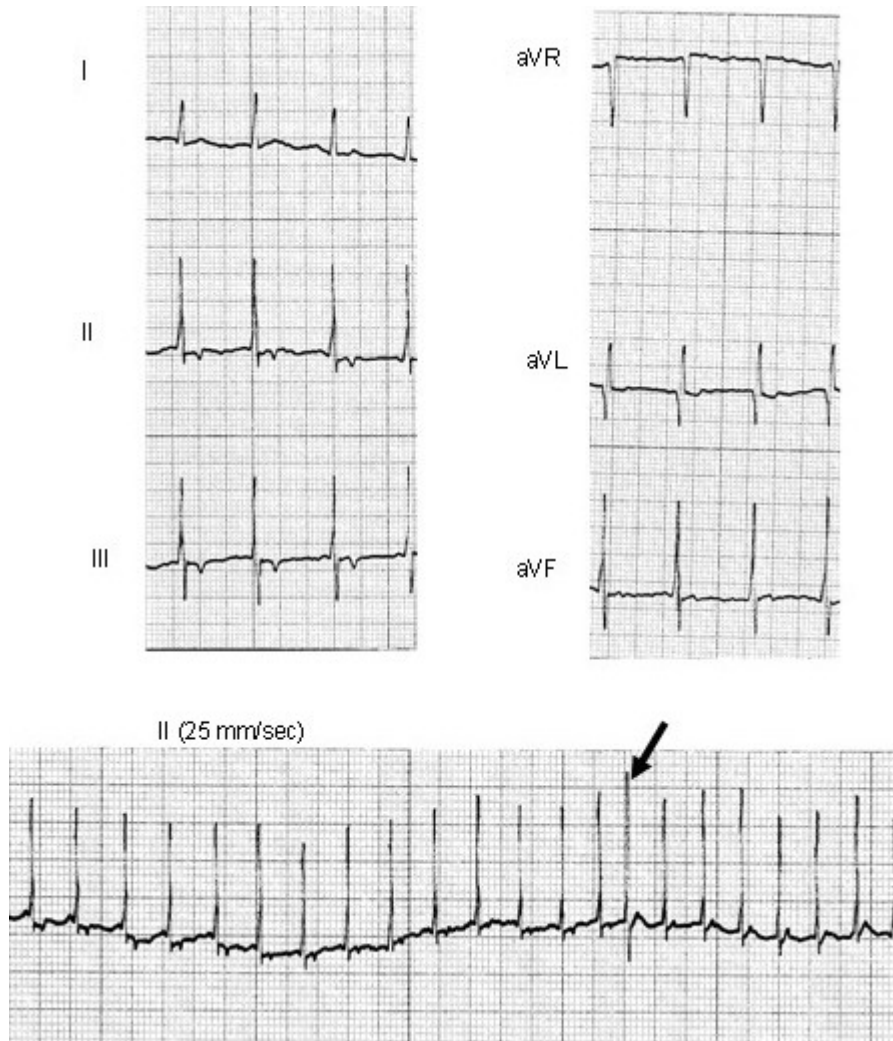


Figure 29: One year old male ferret (Nr.33 NSN group). ECG rhythm strip demonstrates a supraventricular premature complex (arrow). Heart rate is 220 bpm. On top: Six lead ECG, SR, RII 1.7 mV. Note the tiny P waves. (Paper speed 50 mm/sec, sensitivity 1 cm/mV)

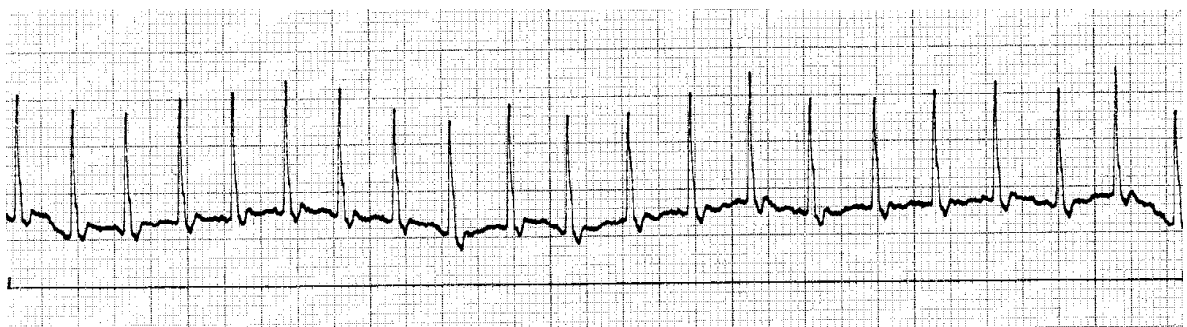


Figure 30: One year old male ferret (Nr.53 NSD group). Lead II ECG tracing demonstrates atrial fibrillation with a heart rate around 190 bpm. On the baseline, the normal P waves are replaced by small undulations. Note the irregular RR interval (between 0.30-0.36 sec) (Paper speed 25 mm/sec, sensitivity 0.5 cm/mV)

## Results

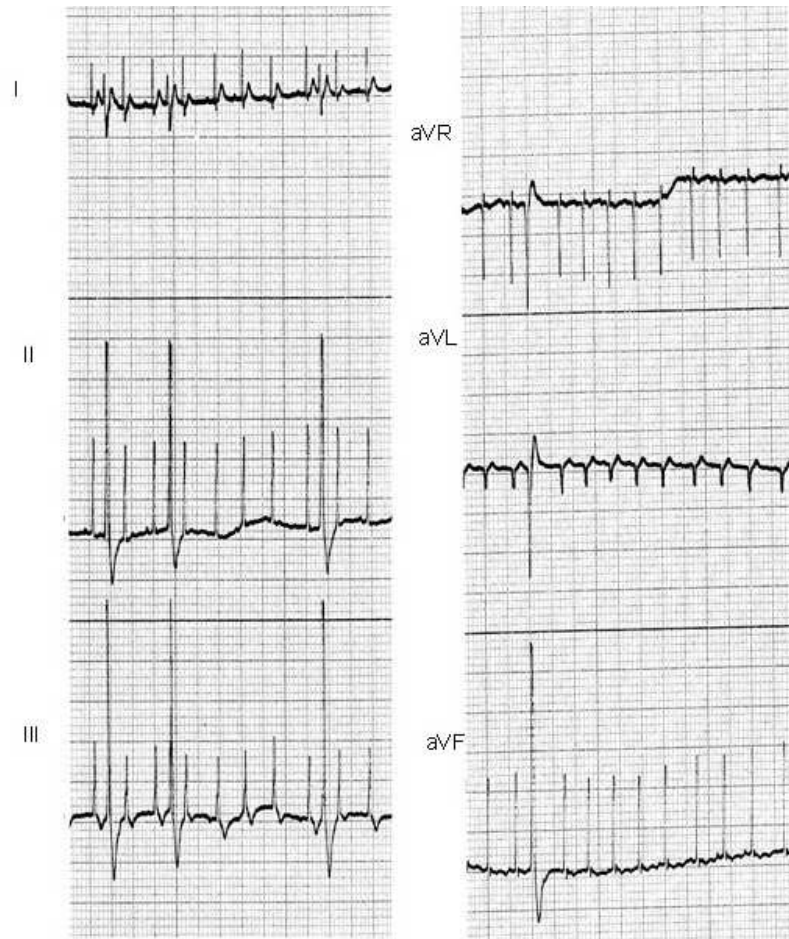


Figure 31: Eight year old female ferret with cardiomyopathy (Nr.1 NSD group). The ECG shows ventricular premature complexes. The rhythm is otherwise regular but broken by premature beats. (Paper speed 25 mm/sec, sensitivity 0.5 cm/mV)

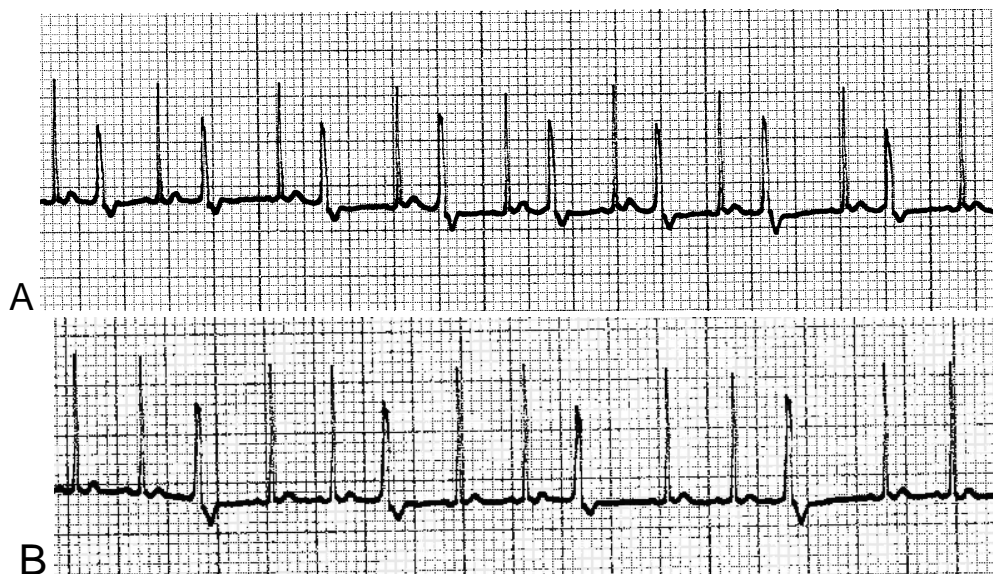


Figure 32: One year old male ferret (Nr.32 NSD group). ECG tracings demonstrate bigeminy (A) and trigeminy (B) patterns. A; Every normal QRS complex is followed by a premature beat. B; Every two normal beats are followed by a premature beat. (Paper speed 25 mm/sec, sensitivity 0.5 cm/mV).

