ECHOCARDIOGRAPHIC STUDIES OF VALVULAR AND VENTRICULAR FUNCTION IN HORSES

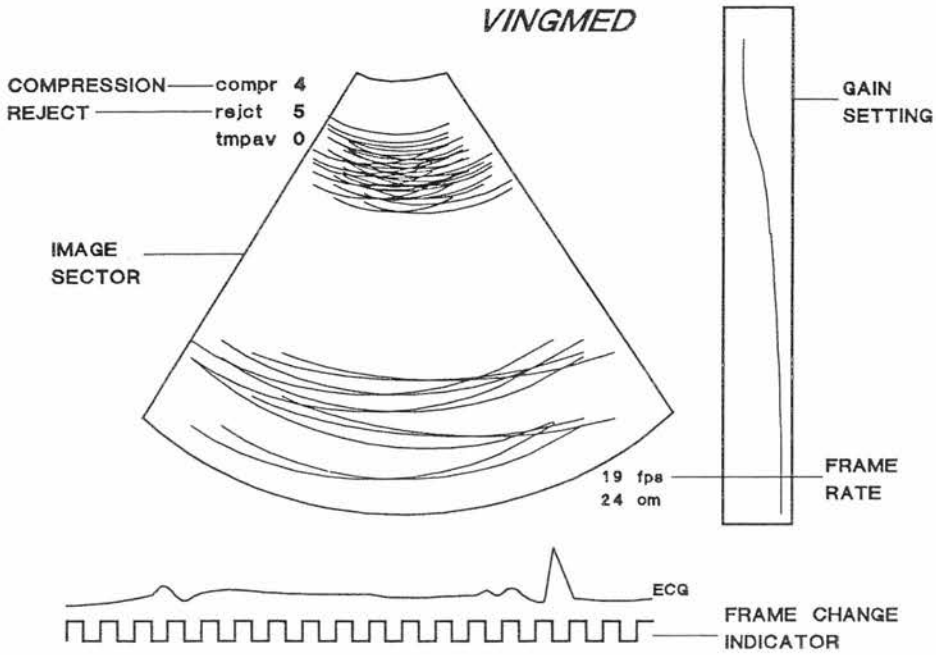
VOLUME 2

FIGURES FOR PART 1

Figure 1 Line drawing of the Vingmed CFM700 monitor, showing the image sector, frame rate indicator, instrument settings and ECG recording.

Figure 2a Right parasternal long-axis view. Reference view, ventricular inlets.

RA = right atrium
RV = right ventricle
TV = tricuspid valve
IVS = interventricular septum
LA = left atrium
LV = left ventricle
MV = mitral valve
LVW = left ventricular wall


VINGMED
COMPRESSION
REJECT
compr 4
reject 5
tmpav 0
IMAGE SECTOR
GAIN SETTING
19 fps
24 cm
FRAME RATE
ECG
FRAME CHANGE INDICATOR

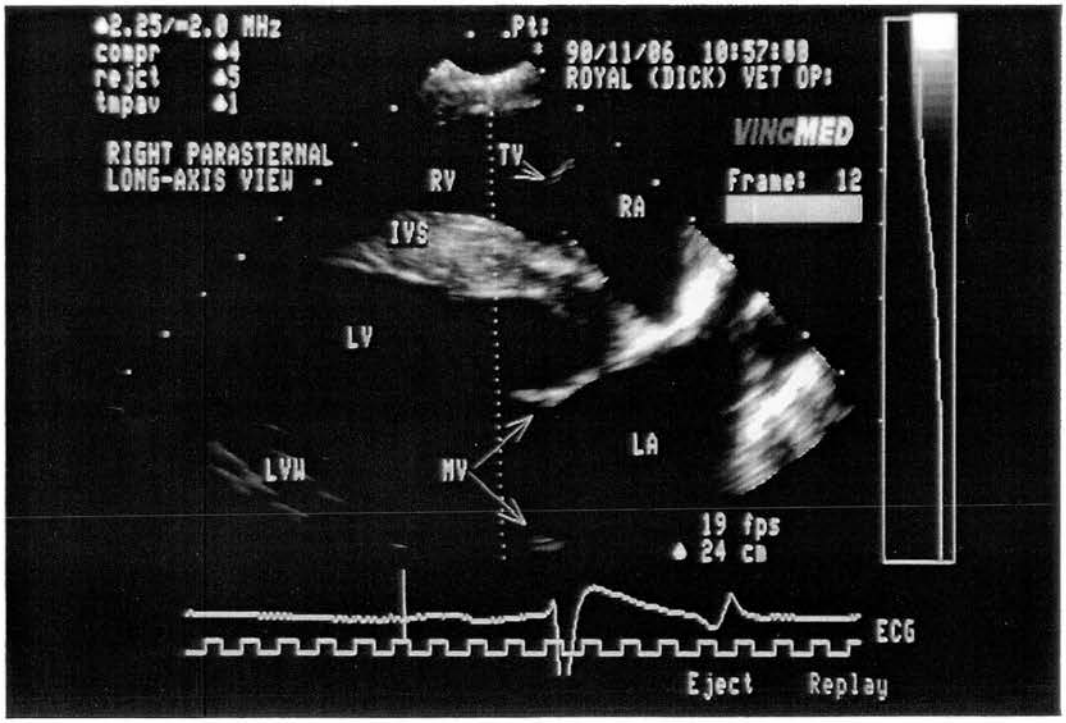
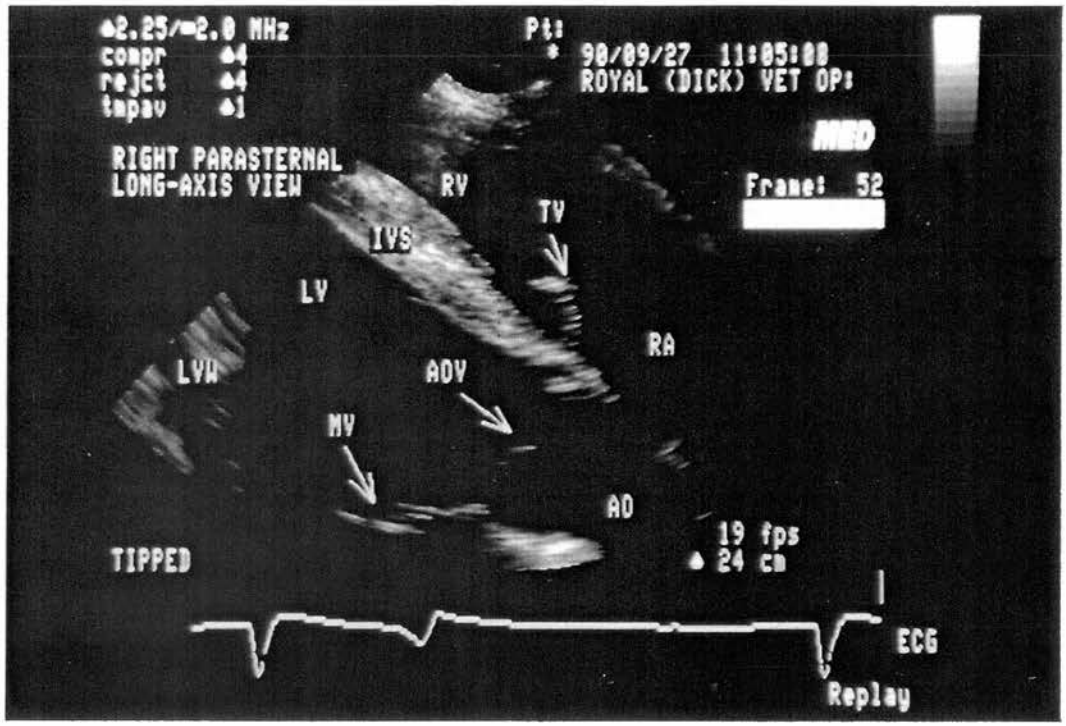

2.25/2.0 MHz
compr 4
reject 5
tmpav 1
Pt:
90/11/06 10:57:08
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
LONG-AXIS VIEW
Frame: 12
TV
RV
RA
IVS
LV
LA
LVW
MV
19 fps
24 cm
ECG
Eject
Replay

Figure 2b Right parasternal long-axis view. Tipped view, left ventricular inlet/outlet.

RA = right atrium
RV = right ventricle
TV = tricuspid valve
IVS = interventricular septum
AO = Aorta
AOV = Aortic valve
LV = left ventricle
LVW = left ventricular wall
MV = mitral valve

Figure 2c Right parasternal long-axis view. Long-axis aorta.

RA = right atrium
RV = right ventricle
TV = tricuspid valve
IVS = interventricular septum
AO = Aorta
AOV = Aortic valve
LV = left ventricle
LVW = left ventricular wall


▲2.25/=2.0 MHz
compr ▲4
reject ▲4
tapav ▲1
Pt:
* 90/09/27 11:05:08
ROYAL (DICK) VET OP:
MED
RIGHT PARASTERNAL
LONG-AXIS VIEW
RV
TV
Frame: 52
IVS
LV
RA
LVW
ADV
MV
AO
19 fps
▲ 24 cm
TIPPED
ECG
Replay

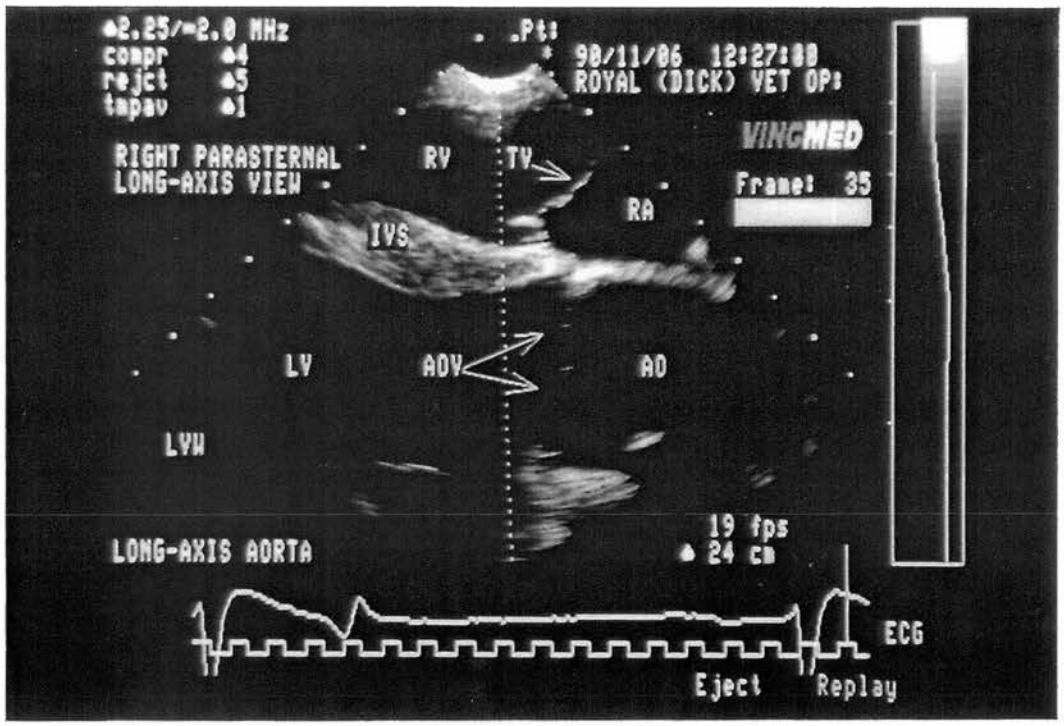
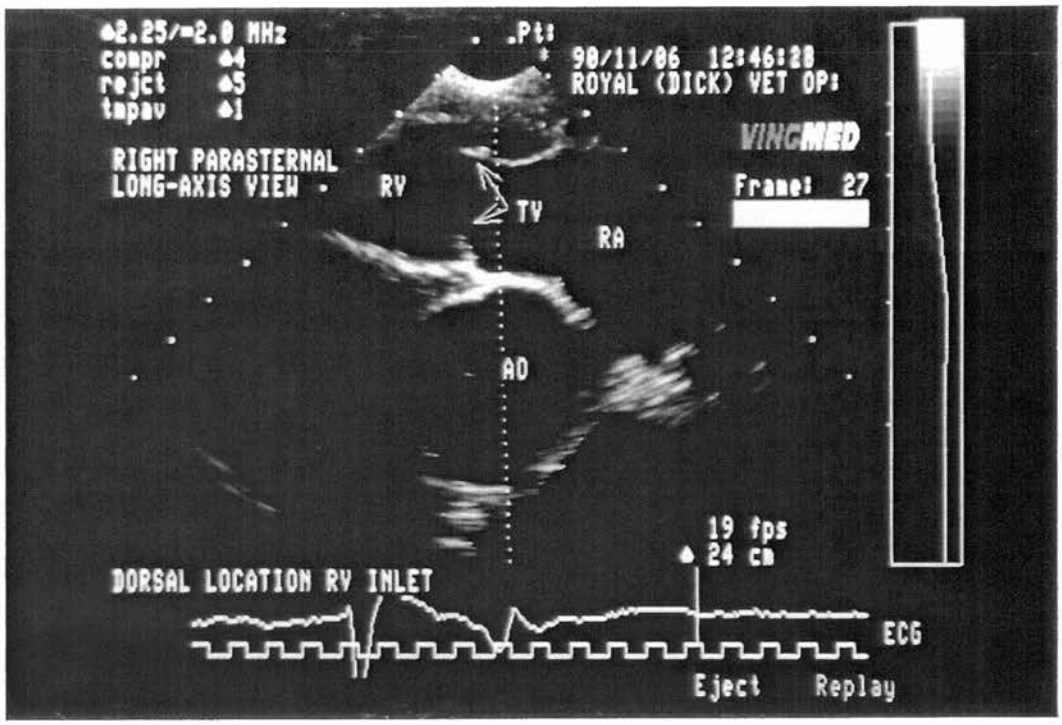

▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tapav ▲1
Pt:
* 90/11/06 12:27:08
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
LONG-AXIS VIEW
RV
TV
Frame: 35
RA
IVS
LV
ADV
AO
LVW
19 fps
▲ 24 cm
LONG-AXIS AORTA
ECG
Eject
Replay

Figure 2d Right parasternal long-axis view. Dorsal location right ventricular inlet.

RA = right atrium
RV = right ventricle
AO = Aorta
TV = tricuspid valve

Figure 2e Right parasternal long-axis view. Apical view, ventricular inlets.

RA = right atrium
RV = right ventricle
TV = tricuspid valve
LA = left atrium
LV = left ventricle
MV = mitral valve


▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tmpav ▲1
.Pt:
90/11/06 12:46:28
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
LONG-AXIS VIEW
RV
TV
RA
Frame: 27
AO
19 fps
▲ 24 cm
DORSAL LOCATION RV INLET
ECG
Eject
Replay

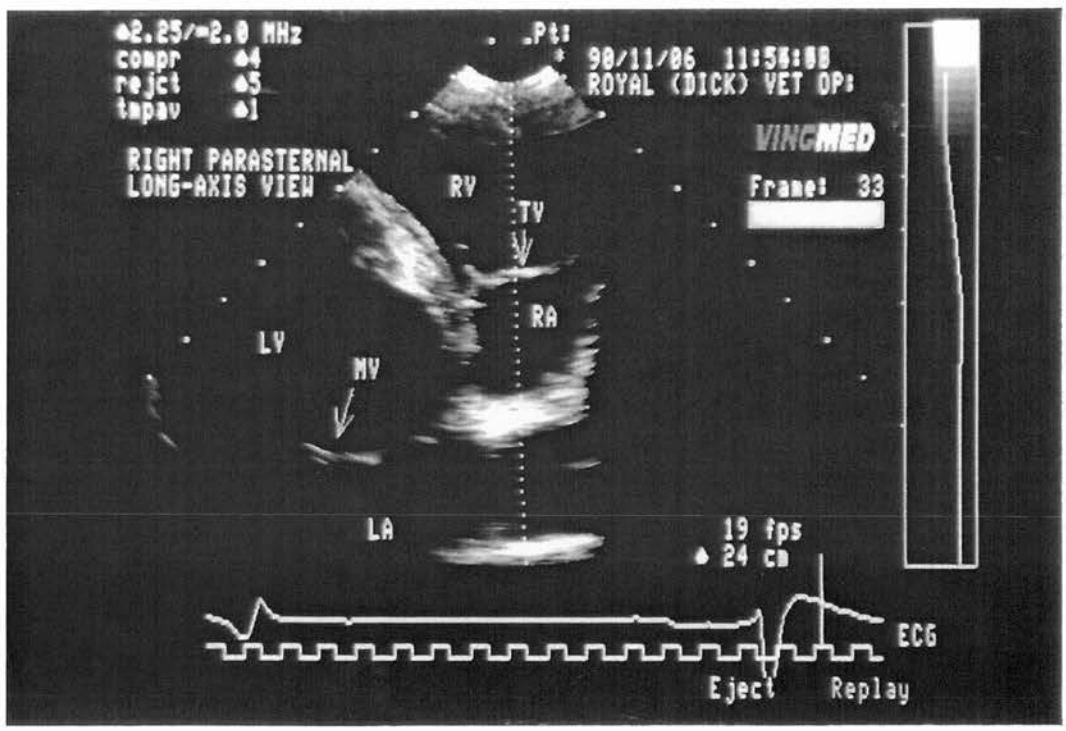
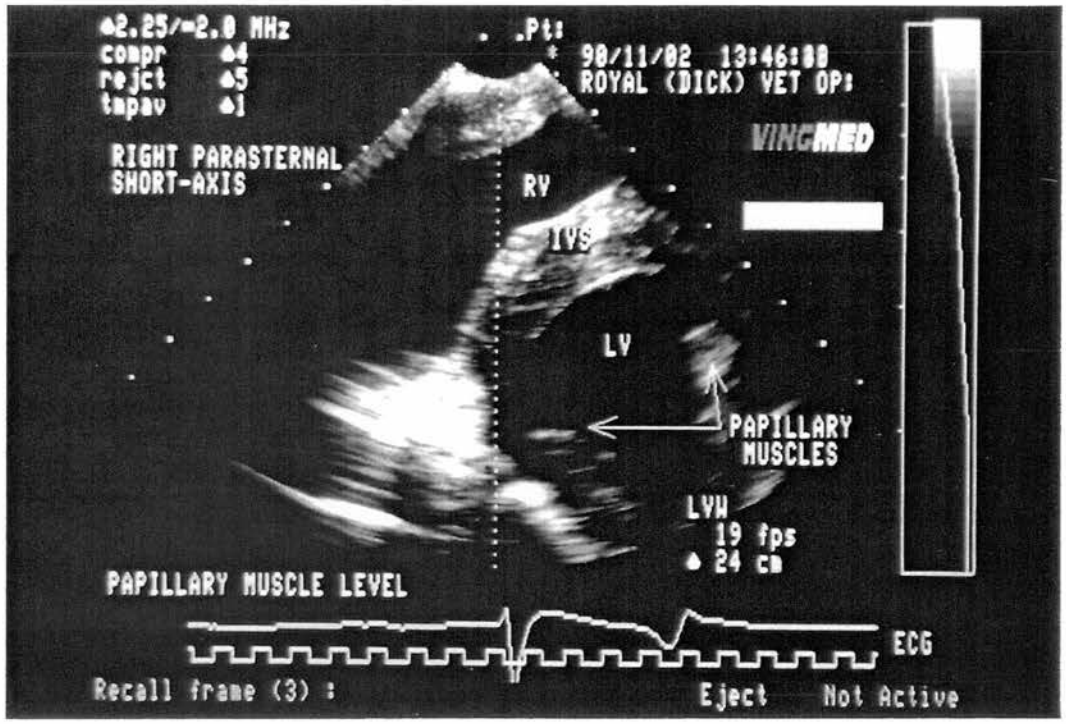

▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tmpav ▲1
.Pt:
90/11/06 11:56:08
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
LONG-AXIS VIEW
RV
TV
RA
Frame: 33
LV
MV
LA
19 fps
▲ 24 cm
ECG
Eject
Replay

Figure 3a Right parasternal short-axis view. Papillary muscle level.

RV = right ventricle
IVS = interventricular septum
LV = left ventricle
LVW = left ventricular wall

Figure 3b Right parasternal short-axis view. Chordal level.

RV = right ventricle
LV = left ventricle
IVS = interventricular septum


▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tmpav ▲1
.Pt:
90/11/02 13:46:88
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
SHORT-AXIS
RV
IVS
LV
PAPILLARY
MUSCLES
LVW
19 fps
▲ 24 cm
PAPILLARY MUSCLE LEVEL
ECG
Recall frame (3) :
Eject
Not Active

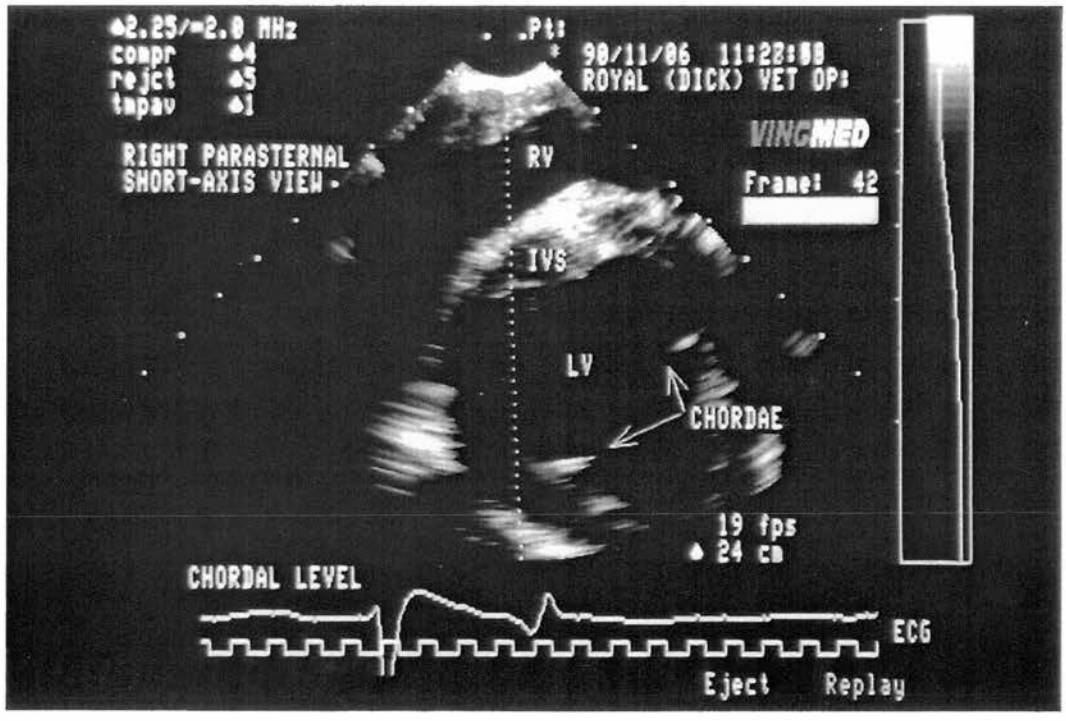
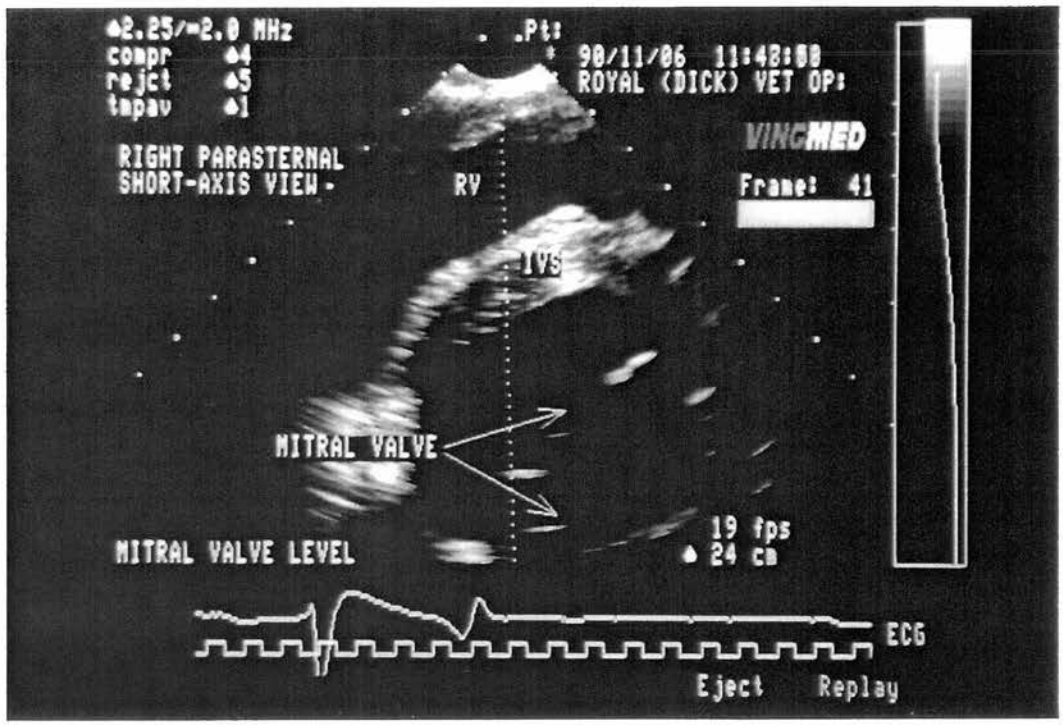

▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tmpav ▲1
.Pt:
90/11/06 11:28:88
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
SHORT-AXIS VIEW
RV
Frame: 42
IVS
LV
CHORDAE
19 fps
▲ 24 cm
CHORDAL LEVEL
ECG
Eject
Replay

Figure 3c Right parasternal short-axis view. Mitral valve level.

RV = right ventricle IVS = interventricular septum

Figure 3d Right parasternal short-axis view. Aortic valve level.

RA = right atrium RV = right ventricle
TV = tricuspid valve


▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tapav ▲1
.Pt:
90/11/06 11:48:08
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
SHORT-AXIS VIEW
RV
Frame: 41
IVS
MITRAL VALVE
19 fps
▲ 24 cm
MITRAL VALVE LEVEL
ECG
Eject
Replay

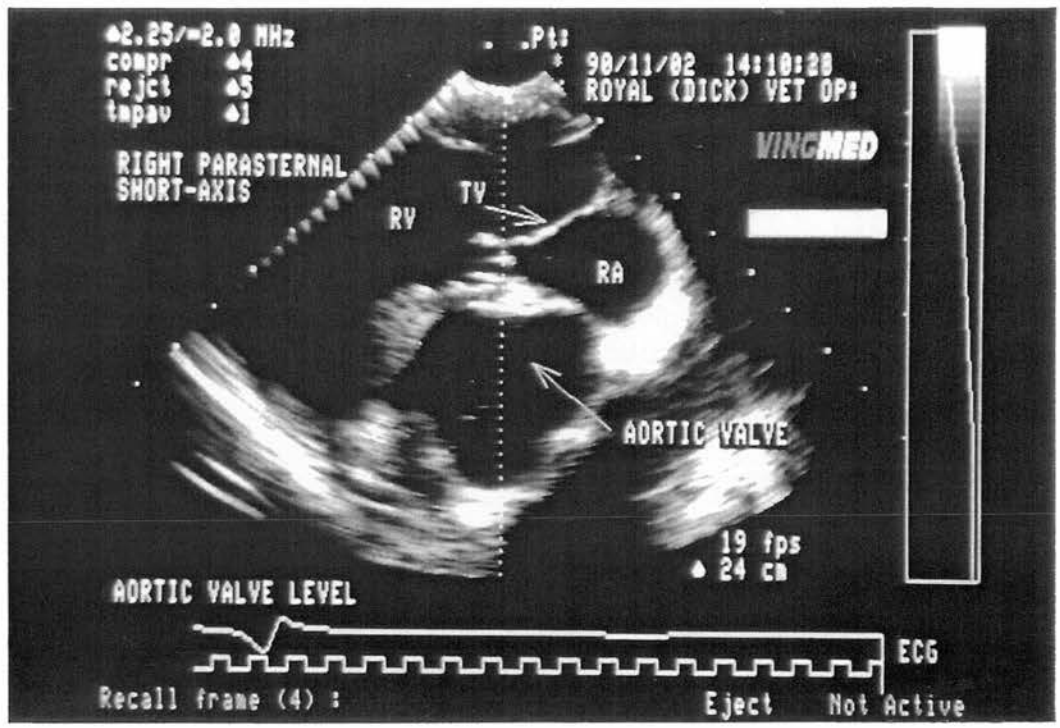
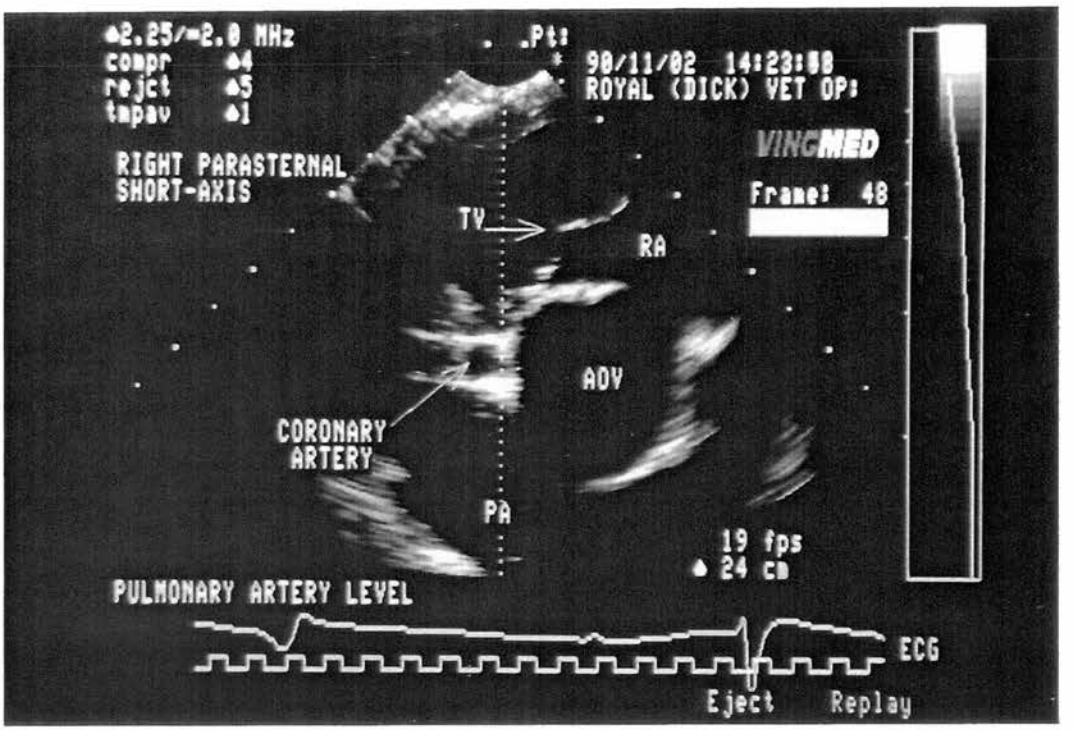

▲2.25/=2.0 MHz
compr ▲4
reject ▲5
tapav ▲1
.Pt:
90/11/02 14:10:28
ROYAL (DICK) VET OP:
VINGMED
RIGHT PARASTERNAL
SHORT-AXIS
TV
RV
RA
AORTIC VALVE
19 fps
▲ 24 cm
AORTIC VALVE LEVEL
ECG
Recall frame (4) :
Eject
Not Active

Figure 3e Right parasternal short-axis view. Pulmonary artery level.

RA = right atrium
AOV = Aortic valve
TV = tricuspid valve
PA = pulmonary artery

Figure 4 Right parasternal angled view. Dorsal location right ventricular outflow tract.

RA = right atrium
TV = tricuspid valve
SV = supraventricular
PV = pulmonary valve
PA = pulmonary artery
RVOT = right ventricular outflow tract


▲2.25/=2.0 MHz
compr ▲4
rejct ▲5
tmpav ▲1
Pt:
90/11/02 14:23:
ROYAL (DICK) VET OP:
VINGMED
Frame: 48
RIGHT PARASTERNAL
SHORT-AXIS
TV
RA
AOV
CORONARY
ARTERY
PA
19 fps
▲ 24 cm
PULMONARY ARTERY LEVEL
ECG
Eject
Replay

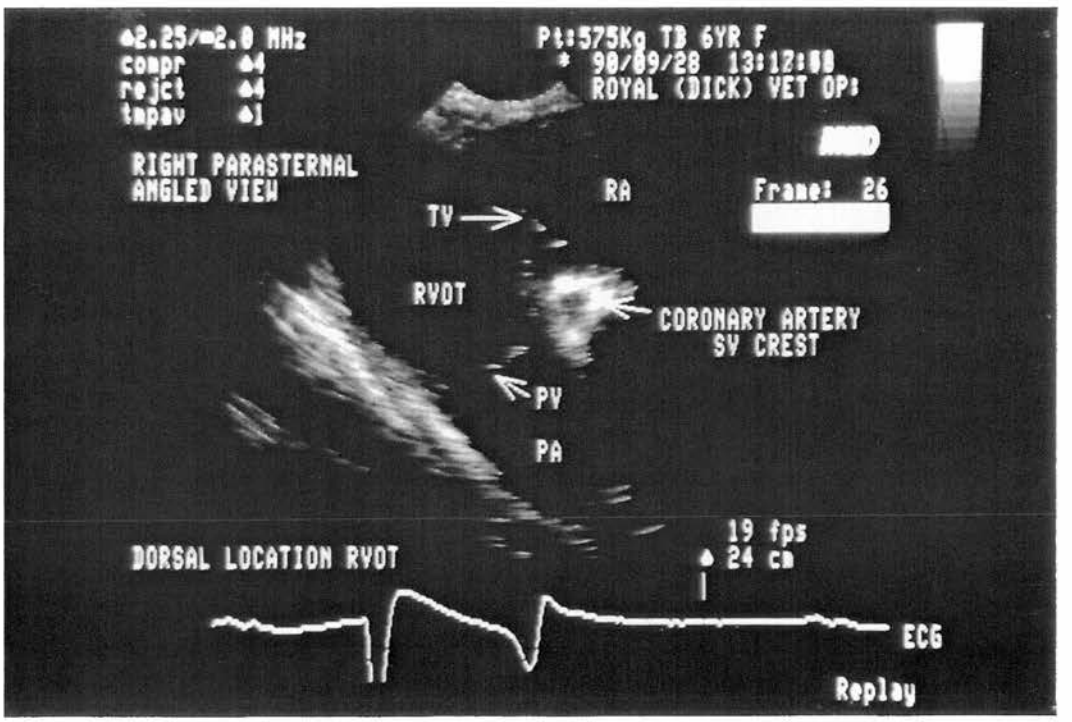
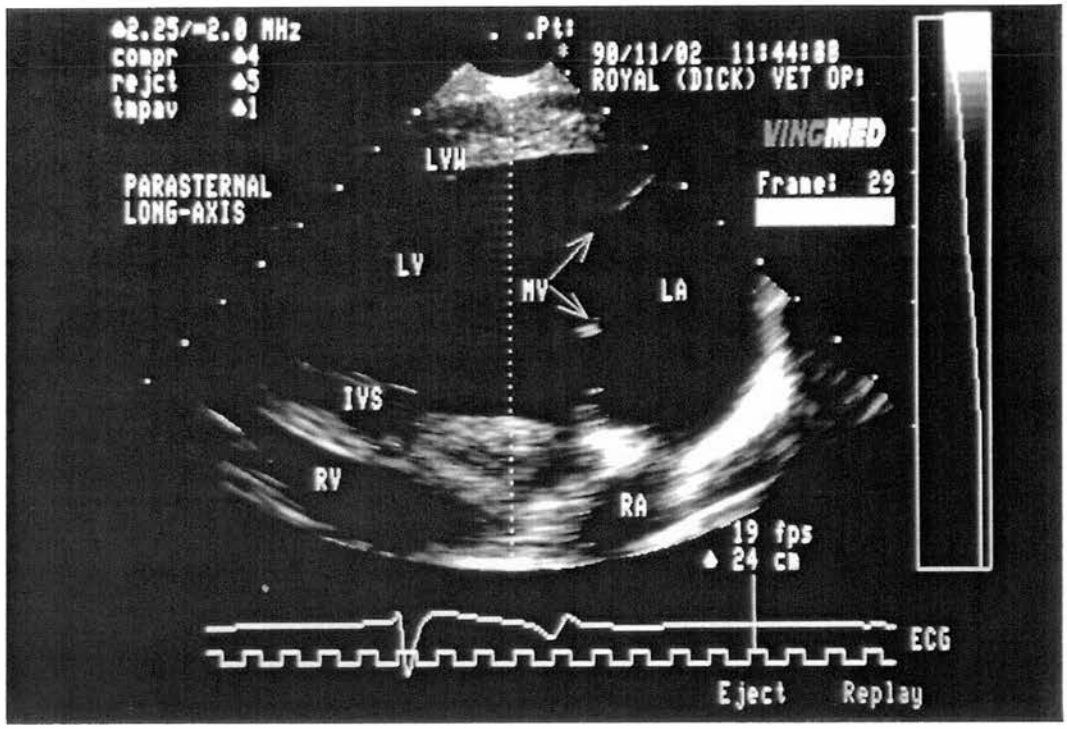

▲2.25/=2.0 MHz
compr ▲4
rejct ▲4
tmpav ▲1
Pt:575Kg TB 6YR F
90/09/28 13:12:
ROYAL (DICK) VET OP:
RIGHT PARASTERNAL
ANGLED VIEW
RA
Frame: 26
TV
RVOT
CORONARY ARTERY
SV CREST
PV
PA
19 fps
▲ 24 cm
DORSAL LOCATION RVOT
ECG
Replay

Figure 5a Left parasternal long-axis view. Reference view, left ventricular inlet.

LA = left atrium
LV = left ventricle
MV = mitral valve
RA = right atrium
RV = right ventricle
IVS = interventricular septum
LVW = left ventricular wall

Figure 5b Left parasternal long-axis view. Apical view, left ventricular inlet.

LA = left atrium
LV = left ventricle
MV = mitral valve
RA = right atrium
RV = right ventricle
IVS = interventricular septum


♦2.25/=2.0 MHz
compr ♦4
reject ♦5
tmpav ♦1
.Pt:
* 90/11/02 11:44:88
ROYAL (DICK) VET OP:
VINGMED
Frame: 29
PARASTERNAL
LONG-AXIS
LVW
LV
MV
LA
IVS
RV
RA
19 fps
♦ 24 cm
ECG
Eject
Replay

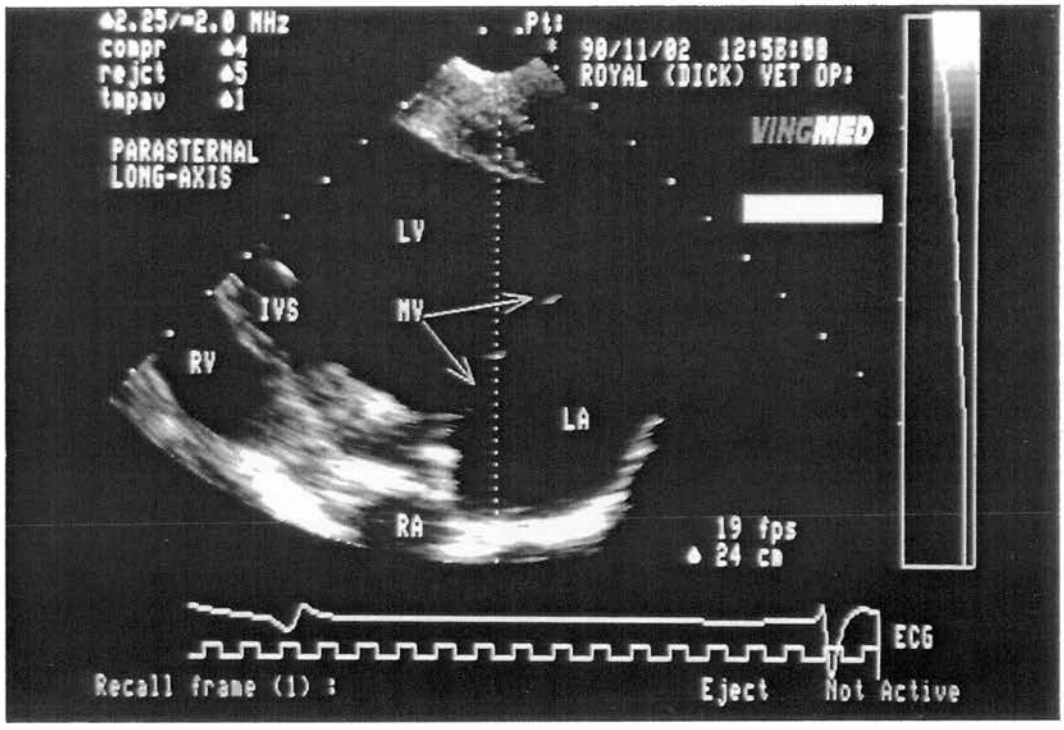

♦2.25/=2.0 MHz
compr ♦4
reject ♦5
tmpav ♦1
.Pt:
* 90/11/02 12:58:88
ROYAL (DICK) VET OP:
VINGMED
PARASTERNAL
LONG-AXIS
LV
IVS
MV
RV
LA
RA
19 fps
♦ 24 cm
ECG
Recall frame (1) :
Eject
Not Active

Figure 5c Left parasternal long-axis view. 5-chambered view.

LV = left ventricle
AO = Aorta
AOV = Aortic valve
RV = right ventricle
LVOT = left ventricular outflow tract
IVS = interventricular septum
RA = right atrium
RVW = right ventricular wall

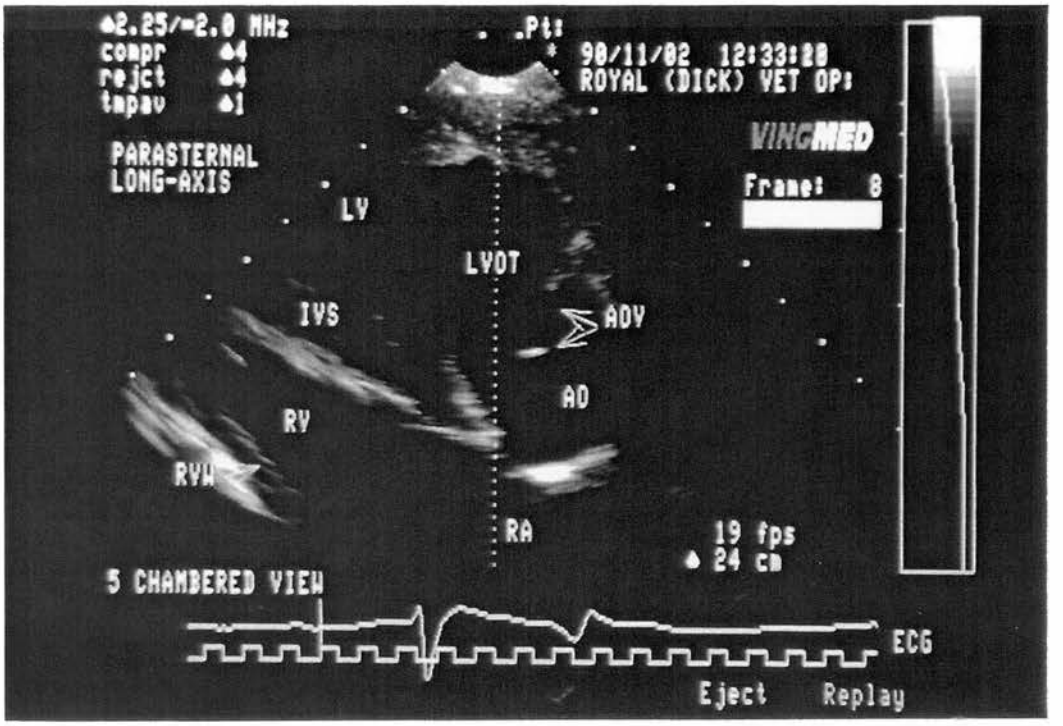
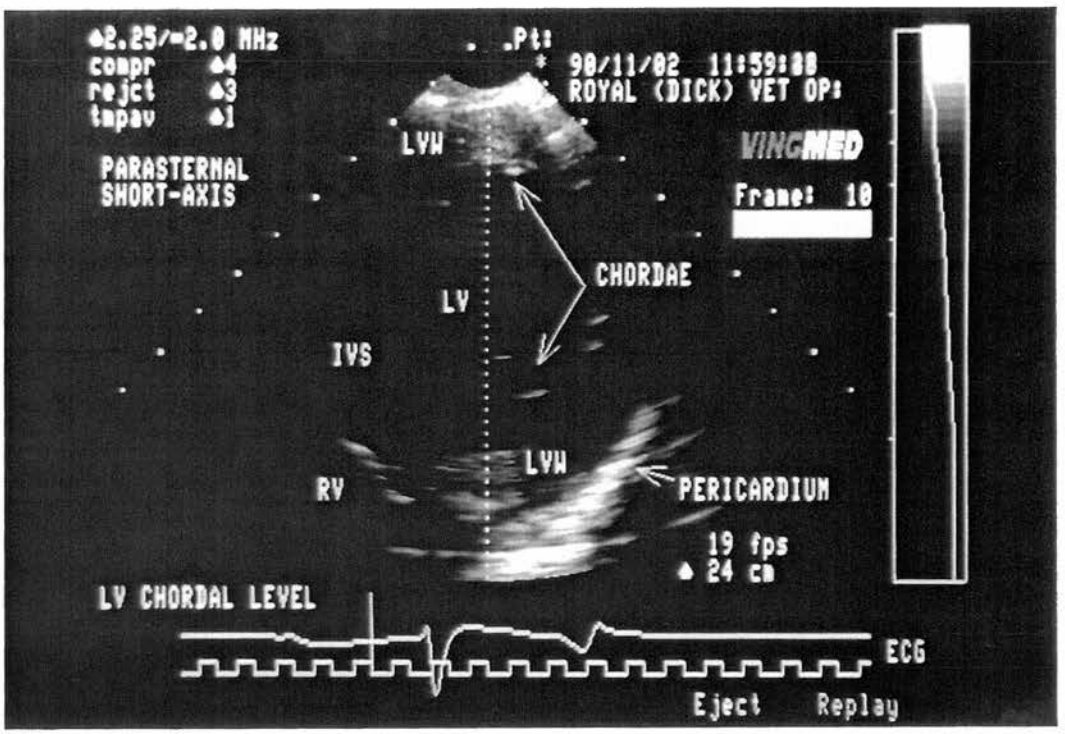

▲2.25/=2.0 MHz
compr ▲4
reject ▲4
tmpav ▲1
.Pt:
90/11/02 12:33:28
ROYAL (DICK) VET OP:
VINGMED
Frame: 8
PARASTERNAL
LONG-AXIS
LV
LVOT
IVS
ADV
AO
RV
RVW
RA
19 fps
▲ 24 cm
5 CHAMBERED VIEW
ECG
Eject
Replay

Figure 6a Left parasternal short-axis view. Left ventricular chordal level.

LV = left ventricle
IVS = interventricular septum
RV = right ventricle
LVW = left ventricular wall

Figure 6b Left parasternal short-axis view. Right ventricular wall.

LV = left ventricle
IVS = interventricular septum
RV = right ventricle
RVW = right ventricular wall


▲2.25/=2.0 MHz
compr ▲4
reject ▲3
tmpav ▲1
.Pt:
* 90/11/02 11:59:08
ROYAL (DICK) VET OP:
VINGMED
Frame: 10
PARASTERNAL
SHORT-AXIS
LVW
CHORDAE
LV
IVS
LVW
RV
PERICARDIUM
19 fps
▲ 24 cm
LV CHORDAL LEVEL
ECG
Eject
Replay

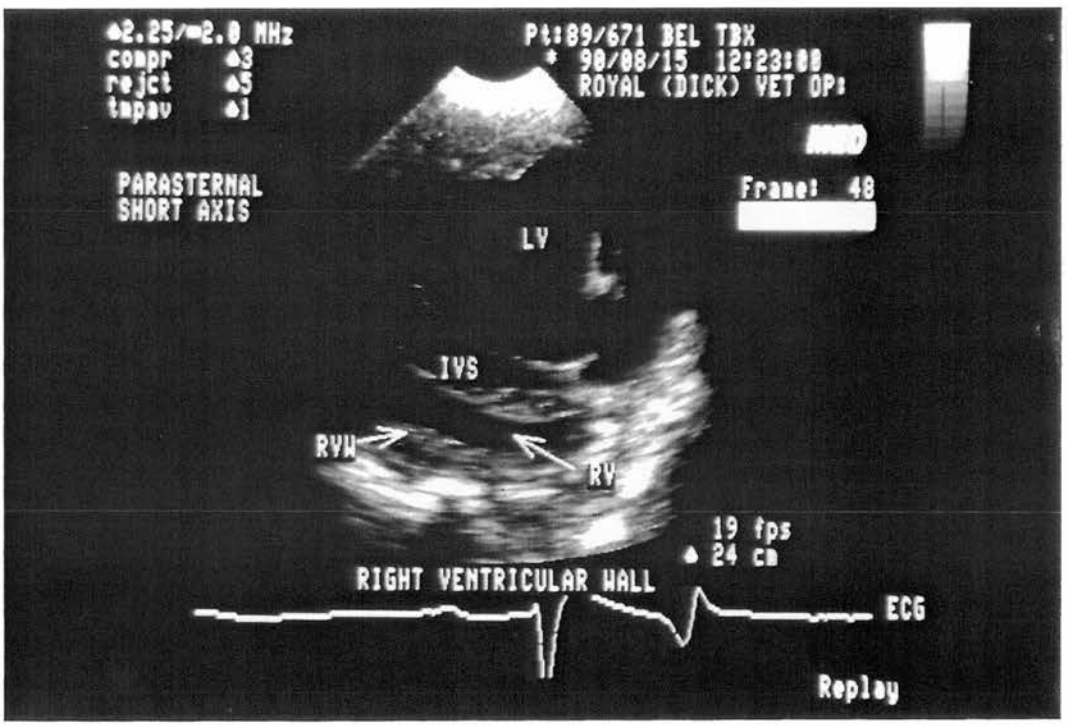
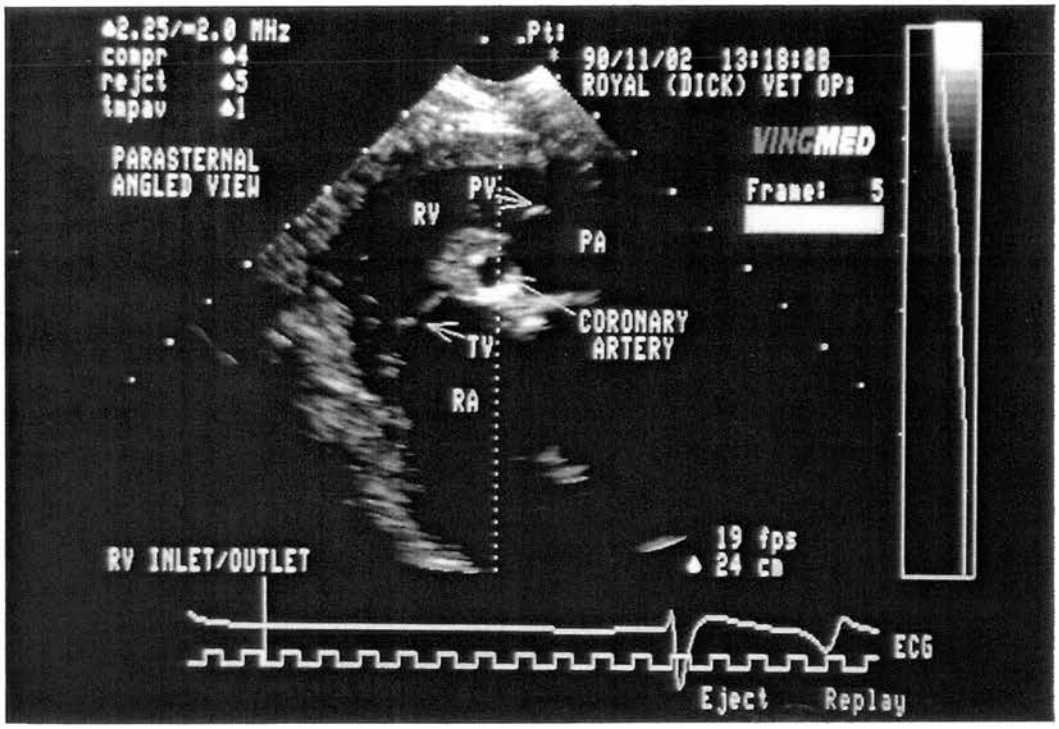

▲2.25/=2.0 MHz
compr ▲3
reject ▲5
tmpav ▲1
Pt:89/671 BEL TBX
* 90/08/15 12:23:08
ROYAL (DICK) VET OP:
PARASTERNAL
SHORT AXIS
Frame: 48
LV
IVS
RVW
RV
19 fps
▲ 24 cm
RIGHT VENTRICULAR WALL
ECG
Replay

Figure 7a Left parasternal angled view. Right ventricular inlet/outlet.

RA = right atrium
TV = tricuspid valve
RV = right ventricle
PA = pulmonary artery
PV = pulmonary valve

Figure 7b Left parasternal angled view. Left ventricular outflow tract/aorta.

MV = mitral valve
AO = Aorta
LVOT = left ventricular outflow tract
AOV = Aortic valve


♦2.25/=2.0 MHz
compr ♦4
reject ♦5
tmpav ♦1
.Pt:
90/11/02 13:18:88
ROYAL (DICK) VET OP:
VINGMED
PARASTERNAL
ANGLED VIEW
Frame: 5
PV
RV
PA
CORONARY
ARTERY
TV
RA
19 fps
♦ 24 cm
RV INLET/OUTLET
ECG
Eject
Replay

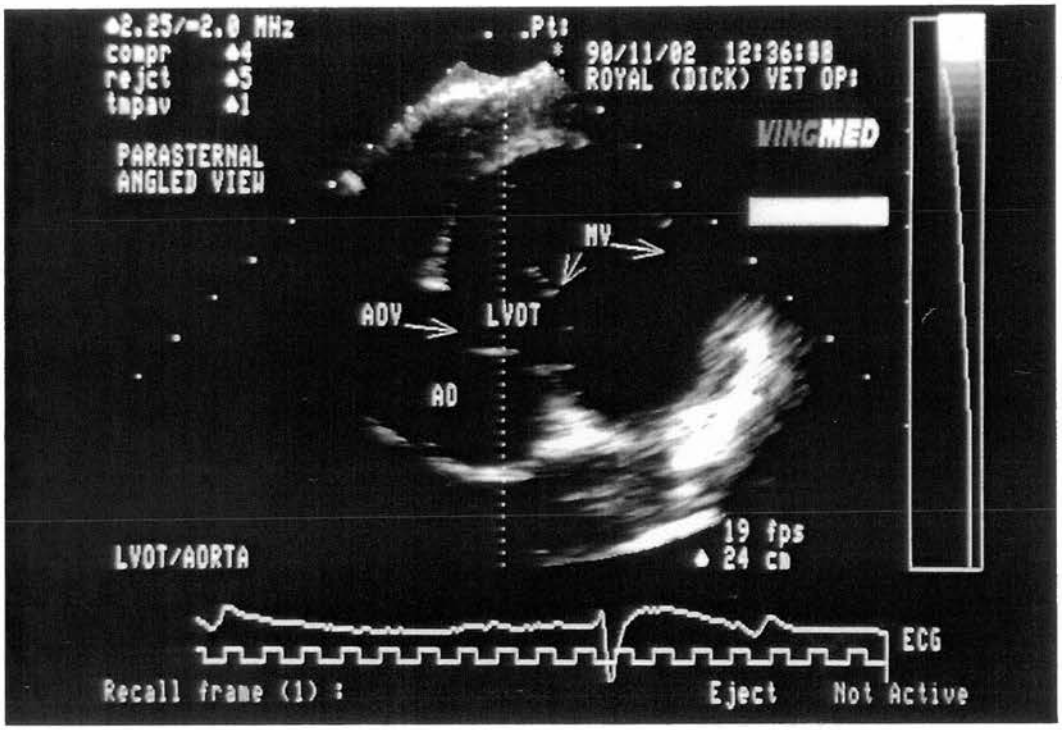
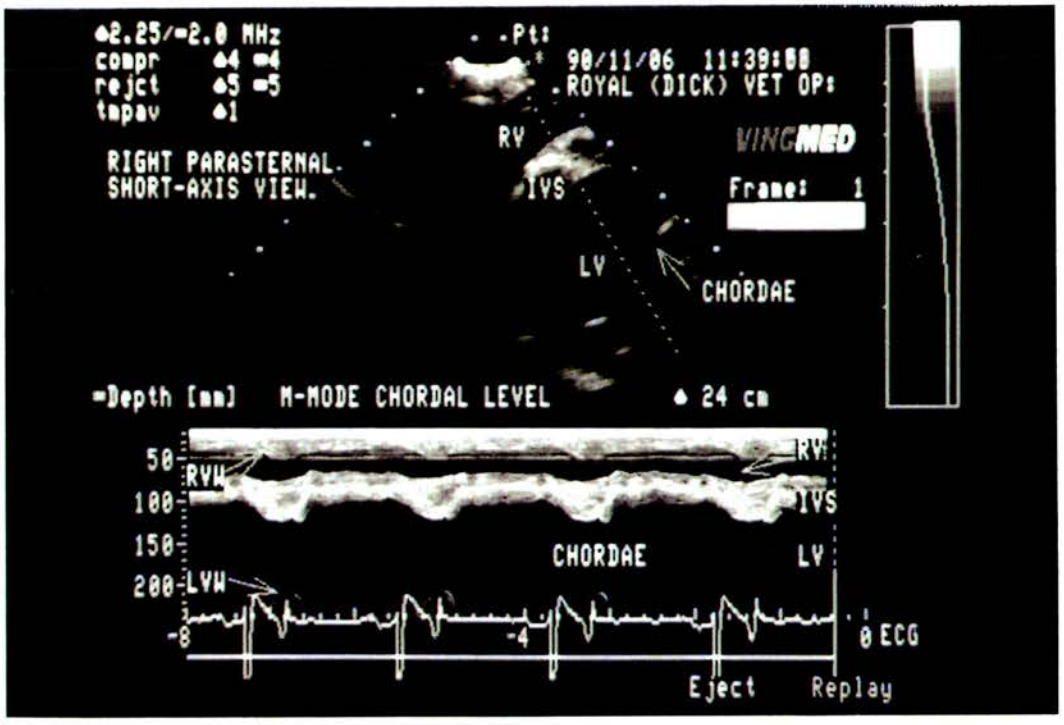

♦2.25/=2.0 MHz
compr ♦4
reject ♦5
tmpav ♦1
.Pt:
90/11/02 12:36:88
ROYAL (DICK) VET OP:
VINGMED
PARASTERNAL
ANGLED VIEW
MV
AOV
LVOT
AO
19 fps
♦ 24 cm
LVOT/AORTA
ECG
Recall frame (1) :
Eject
Not Active

Figure 8 M-mode taken from the right parasternal short-axis view, chordal level. The left ventricle has been placed to the right of the sector display to ensure the M-mode cursor bisected the ventricle.

RV = right ventricle
IVS = interventricular septum
CHORDAE = chordae tendineae
LV = left ventricle
RVW = right ventricular wall
LVW = left ventricular wall

Figure 9 M-mode taken from the right parasternal short-axis view, aortic valve level. The aortic valve is visible during systole and diastole along the middle of the M-mode display. The tricuspid valve visible during systole, is seen at the top of the M-mode display.


♦2.25/=2.0 MHz
compr ♦4 =4
reject ♦5 =5
tmpav ♦1
Pt:
90/11/06 11:39:08
ROYAL (DICK) VET OP:
VINGMED
Frame: 1
RIGHT PARASTERNAL
SHORT-AXIS VIEW.
RV
IVS
LV
CHORDAE
=Depth [mm]
M-MODE CHORDAL LEVEL
♦ 24 cm
50
100
150
200
RVW
IVS
CHORDAE
LV
LVW
-8
-4
0 ECG
Eject
Replay

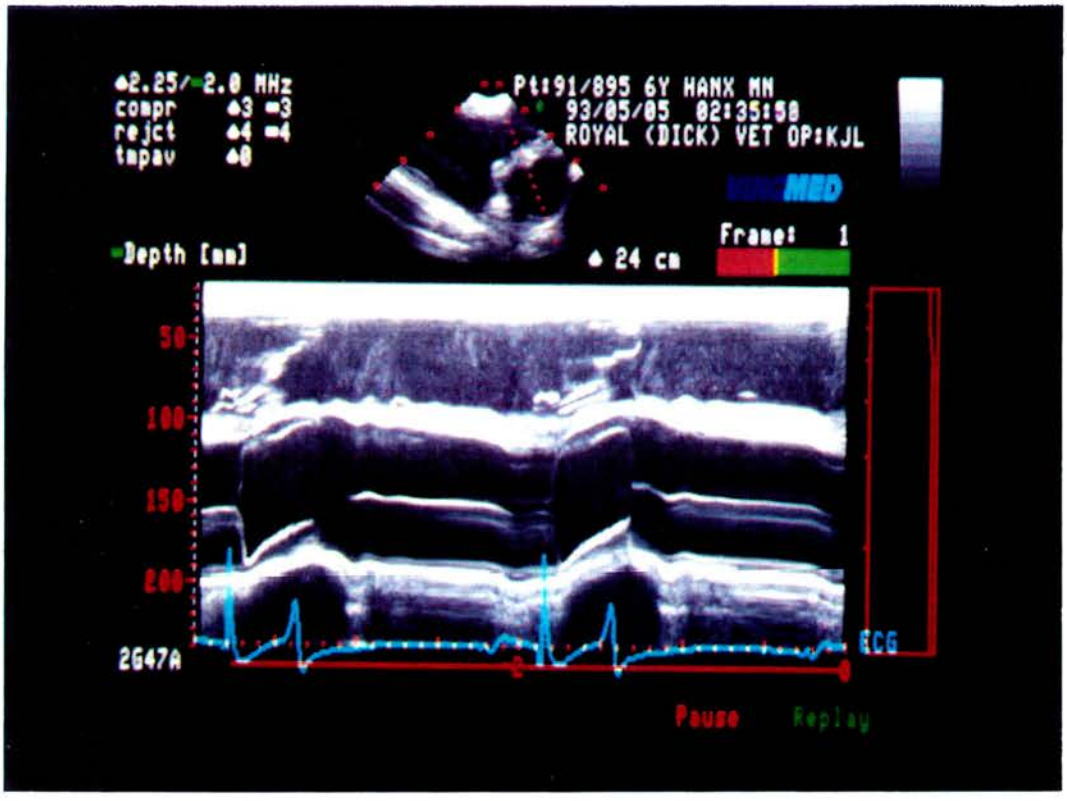
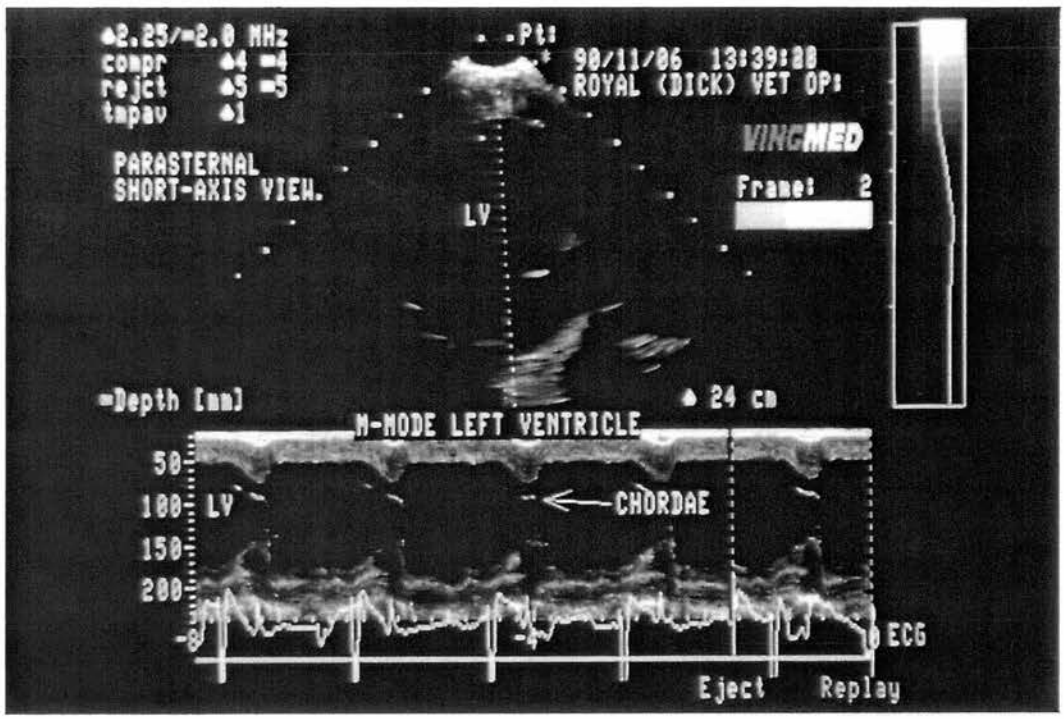

♦2.25/=2.0 MHz
compr ♦3 =3
reject ♦4 =4
tmpav ♦0
Pt:91/895 6Y HANX MN
93/05/05 02:35:58
ROYAL (DICK) VET OP:KJL
MED
Frame: 1
=Depth [mm]
♦ 24 cm
50
100
150
200
2647A
ECG
Pause
Replay

Figure 10 M-mode taken from the left parasternal short-axis view chordal level. The M-mode cursor crosses the left ventricular free wall, and the junction of the left ventricular wall and interventricular septum.