## Results

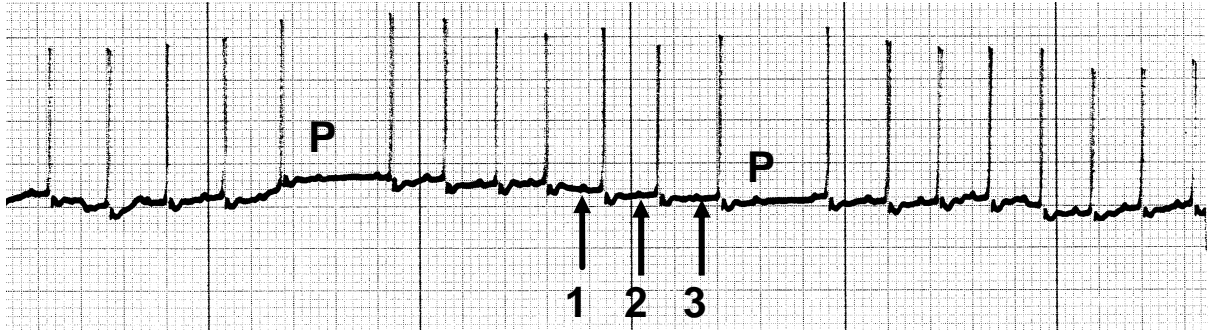


Figure 33: Four year old male ferret (Nr.32 NSD group). Lead II tracing shows a second degree AV block. Some P waves are not followed by a QRS complex. In the middle of the tracing the PR interval becomes gradually prolonged from 0.05 sec at arrow 1, 0.06 sec at the arrow 2 and 0.07 sec at the arrow 3 resulting in a Mobitz type I (Wenkebach) AV block. (Paper speed 25 mm/sec, sensitivity 1 cm/mV)

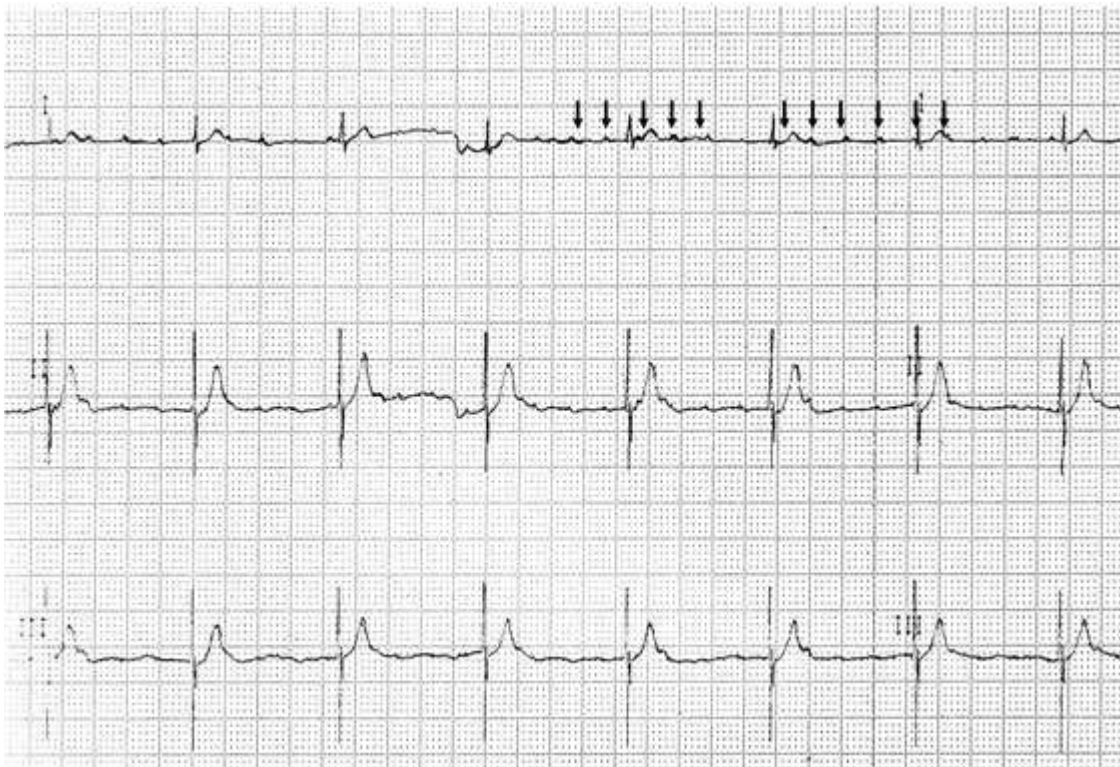


Figure 34: Nine year old male ferret (Nr. s8 SD group). The patient shows signs of syncope for the last 3 month. The ECG recording exhibits more P waves than QRS complexes. There is no regular relationship between the P waves and QRS complexes. The atria are beating at their own rate (250 bpm approximately) and the ventricles are beating at a rate of 70 bpm. Diagnosis: complete AV block or third degree AV block. (Paper speed 25 mm/sec, sensitivity 1 cm/mV)

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Figure 35: Two year old male ferret (Nr.53 NSD group). This ECG example can be interpreted as LBBB because of the QRS duration up to 0.08 sec. (Paper speed 50 mm/sec, sensitivity 1 cm/mV)

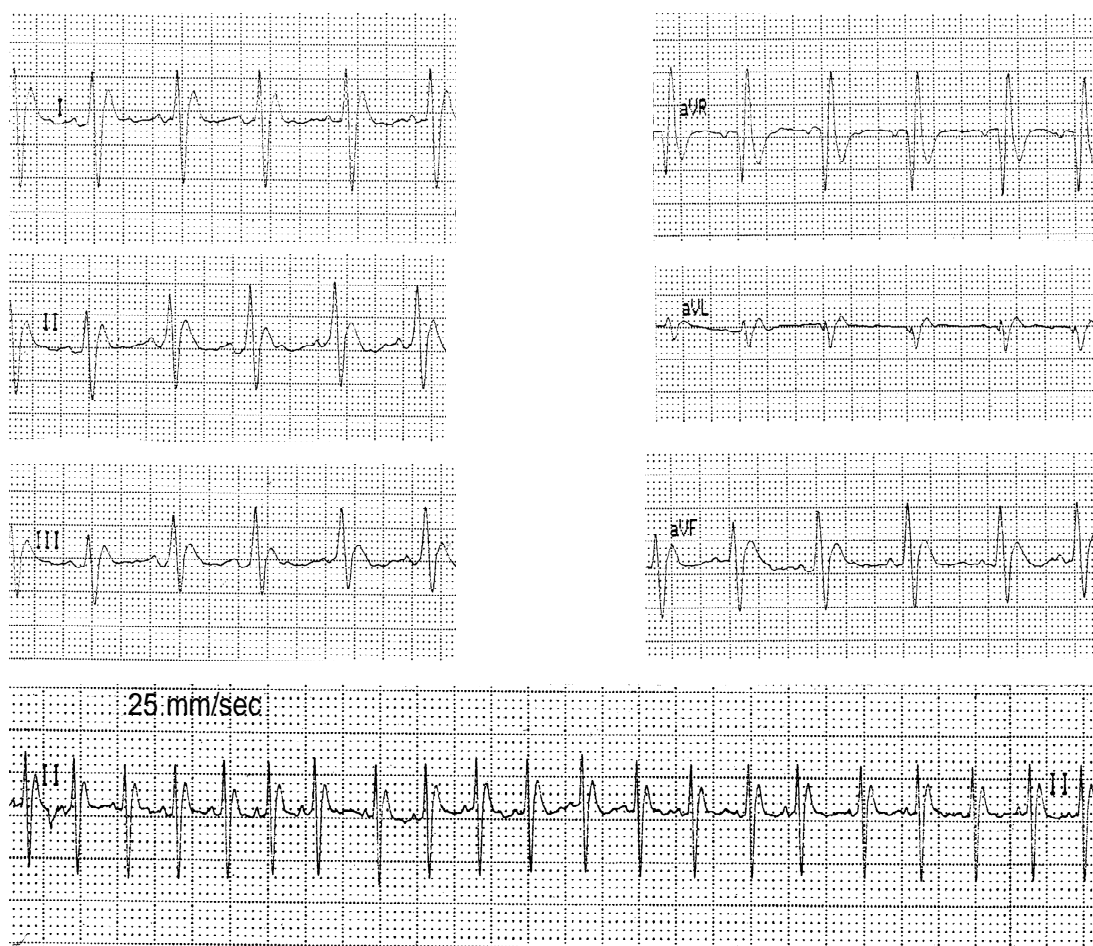


Figure 36: Two year old male ferret with DCMP (Nr.4 NSD group). These tracings demonstrate right bundle branch block (RBBB). The P waves are normal but the QRS complexes are large and wide. The QRS duration is 0.07-0.08 sec. The S waves are large and wide in lead I, II, III and aVF. The T wave amplitude is remarkably high (0.3 mV) and about 50% of the R wave. (Paper speed 50 mm/sec, sensitivity 1 cm/mV)

## Results

### Mean electrical axis

Fifty ECG were used to determine the mean electrical axis in the frontal plane. Twenty five cases belonged to normal groups (group A, NSN and group C, SN) and the other twenty six cases belonged to disease groups (group B, NSD and group D, SD). The mean electrical axis was calculated by using the net deflections of the QRS complex in lead I and lead aVF (See Figure 12, page 25 for more details).