LV = left ventricle
CHORDAE = chordae tendineae

Figure 11 M-mode taken from the left parasternal short-axis view, right ventricular wall. The M-mode cursor crosses the right ventricular wall perpendicularly

RV = right ventricle
LV = left ventricle
IVS = interventricular septum
RVW = right ventricular wall


▲2.25/=2.0 MHz
compr ▲4 =4
reject ▲5 =5
tmpav ▲1
Pt:
90/11/06 13:39:28
ROYAL (DICK) VET OP:
VINGMED
PARASTERNAL
SHORT-AXIS VIEW.
Frame: 2
LV
=Depth [mm]
▲ 24 cm
M-MODE LEFT VENTRICLE
50
100
150
200
LV
CHORDAE
ECG
Eject
Replay

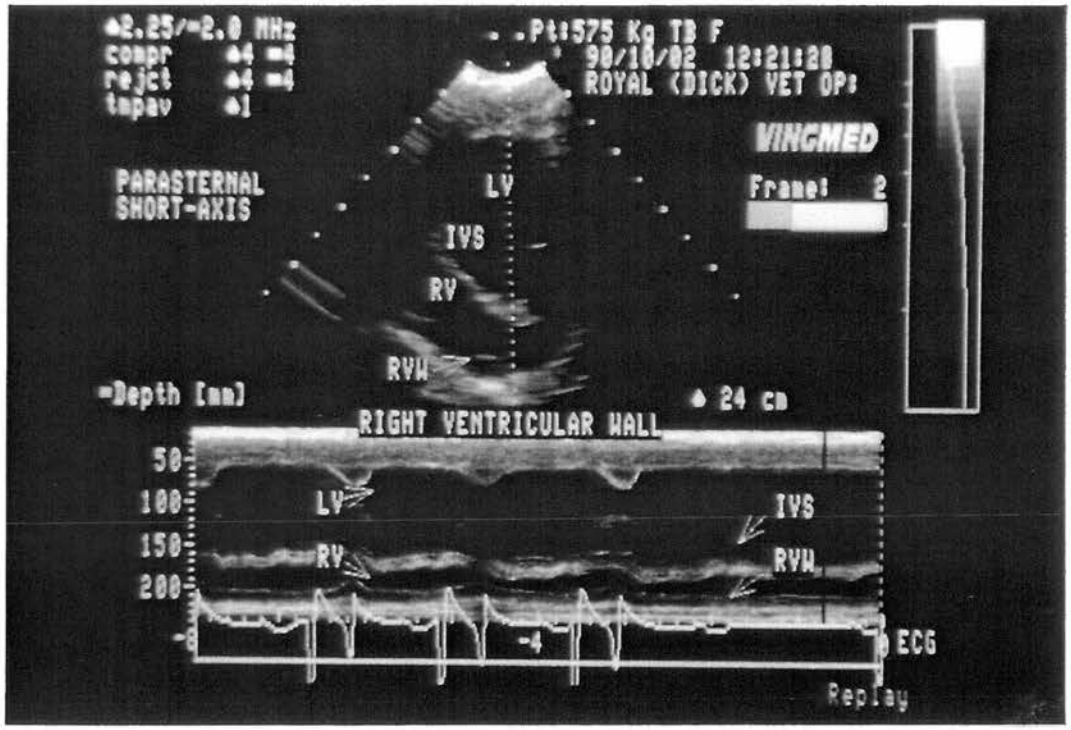

▲2.25/=2.0 MHz
compr ▲4 =4
reject ▲4 =4
tmpav ▲1
Pt:575 Kg TB F
90/10/02 12:21:28
ROYAL (DICK) VET OP:
VINGMED
PARASTERNAL
SHORT-AXIS
Frame: 2
LV
IVS
RV
RVW
=Depth [mm]
▲ 24 cm
RIGHT VENTRICULAR WALL
50
100
150
200
LV
IVS
RV
RVW
ECG
Replay

Figure 12 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the left ventricular internal dimension in diastole (LVIDd Med). Measurements were made from an M-mode derived from the right parasternal short-axis view chordal level. * represents a significant difference between the control group and groups 1-5 (Mann-Whitney test).

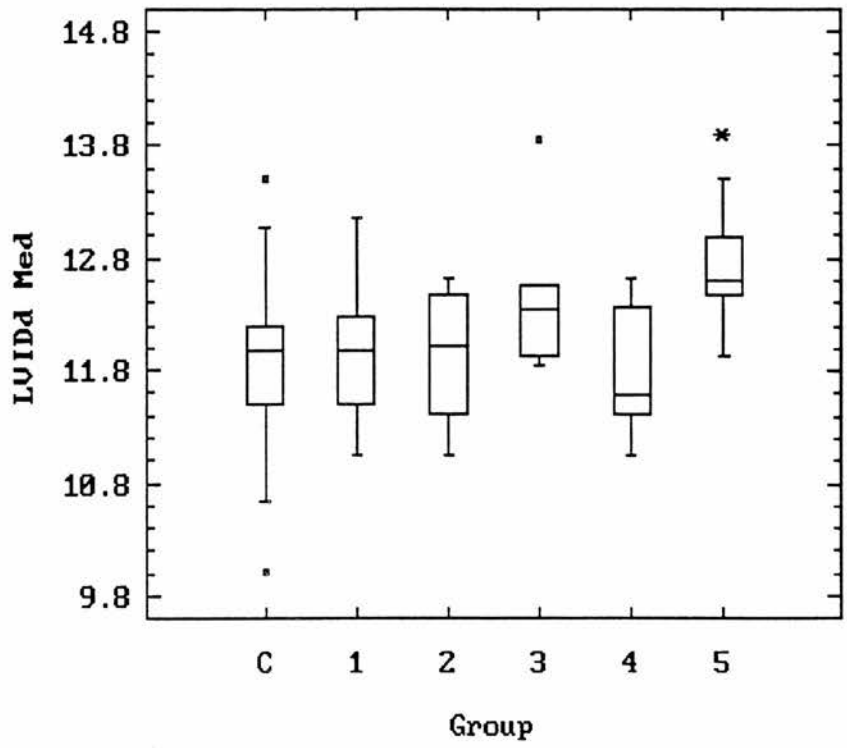
The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median measurements of the left ventricular internal dimension in diastole (LVIDd Med). Measurements are given in centimetres.

Figure 13 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the left ventricular internal dimension in systole. Measurements were made from an M-mode derived from the left parasternal short-axis view chordal level. * represents a significant difference between the control group and groups 1-5 (Mann-Whitney test).

The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median measurements of the left ventricular internal dimension in systole (LLVIDs Med). Measurements are given in centimetres.


14.8
13.8
12.8
11.8
10.8
9.8
LVIDd Med
C
1
2
3
4
5
Group

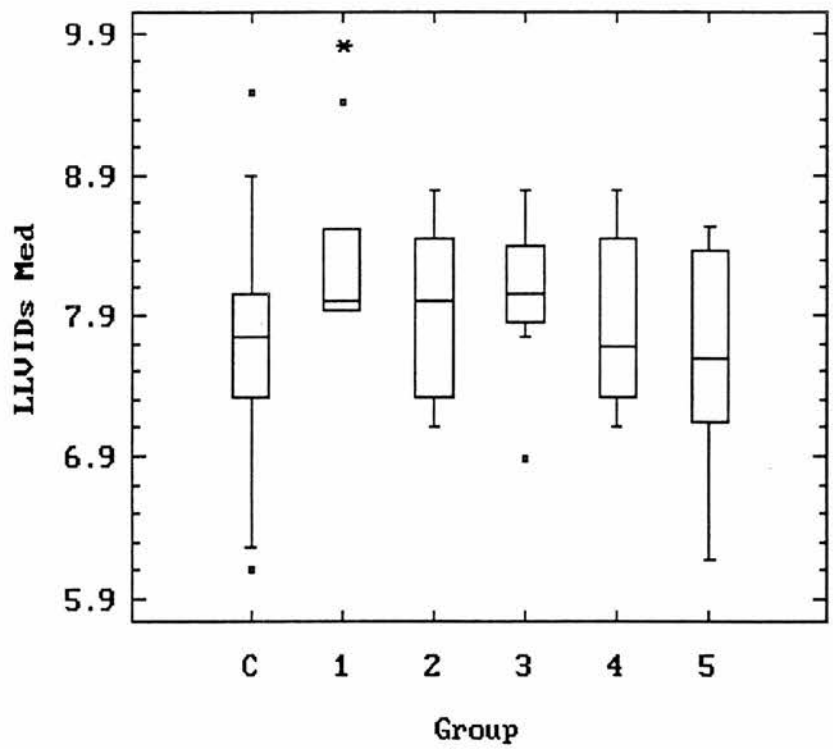

9.9
8.9
7.9
6.9
5.9
LLVIDs Med
C
1
2
3
4
5
Group

Figure 14 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the left ventricular fractional shortening calculated from measurements from the left hemithorax. * represents a significant difference between the control group and groups 1-5 (Mann-Whitney test).

The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median measurements of the fractional shortening calculated from measurements from the left hemithorax. (LFS Med). Measurements are expressed as a percentage.

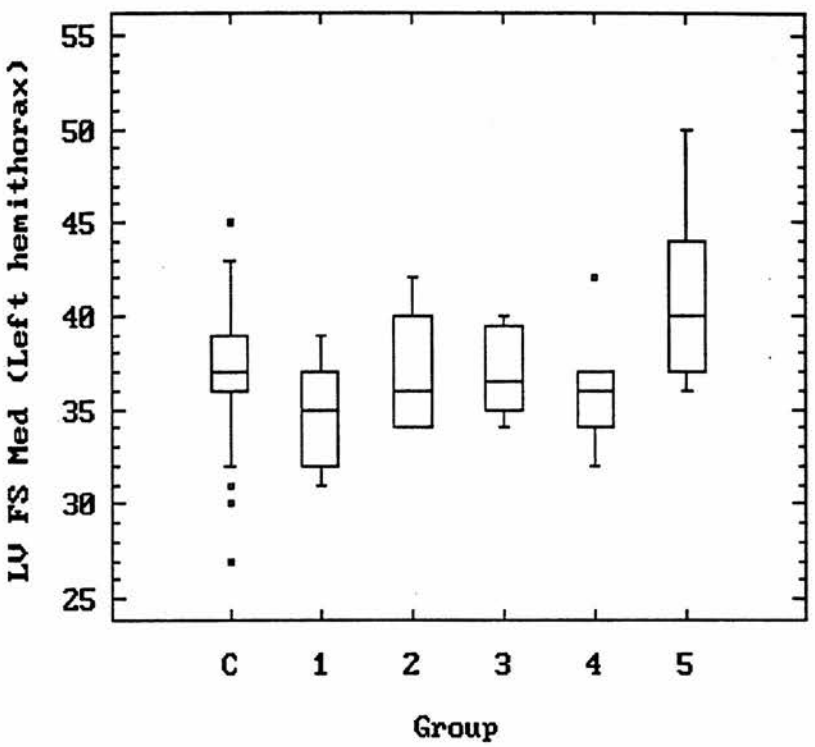
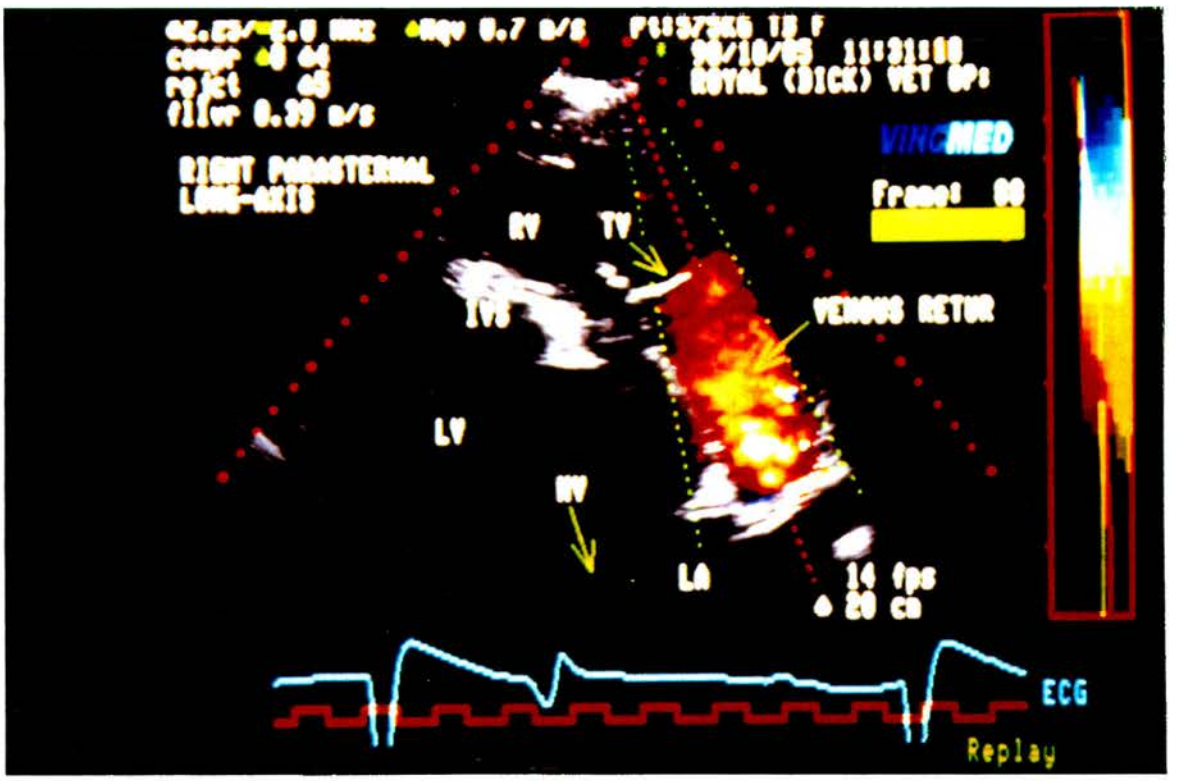

LV FS Med (Left hemithorax)
55
50
45
40
35
30
25
C
1
2
3
4
5
Group

Figure 15 Colour flow Doppler study from a right parasternal long-axis view, showing a red flow signal in the right atrium during the second part of systole. The lighter shades of red represent areas of higher velocity flow. The timing of the flow signal is indicated by the ECG trace at the far right of the screen.

TV = tricuspid valve
IVS = interventricular septum
MV = mitral valve
RV = right ventricle
LA = left atrium
LV = left ventricle

Figure 16 Colour flow Doppler study from a right parasternal long-axis view, showing a red flow signal in the right atrium, right ventricle and across the open tricuspid valve during early diastole. The lighter shades of red represent a central core of higher velocity flow. The timing of the flow signal is indicated by the ECG trace at the far right of the screen.

RA = right atrium
IVS = interventricular septum
MV = mitral valve
RV = right ventricle
LA = left atrium
LV = left ventricle


RIGHT PARASTERNAL
LONG-AXIS
RV
TV
IVS
VENOUS RETUR
LV
MV
LA
14 fps
ECG
Replay

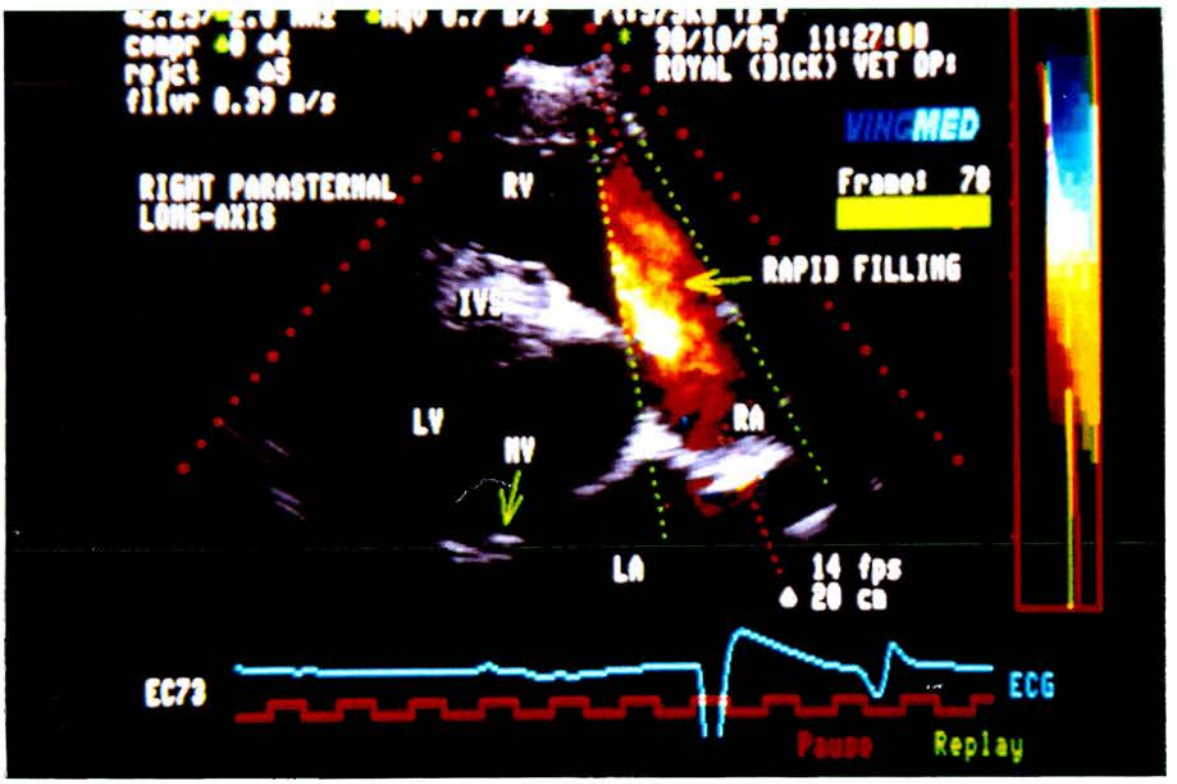
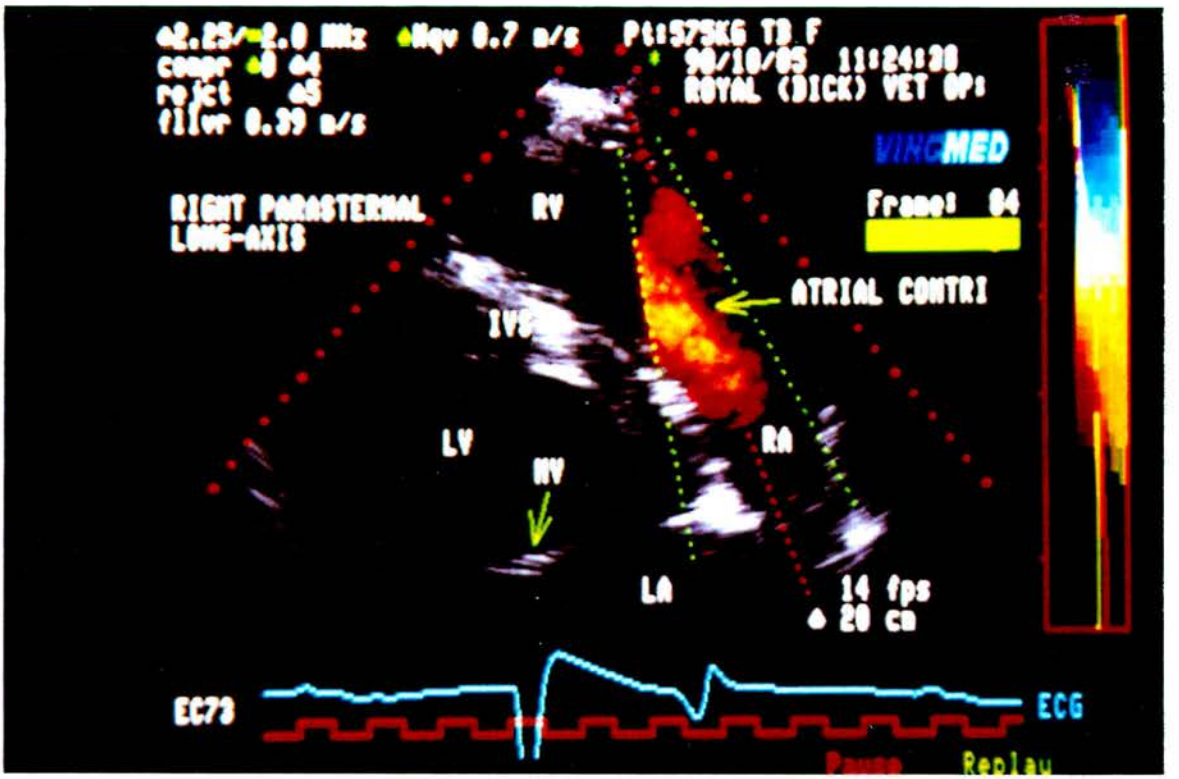

RIGHT PARASTERNAL
LONG-AXIS
RV
RAPID FILLING
IVS
LV
RA
MV
LA
14 fps
ECG
Pause
Replay

Figure 17 Colour flow Doppler study from a right parasternal long-axis view, showing a red flow signal in the right atrium, right ventricle and across the open tricuspid valve following the P wave of the ECG. The lighter shades of red represent a central core of higher velocity flow. The timing of the flow signal is indicated by the ECG trace at the far right of the screen.

RA = right atrium
IVS = interventricular septum
MV = mitral valve
RV = right ventricle
LA = left atrium
LV = left ventricle

Figure 18 Colour M-mode study recorded from the cursor, shown in Figure 17 as a red dotted line passing through the right ventricle, tricuspid valve and right atrium. The images recorded along this line, are displayed on the y axis of the M-mode, and are plotted against time on the x axis. The red flow signal (A) indicates the normal diastolic flow into the right ventricle following the atrial contraction. To the right of this, a further red signal (VR) is displayed below the tricuspid valve. This signal represents the venous return during systole. The red flow signal (E) represents flow from the right atrium, across the tricuspid valve into the right ventricle during rapid filling of the ventricle.


RIGHT PARASTERNAL
LONG-AXIS
RV
IVS
LV
MV
RA
LA
ATRIAL CONTRI
Frame: 84
14 fps
20 cm
ECG
Pause
Replay
VINCMED
ROYAL (DICK) VET OPs

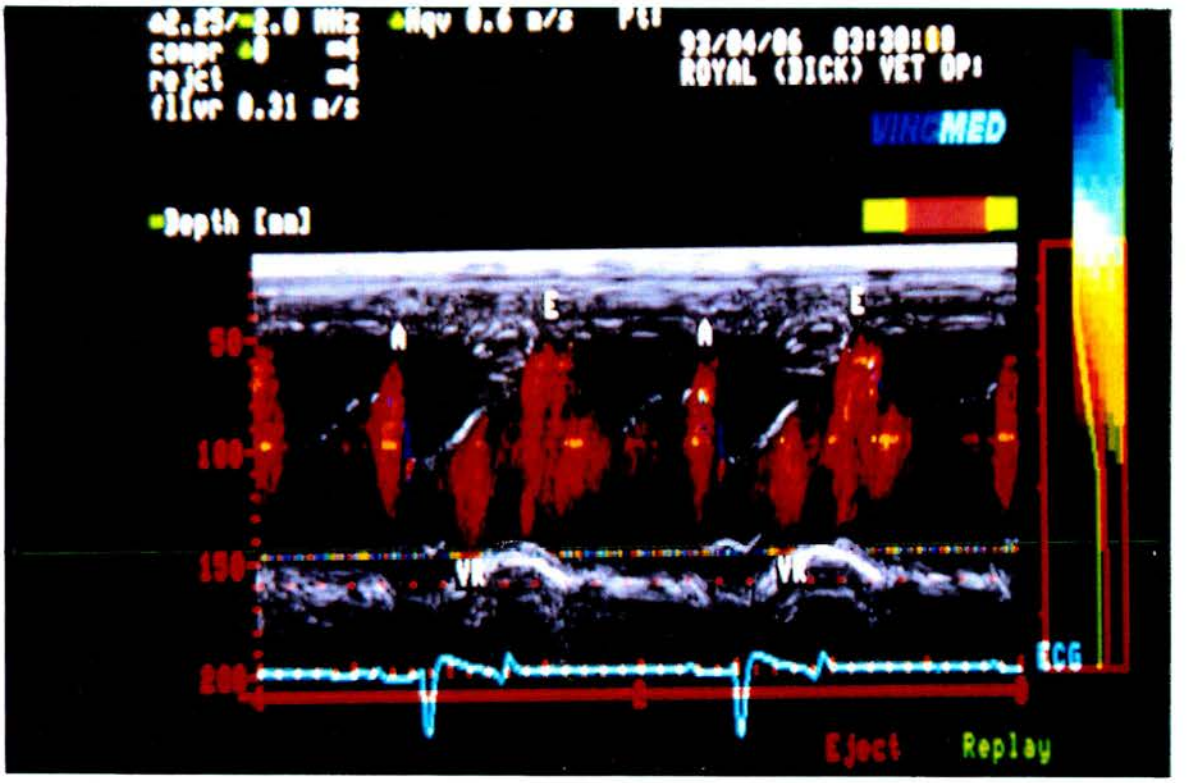
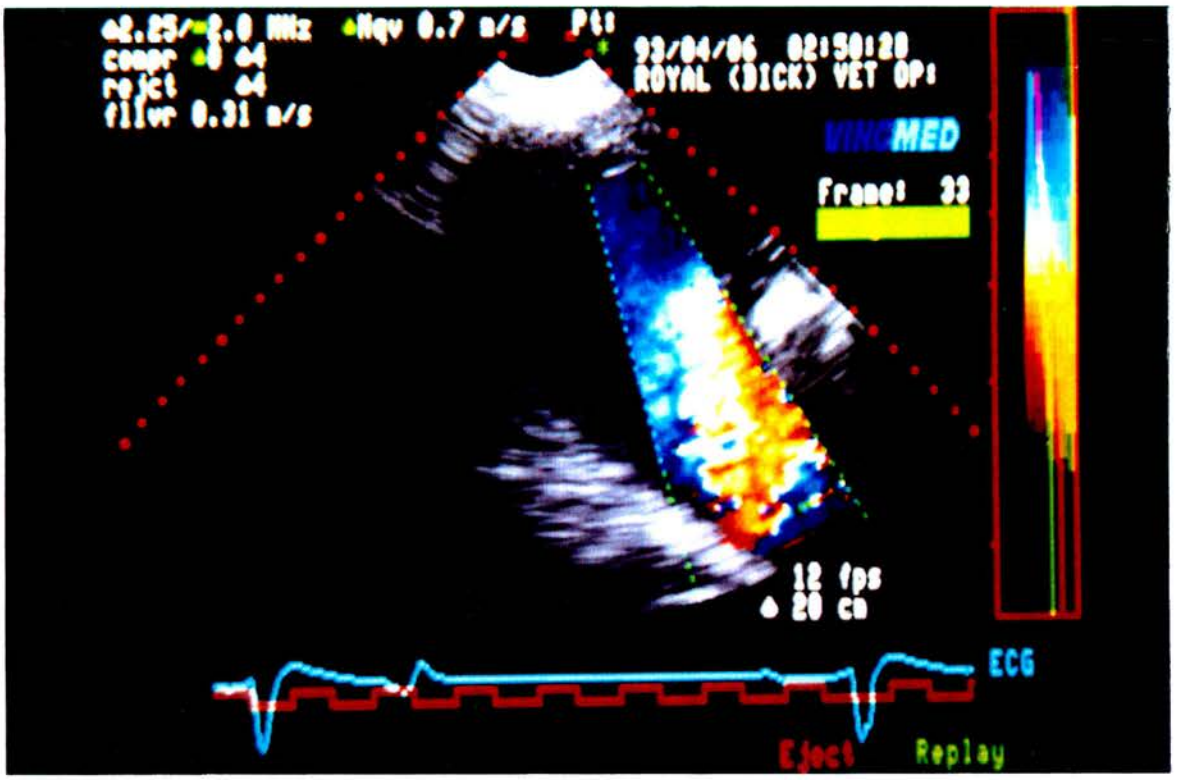

Depth [mm]
E
A
E
A
E
VR
VR
ECG
Eject
Replay
VINCMED
ROYAL (DICK) VET OPs

Figure 19 Colour flow study from the right parasternal angled view, dorsal location right ventricular outflow tract. Blood flow in the right ventricle, at the top of the colour sector, is coded blue. As the flow velocity increases as blood flows into the right ventricular outflow tract, flow is coded in lighter shades of blue. At the level of the supraventricular crest the flow velocity exceeds the Nyquist limit and signal aliasing occurs. The aliased signal is coded red.