In the clinical normally groups (n=25), one case showed a negative net deflection of the QRS in lead I and one case in lead aVF. The average mean electrical axis in the clinical normal groups was 59.58 degrees. 84% (21/25) of the normal groups had a MEA range from 30 to 100 degrees. Three cases (3/25, 12%) had a MEA less than 30 degree (-10, 11.5 and 23 degree) and one case (1/25, 4%) had a MEA angle more than 100 degree (104.5 degree). (Table 10, 11 and Figure 37)

In the disease groups (n=25), only one case revealed a negative net deflection of the QRS in lead I. The average MEA was 70.30 degrees. Twenty four cases had a MEA ranging from 30 to 90 degree (24/25, 96%). One case (1/25, 4%) had a MEA more than 100 degrees (125 degree) (Table 10 and 11)

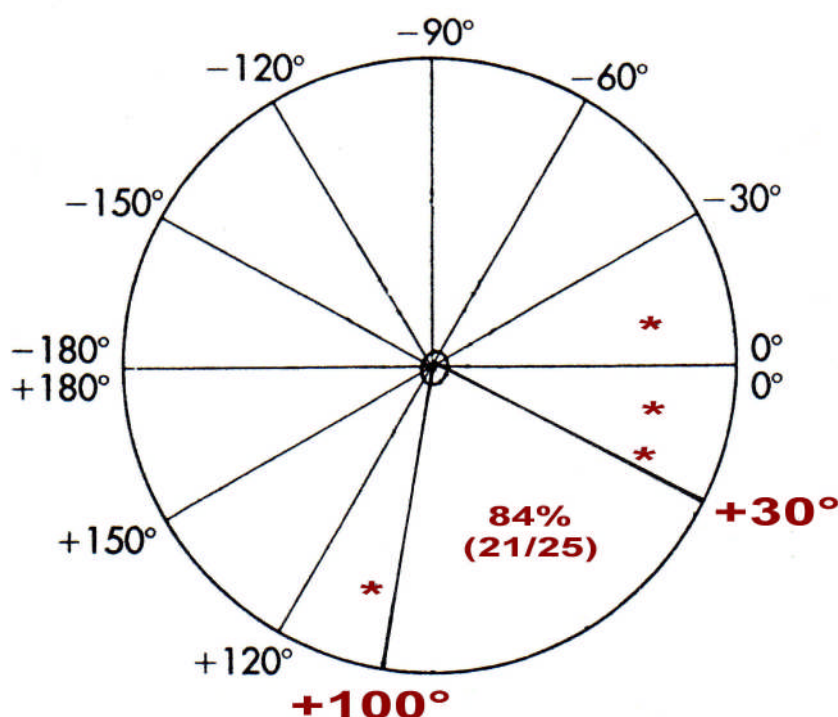


Figure 37: MEA in clinical normal group. Eighty four percent of the animals had a MEA angle 27 to 100 degree and four other cases had an angle different from the major population (\*).

## Results

Table 10: MEA values in normal (group A, NSN and group C, SN) and disease (group B, NSD and group D, SD) groups.

Groups	MEA (degrees)				
	Max	Min	Mean	Median	SD
Normal groups	104.5	-10	59.58	60	26.69
Disease groups	125	43.5	70.30	72	17.04

Table 11: Classification of MEA (degree) in normal (group A, NSN and group C, SN) and disease (group B, NSD and group D, SD) groups.

MEA (degree)	Number of cases	
	Normal groups (N=25)	Disease groups (N=25)
< 30	3	0
30-40	2	0
41-50	4	4
51-60	4	3
61-70	1	5
71-80	5	8
81-90	5	4
91-100	0	0
> 100	1	1

### 4.3 Radiography

All 96 animals underwent a radiographic examination only 43 of appropriate quality films (eg. positioning etc.) were selected to evaluate the heart and associated structures in the following paragraph. The chest films of 18 animals belonged to the normal groups (group A, NSN and group C, SN) and the films of the other 25 animals belonged to the disease groups (group B, NSD and group D, SD). The average body weight in the normal groups and disease groups were 0.99 kg (maximum 2 kg, minimum 0.5 kg, SD 0.393) and 1.32 kg (maximum 2.3 kg, minimum 0.7 kg, SD 0.363), respectively. In the normal groups, the mean age was 21.17 months compared to 30.96 months in the disease groups.

#### Modified VHS method

The short and long axis of a heart silhouette on the lateral position, dorsoventral position as well as the length of T5 to T8 were measured and calculated and compared to the length of T5-8. In lateral recumbency, the mean length of the long axis and the short axis of the cardiac silhouette and length of T5-8 of the disease groups were higher than in the normal groups. The mean length of the cardiac silhouette long axis, short axis, and T5-8 of the normal groups were 2.81, 2.24 and 3.64 cm compared to the values of the disease groups 3.19, 2.67 and 4.04 cm respectively (Table 12). The mean modified VHS (Stepien et al., 1999) of the normal groups compared to the disease groups was 5.57 to 5.79.

#### ICS score method

The heart silhouette on the lateral view was measured and compared to the number of the ICS. In the normal groups, the mean values were 2.28 ICS compared to 2.70 ICS in the disease groups (Figure 38 and 39). The maximum value in the normal groups was 3.00 ICS compared to 4.00 ICS in the disease groups. The median value of the ICS in the normal groups was also lesser than the ICS value in the disease groups (2.3 ICS vs. 2.5 ICS). For more details see table 12.

#### Heart/thoracic ratio

In the normal groups, the heart/thoracic ratio method showed a mean height of the heart measured from the cardiac apex to the base (L) was 2.81 cm (maximum 3.60 cm, minimum 2.00 cm, median 2.75 cm, SD 0.516). The mean height of the thoracic cavity measured from the upper to the lower thoracic wall through the heart base and apex (T) (See Figure 23, page 39) was 5.09 cm (maximum 6.50 cm, minimum 3.50 cm, median 4.85 cm, SD 0.970). The mean heart/thoracic ratio was therefore 0.55 (maximum 0.73, minimum 0.43, median 0.55, SD 0.064)

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In the disease groups, the mean height of the heart was 3.19 cm (maximum 3.70 cm, minimum 2.50 cm, median 3.20 cm, SD 0.327). The mean height of the thoracic cavity measured from the upper to the lower thoracic wall through the heart base and apex (T) was 5.82 cm (maximum 6.70 cm, minimum 5.00 cm, median 6.00 cm, SD 0.515). The mean heart/thoracic ratio was 0.54 (maximum 0.60, minimum 0.41, median 0.55, SD 0.041).

Table 12: Cardiac measurement values from lateral position (Lat).ICS, intercostal space; Lat L, lateral long axis; Lat S, lateral short axis; Lat T5-8, T5-8 length on lateral; VHS Lat, vertebral heart score on the lateral view.

Groups	Values	Lat L(cm)	Lat S(cm)	Lat T5-8(cm)	VHS Lat	ICS
Normal	N (cases)	18	18	18	18	18
	Maximum	3.60	3.00	5.0	6.75	3.00
	Minimum	2.00	1.50	2.90	4.75	2.00
	Median	2.75	2.20	3.45	5.75	2.30
	Mean	2.81	2.24	3.64	5.57	2.28
	SD	0.516	0.448	0.526	0.568	0.303
Disease	N (cases)	25	25	25	25	25
	Maximum	3.70	3.20	4.50	6.50	4.00
	Minimum	2.50	2.00	3.30	5.25	2.00
	Median	3.20	2.70	4.10	5.75	2.50
	Mean	3.19	2.67	4.04	5.79	2.70
	SD	0.327	0.322	0.312	0.366	0.500



*Results*

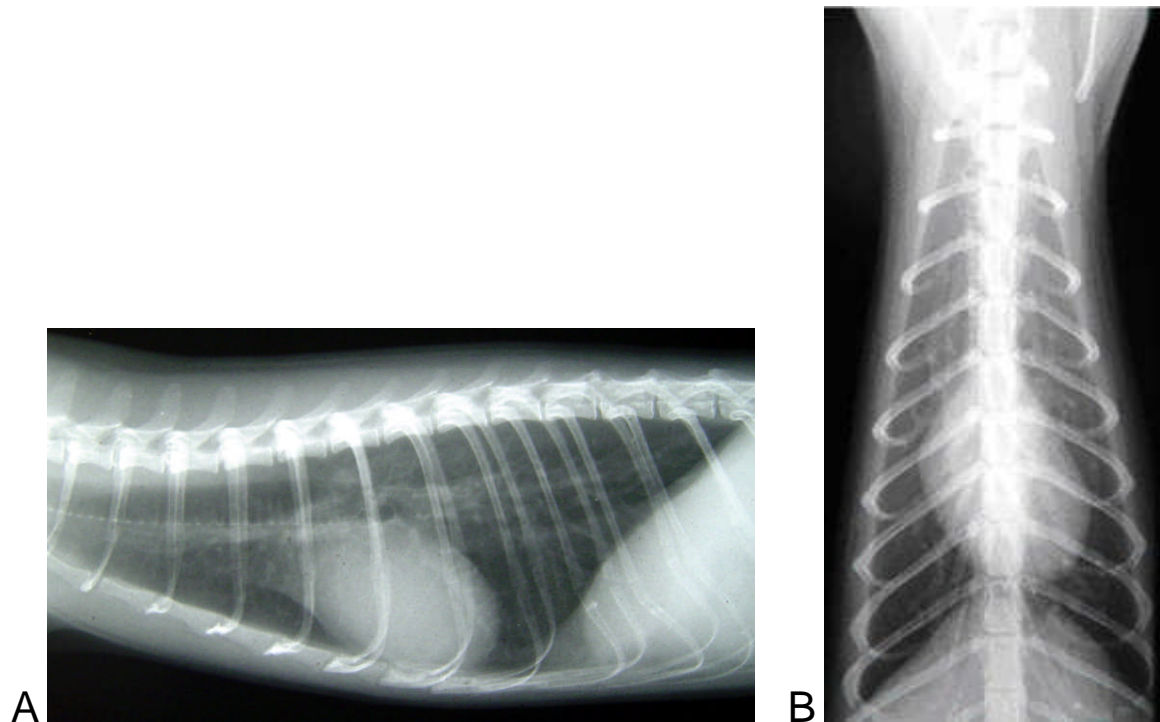


Figure 38: Two year old female ferret (Group A, NSN) shows normal thoracic radiographs on lateral (A) and dorsoventral views (B). The lateral thoracic radiograph shows a normal cardiac silhouette with 2.5 ICS width.