Figure 20 Colour flow study from the right parasternal angled view, dorsal location right ventricular outflow tract. Flow is coded red, moving towards the transducer (top of image), during diastole. A central core of higher velocity flow is coded in lighter shades of red.

RA = right atrium PA = pulmonary artery
RVOT = right ventricular outflow tract


ROYAL (DICK) VET OPs
VINGMED
Frame: 33
12 fps
20 cm
ECG
Eject
Replay

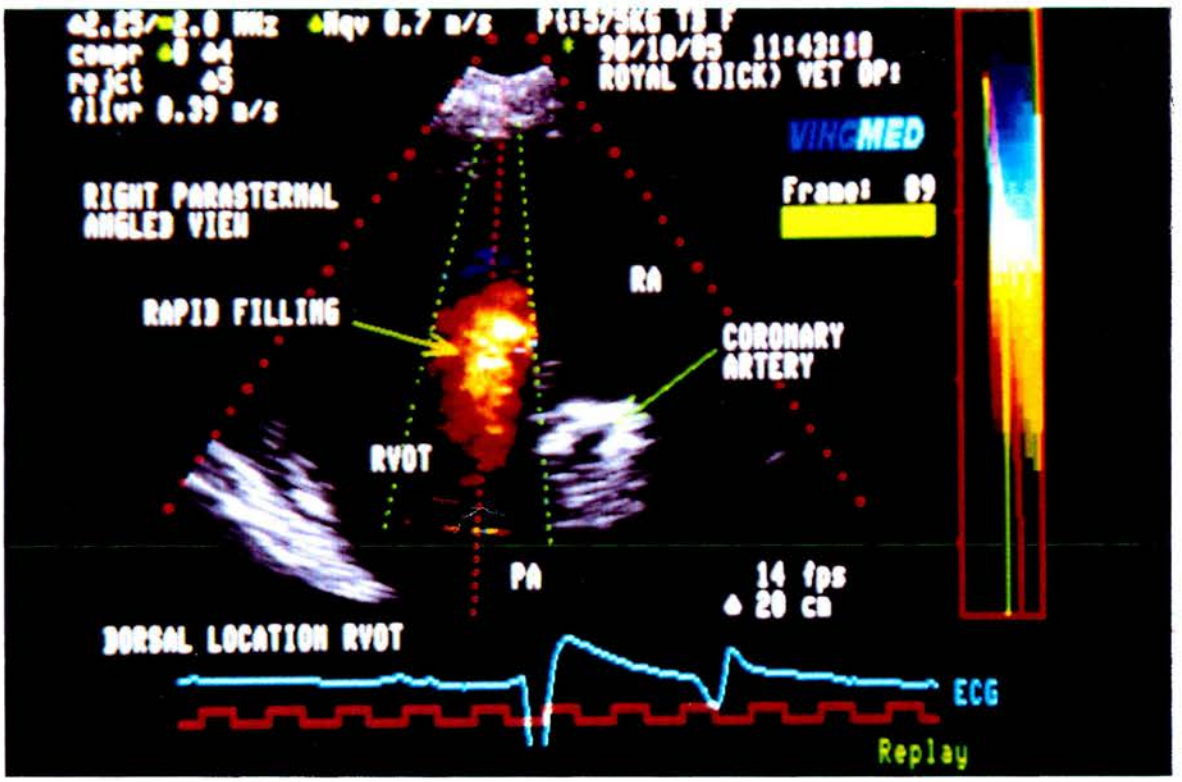
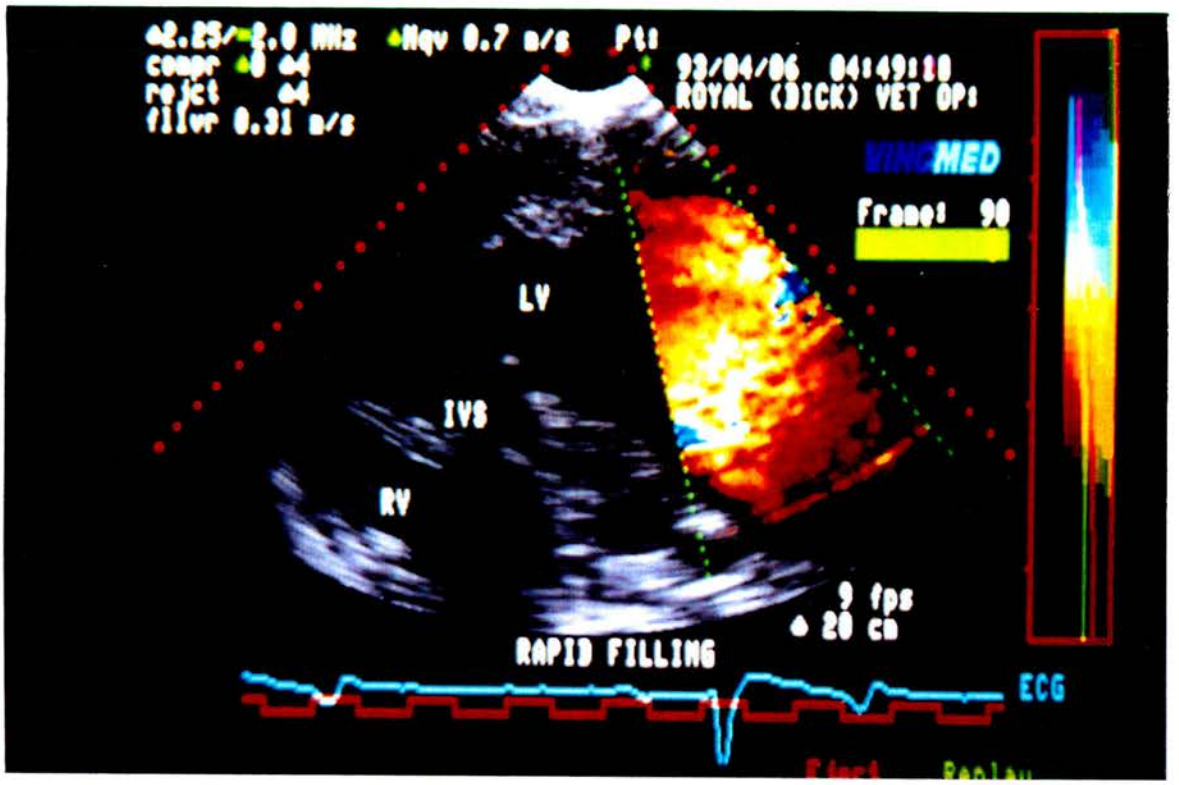

ROYAL (DICK) VET OPs
VINGMED
Frame: 89
RIGHT PARASTERNAL
ANGLED VIEW
RA
RAPID FILLING
CORONARY
ARTERY
RVOT
PA
14 fps
20 cm
DORSAL LOCATION RVOT
ECG
Replay

Figure 21 Colour flow Doppler study from a left parasternal long-axis view, showing a red flow signal in the left atrium, left ventricle and across the open mitral valve, during early diastole. The lighter shades of red represent a central core of higher velocity flow. An aliased signal (coded blue) can also be seen. The timing of the flow signal is indicated by the ECG trace at the far right of the screen.

LV = left ventricle

RV = right ventricle
IVS = interventricular septum

Figure 22 Colour M-mode study recorded from a single imaging line passing through the left ventricle, mitral valve and left atrium. In the centre of the image a red aliased signal idicates flow due to a non conducted atrial contraction. To the right of this signal a blue signal (MR) with an aliased core indicates diastolic mitral regurgitation, following the blocked P wave.


ROYAL (DICK) VET OPt
VINGMED
Frame: 90
LV
IVS
RV
9 fps
20 cm
RAPID FILLING
ECG

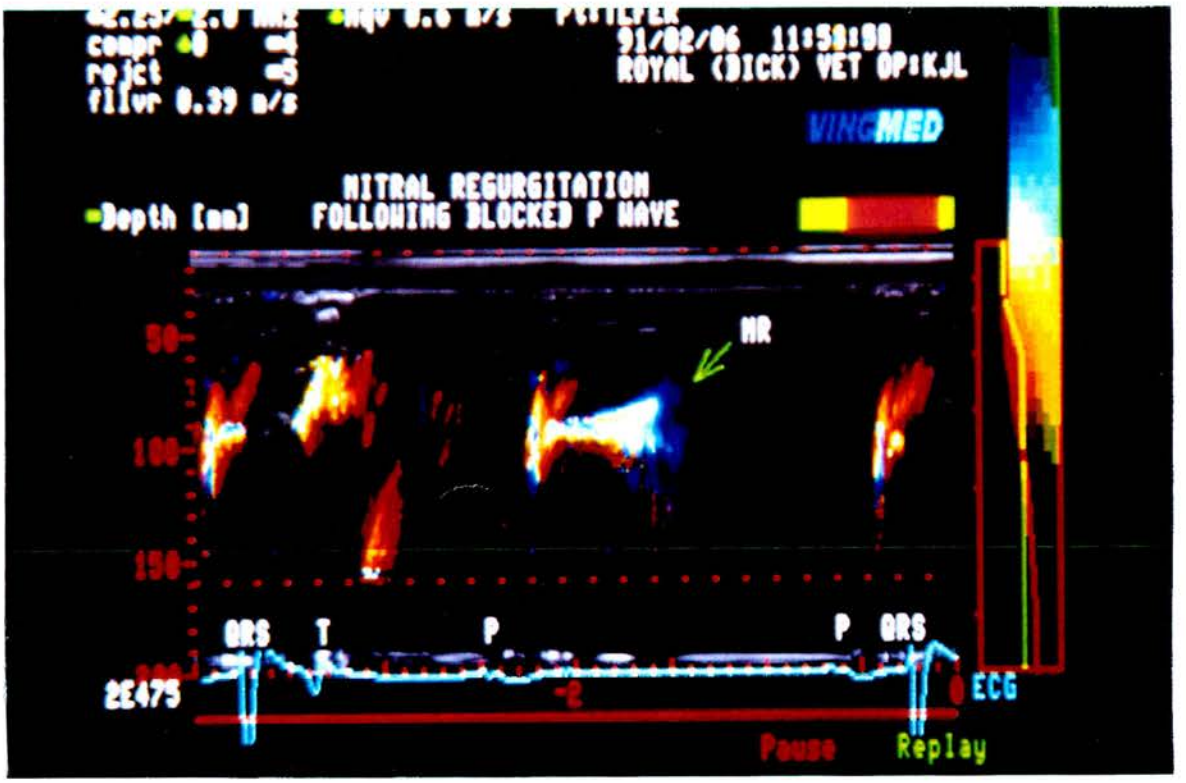

ROYAL (DICK) VET OP:KJL
VINGMED
MITRAL REGURGITATION
FOLLOWING BLOCKED P WAVE
Depth [mm]
MR
QRS
T
P
P
QRS
ECG
Pause
Replay

Figure 23 Colour flow Doppler study of the aortic outflow in systole from a left parasternal 5-chambered view. The flow signal is coded blue in the left ventricle but is aliased (coded red) in the left ventricular outflow tract and aorta.

LV = left ventricle

RV = right ventricle
IVS = interventricular septum

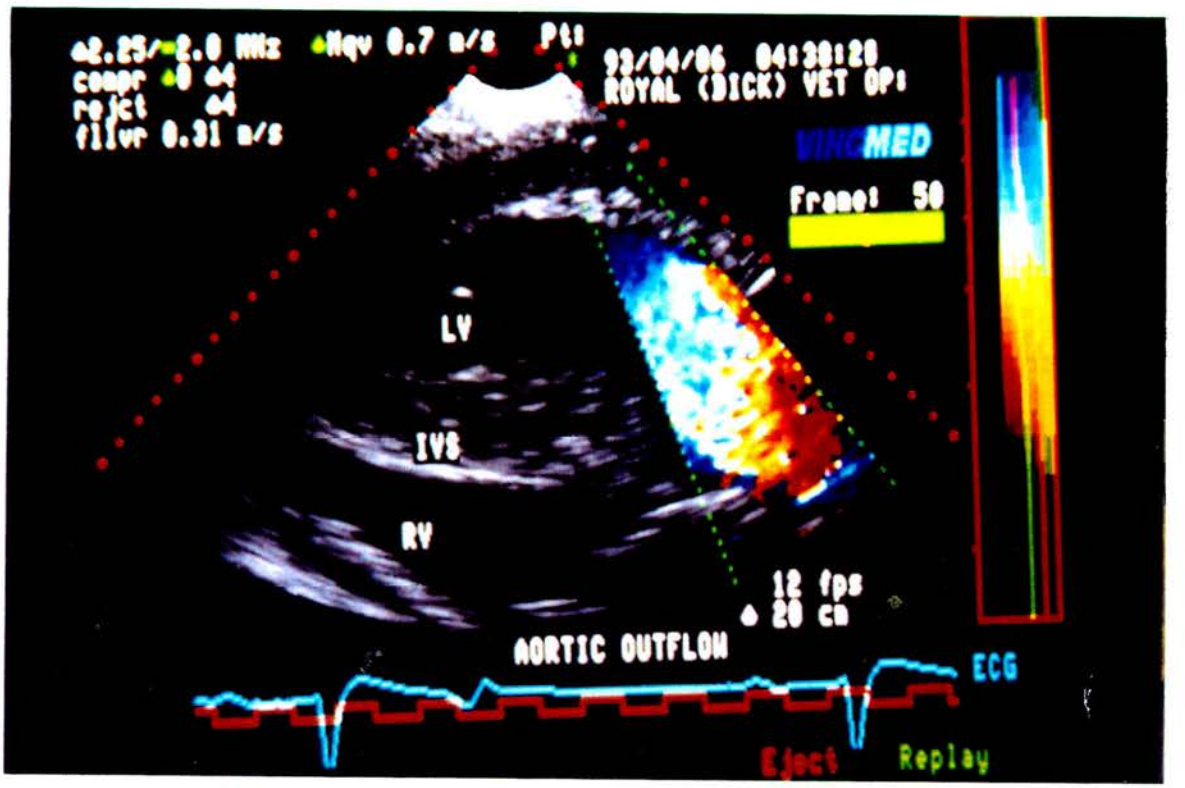
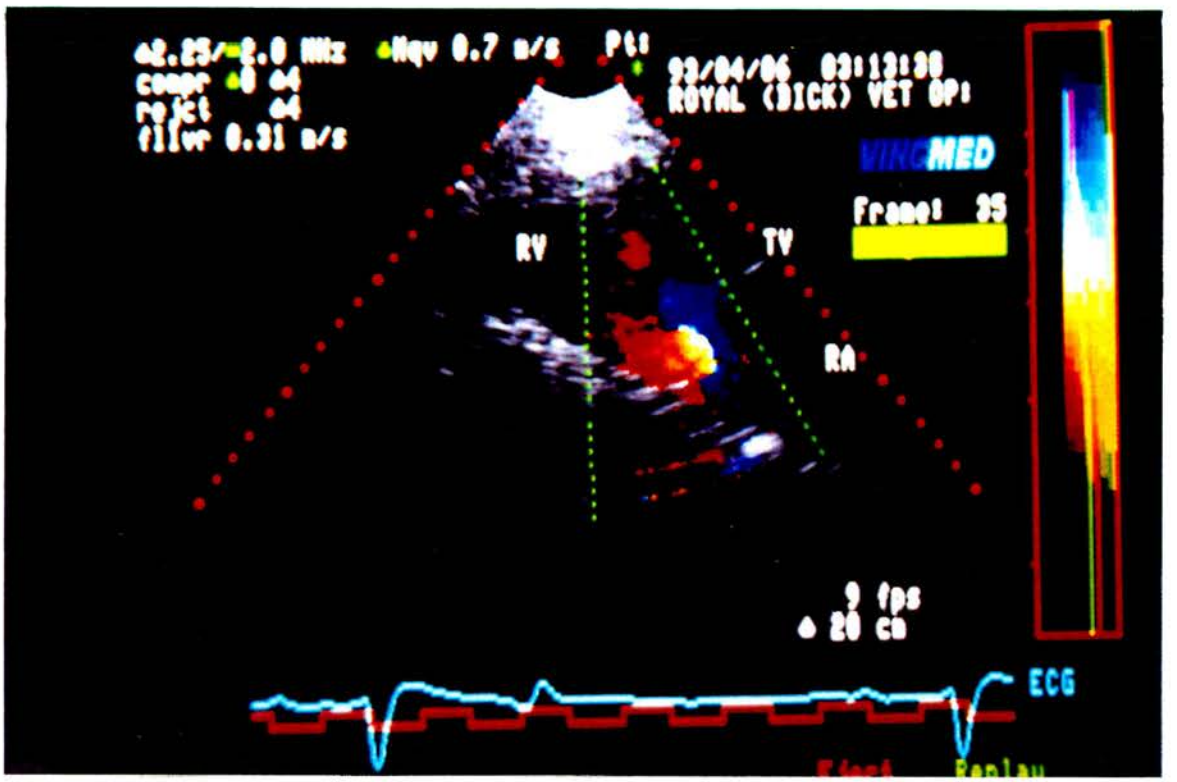

2.25/2.0 MHz
Hqv 0.7 m/s
Pt1
compr 0 dB
reject dB
filter 0.31 m/s
93/04/06 04:38:28
ROYAL (DICK) VET OPs
VINGMED
Frame: 50
LV
IVS
RV
12 fps
20 cm
AORTIC OUTFLOW
ECG
Eject
Replay

Figure 24 Colour flow study from a right parasternal long-axis view, long-axis aorta, at the onset of systole. The colour flow sector is positioned over the right ventricular inlet. A closure signal coded red and blue with a high velocity core is seen at the level of the tricuspid valve.

RA = right atrium
RV = right ventricle
TV = tricuspid valve

Figure 25 Colour flow study from a right parasternal long-axis view, showing a small blue aliased jet at the level of the tricuspid valve. This indicates blood flow from right ventricle to right atrium. This colour frame was recorded after the T wave of the ECG as indicated at the bottom right of the figure.

RA = right atrium
RV = right ventricle


RV
TV
RA
ECG

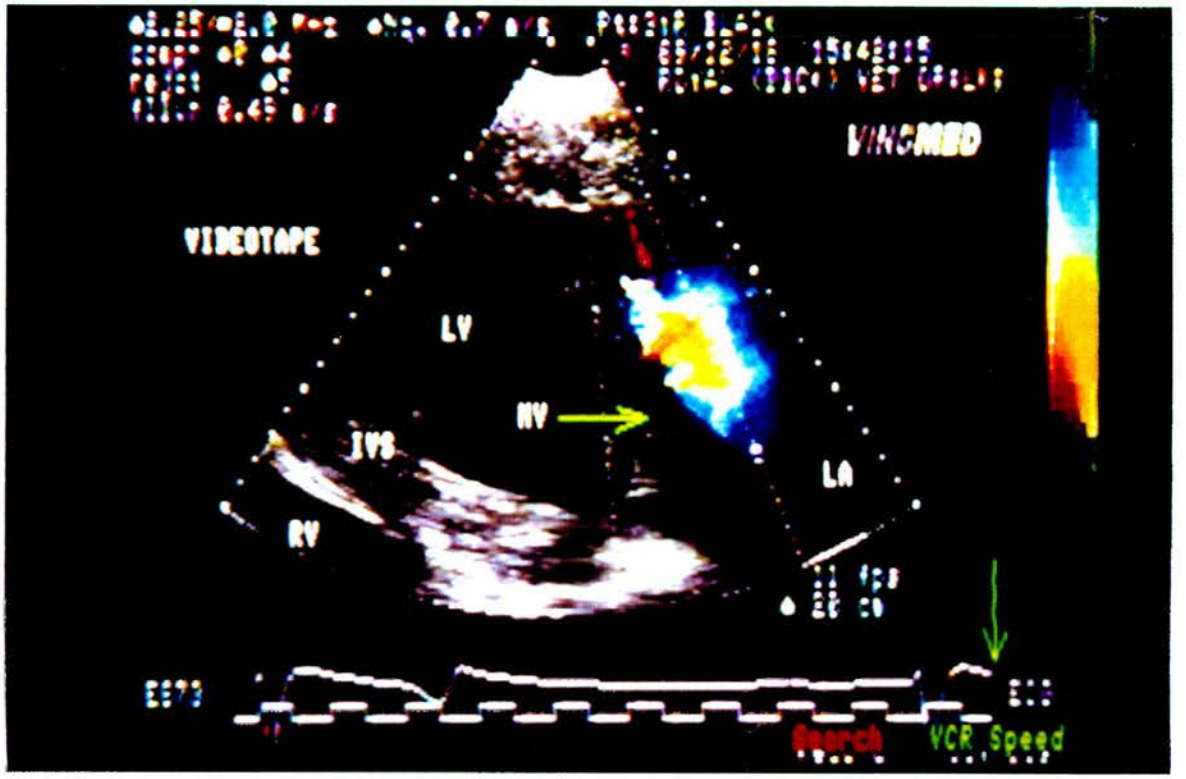
RV
RA
ECG
Eject
Replay

Figure 26 Colour flow study from a left parasternal long-axis apical view. A large blue signal with a central aliased core is shown on the left atrial side of the mitral valve. This colour signal was present for one colour frame only and was then replaced by the small regurgitant jet shown in Figure 27.

LA = left atrium
MV = mitral valve
LV = left ventricle
RV = right ventricle
IVS = interventricular septum

Figure 27 Colour flow study from a left parasternal long-axis apical view. A small blue aliased signal is shown on the left atrial side of the mitral valve. This colour signal followed the large closure pattern shown in Figure 26.

LA = left atrium
MV = mitral valve
LV = left ventricle
RV = right ventricle
IVS = interventricular septum


VINCMED
VIDEOTAPE
LV
MV
IVS
LA
RV
Search
VCR Speed

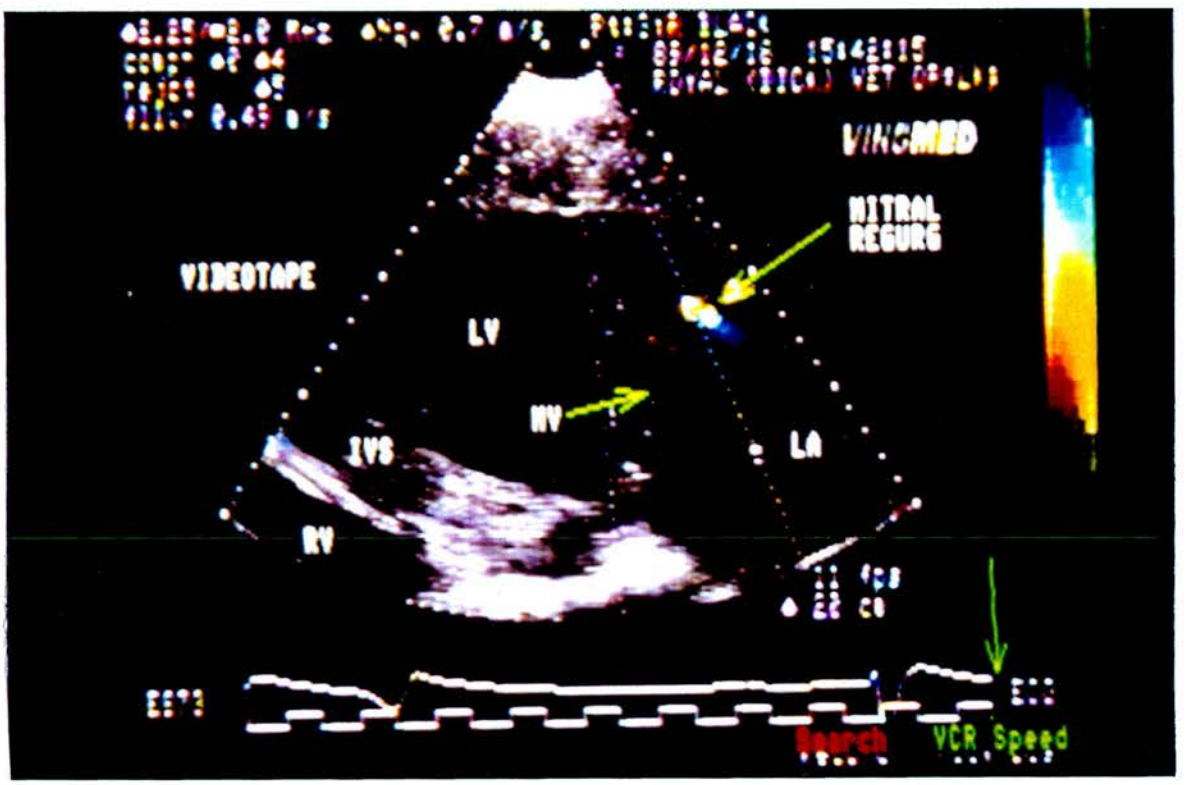
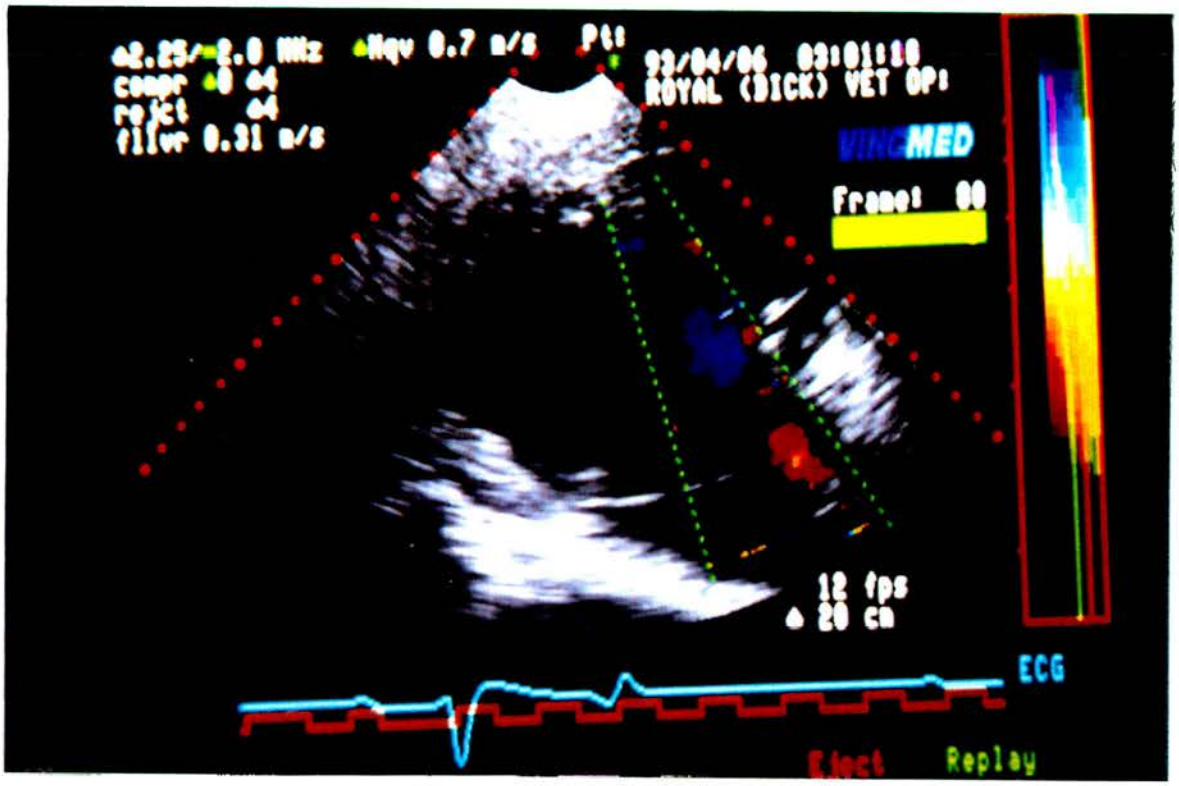

VINCMED
MITRAL REGURG
VIDEOTAPE
LV
MV
IVS
LA
RV
Search
VCR Speed

Figure 28 Colour flow study from a right parasternal angled view, dorsal location right ventricular outflow tract. A red flow signal of pulmonary insufficiency is present on the ventricular side of the pulmonary valve immediately following the P wave of the ECG.

Figure 29 Colour flow study from a right parasternal short-axis view at the aortic valve level. A blue aliased signal of tricuspid regurgitation is shown on the right atrial side of the tricuspid valve during systole. The blue signal in the aorta represents blood flowing from the left ventricle into the aorta during systole.