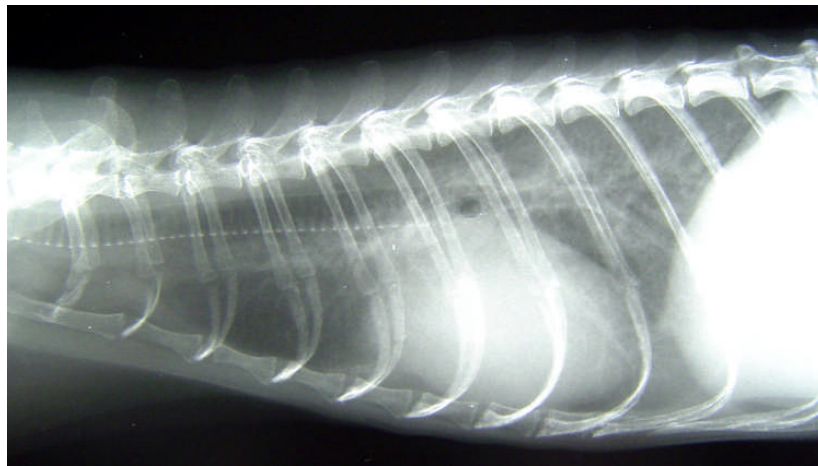


Figure 39: Eight year old male ferret (Group B, NSD). The thoracic radiograph reveals cardiomegaly. The cardiac silhouette measures 3 ICS. The lung fields show an increase in tissue density, especially at the caudodorsal region.

## Results

In the DV view, the measurement of the mean cardiac silhouette axis in the normal groups (group A, NSN and group C, SN) were 3.60 cm in long axis and 2.48 cm in short axis length. In the disease groups (group B, NSD and group D, SD), the mean long axis length was 4.11 cm and short axis was 2.90 cm. The mean length of T5-T8 on the DV view was 3.58 cm and 3.99 cm in the normal and the disease groups respectively. Modified VHS showed a mean value 6.82 in the normal groups and 6.98 in the disease groups (Table 13).

Table 13: Cardiac measurement values from dorsoventral position. DV L, dorsoventral long axis; DV S, dorsoventral short axis; DV T5-8, T5-8 on dorsoventral view; VHS DV, vertebral heart score on the dorsoventral view.

Groups	Values	DV L (cm)	DV S (cm)	DV T5-8 (cm)	VHS DV
Normal	N (cases)	18	18	18	18
	Maximum	4.70	3.20	4.50	8.25
	Minimum	2.60	1.70	3.00	5.75
	Median	3.45	2.35	3.40	6.63
	Mean	3.60	2.48	3.58	6.82
	SD	0.741	0.452	0.425	0.742
Disease	N (cases)	25	25	25	25
	Maximum	4.70	3.50	4.50	7.75
	Minimum	3.40	2.30	3.30	6.00
	Median	4.20	3.00	4.00	7.00
	Mean	4.11	2.90	3.99	6.98
	SD	0.375	0.276	0.311	0.444

The cardiac contour was interpreted in all cases. Eighteen out of 43 cases revealed a globoid cardiac shape and/or increase of convexity at the apex of the heart (Figure 40). Five cases belong to the normal groups and the remaining 13 cases were belonging to the disease groups. Nine out of 43 cases had a cardiac silhouette without contact to the sternum. Eight out of nine cases without sternal contact are coming from the disease groups (Figure 41). Twenty three out of 43 cases revealed an evidence of fat in the ligament which connects the heart to the diaphragm (Figure 42). On the lateral view, the anterior bronchial artery and vein were interpreted to determine an evidence of pulmonary congestion. In most of the thoracic radiographs one could not identify the anterior lung vessels. The main bronchial artery and vein were identified only in four cases from 43 cases and all of these

## Results

belong to normal groups. The vessel diameters in all cases were normal in size. The tracheal positions in all animals were also evaluated. On the lateral view, most animals (38 out of 43 cases, 88.37%) had the trachea parallel or at an angle less than 10 degrees compared to the vertebral column (Figure 43). Eighteen from these belonged to the normal groups and the remaining belonged to disease groups. Only five cases (11.63%) had an angle between 10-20 degrees. Though visible separation of the stem bronchi occurred in severe DCMP, no evidence of main bronchial compression caused by left atrial enlargement was detected in any case. Six cases in the disease groups (6/25, 24%) revealed evidence an increase of tissue density possibly caused by lung congestion and/or a infectious-inflammatory process. Bronchial patterns were detected in two cases and air bronchograms were also detected in two cases. One case showed evidence of pneumonia with mixed patterns of bronchial and/or interstitial opacification. Pleural effusion was detected in one case.

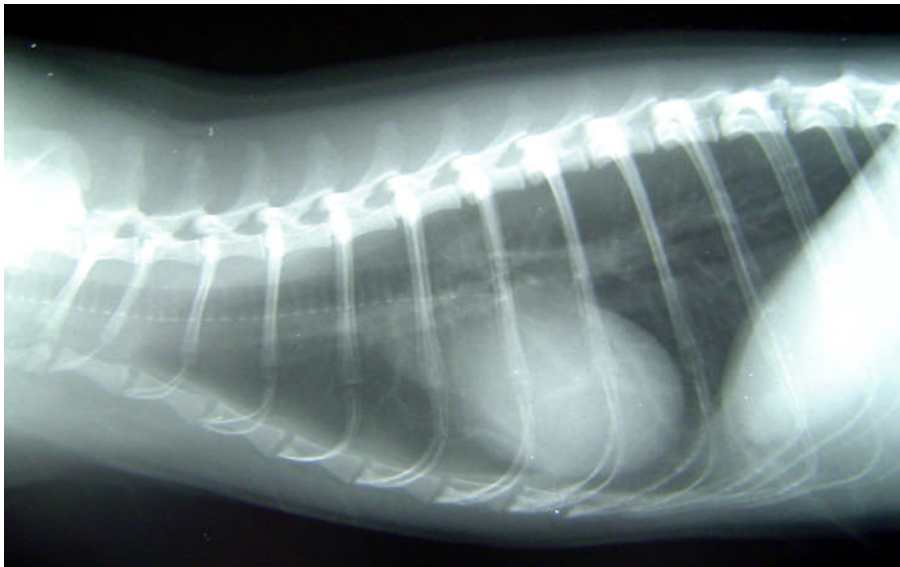


Figure 40: Seven month old male ferret (Group B, NSD). The lateral thoracic radiograph shows a globoid cardiac contour.

## Results

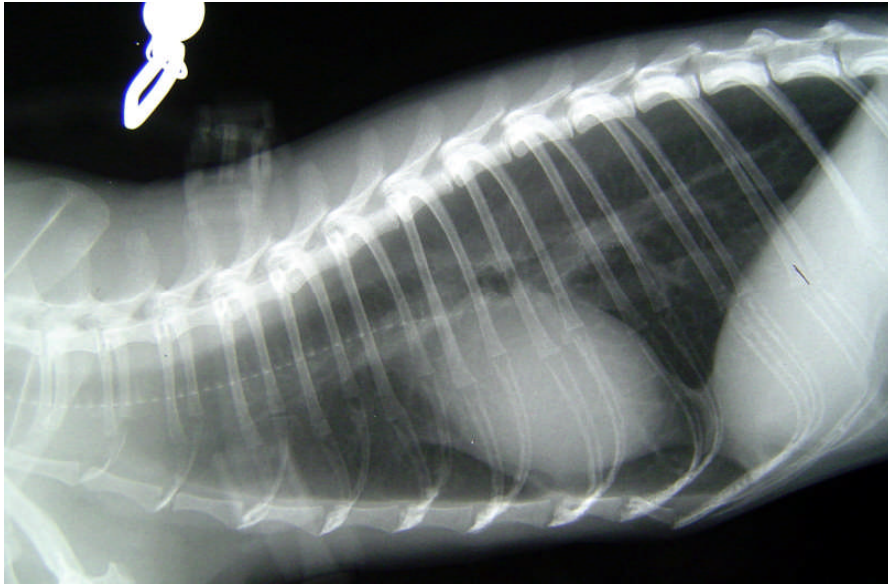


Figure 41: Two year old male ferret (Group B, NSD). The heart silhouette has no contact with the sternum.

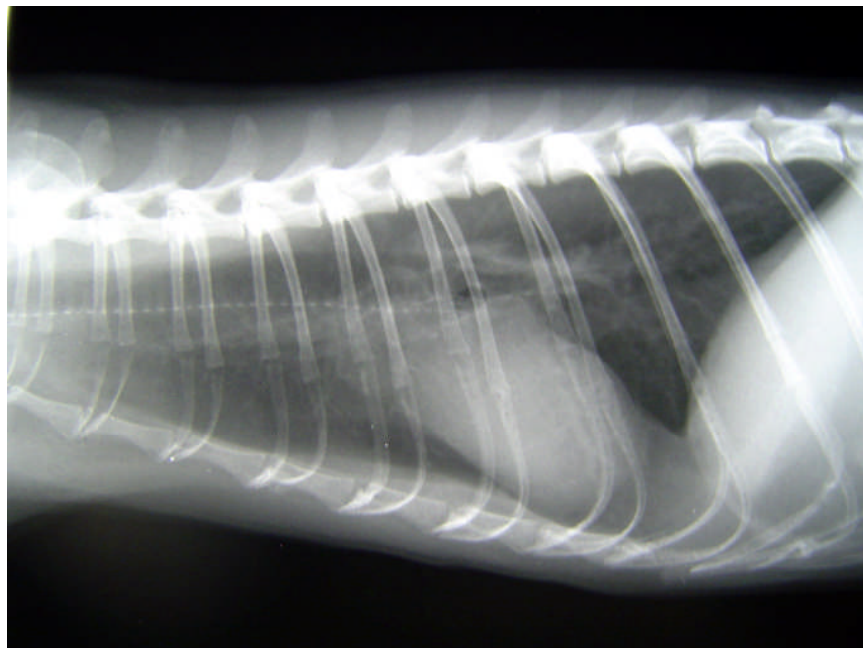


Figure 42: One year old male ferret (Group A, NSN). Evidence of fat at the sternum and in the phrenicopericardial ligament which connects the heart to the diaphragm. The presence of a notable amount of fat in the ligament was based on the little difference in opacification between the cardiac silhouette and the ligament.

## Results

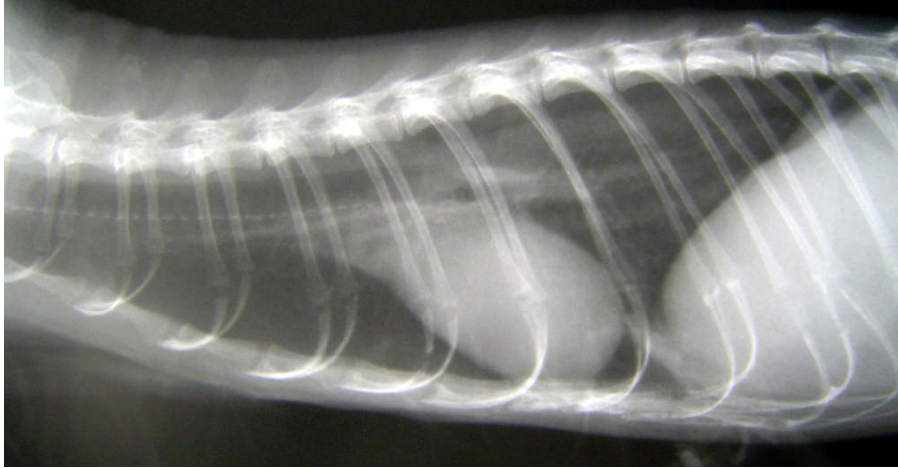
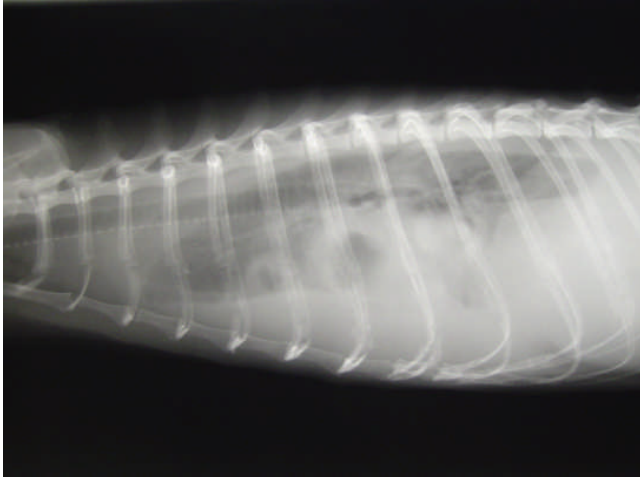


Figure 43: Eight year old female ferret (Group A, NSN). In the thoracic radiograph, the trachea shows an angle less than 10 degree compared to the vertebral column.

Dyspneic cases not included in the CVS groups.

Thirty one animals were added to the study. These animals had evidence of dyspnea when visiting the Small Animal Clinic. The thoracic radiographs were made in order to find out the causes of dyspnea. Pneumonia in this report was diagnosed by evidence of infectious–inflammatory density changes of the lung fields or presented evidence of interstitial edema and/or alveolar edema on the X-ray film. Interstitial edema was diagnosed by the appearance of diffuse increased opacity of the lung fields owing to a hazy interstitial opacity. The alveolar edema was diagnosed if the evidence of fluid filling the alveolar air spaces and peripheral bronchioles, causing a coalescent fluffy alveolar infiltrate or presenting evidence of air bronchograms. In this group, the animals were between one to six years old (mean 2.84 years old). Within this group thirteen animals were male (41.94%) and 17 animals were female (58.06%). Pneumonia was the most radiographic abnormality in this extra group and presented 38.71% (12 cases) of the dyspneic animals. Pleural effusion was found concurrently in one case together with pneumonia (Figure 44). On the radiographic examination, cardiomegaly was detected in five cases (16.13%) and an abnormal precardial mass was found in two cases (6.45%) (Figure 45). The other abnormalities: tracheal collapse, pneumothorax, diaphragmatic hernia and ascites were found in nine cases (29.03%). In three radiographs (9.68%) no definitive changes of the lung or cardiac silhouette were observed despite of the dyspnea.

A



B



Figure 44: Thoracic radiograph from an emergency patient. The animal was dyspneic at home and during examination. The lateral (A) and dorsoventral (B) thoracic radiograph shows pleural effusion. A and B, The pleural effusion obscured the cardiac silhouette. B, the fluids separate the lung lobe from the thoracic wall and cause linear opacities between lung lobe and thoracic wall (arrows).

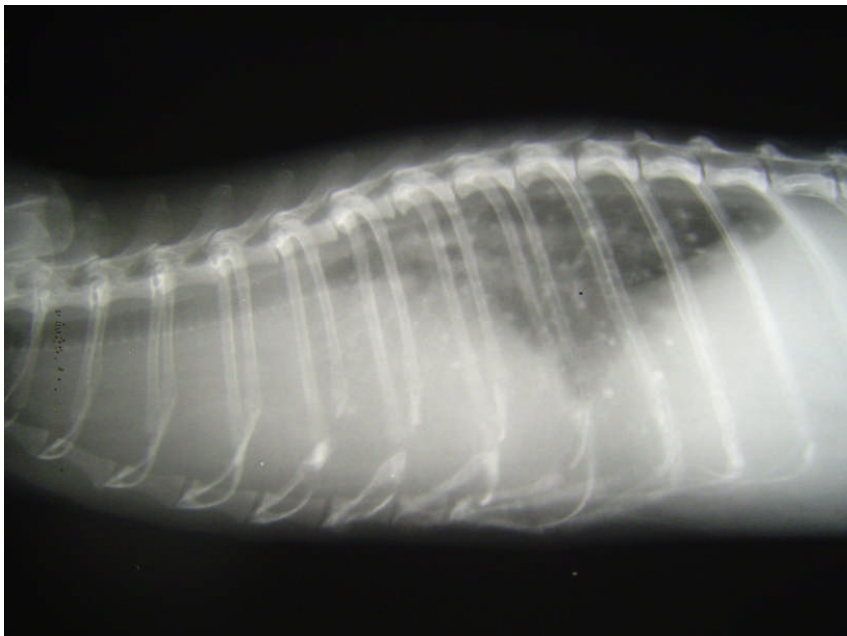


Figure 45: Five year old male ferret. Thoracic radiograph shows increase of density cranial to the heart. The definitive diagnosis of precardial mass was made by echocardiography. The mass pushes the trachea dorsally against the vertebral column. The lung field shows granular opacities that can be interpreted as metastasis of the tumor or a concurrent inflammatory infiltration.

#### 4.4 Echocardiography

Forty five animals were examined echocardiographically. Among these patients, eleven cases (24.44%) were classified into the normal groups (group A, NSN and group C, SN). The other 34 cases (75.56%) belonged to the disease groups (group B, NSD and group D, SD).

In the normal groups, ten cases who underwent a complete clinical examination without any sedative drugs were enrolled into group A (NSN group) and just only one case was sedated and therefore belong to group C (SN group).

In the disease groups, 22 cases who had not received sedative medication belonged to group B (NSD group) and twelve cases who received sedative drugs during clinical examinations belonged to group D (SD group).

In the right parasternal position of the 2-D mode, the left and right heart chambers as well as cardiac valves, LVOT and AO were evaluated. In the normal groups the 2-D mode echocardiography of the right parasternal long axis view showed the interventricular septum was straight and intact. The interventricular septum thickness was around the same level of the LV wall thickness. By subjective interpretation, the LA size was a little bigger than the aorta. The mitral valves were thin and showed the same thickness through the whole structure.

In the disease groups, the most frequent abnormalities were an enlargement of the LV and LA as well as a hypocontractility of the left ventricle (Figure 46). These features were found mostly in patients with DCMP. Although the LA enlargement was noted as one of the frequent abnormalities, neither echocardiographic smoke nor LA thromboemboli were found. The left ventricular free wall and interventricular septum were thin in most patients which were affected with DCMP (Figure 47). Pleural and pericardial effusions were also demonstrated in the disease groups (Figure 46). One patient suffering from pericardial effusion had only a small quantity of fluid which existed without signs of cardiac tamponade. Mitral valve lesions were detected in one patient (Figure 48). Two-dimensional echocardiogram revealed the thickening of the mitral valve but no evidence of mitral valve prolapse was recorded. No remarkable lesions on the tricuspid, pulmonic as well as aortic valves were noted.