RA = right atrium
RV = right ventricle
TV = tricuspid valve
AO = aorta


Pt:
ROYAL (DICK) VET DP:
VINGMED
Frame: 00
12 fps
20 cm
ECG
Eject
Replay

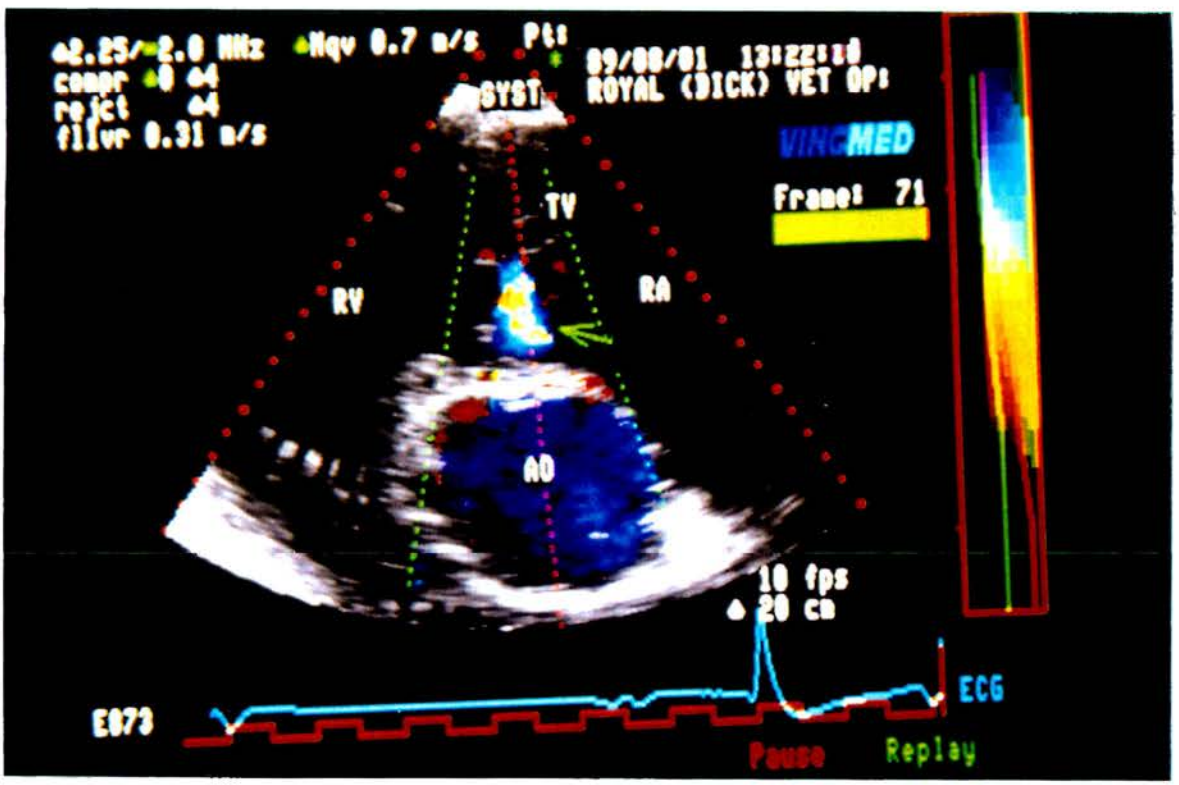
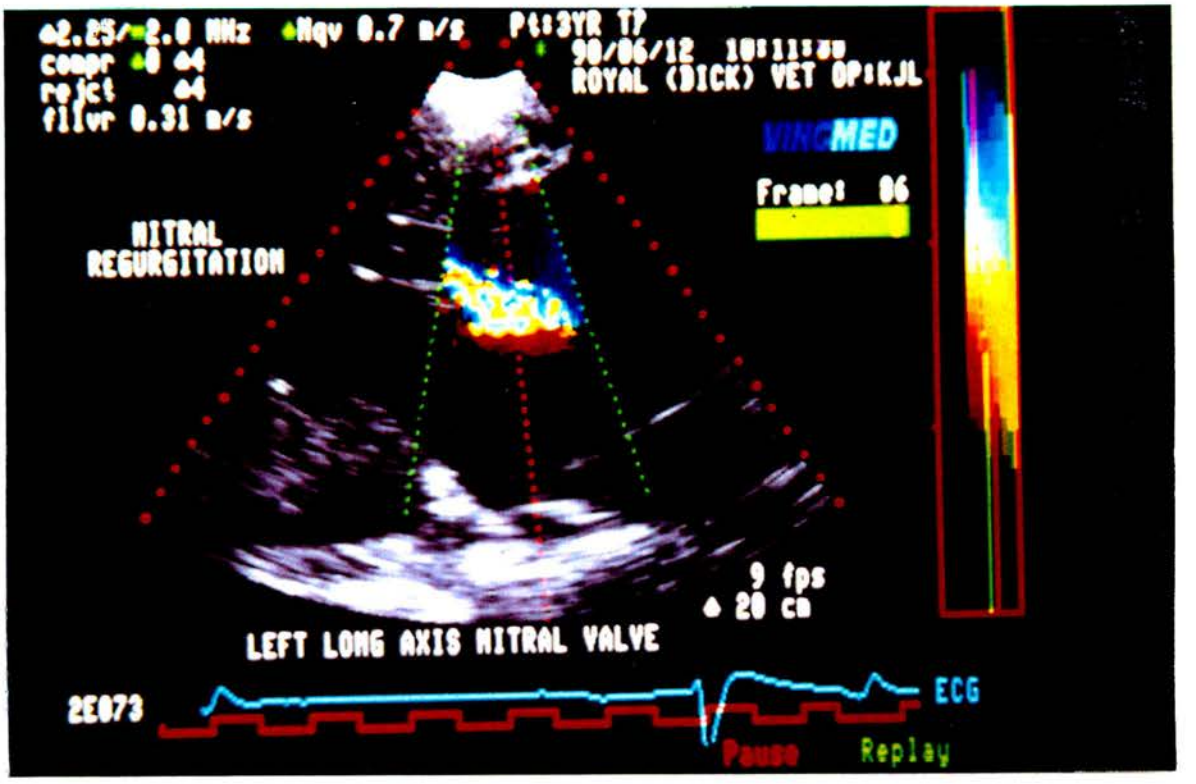

Pt:
ROYAL (DICK) VET DP:
SYST
VINGMED
Frame: 71
TV
RV
RA
AO
10 fps
20 cm
ECG
Pause
Replay

Figure 30 Colour flow study from a left parasternal long-axis view. An aliased blue jet of mitral regurgitation is shown on the left atrial side of the mitral valve at the end of systole. A jet of blood is flowing away from the transducer from left ventricle to left atrium. Chordae tendineae of the mitral valve can be seen in the left ventricle, to the left of the regurgitant jet.

Figure 31 Colour flow study from a left parasternal long-axis reference view. An aliased red jet of mitral regurgitation is shown on the left atrial side of the mitral valve during systole. In contrast to Figure 30, the jet of blood is flowing towards the transducer and therefore is coded in a red colour. Chordae tendineae of the mitral valve can be seen in the left ventricle.

LA = left atrium
LV = left ventricle
MV = mitral valve
MR = mitral regurgitation


Pt:3YR TP
90/06/12
ROYAL (DICK) VET OP:KJL
VINCMED
Frame: 86
MITRAL
REGURGITATION
9 fps
20 cm
LEFT LONG AXIS MITRAL VALVE
2E073
ECG
Pause
Replay

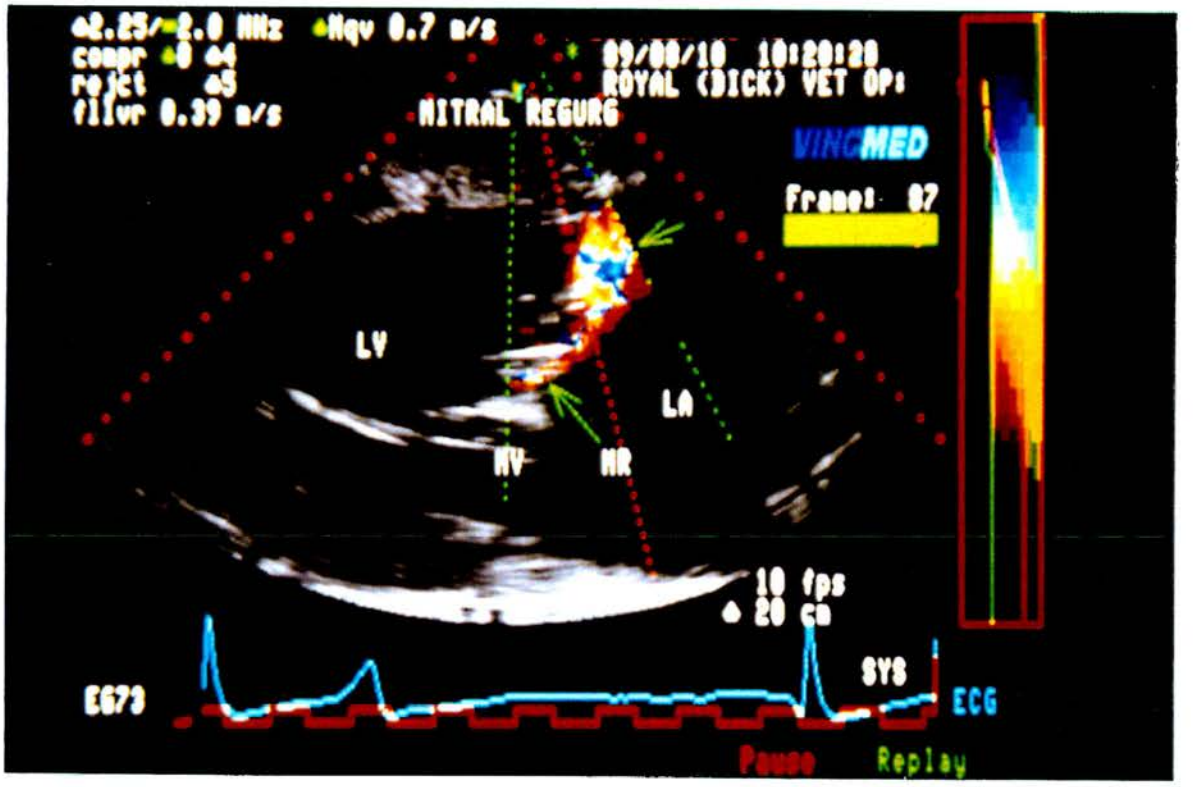
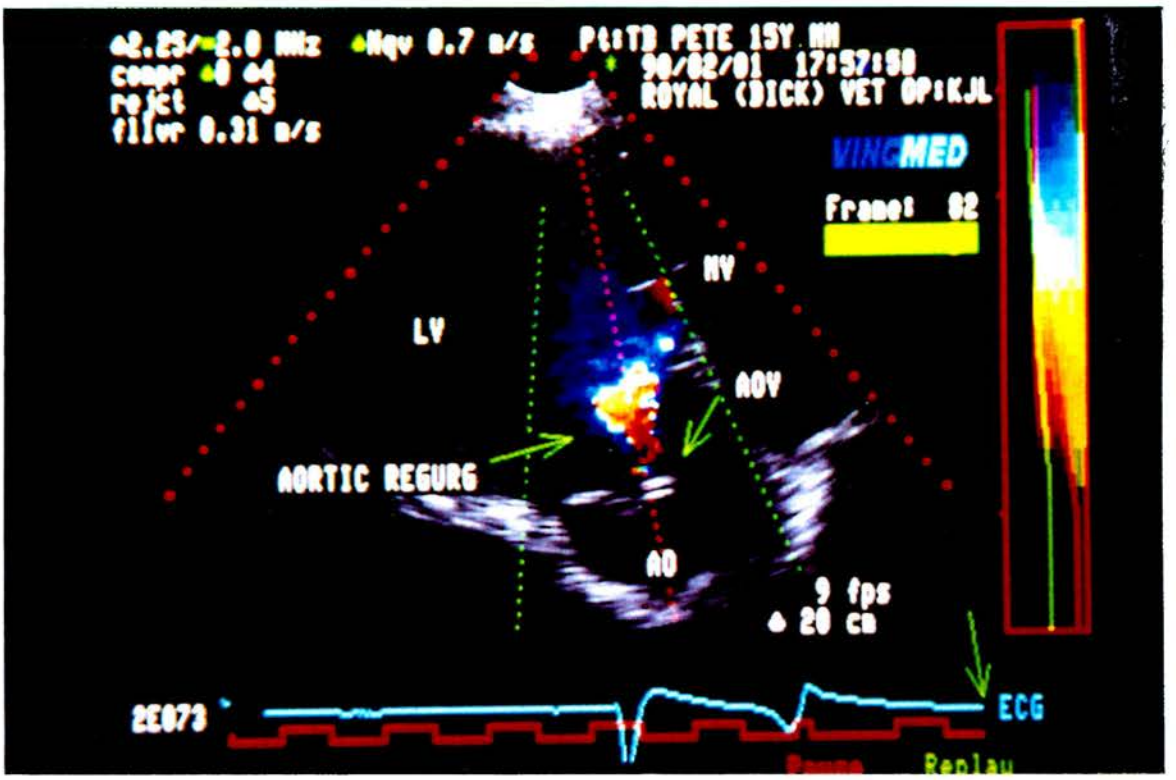

MITRAL REGURG
VINCMED
Frame: 87
LV
LA
MV
MR
10 fps
20 cm
SYS
E073
ECG
Pause
Replay

Figure 32 Colour flow study from a left parasternal 5-chambered view. An aliased jet of aortic regurgitation is shown on the ventricular side of the aortic valve in early diastole.

MV = mitral valve
LV = left ventricle
AO = aorta
AOV = aortic valve

Figure 33 Colour flow study from a right parasternal long-axis view, long-axis aorta. An aliased jet of aortic regurgitation is shown on the ventricular side of the aortic valve in diastole.

RA = right atrium
LV = left ventricle
AR = aortic regurgitation
LVOT = left ventricular outflow tract
RV = right ventricle
AO = aorta
PAP = pulmonary artery pressure


Pt:TB PETE 15Y MM
ROYAL (DICK) VET OP:KJL
VINGMED
Frame: 82
LV
MV
AOV
AORTIC REGURG
AO
9 fps
20 cm
ECG
Pause
Replay

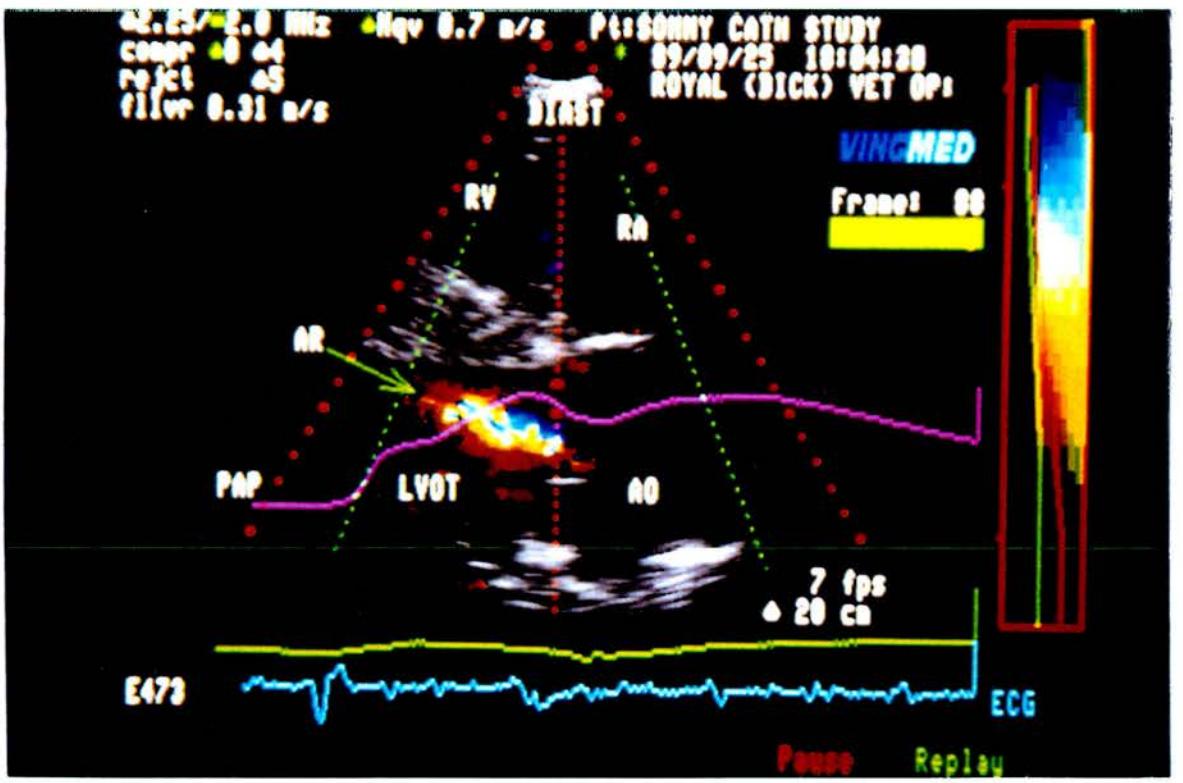
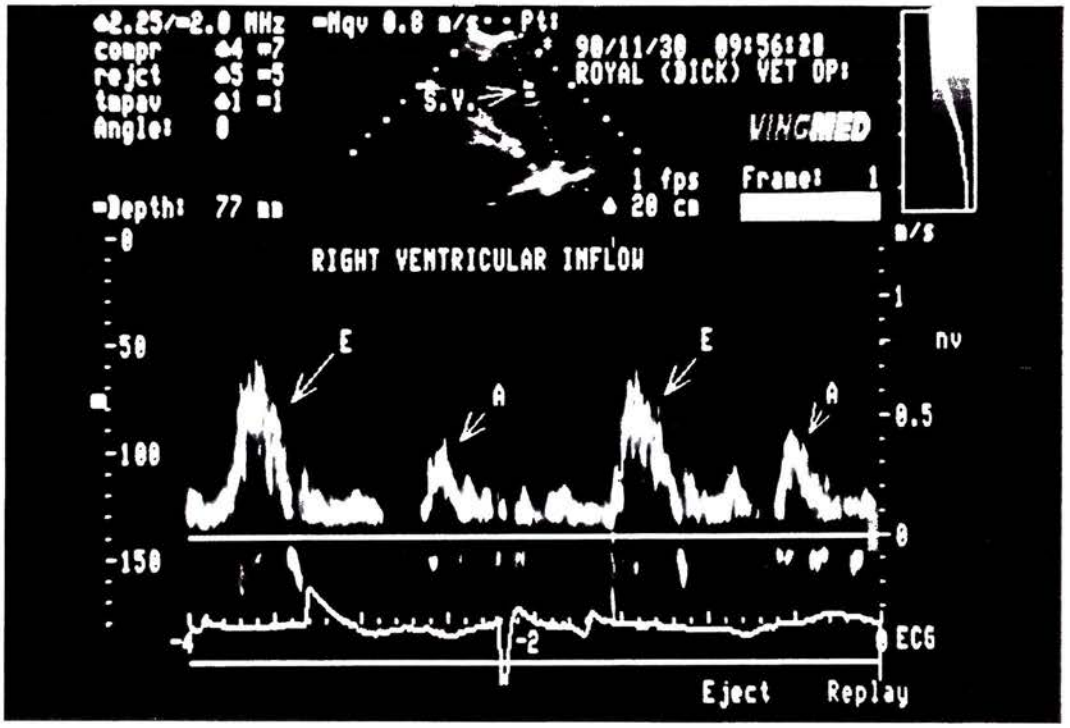

Pt:SONNY CATH STUDY
ROYAL (DICK) VET OP:
VINGMED
Frame: 88
DIAST
RV
RA
AR
PAP
LVOT
AO
7 fps
20 cm
ECG
Pause
Replay

Figure 34 Pulsed wave Doppler study of the tricuspid inflow from a right parasternal long-axis apical view. Flow velocities are recorded from a sample volume positioned on the ventricular side of the tricuspid valve. The sample volume is displayed on the small image sector at the top of the figure. The velocity scale, in metres per second, is shown on the right of the Doppler display. Blood is flowing towards the transducer and therefore is displayed above the baseline of the Doppler display.

E = rapid filling wave A = atrial contraction.
S.V. = sample volume

Figure 35 Diagram representing the ventricular filling velocities recorded by Doppler echocardiography. The peak E and A velocity are measured in metres per second (m/s). The deceleration time (dt) is measured by extrapolating the downstroke of the E signal to the baseline. The deceleration time is given in seconds.


RIGHT VENTRICULAR INFLOW
E
A
E
A
S.V.
ROYAL (DICK) VET OP:
VINGMED
1 fps
Frame: 1
m/s
nv
ECG
Eject
Replay

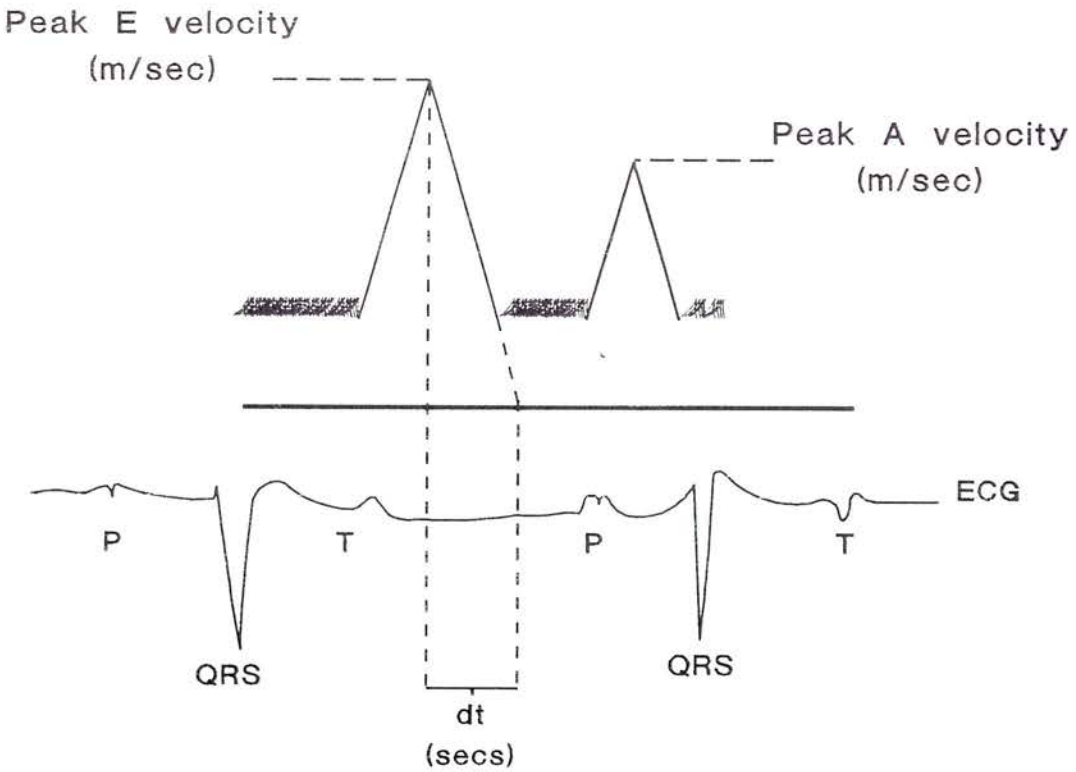

Peak E velocity
(m/sec)
Peak A velocity
(m/sec)
ECG
P
T
P
T
QRS
QRS
dt
(secs)

Figure 36 Pulsed wave Doppler study of the tricuspid inflow from a right parasternal short-axis angled view. The sampling site is displayed on the small image sector at the top of the figure. The velocity scale, in metres per second, is shown on the right of the Doppler display. Blood is flowing towards the transducer and therefore is displayed above the baseline of the Doppler display.

E = rapid filling wave
A = atrial contraction.
S.V. = sample volume
RA = right atrium

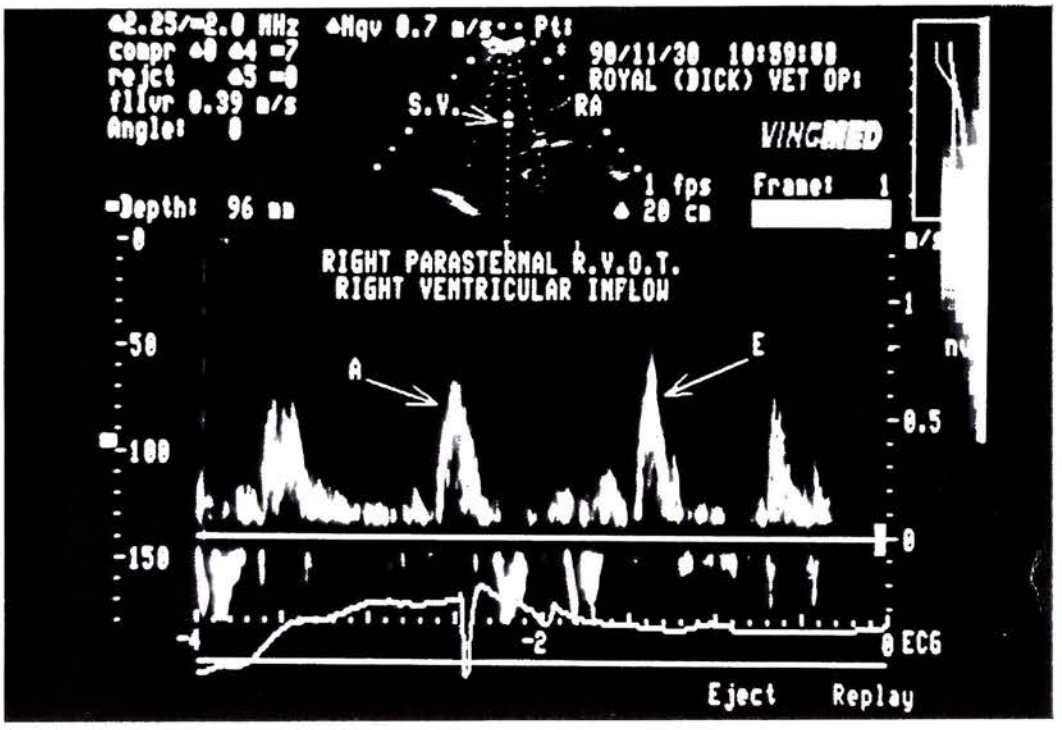
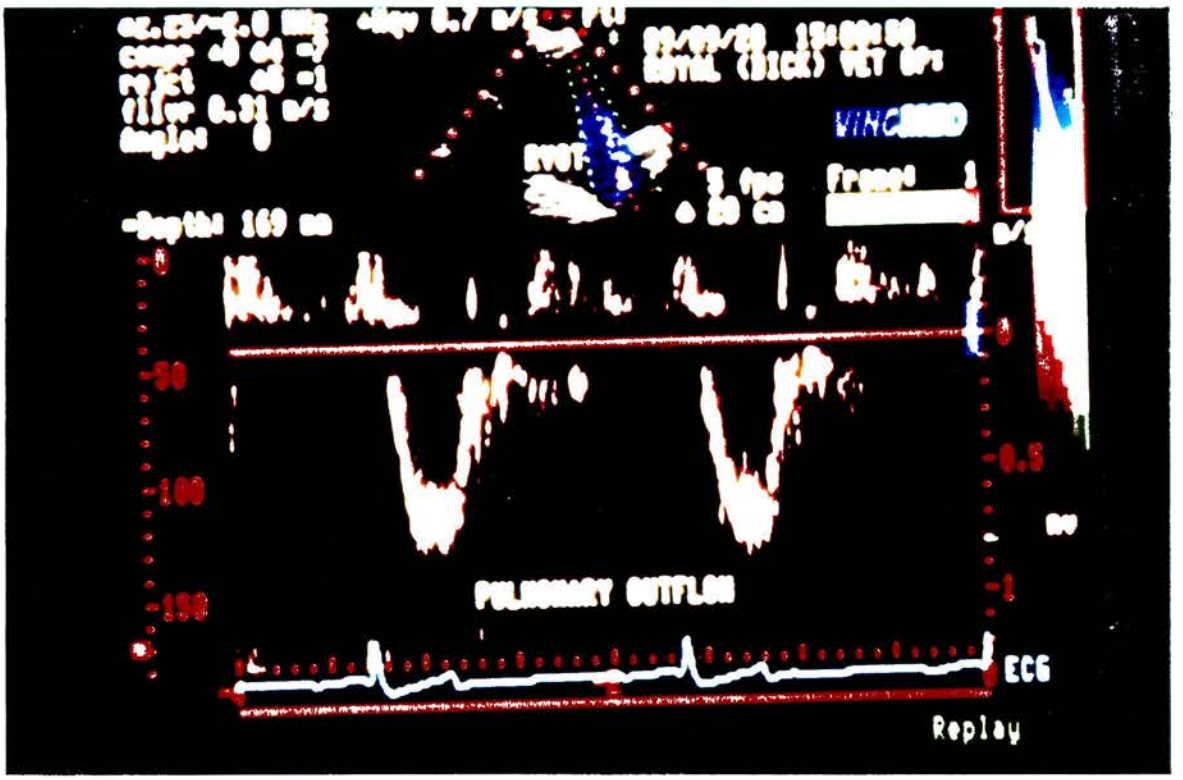

2.25/2.0 MHz
Mqv 0.7 m/s
Pt:
compr 0 4 7
reject 5 0
filvr 0.39 m/s
Angle: 0
90/11/30 10:59:08
ROYAL (DICK) VET OP:
S.V.
RA
VINGMED
1 fps
Frame: 1
20 cm
Depth: 96 mm
RIGHT PARASTERNAL R.V.O.T.
RIGHT VENTRICULAR INFLOW
A
E
m/s
1
0.5
0
-0
-50
-100
-150
-4
-2
0 ECG
Eject
Replay

Figure 37 Pulsed wave Doppler study from the pulmonary artery. The pulsed wave Doppler sampling site is represented by two red dots which can be seen positioned in the blue coded outflow on the two-dimensional image. The velocity scale, in metres per second, is shown on the right of the Doppler display. Blood is flowing away from the transducer and therefore is displayed below the baseline of the Doppler display.

Figure 38 Diagram representing the ventricular outflow velocities recorded by Doppler echocardiography. The peak velocity (VMax) is measured in metres per second (m/s). The peak acceleration, in metres per second^2, is measured from the middle of the upstroke of the Doppler waveform to the peak velocity. The area under the curve (VTI) is measured in centimetres. The pre-ejection period (PEP) and ejection time (EjT) are given in seconds. The acceleration time, in seconds (dt) is measured from the onset of the Doppler waveform to the start of the maximum velocity plateau.


PULMONARY OUTFLOW
ECG
Replay

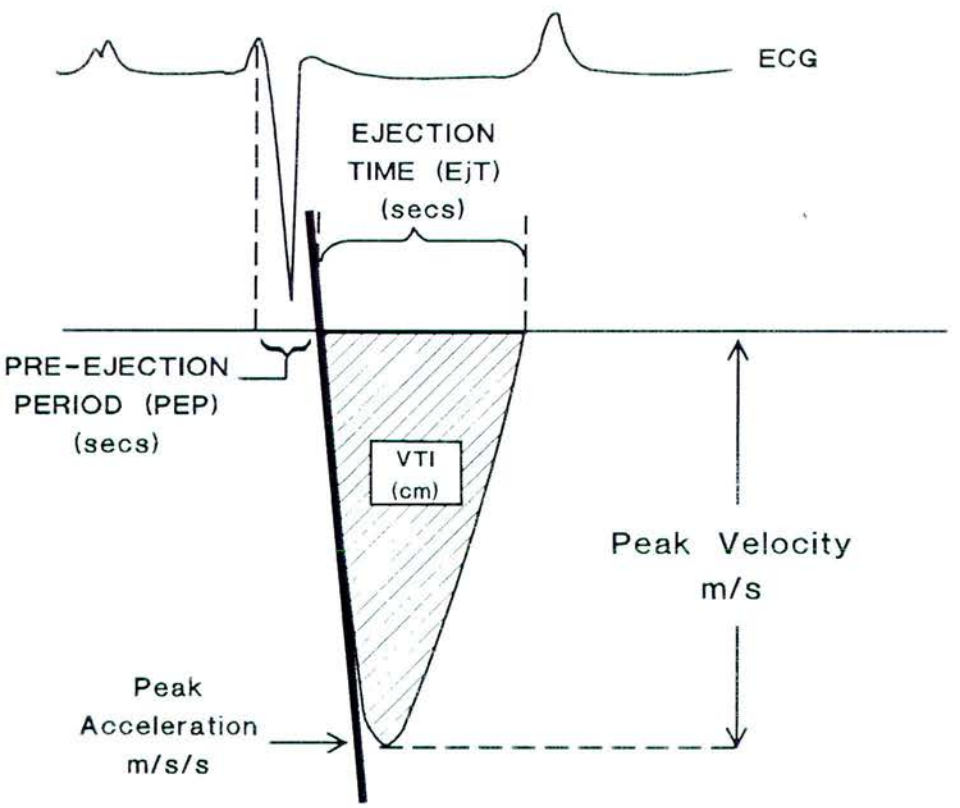
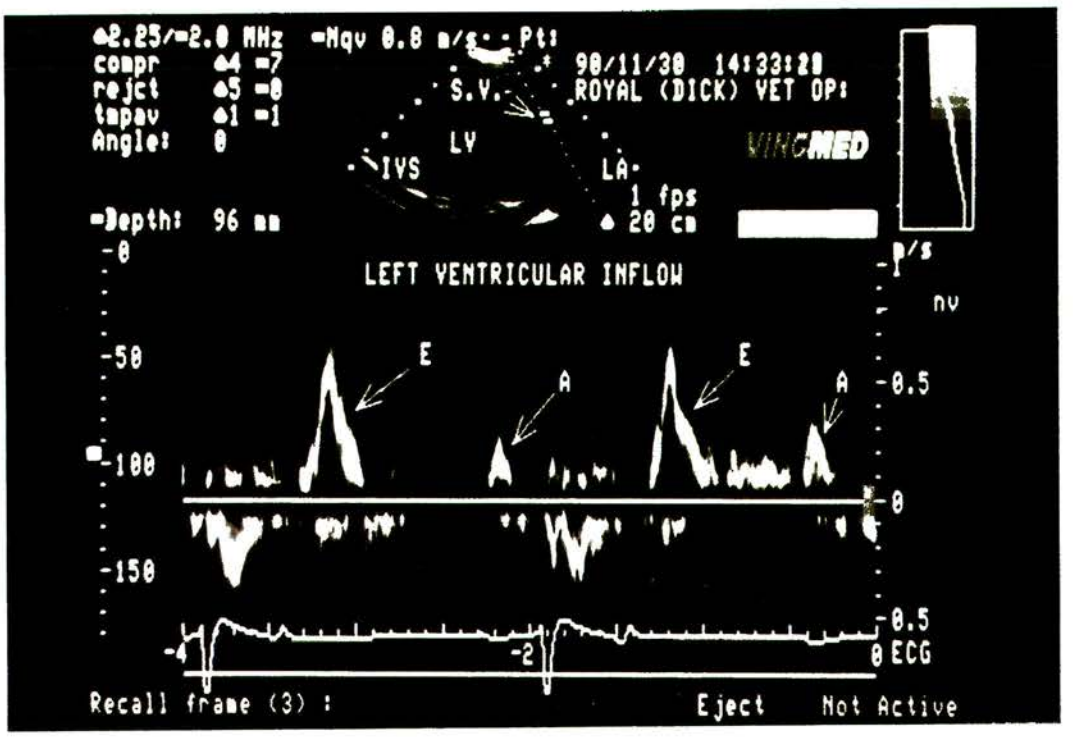

ECG
EJECTION
TIME (EjT)
(secs)
PRE-EJECTION
PERIOD (PEP)
(secs)
VTI
(cm)
Peak Velocity
m/s
Peak
Acceleration
m/s/s

Figure 39 Pulsed wave Doppler study of the mitral inflow from a left parasternal long-axis view. Flow velocities are recorded from a sample volume positioned on the ventricular side of the mitral valve. The sampling site is displayed on the small image sector at the top of the figure. The velocity scale, in metres per second, is shown on the right of the Doppler display. Blood is flowing towards the transducer and therefore is displayed above the baseline of the Doppler display.