In the Doppler examination (n=22), the mitral inflow pattern was often observed to have an overlapping of the E and A waves due to the high heart rate in this species. Mitral regurgitation was most often recorded (Figure 49 and 50). Low velocity regurgitation jets could also be detected on the tricuspid, aortic and pulmonic valve. Remarkable mitral regurgitation was found mostly in DCMP patients. The pulmonic and aortic velocities were recorded in nine and fourteen cases respectively. All of these cases had no anatomic valve abnormalities. The pulmonic flow velocity (n=9) was detected at a range from 0.5 to 1.15

## Results

m/sec (mean 0.76 m/sec, median 0.60 m/sec, SD 0.245). The aortic flow velocity (n=14) was ranging from 0.6 to 1 m/sec (mean 0.80 m/sec, median 0.80 m/sec, SD 0.144). (Figure 51)

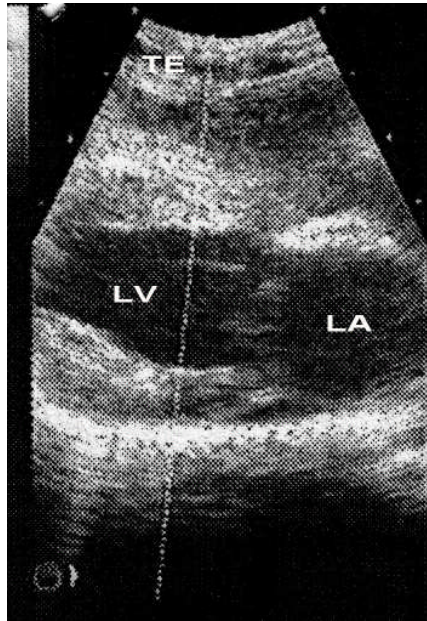


Figure 46: Eight year old male ferret (Nr.10 NSD group). Two-dimensional echocardiogram records from the right parasternal long axis view. The left atrium is enlarged. There is mild pleural effusion shown at the top of the figure (TE). LA, left atrium; LV, left ventricle; TE, pleural effusion.

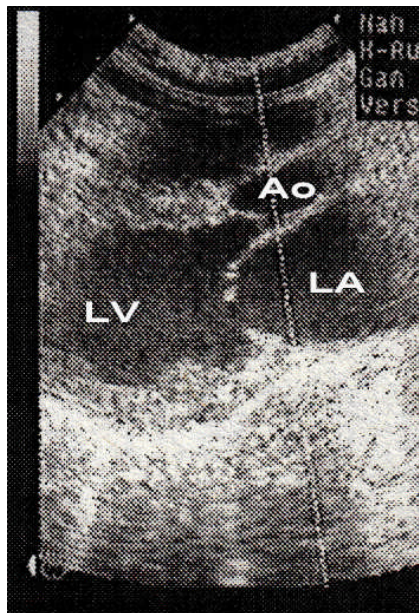


Figure 47: Five year old male ferret (Nr. s13 SD group). Echocardiography reveals massive enlargement of the left atrium as well as the left ventricle. The left ventricular wall and IVS were relatively thin. The patient was diagnosed to have DCMP.



## Results

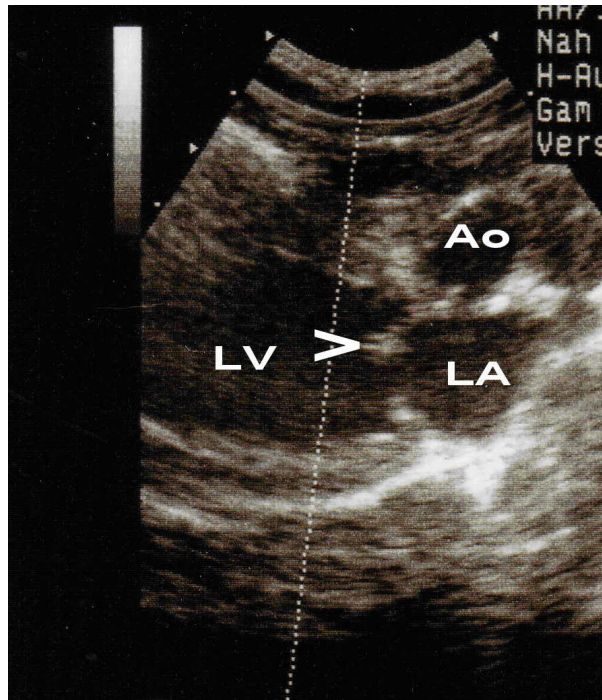


Figure 48: One year old male ferret (Nr.45 NSD group). The right parasternal long axis demonstrates mitral valve lesion (arrow). The leaflets are thickened. The left atrium is enlarged when compared to the aortic diameter.

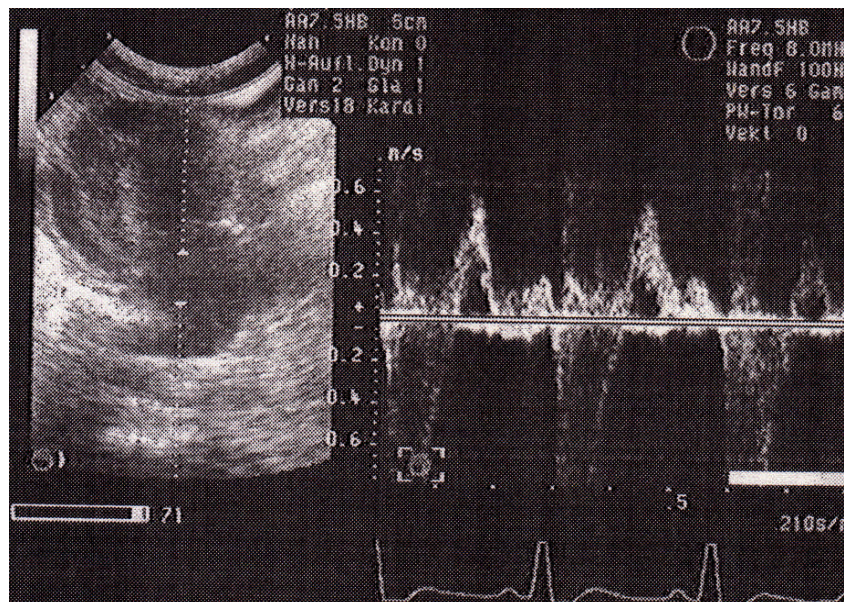


Figure 49: Five year old male ferret (Nr. s13 SD group). At the physical examination, a mild systolic heart murmur (2<sup>o</sup>) was heard on the left side of the thorax. Doppler echocardiography shows a mitral regurgitation jet (negative waves).

## Results

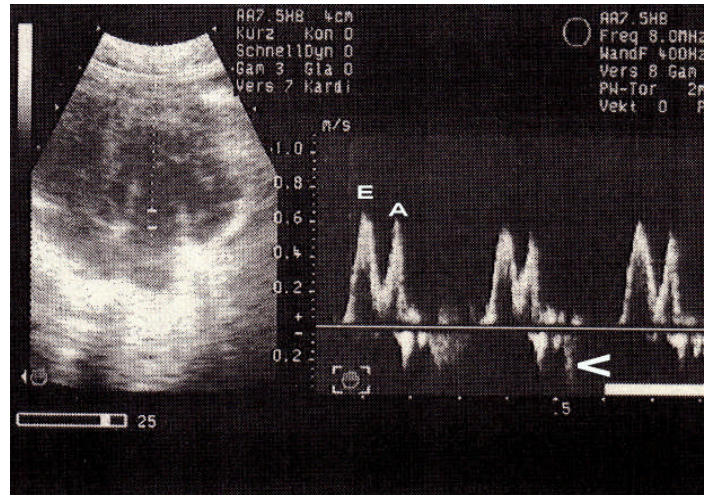


Figure 50: Two year old male ferret (Nr.4 NSD group). Mitral flow recorded from the left parasternal apical four chamber view. There is a positive wave with M configuration. The E peak corresponds to rapid ventricular filling. The A peak represents the flow associated with atrial contraction. A mitral regurgitation jet is also detected in this case (open arrow).

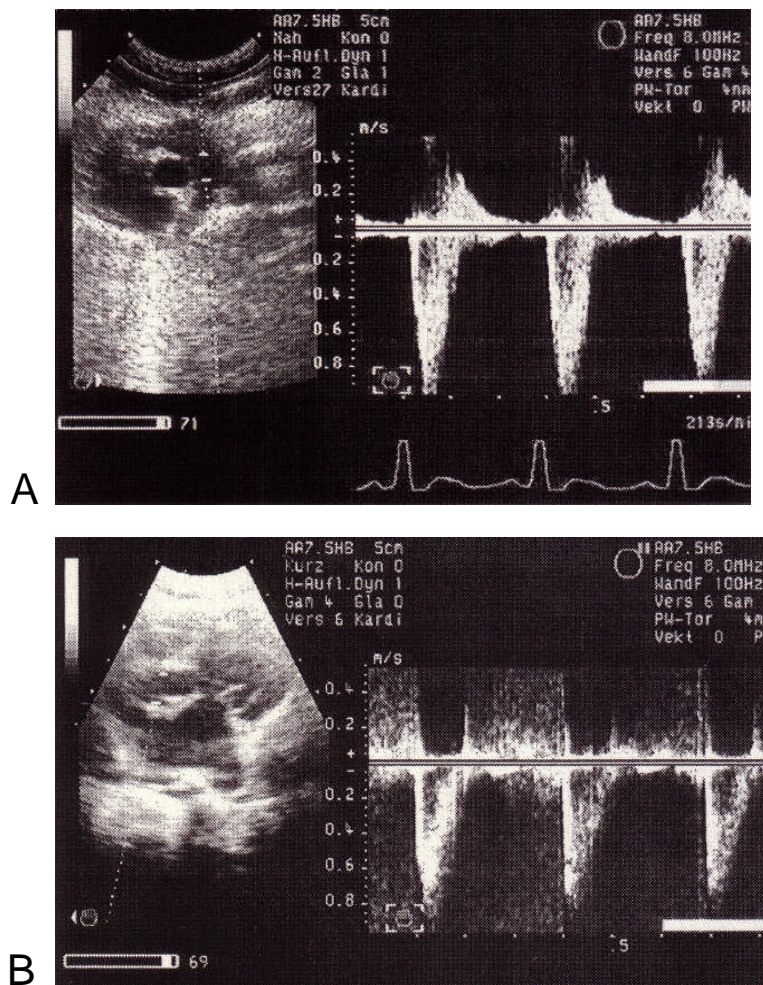


Figure 51: Doppler echocardiography demonstrates pulmonic and aortic flow. A; Nine year old male ferret (Nr. s16 SD group) shows a pulmonic flow at a velocity around 1 m/sec. The flow shape looks symmetric and rounded in appearance. B; Five year old female ferret (Nr. s14 SD group) demonstrates an aortic flow pattern (around 0.9 m/sec). There is also indication of aortic regurgitation.