E = rapid filling wave
A = atrial contraction.
S.V. = sample volume
LA = left atrium
LV = left ventricle
IVS = interventricular septum

Figure 40 Pulsed wave Doppler study from the aorta. The pulsed wave Doppler sampling site is represented by two red dots which can be seen positioned in the blue coded outflow on the two-dimensional image. The velocity scale, in metres per second, is shown on the right of the Doppler display. Blood is flowing away from the transducer and therefore is displayed below the baseline of the Doppler display.

LV = left ventricle
RV = right ventricle
IVS = interventricular septum
LVOT = left ventricular outflow tract


2.25/2.0 MHz
compr
reject
tapav
Angle:
Mqv 0.8 m/s
Pt:
90/11/30 14:33:28
ROYAL (DICK) VET OP:
S.V.
LV
IVS
LA
1 fps
20 cm
Depth: 96 mm
LEFT VENTRICULAR INFLOW
E
A
E
A
ECG
Recall frame (3) :
Eject
Not Active

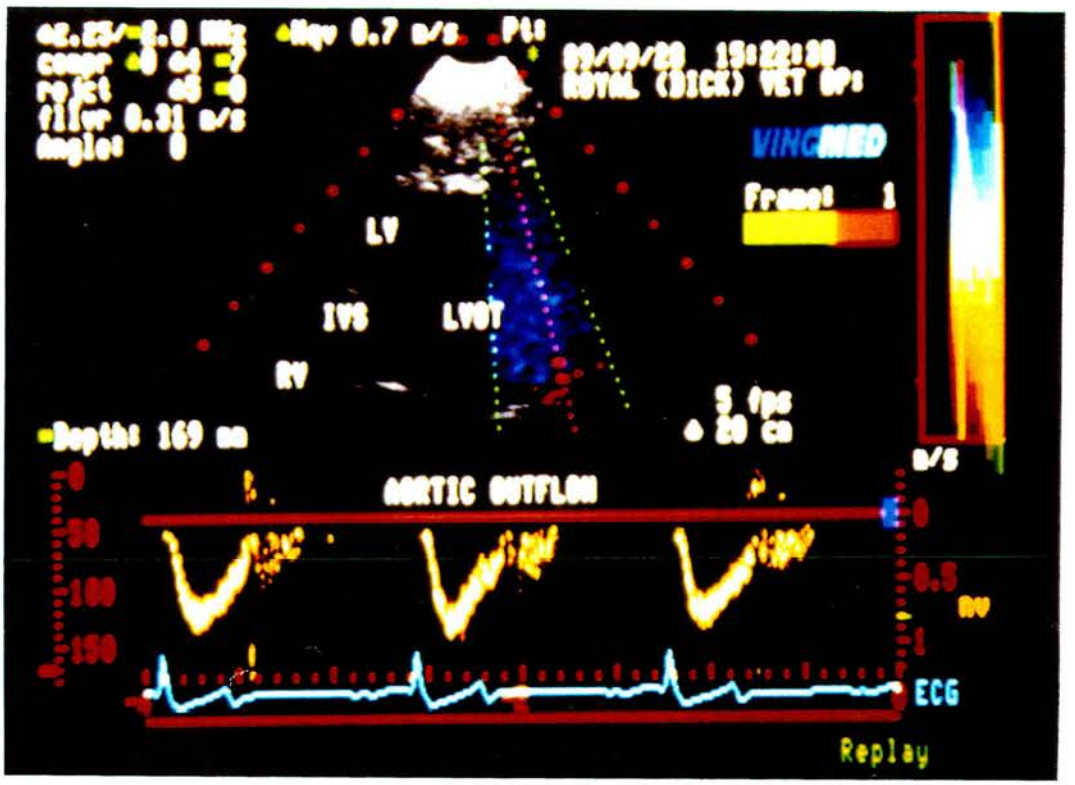

Mqv 0.7 m/s
Pt:
LV
IVS
LVOT
RV
5 fps
20 cm
Depth: 169 mm
AORTIC OUTFLOW
ECG
Replay

Figure 41 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the time to onset of the tricuspid E wave (QE Med) in different groups of horses. Doppler waveforms were recorded from a right parasternal long-axis view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

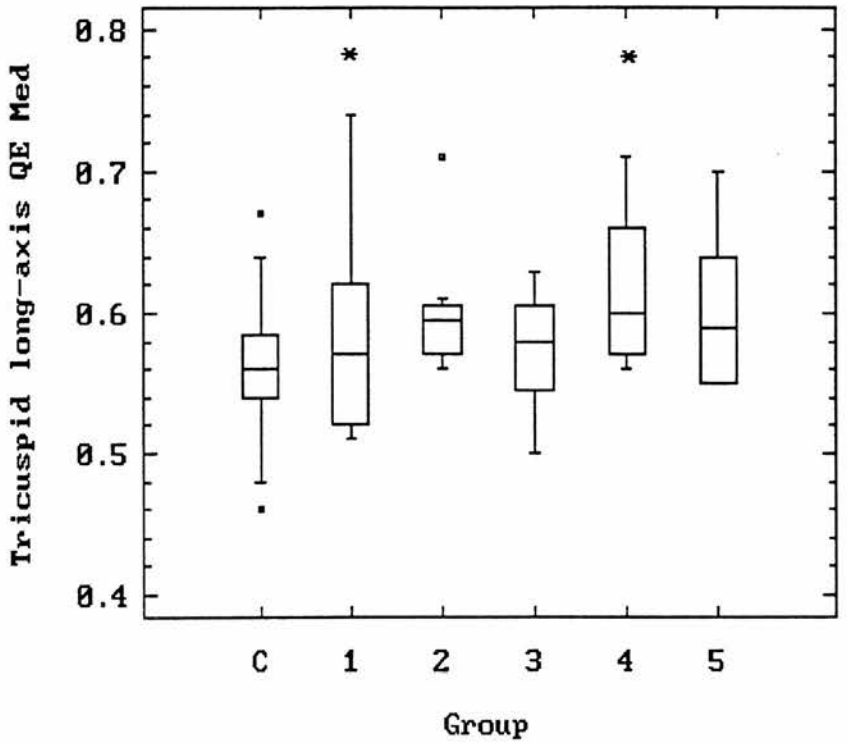
The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median measurements of the time to onset of the tricuspid E wave (QE Med). Measurements are given in seconds.

Figure 42 Box and whisker plots displaying the range, interquartile range and mean of median peak E velocity measurements (E Med) in different groups of horses. Doppler waveforms were recorded from the left parasternal long-axis view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median measurements of the peak E velocity (E Med). Measurements are given in metres per second.


Tricuspid long-axis QE Med
0.8
0.7
0.6
0.5
0.4
C
1
2
3
4
5
Group

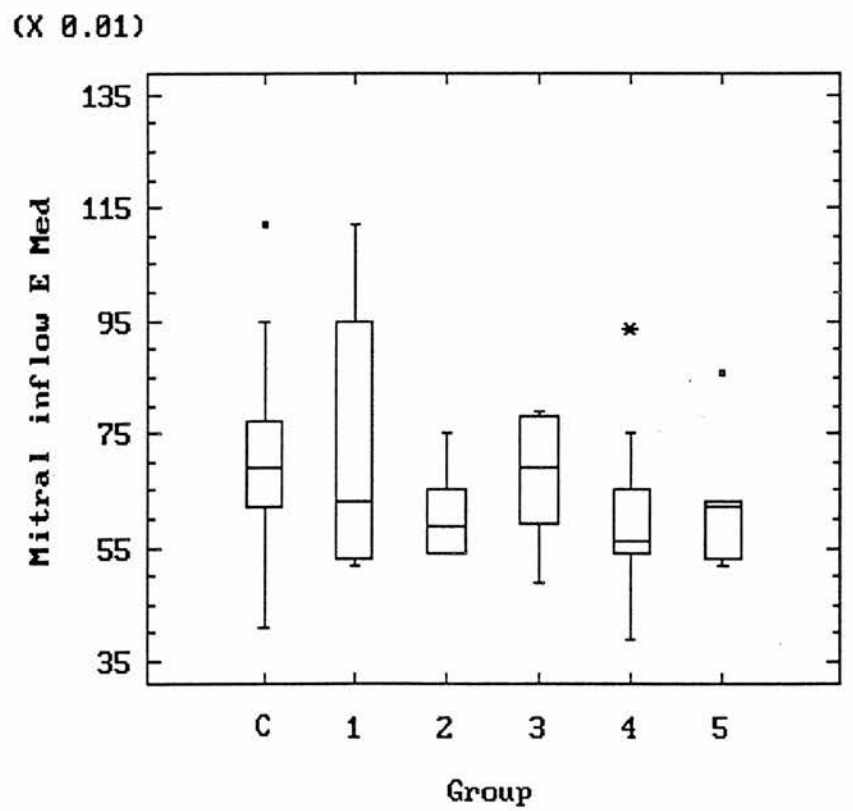

(X 0.01)
Mitral inflow E Med
135
115
95
75
55
35
C
1
2
3
4
5
Group

Figure 43 Box and whisker plots displaying the range, interquartile range and mean of median aortic peak velocity measurements (VMax Med) in different groups of horses. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

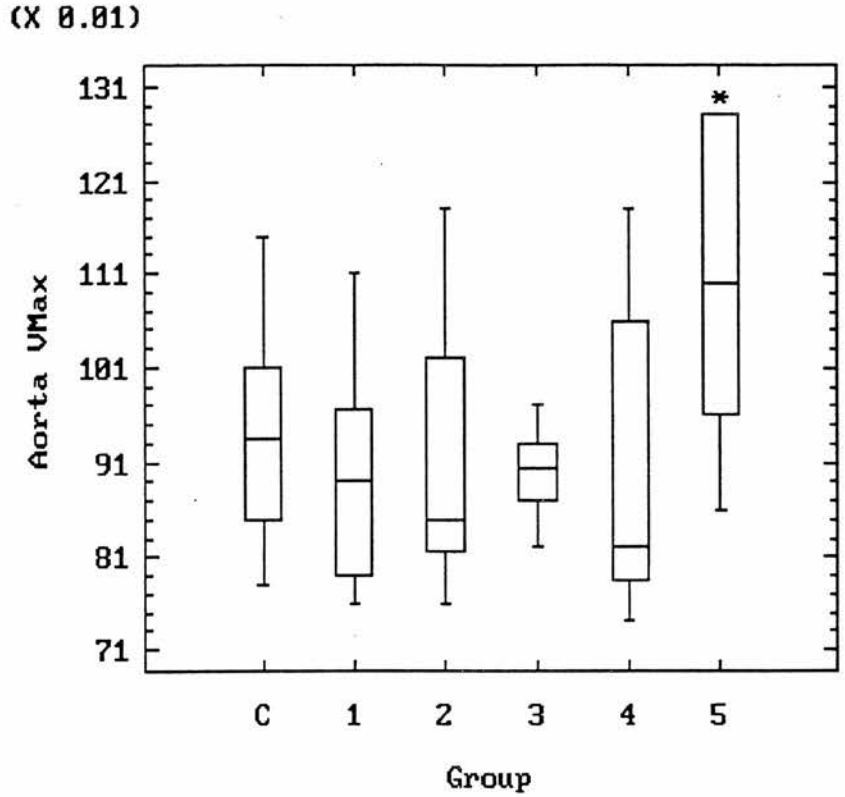
The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median aortic peak velocity measurements (VMax) Med). Measurements are given in metres per second.

Figure 44 Box and whisker plots displaying the range, interquartile range and mean of median aortic peak acceleration measurements (dv/dt Med) in different groups of horses. Doppler waveforms were recorded from the left parasternal long-axis, 5-chambered view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

The y axis displays median aortic peak acceleration measurements (dv/dt Med). Measurements are given in metres per second^2.


(X 0.01)
Aorta VMax
131
121
111
101
91
81
71
*
C
1
2
3
4
5
Group

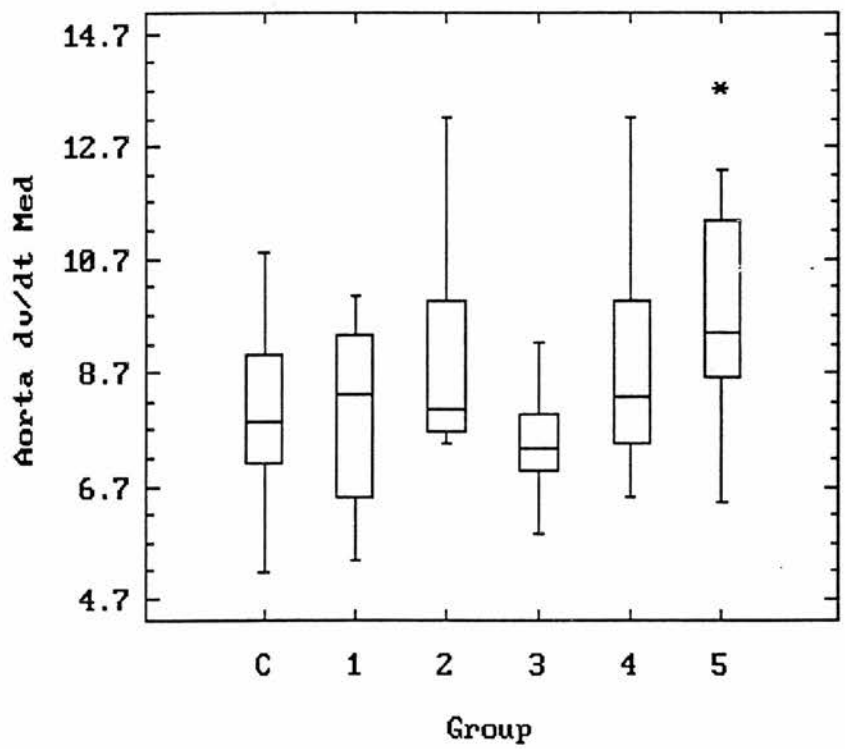

Aorta dv/dt Med
14.7
12.7
10.7
8.7
6.7
4.7
*
C
1
2
3
4
5
Group

Figure 45 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the aortic velocity time integral (VTI Med) in different groups of horses. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

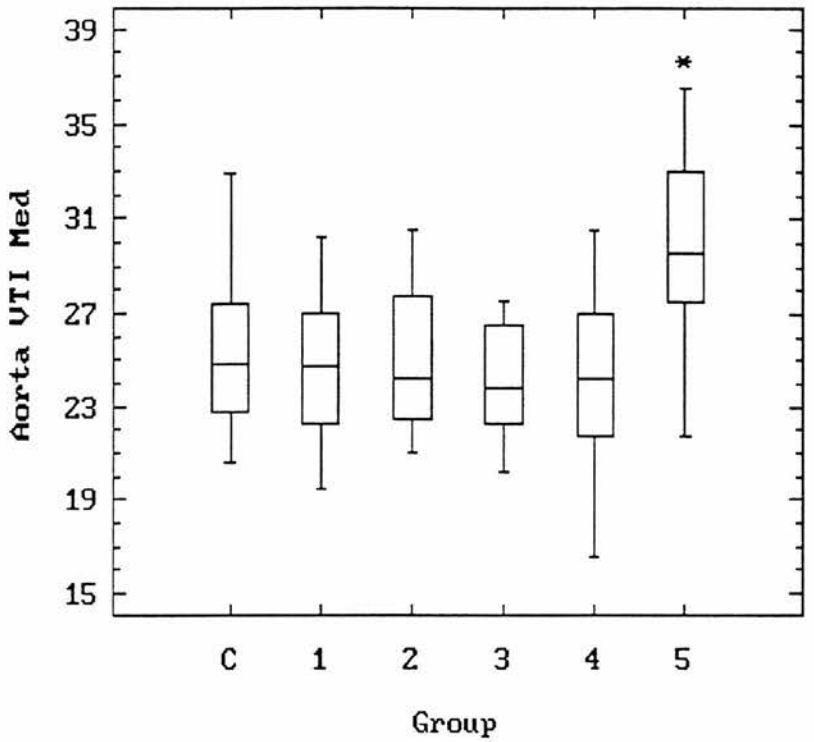
The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

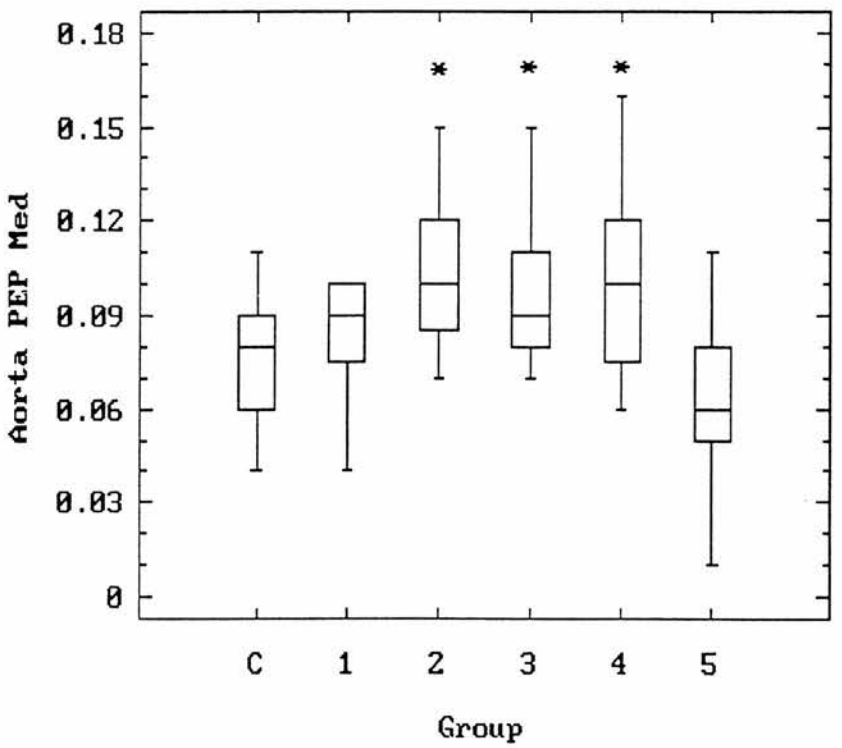
The y axis displays median measurements of the aortic velocity time integral (VTI Med). Measurements are given in centimetres.

Figure 46 Box and whisker plots displaying the range, interquartile range and mean of median measurements of the aortic pre-ejection period (PEP Med) in different groups of horses. Doppler waveforms were recorded from the left parasternal long-axis, 5-chambered view. * represents significant differences between the control group and groups 1-5 (Mann-Whitney test).

The x axis displays the groups of horses studied;
C = control group
1 = horses with a systolic murmur over the mitral valve
2 = horses with a systolic murmur over the tricuspid valve
3 = horses with a low grade systolic murmur over the tricuspid valve
4 = horses with a high grade systolic murmur over the tricuspid valve
5 = horses with a diastolic murmur over the aortic valve

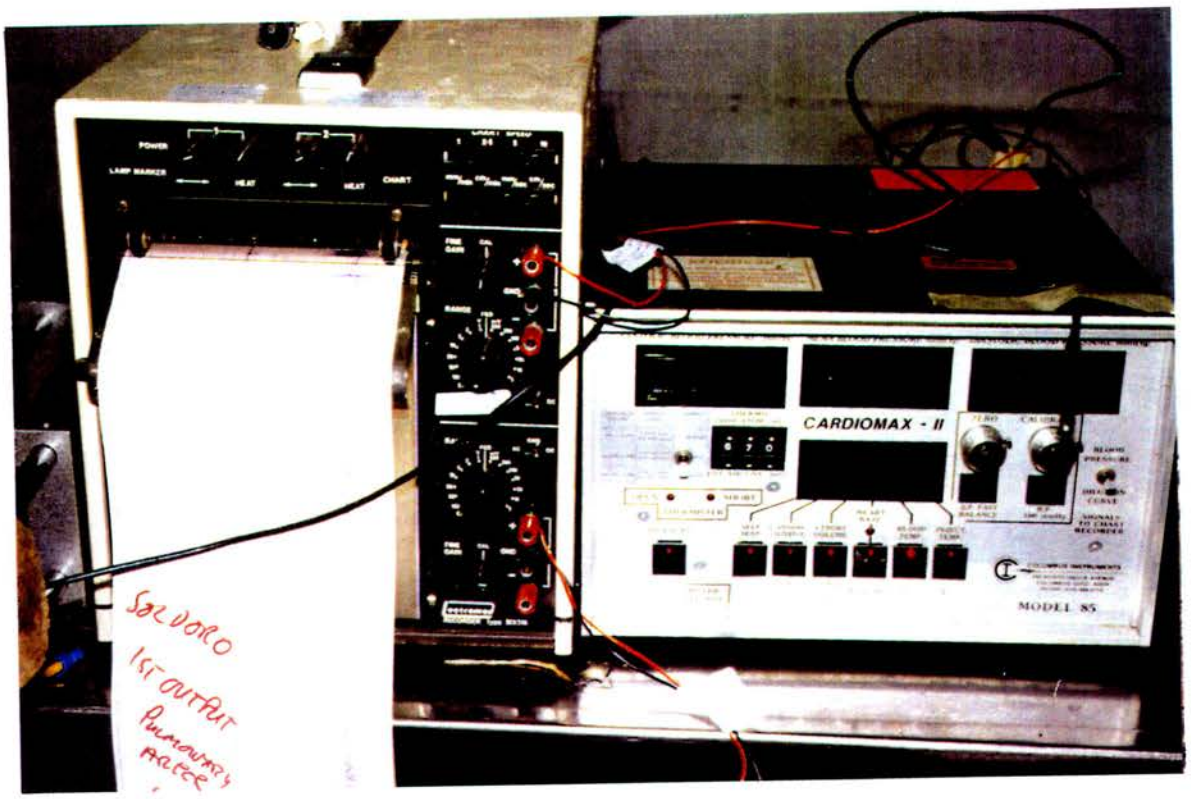
The y axis displays median measurements of the aortic pre-ejection period (PEP Med). Measurements are given in seconds.


Aorta VTI Med
39
35
31
27
23
19
15
*
C
1
2
3
4
5
Group


Aorta PEP Med
0.18
0.15
0.12
0.09
0.06
0.03
0
*
*
*
C
1
2
3
4
5
Group

FIGURES FOR PART 2

Figure 47 Columbus Instruments Cardiomax II cardiac output computer used for all cardiac output estimations. Thermodilution curves were recorded on the Lectromed Multitrace 2 chart recorder. Some of the features of the Cardiomax II are shown in the diagram of the equipment.


CARDIOMAX - II
MODEL 85

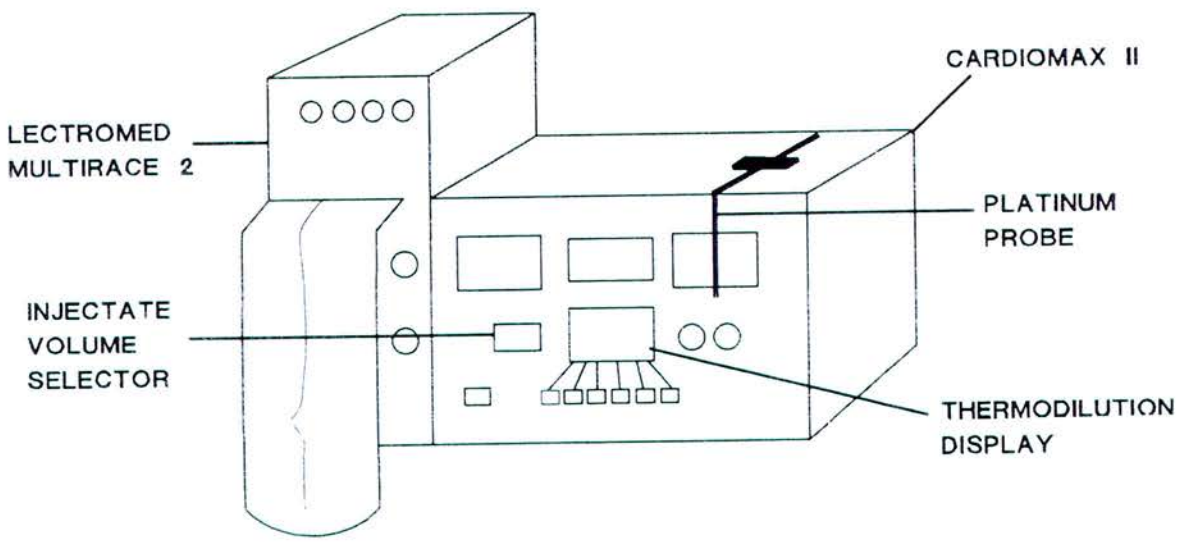
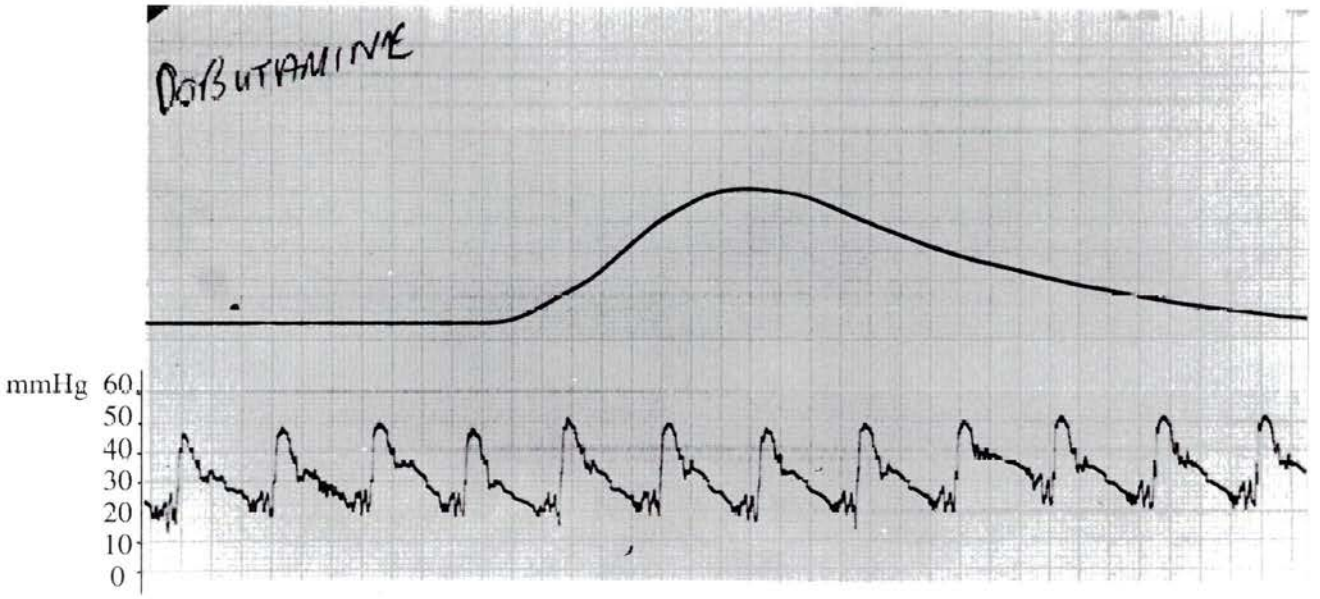
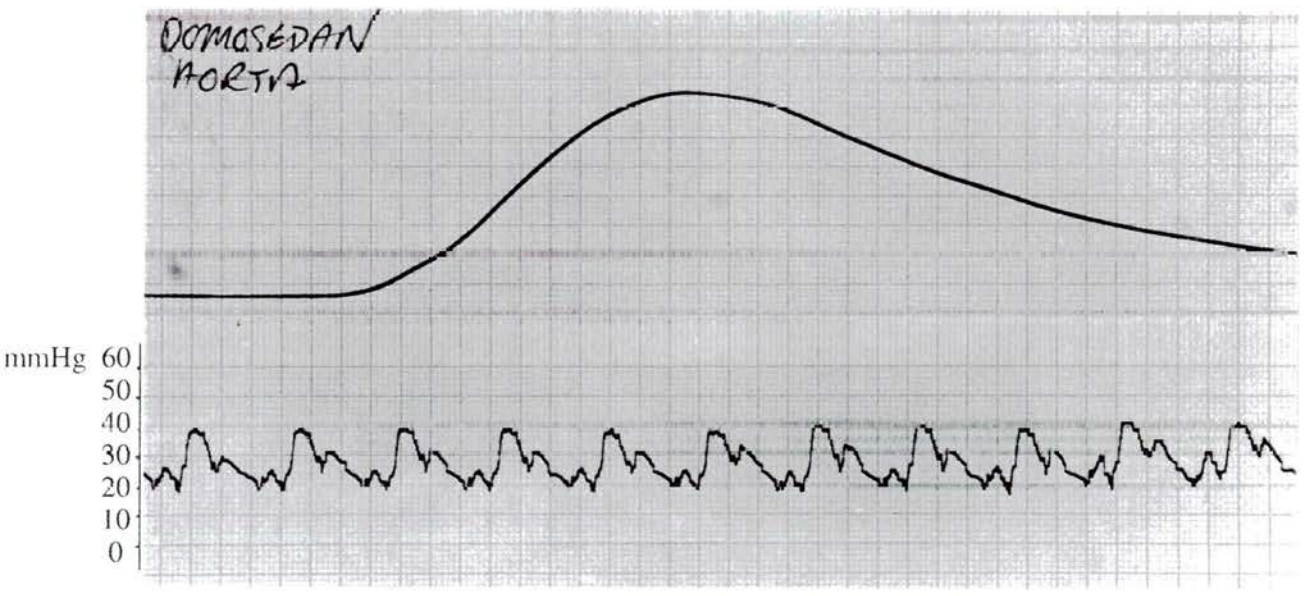

CARDIOMAX II
LECTROMED
MULTIRACE 2
PLATINUM
PROBE
INJECTATE
VOLUME
SELECTOR
THERMODILUTION
DISPLAY

Figure 48 Thermodilution curve of a cardiac output estimation during the infusion of 4µg/kg/min dobutamine. The pressure waveform from the pulmonary artery is displayed below the curve.

Figure 49 Thermodilution curve of a cardiac output estimation performed after the administration of 10µg/kg detomidine and 20µg/kg butorphanol. The area under the thermodilution curve is greater than that shown in Figure 48. This is due to the decreased cardiac output with this drug combination. The pressure waveform from the pulmonary artery is displayed below the curve.



Paper speed 10mm/sec



Paper speed 5mm/sec

Figure 50 Pulsed wave Doppler recording from the pulmonary artery during the injection of 45mls of dextrose saline into the right atrium, for the measurement of cardiac output by thermodilution. The injectate caused enhancement of the Doppler signal.

S.V. = sample volume. PA = pulmonary artery

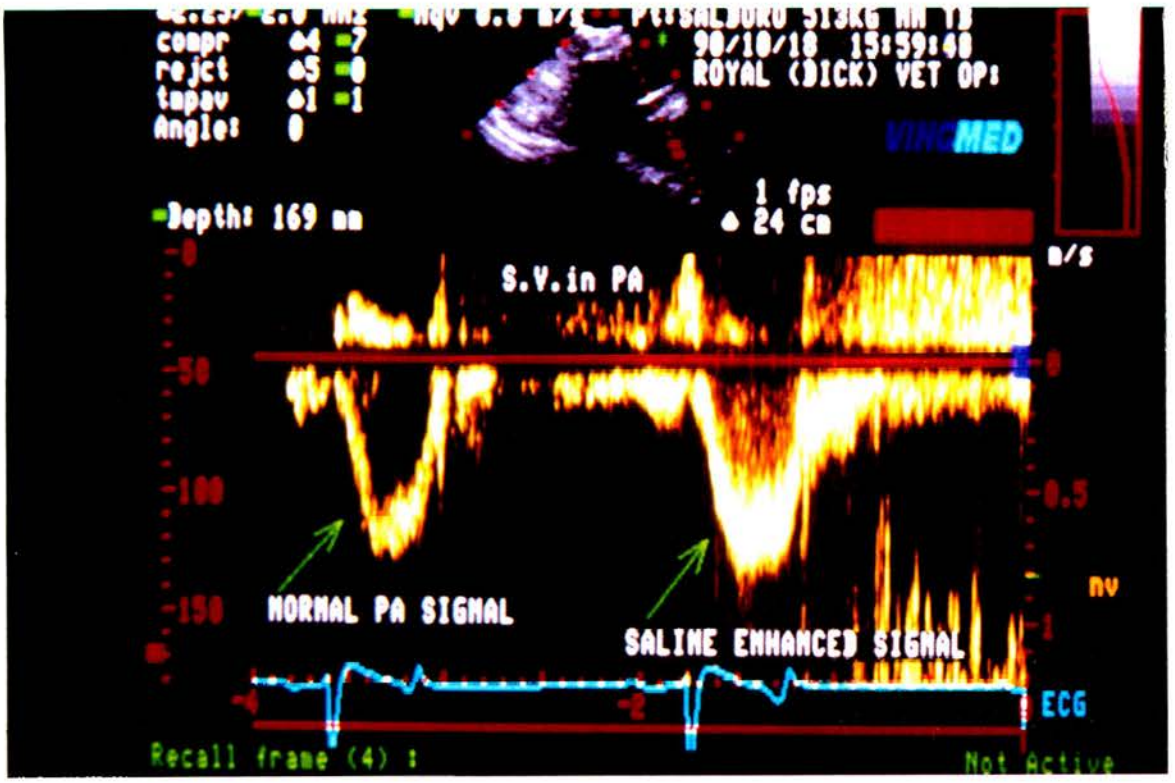
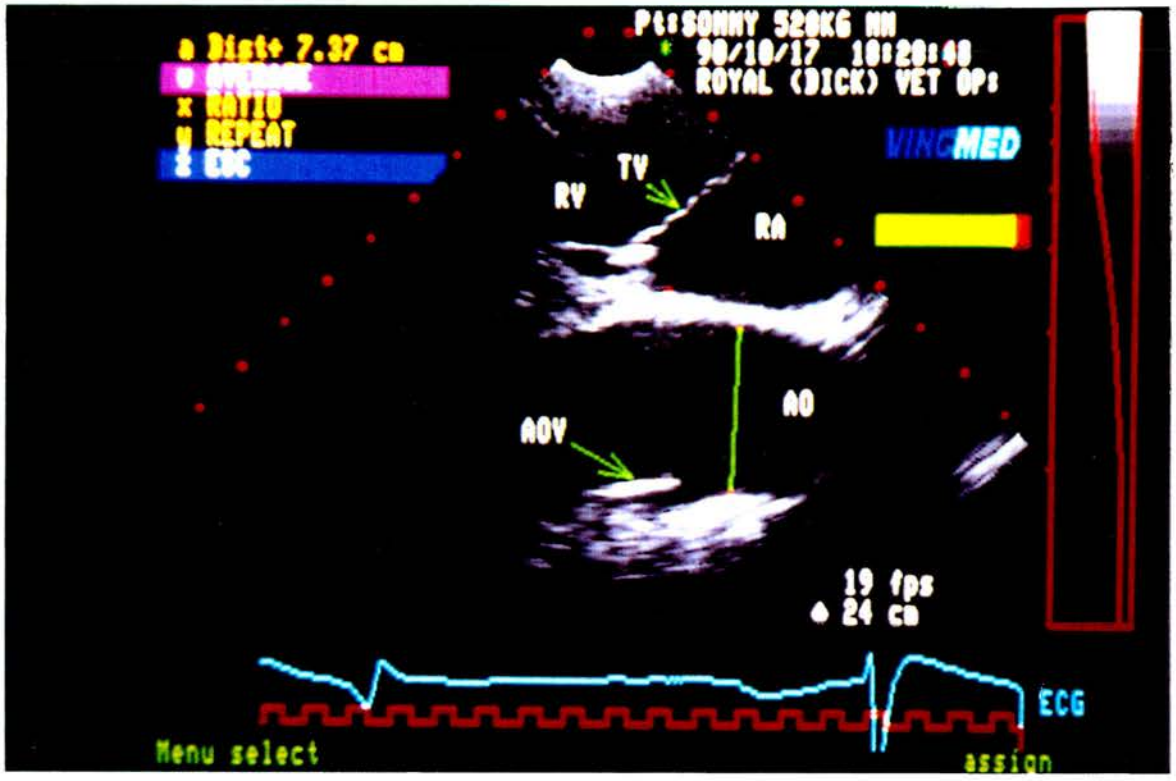

compr
reject
tmpav
Angle:
90/10/18 15:59:40
ROYAL (DICK) VET OP:
VINCMED
1 fps
Depth: 169 mm
24 cm
S.V.in PA
cm/s
-50
-100
-150
0.5
mv
NORMAL PA SIGNAL
SALINE ENHANCED SIGNAL
ECG
Recall frame (4) :
Not Active

Figure 51 Right parasternal long-axis view, long-axis aorta. The green line has been drawn, using electronic calipers, to measure the aortic diameter, which is displayed at the top left of the figure. This measurement is recorded from the ascending aorta using the trailing edge to leading edge method. The diagram below this image shows five of the six methods of measurement used in this study.

1 = Sinus of Valsalva, leading edge to leading edge measurement
2 = Aortic valve leading edge to leading edge measurement
3 = Aortic valve trailing edge to leading edge measurement
4 = Ascending aorta leading edge to leading edge measurement
5 = Ascending aorta trailing edge to leading edge measurement

All measurements were made at right angles to the long-axis of the vessel or sinus. The diagram merely indicates the approximate sites of these measurements. Measurements 2 and 3 were made at the same location, at the valve tips. Measurement 1 was made at the widest part of the sinus of Valsalva. Measurements 4 and 5 were made at the same location at the base of the ascending aorta just beyond the sino-tubular junction.

RA = right atrium
TV = tricuspid valve
IVS = interventricular septum
LVOT = left ventricular outflow tract
RV = right ventricle
AO = aorta
AOV = aortic valve.


Pt:SONNY 520KG NN
90/10/17 10:20:40
ROYAL (DICK) VET OPs
VINCMED
TV
RV
RA
AO
AOV
19 fps
24 cm
ECG
Menu select

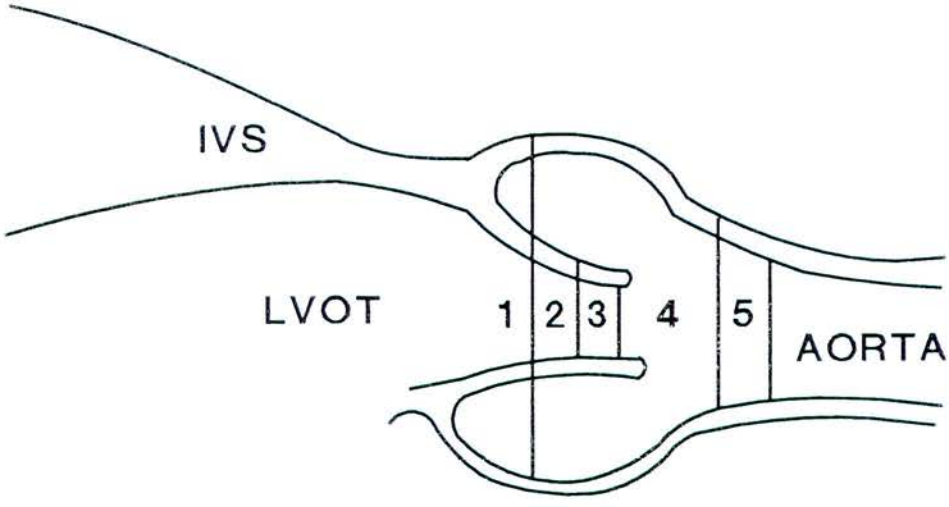
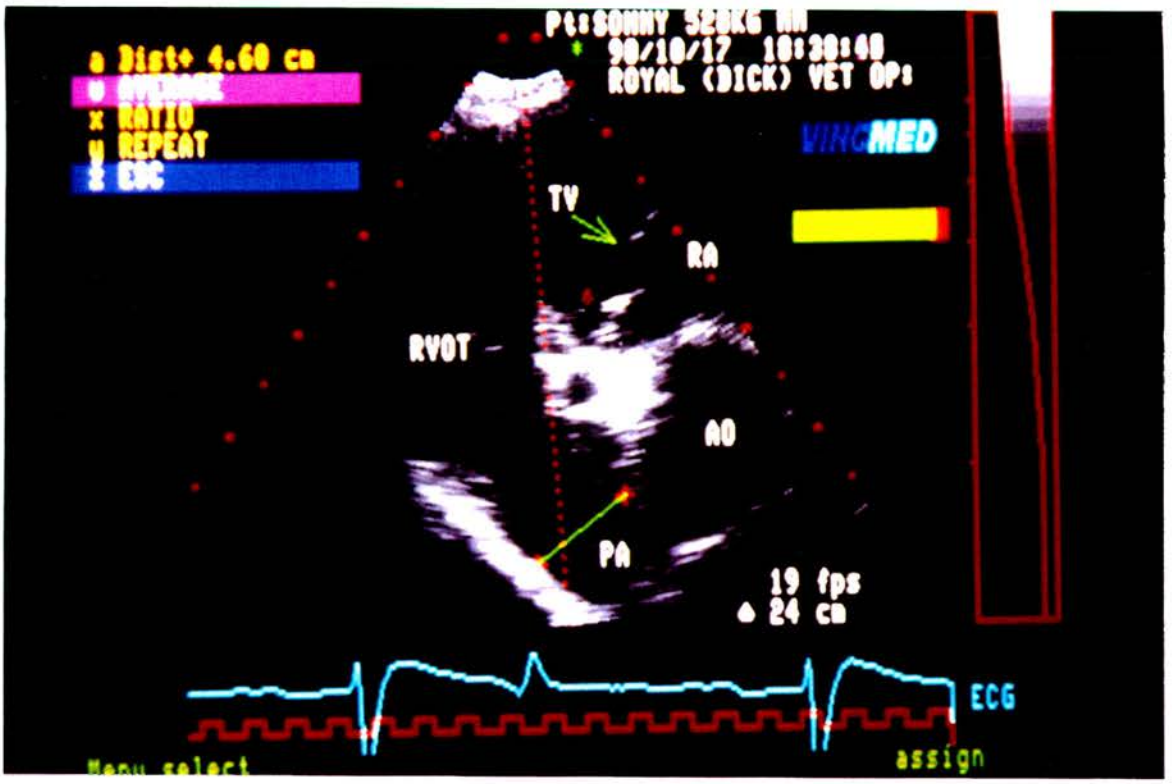

IVS
LVOT
1
2
3
4
5
AORTA

Figure 52 Right parasternal angled view of the right ventricular outflow tract. The green line has been drawn, using electronic calipers, to measure the pulmonary diameter, which is displayed at the top left of the figure. This measurement is recorded using the trailing edge to leading edge method, so that the thickness of the vessel walls is not included in the measurement (Inner edge). The diagram below this image shows the methods of measurement used in this study.

1 = Inner edge, trailing edge to leading edge measurement, does not include the thickness of the vessel walls.
2 = Right wall, measurement includes the thickness of the right vessel wall.
3 = Both walls, measurement includes the thickness of both vessel walls.

All measurements were made at the same location

RA = right atrium	AO = aorta
TV = tricuspid valve	RVOT = right ventricular outflow tract


Dist= 4.60 cm
x RATIO
y REPEAT
z END
TV
RA
RVOT
AO
PA
19 fps
24 cm
ECG
assign

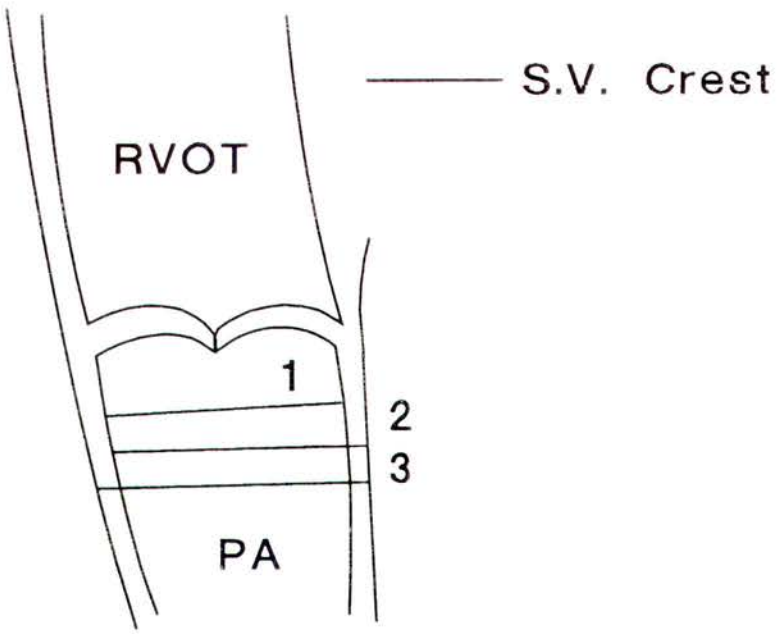
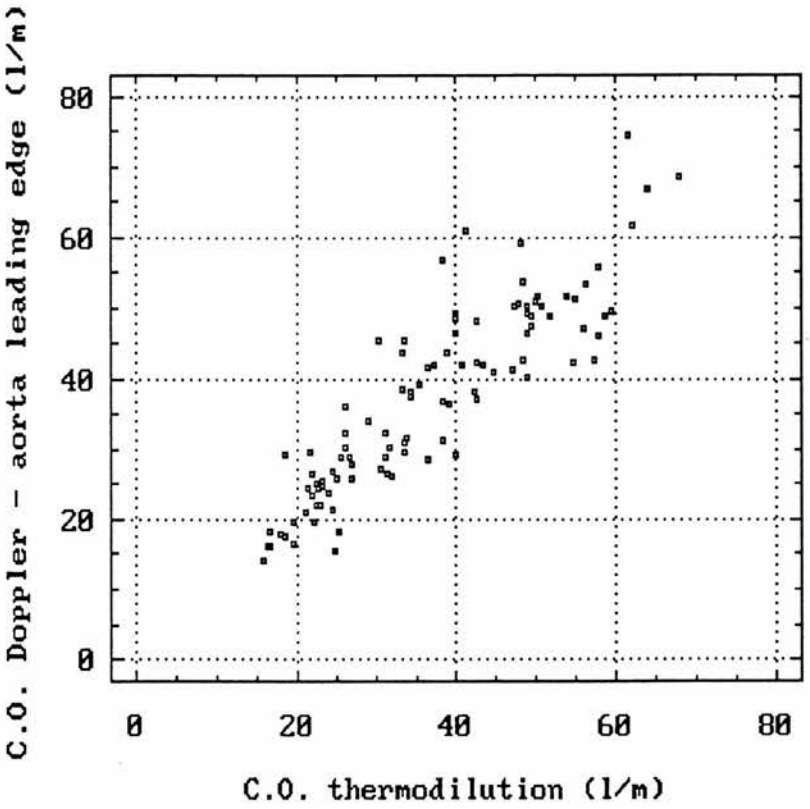

S.V. Crest
RVOT
1
2
3
PA

Figure 53a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from the ascending aorta, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102.

Figure 53b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from the ascending aorta, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = -0.43 litres per minute.
Limits of agreement = -12.69 to 11.83 litres per minute.


C.O. Doppler - aorta leading edge (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

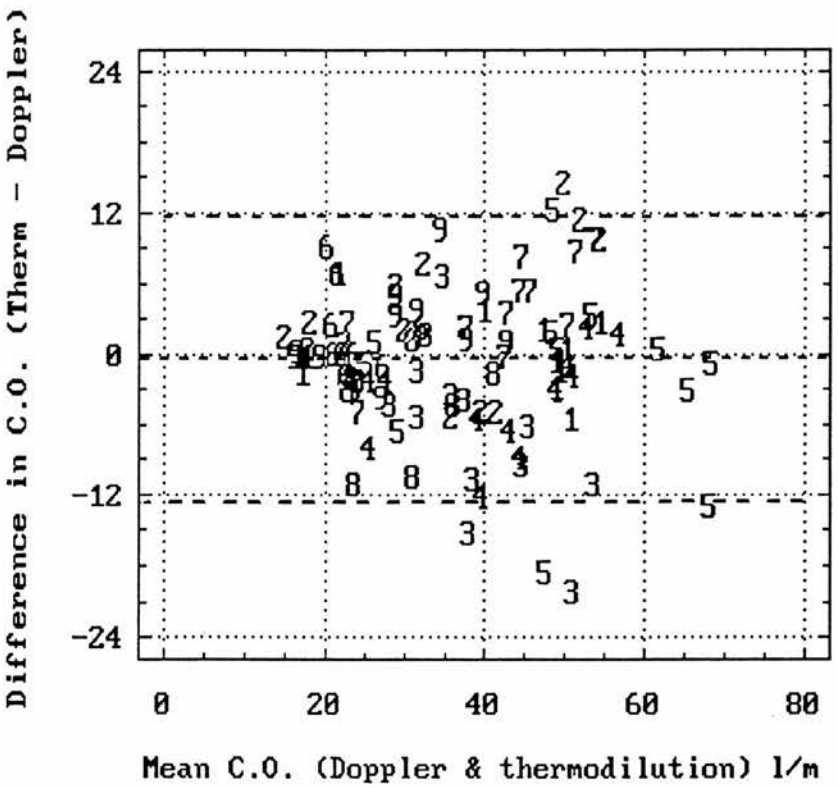
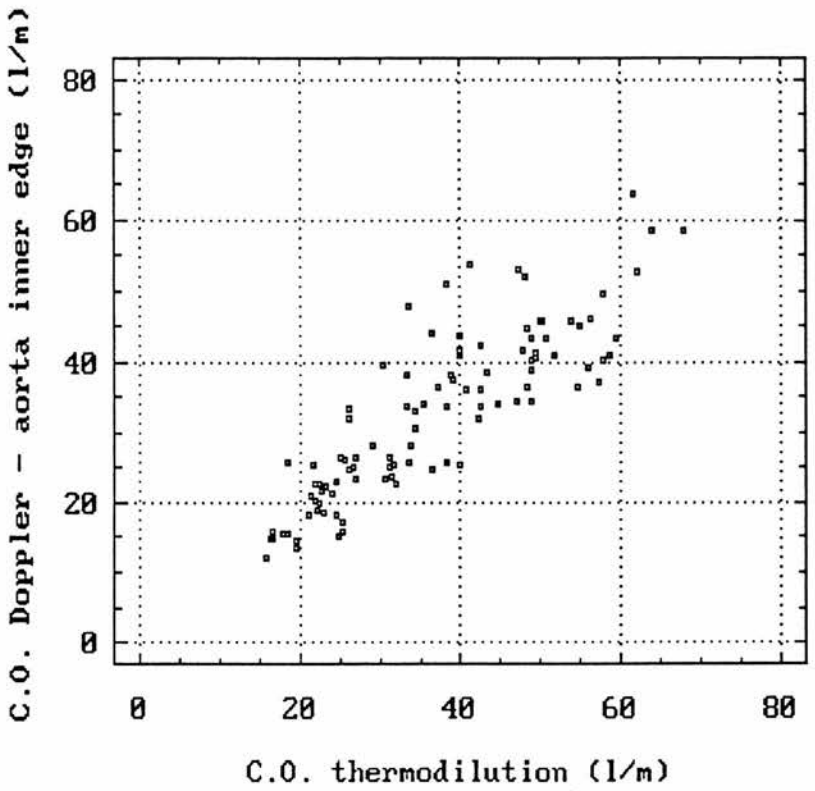

Difference in C.O. (Therm - Doppler)
24
12
0
-12
-24
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 54a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from the ascending aorta, by the trailing edge to leading edge method (Inner edge). Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Figure 54b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from the ascending aorta, by the trailing edge to leading edge method (Inner edge). Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 4.11 litres per minute.
Limits of agreement = -9.30 to 17.28 litres per minute.


C.O. Doppler - aorta inner edge (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

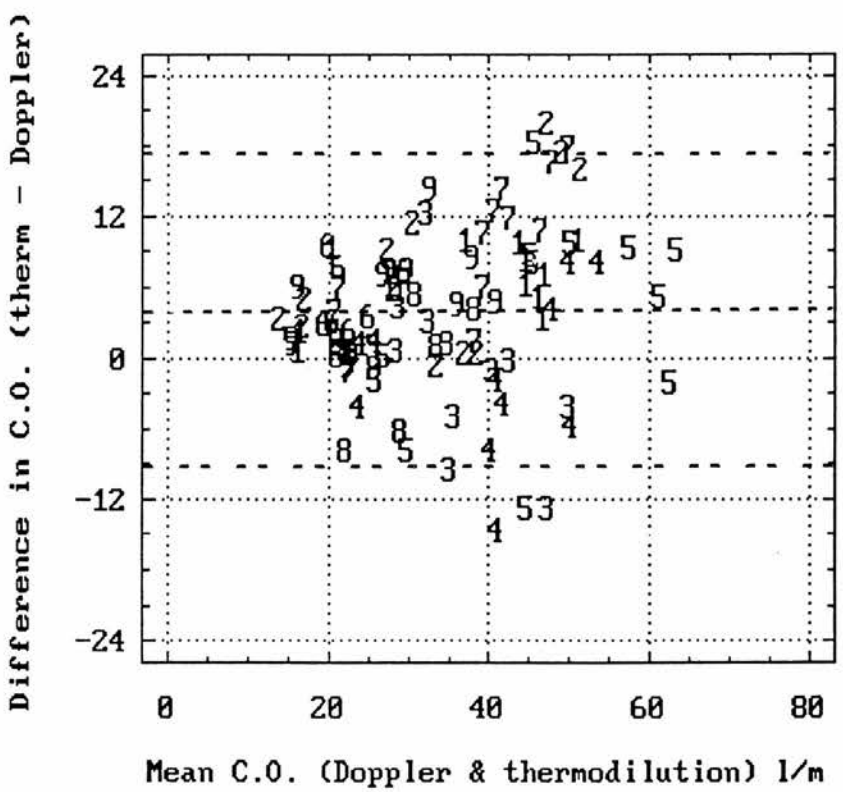
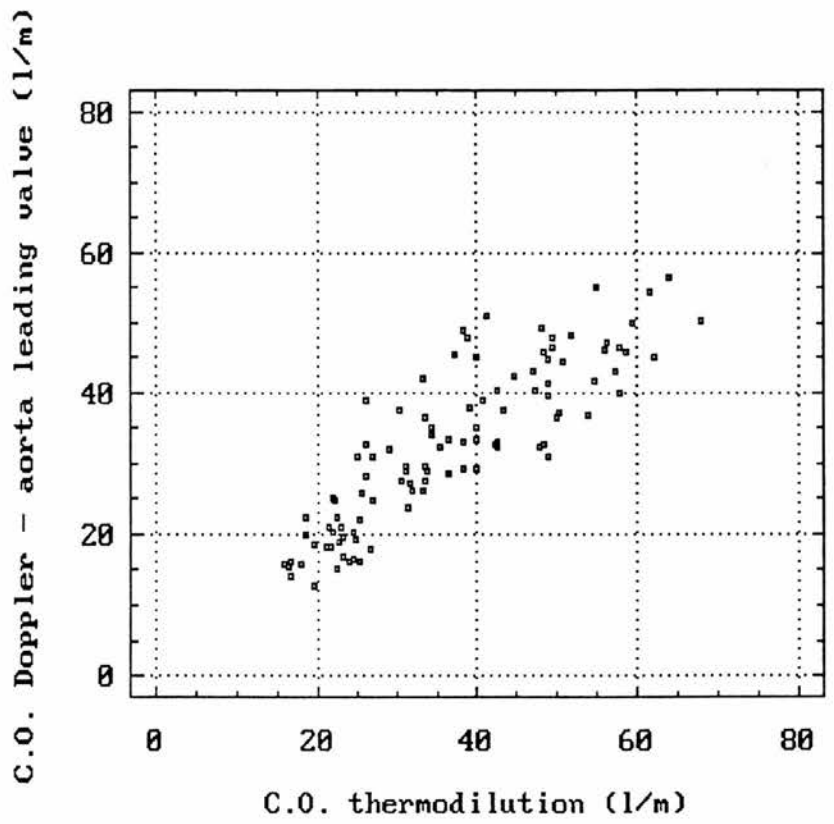

Difference in C.O. (therm - Doppler)
24
12
0
-12
-24
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 55a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the level of the valve, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Figure 55b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the level of the valve, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 4.01 litres per minute.
Limits of agreement = -8.94 to 16.96 litres per minute.


C.O. Doppler - aorta leading valve (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

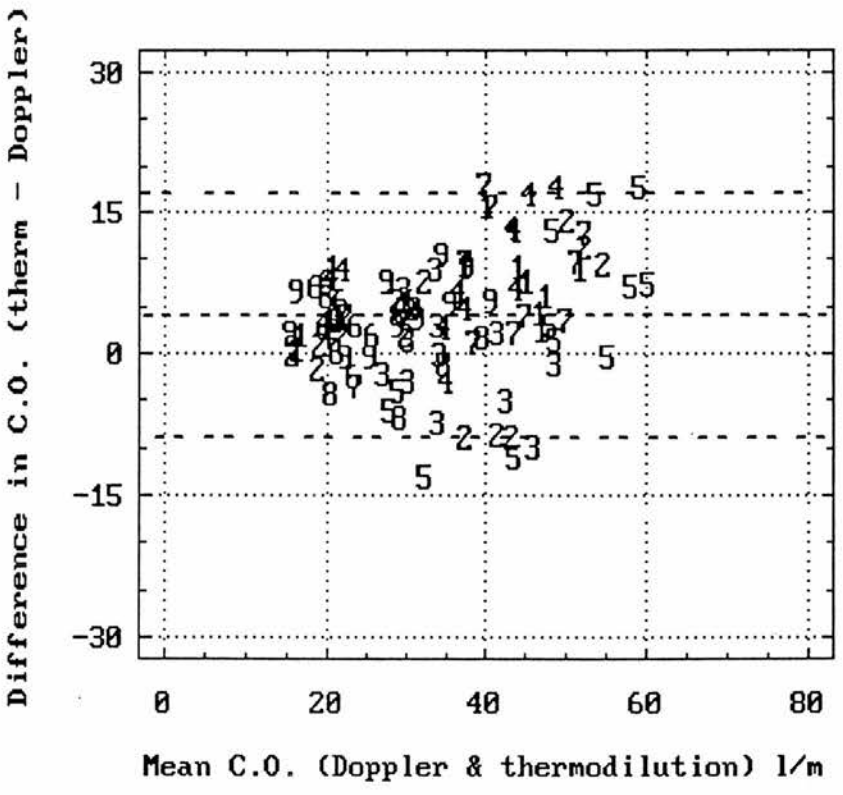
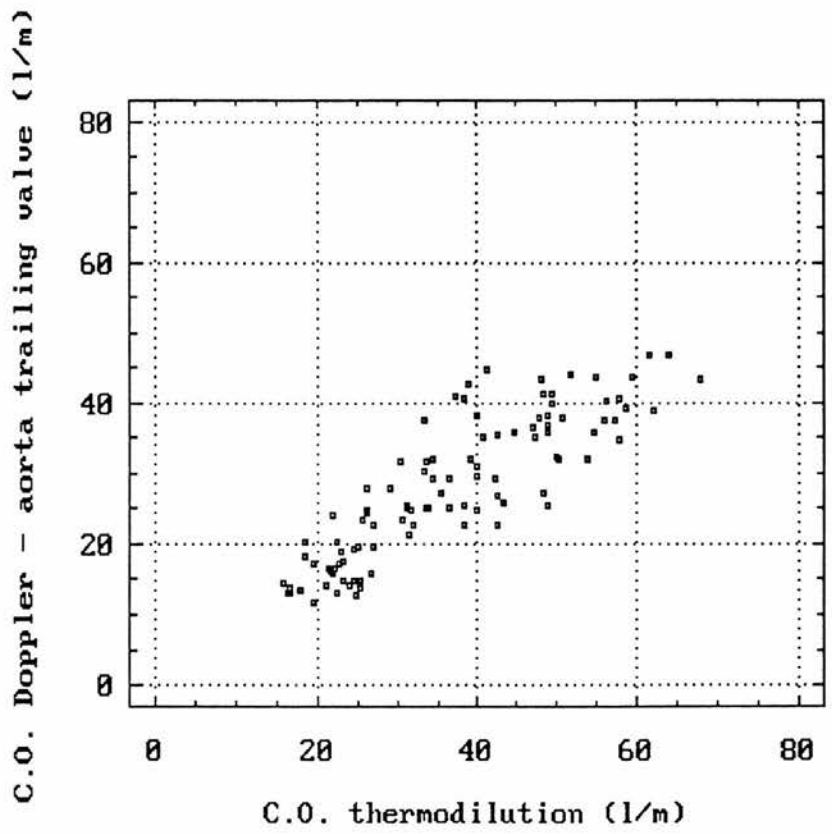

Difference in C.O. (therm - Doppler)
30
15
0
-15
-30
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 56a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the level of the valve, by the trailing edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Figure 56b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the level of the valve, by the trailing edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 8.65 litres per minute.
Limits of agreement = -4.76 to 21.82 litres per minute.