## Results

### Measurements of the left ventricle (Table 14-17)

#### Normal groups (NSN group and SN group) (Figure 52 and 53):

Because there is only one sedated normal animal in the SN group and the measurement does not differ from the NSN group they are described together as normal groups. During the diastolic period, the mean of the left ventricular diastolic dimension (LVDd) was 1.04 cm. The interventricular septum mean value at the end diastolic period (IVSd) was 0.35 cm in thickness. The left ventricular wall thickness at end diastole (LVWd) showed a mean value of 0.36 cm. At the systolic period, the mean left ventricular dimension (LVDs) was 0.60 cm. The mean of the interventricular septum (IVSs) and the left ventricular wall (LVWs) were equal in thickness. More details see table 14 and 15.

#### Disease groups (NSD group and SD group) (Figure 52 and 54-56):

During the diastolic period, the mean of the LVDd in the disease groups was 1.20 cm. The sedated animals (SD group) had a left ventricular dimension mean value that was bigger than in nonsedated animals (NSD group) (Table 16 and 17). IVSd thickness in the disease groups was 0.29 cm in average (Table 14). The LVWd was 0.33 cm thickness in average (Table 14). At the systolic period, LVDs was 0.85 cm (Table 14). The thickness of the IVSs and LVWs were 0.38 and 0.42 cm respectively (Table 14).

### Evaluation of the systolic function (fractional shortening) (Table 14 and Figure 52)

#### Normal groups (NSN group and SN group):

The fractional shortening (FS) in the normal groups revealed values between 38% to 53% with a 42.48% as the mean value.

#### Disease groups (NSD group and SD group):

In the disease groups FS was 30.42% as a mean value. It showed that the systolic function is worse than in the normal groups (Figure 54).

### Evaluation of the aorta and left atrial size (Table 14)

#### Normal groups (NSN group and SN group):

The left atrial size in the normal groups showed a 0.98 to 0.54 cm in dimension (mean 0.74). The aortic root had a 0.65 cm maximum dimension and 0.45 cm for the smallest size. Therefore the LA/AO ratio could be calculated 1.00 to 1.52 (mean 1.32).

#### Disease groups (NSD group and SD group):

The mean left atrial dimension in the disease groups was 0.80 cm and the aortic root size in these groups was 0.57 cm. It made the LA/AO ratio in the disease groups bigger than in the

## Results

normal groups (mean value 1.41 in disease groups vs 1.32 in normal groups). See also Figure 57.

Table 14: M-mode echocardiographic values from normal (NSN group and SN group) and disease (NSD group and SD group) groups.

M-mode values	Normal Groups (N = 11)					Disease Groups (N = 34)				
	Max	Min	Mean	Median	SD	Max	Min	Mean	Median	SD
LVDd (cm)	1.42	0.69	1.04	1.12	0.225	1.95	0.47	1.20	1.21	0.323
LVDs (cm)	0.86	0.04	0.60	0.62	0.142	1.44	0.26	0.85	0.82	0.270
IVSd (cm)	0.56	0.19	0.35	0.32	0.125	0.44	0.16	0.29	0.29	0.073
IVSs (cm)	0.71	0.31	0.49	0.47	0.149	0.55	0.17	0.38	0.39	0.091
LVWd (cm)	0.63	0.20	0.36	0.36	0.109	0.49	0.22	0.33	0.31	0.074
LVWs (cm)	0.75	0.35	0.49	0.47	0.101	0.69	0.04	0.42	0.43	0.119
FS (%)	53.22	37.98	42.48	42.31	4.371	52.07	11.95	30.42	28.54	9.203
LA (cm)	0.98	0.54	0.74	0.68	0.145	1.29	0.52	0.80	0.73	0.206
AO (cm)	0.65	0.45	0.56	0.56	0.070	0.69	0.39	0.57	0.59	0.079
LA/AO	1.52	1	1.32	1.38	0.180	2.12	0.98	1.41	1.43	0.283

Table 15: M-mode echocardiographic values from nonsedated normal group (NSN group).

M-mode values	NSN Group (N =10)				
	Max	Min	Mean	Median	SD
LVDd (cm)	1.42	0.69	1.05	1.14	0.237
LVDs (cm)	0.86	0.40	0.61	0.64	0.142
IVSd (cm)	0.56	0.19	0.35	0.31	0.131
IVSs (cm)	0.71	0.31	0.49	0.46	0.157
LVWd (cm)	0.63	0.20	0.35	0.36	0.115
LVWs (cm)	0.75	0.35	0.48	0.46	0.105
FS (%)	47.16	37.98	41.40	41.73	2.668
LA (cm)	0.98	0.54	0.74	0.73	0.149
AO (cm)	0.65	0.45	0.56	0.57	0.074
LA/AO	1.52	1.00	1.34	1.39	0.179

## Results

Table 16: M-mode echocardiographic values from nonsedated disease group (NSD group)

M-mode values	NSD Group (N = 22)				
	Max	Min	Mean	Median	SD
LVDd (cm)	1.69	0.47	1.14	1.15	0.323
LVDs (cm)	1.30	0.26	0.77	0.74	0.266
IVSd (cm)	0.44	0.18	0.28	0.29	0.069
IVSs (cm)	0.55	0.17	0.38	0.39	0.092
LVWd (cm)	0.49	0.22	0.33	0.32	0.079
LVWs (cm)	0.69	0.28	0.44	0.44	0.115
FS (%)	52.07	11.95	33.30	32.92	9.654
LA (cm)	1.15	0.52	0.80	0.76	0.184
AO (cm)	0.69	0.39	0.57	0.59	0.077
LA/AO	1.92	0.98	1.41	1.46	0.252

Table 17: M-mode echocardiographic values from sedated disease group (SD group).

M-mode values	SD Group (N = 12)				
	Max	Min	Mean	Median	SD
LVDd (cm)	1.95	0.89	1.32	1.37	0.304
LVDs (cm)	1.44	0.68	0.99	1.03	0.226
IVSd (cm)	0.44	0.16	0.31	0.32	0.080
IVSs (cm)	0.54	0.25	0.40	0.41	0.090
LVWd (cm)	0.44	0.22	0.31	0.30	0.063
LVWs (cm)	0.50	0.04	0.39	0.41	0.125
FS (%)	33.11	12.26	25.15	25.95	5.413
LA (cm)	1.29	0.58	0.81	0.73	0.250
AO (cm)	0.69	0.42	0.57	0.56	0.867
LA/AO	2.12	1.06	1.42	1.40	0.344

## Results

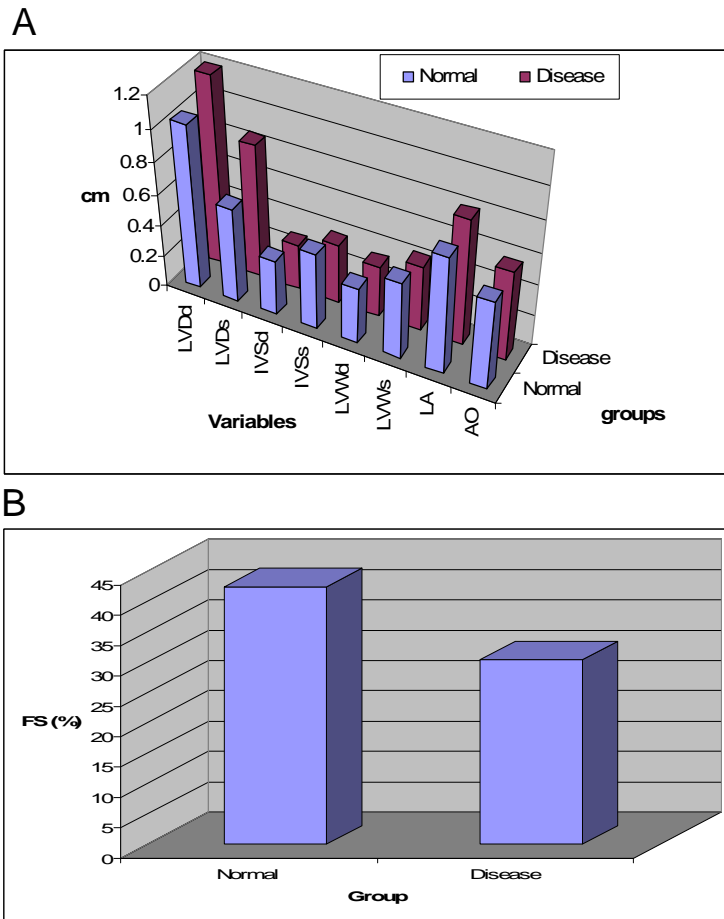


Figure 52: A; Comparative M-mode echocardiographic mean values (cm) of the LV, LA and AO between normal and disease groups. B; Comparison of fractional shortening between normal and disease groups.

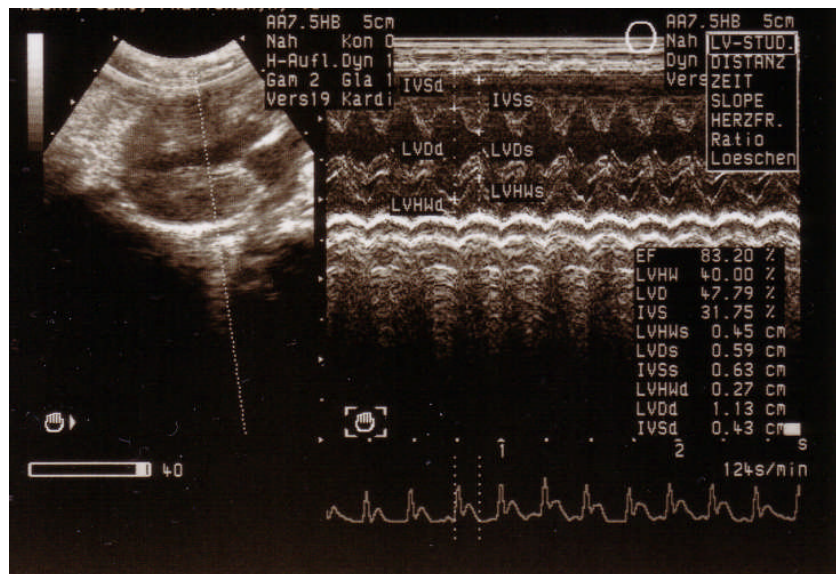


Figure 53: One year old female ferret. M-mode echocardiography measured from the right parasternal left ventricular out flow view. The left ventricle contraction is normal. FS is 47.8%. The papillary muscle was extremely thick.

## Results

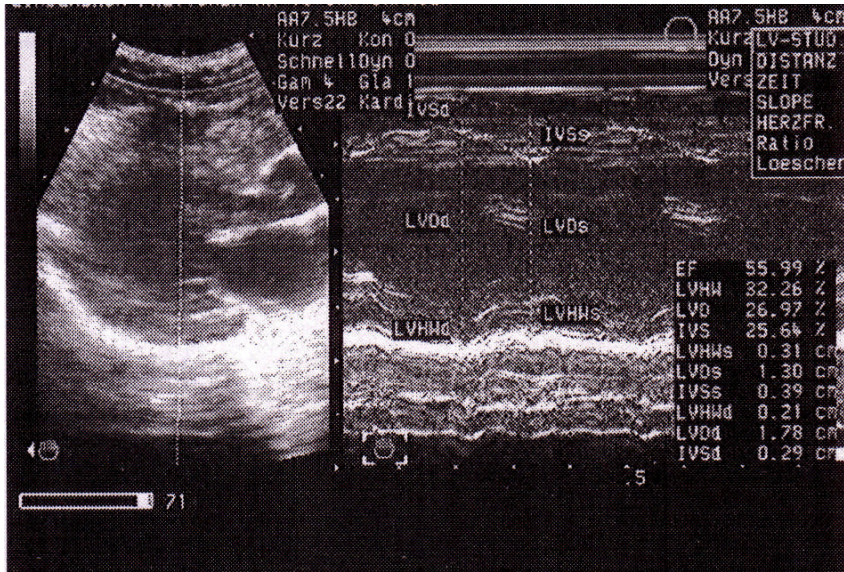


Figure 54: Three year old male ferret (Nr.14 NSD group) with DCMP. M-mode shows a massive dilatation of the left ventricle (LVDD = 1.78 cm). On the 2-D view, the left atrium is enlarged compared to the aortic root. FS is 26.97%.

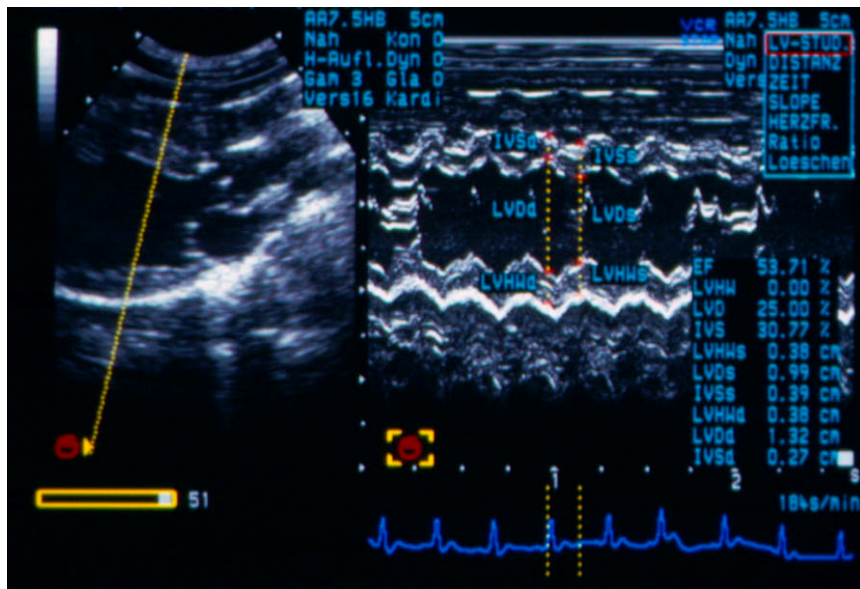


Figure 55: One year old male ferret (Nr.45 NSD group). The echocardiographic features characterize the dilatation of the LV with decreasing in the IVSd thickness. No LA dilatation could be noted.

## Results

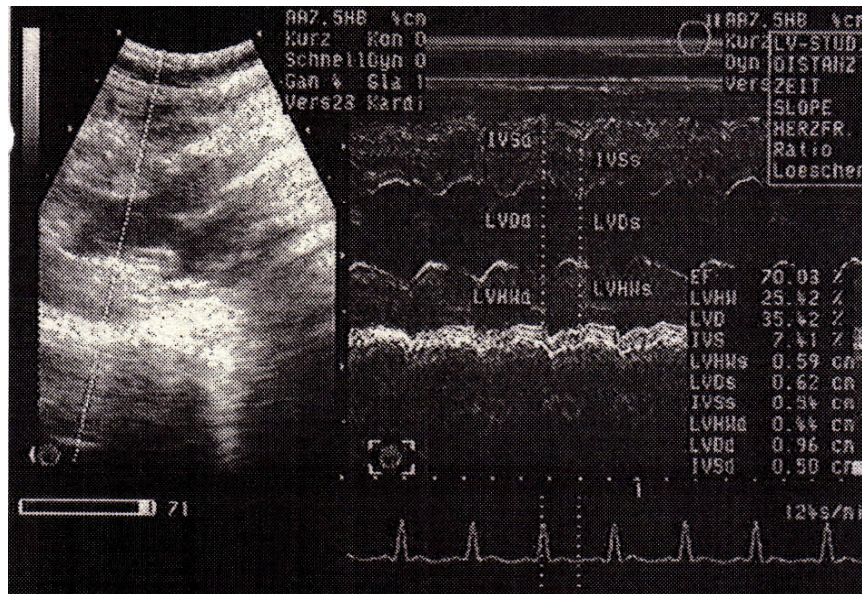


Figure 56: Two year male ferret (Nr.37 NSD group). The patient was in normal body condition. On the auscultation revealed a 1-2/5 grade systolic heart murmur on the left side. FS is 35.42% on the echocardiographic examination. Occult DCMP is suspected.

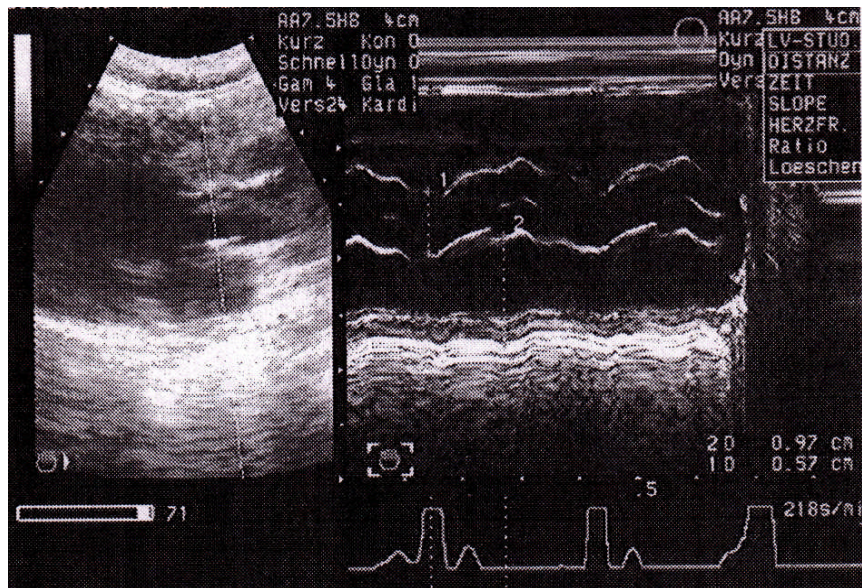


Figure 57: One year old male ferret (Nr.29 NSD group). 2-D guided M-mode at the left ventricular outflow view. The LA to AO ratio is measured on this view. The LA is enlarged and the LA/AO ratio is elevated to 1.70.