C.O. Doppler - aorta trailing value (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

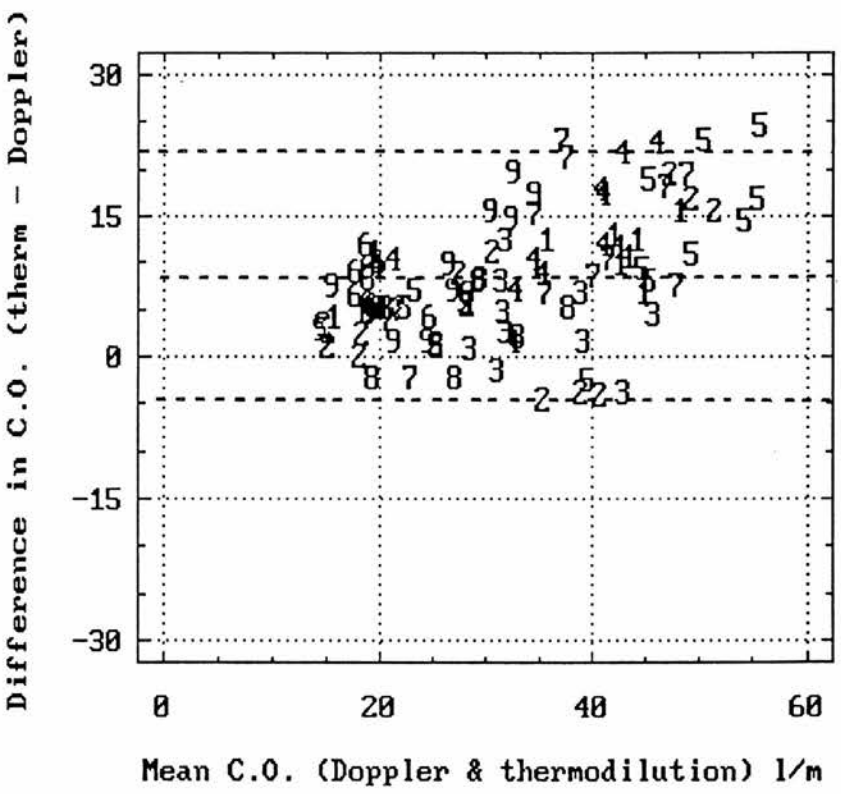
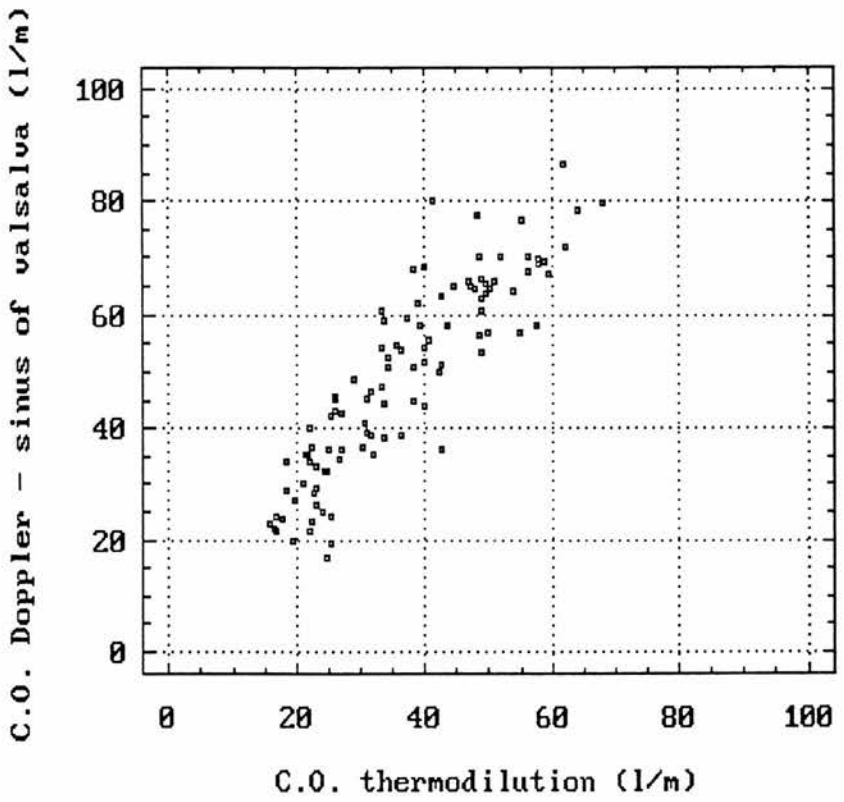

Difference in C.O. (therm - Doppler)
30
15
0
-15
-30
0
20
40
60
Mean C.O. (Doppler & thermodilution) l/m

Figure 57a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the sinus of Valsalva, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Doppler measurements tend to overestimate cardiac output compared to thermodilution.

Figure 57b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured at the sinus of Valsalva, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses. Doppler measurements tend to overestimate cardiac output compared to thermodilution.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = -12.27 litres per minute.
Limits of agreement = -28.09 to 3.55 litres per minute.


C.O. Doppler - sinus of valsalva (l/m)
100
80
60
40
20
0
0
20
40
60
80
100
C.O. thermodilution (l/m)

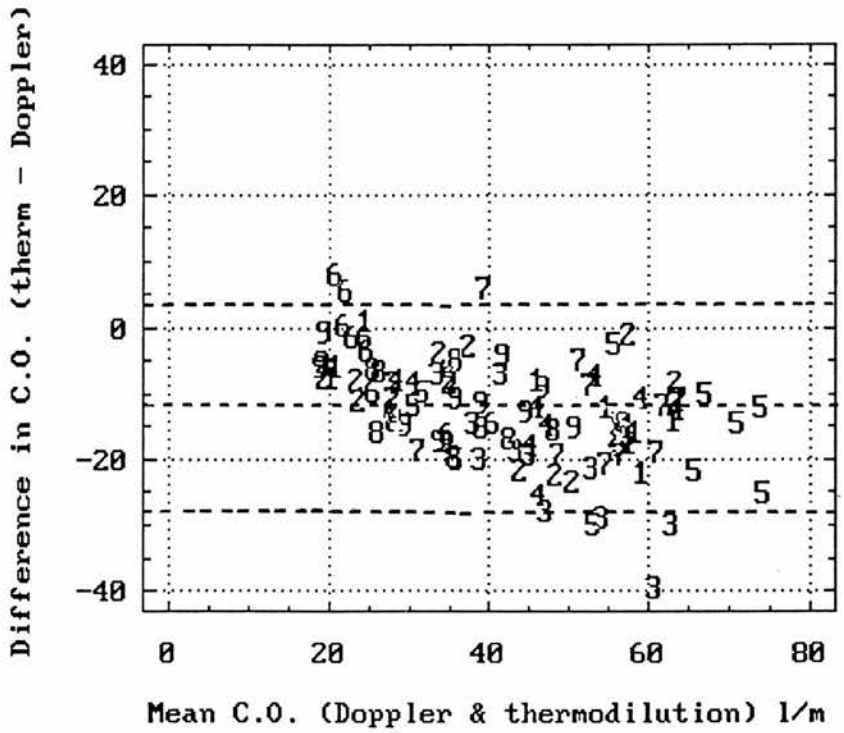
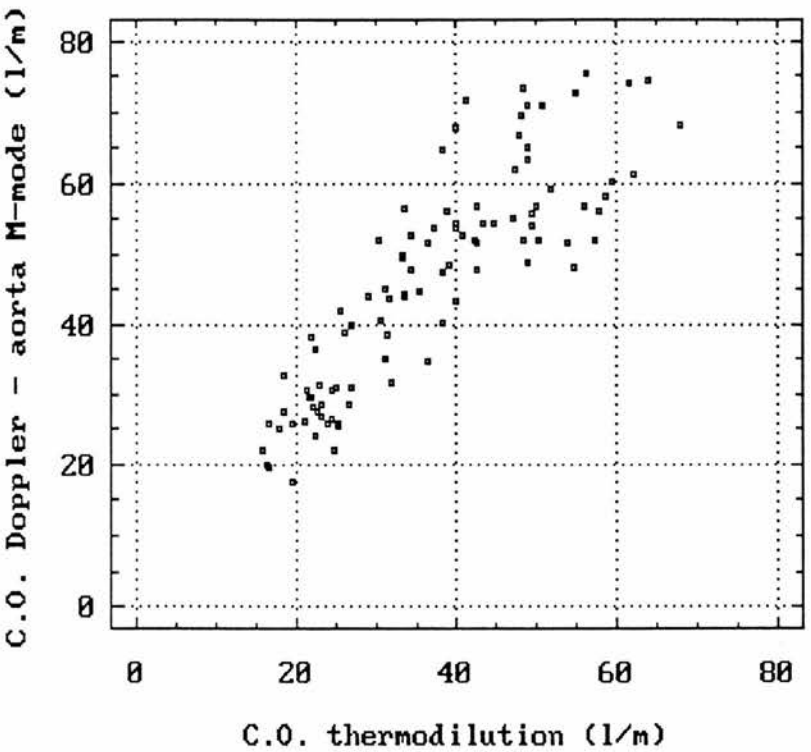

Difference in C.O. (therm - Doppler)
40
20
0
-20
-40
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 58a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from an M-mode study by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Doppler measurements tend to overestimate cardiac output compared to thermodilution.

Figure 58b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the aorta, with the aortic diameter measured from an M-mode study, by the leading edge to leading edge method. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 102. Numbers 1-9 represent cardiac output estimations from individual horses. Doppler measurements tend to overestimate cardiac output compared to thermodilution.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = -9.17 litres per minute.
Limits of agreement = -24.28 to 5.94 litres per minute.


C.O. Doppler - aorta M-mode (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

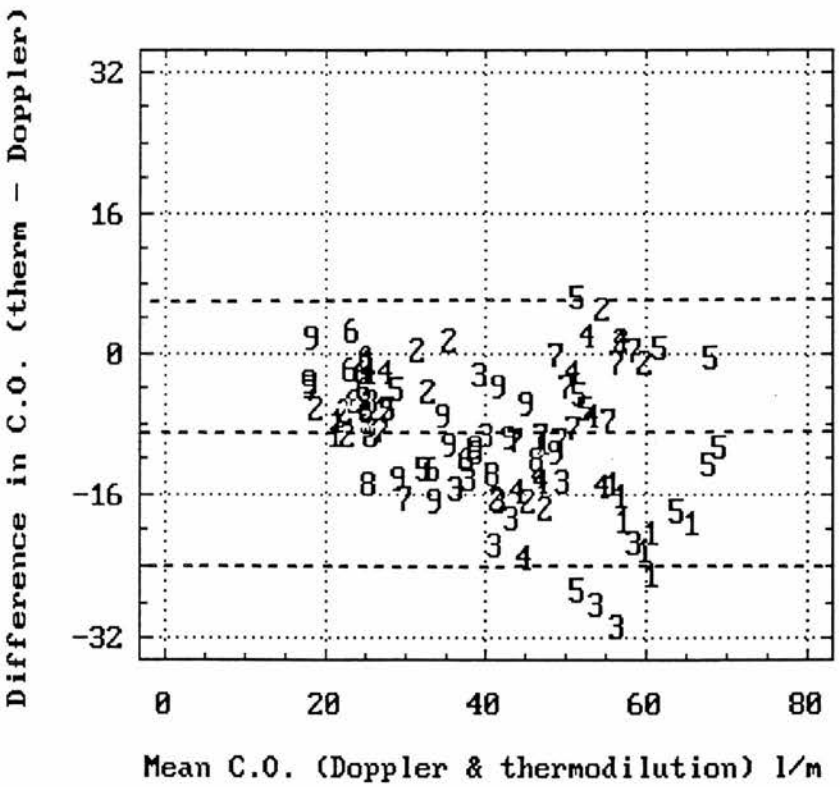
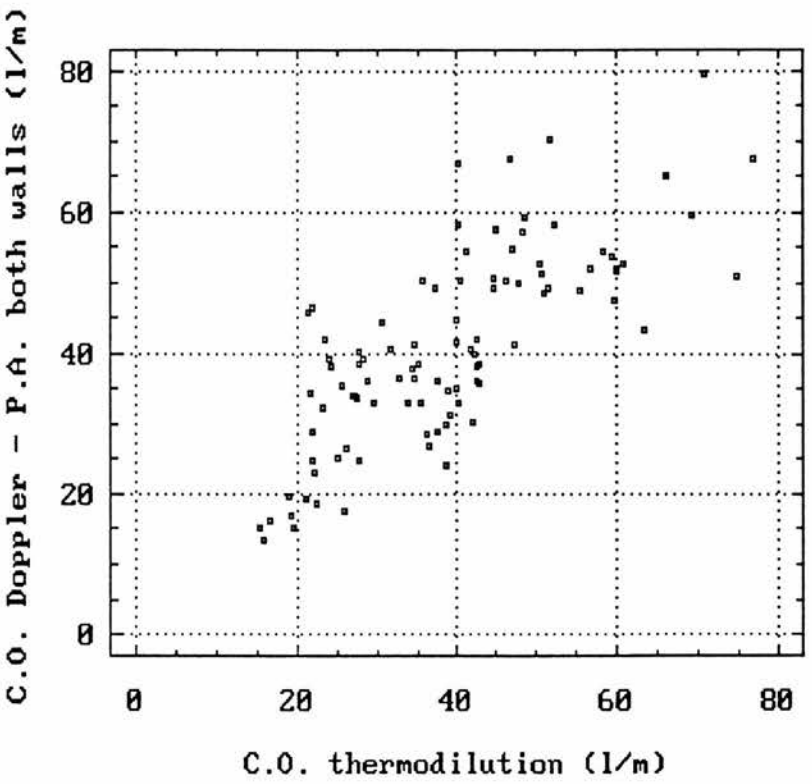

Difference in C.O. (therm - Doppler)
32
16
0
-16
-32
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 59a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of both vessel walls. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97.

Figure 59b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of both vessel walls. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = -2.07 litres per minute.
Limits of agreement = -20.81 to 16.67 litres per minute.


C.O. Doppler - P.A. both walls (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

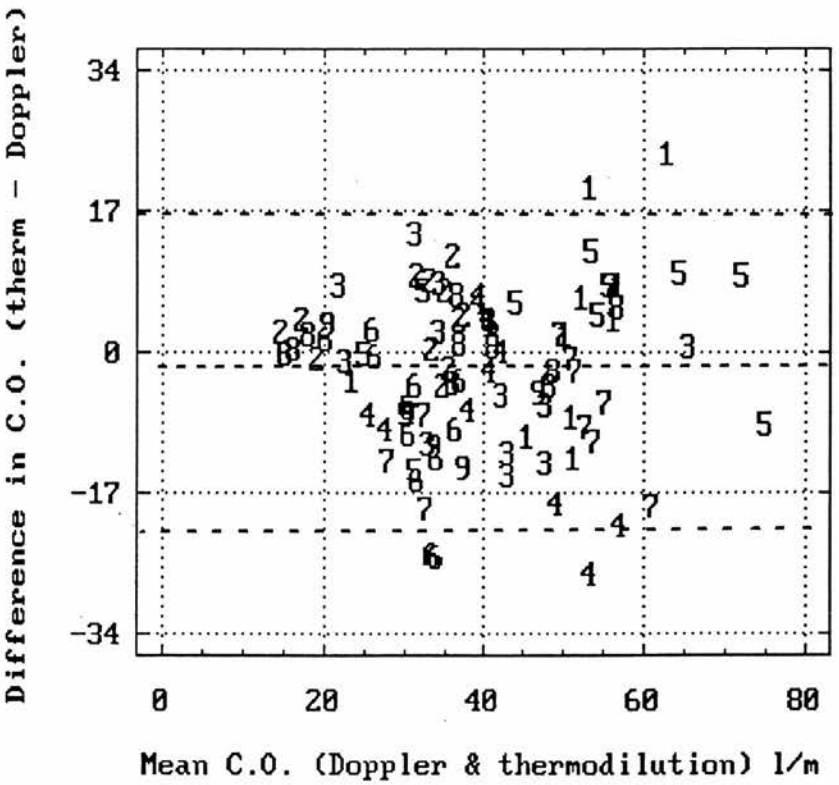
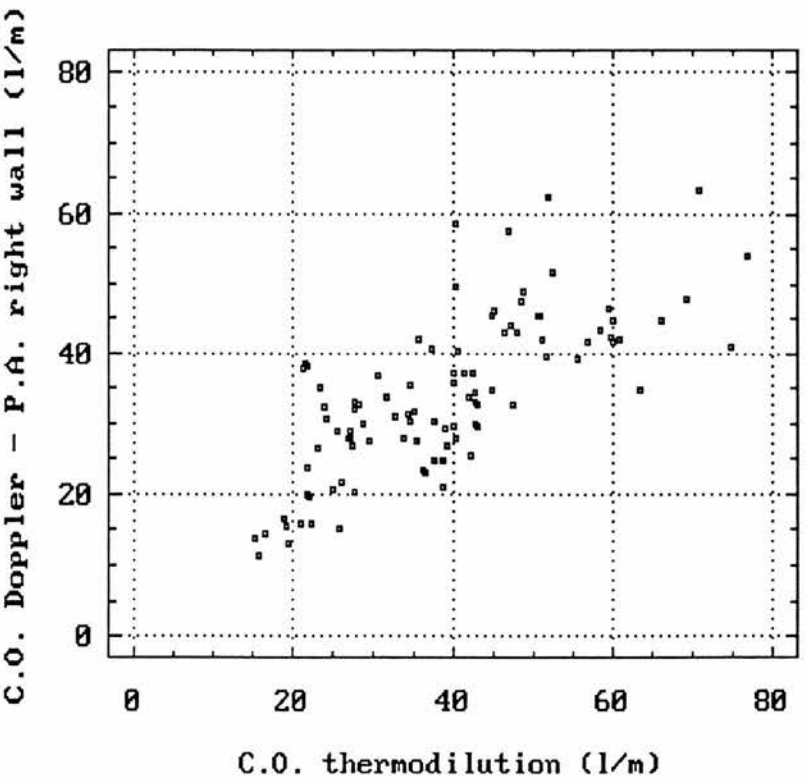

Difference in C.O. (therm - Doppler)
34
17
0
-17
-34
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 60a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of the right vessel wall. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97.

Figure 60b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of the right vessel wall. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 4.78 litres per minute.
Limits of agreement = -14.15 to 23.71 litres per minute.


C.O. Doppler - P.A. right wall (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

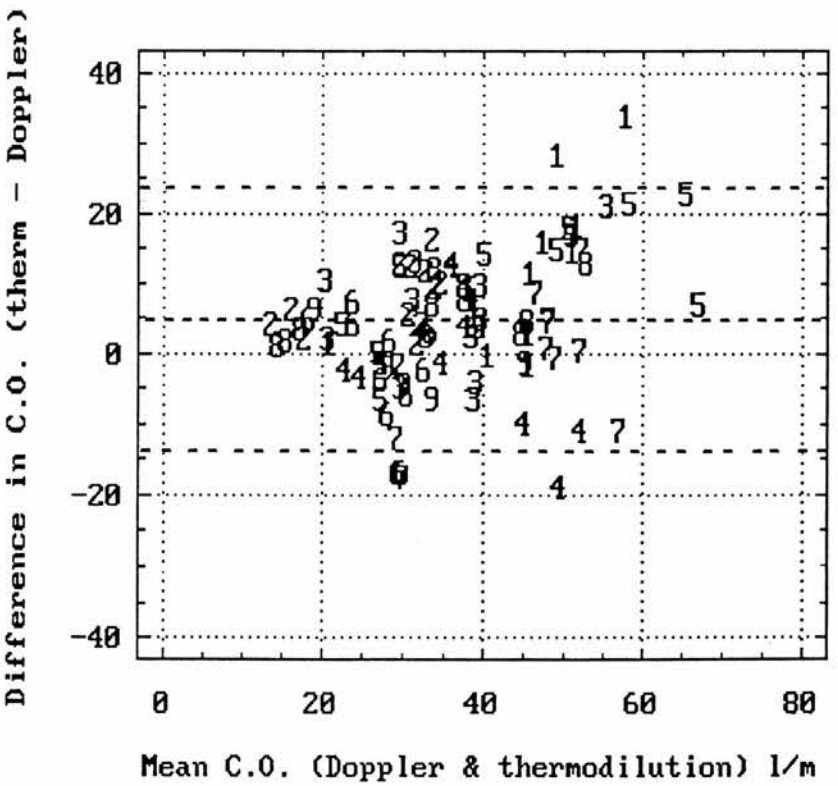
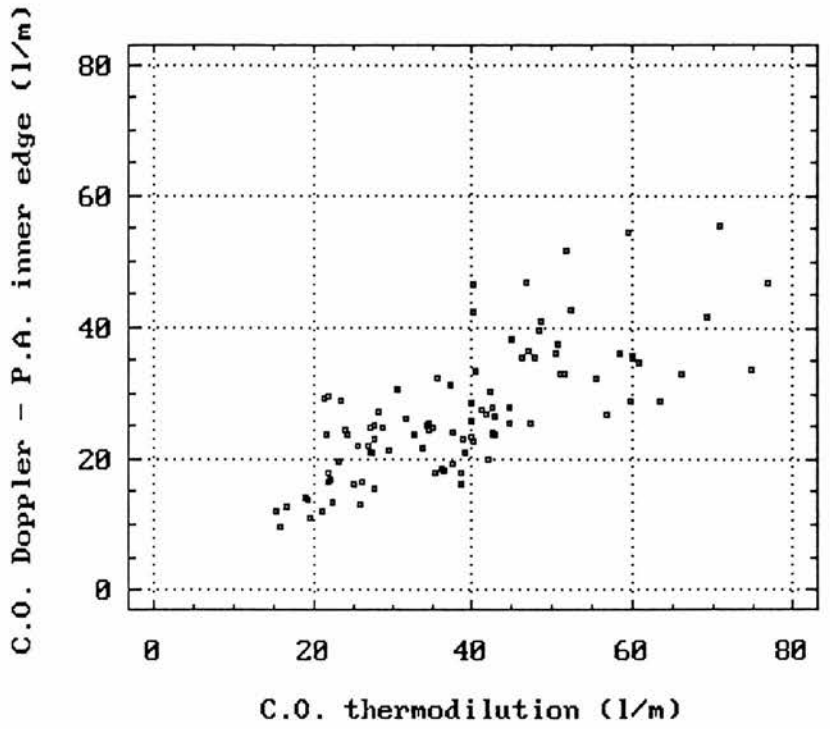

Difference in C.O. (therm - Doppler)
40
20
0
-20
-40
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 61a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measurement not including the thickness of the vessel walls. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Figure 61b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measurement not including the thickness of the vessel walls. Doppler waveforms were recorded immediately before the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 97. Doppler measurements tend to underestimate cardiac output compared to thermodilution. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 11.64 litres per minute.
Limits of agreement = -7.08 to 30.36 litres per minute.


C.O. Doppler - P.A. inner edge (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

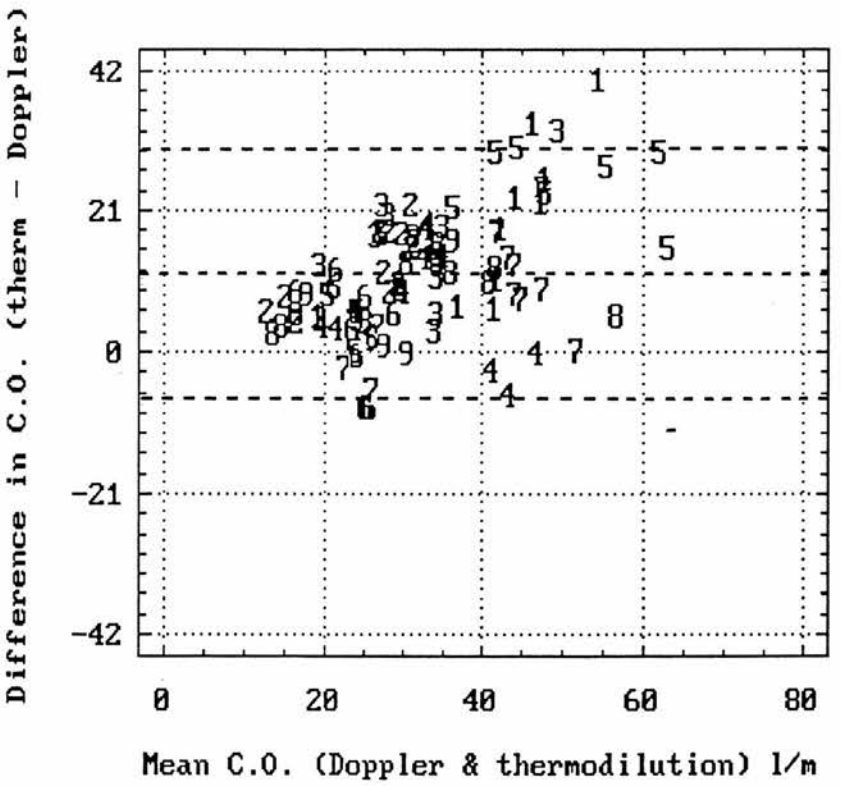
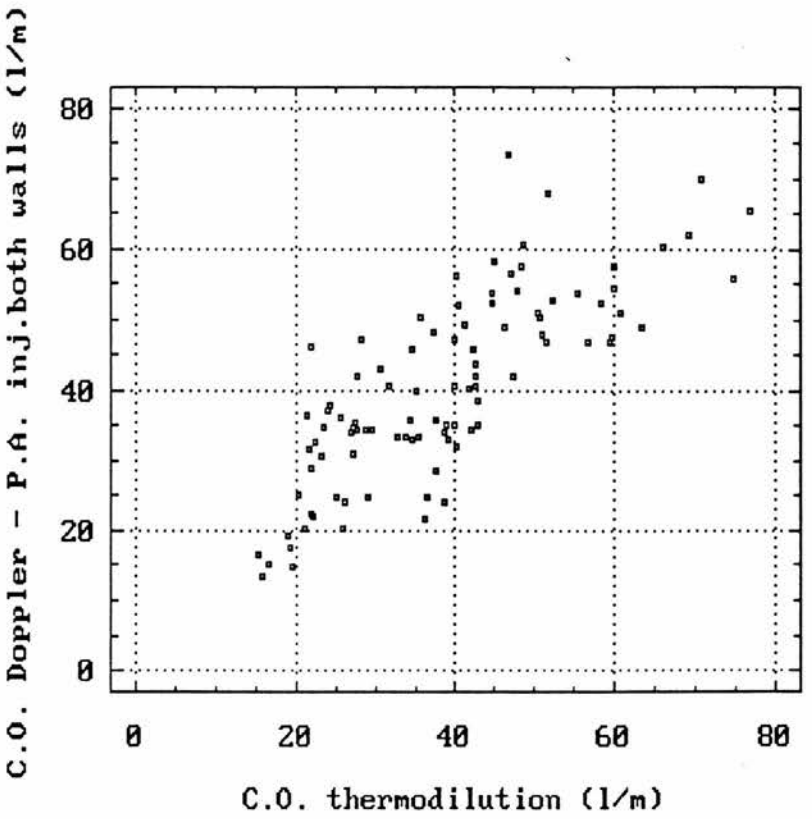

Difference in C.O. (therm - Doppler)
42
21
0
-21
-42
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 62a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of both vessel walls. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98.

Figure 62b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of both vessel walls. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = -1.08 litres per minute.
Limits of agreement = -19.20 to 15.60 litres per minute.


C.O. Doppler - P.A. inj.both walls (l/m)
0
20
40
60
80
C.O. thermodilution (l/m)

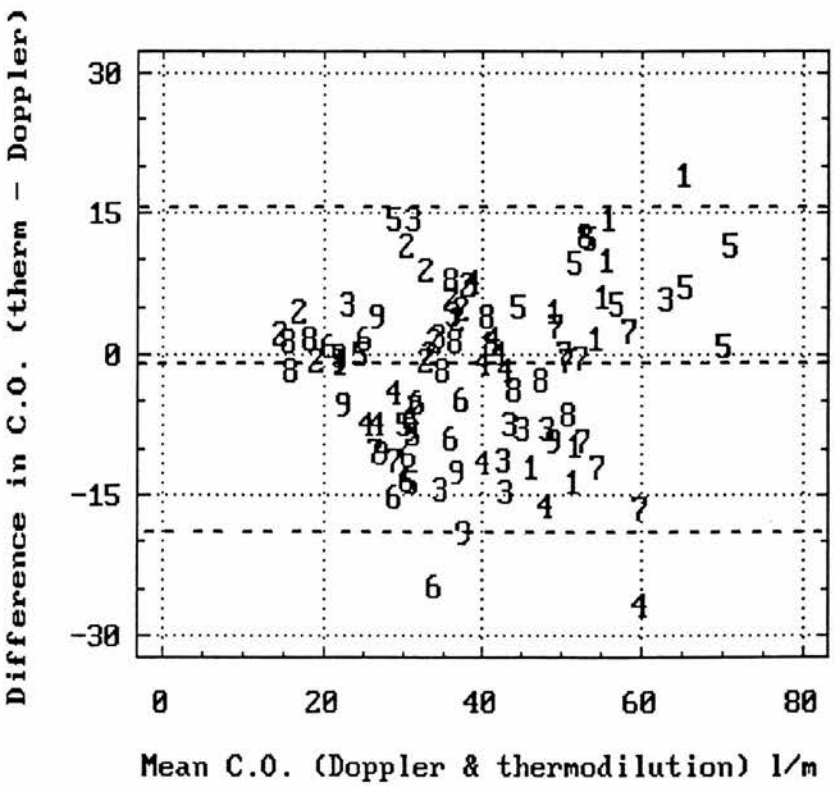
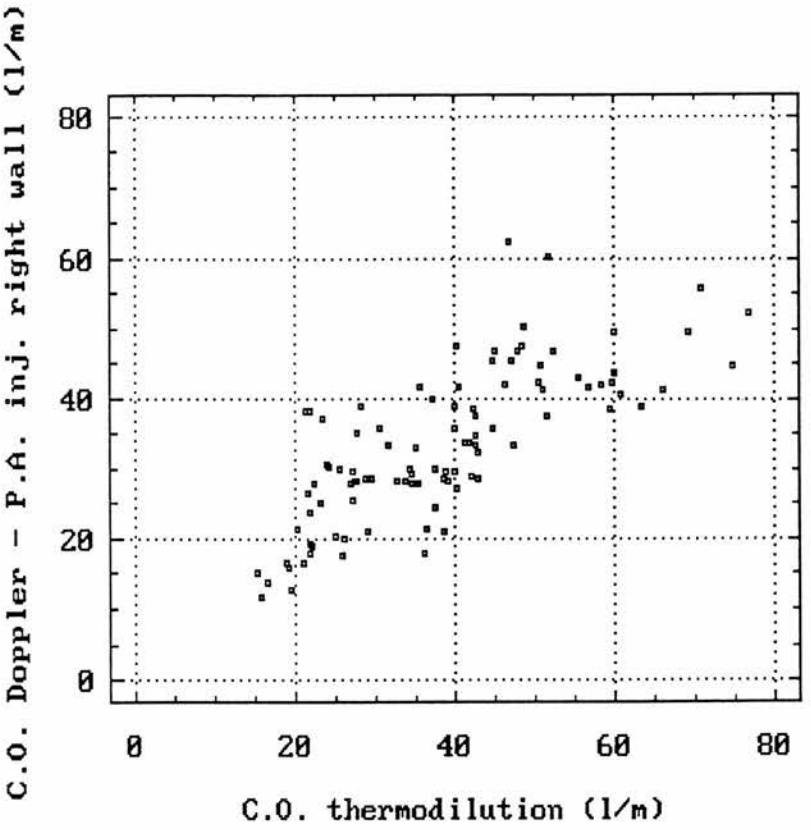

Difference in C.O. (therm - Doppler)
30
15
0
-15
-30
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 63a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of the right wall of the vessel. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98.

Figure 63b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measured to include the thickness of the right wall of the vessel. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 4.73 litres per minute.
Limits of agreement = -14.75 to 24.21 litres per minute.


C.O. Doppler - P.A. inj. right wall (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

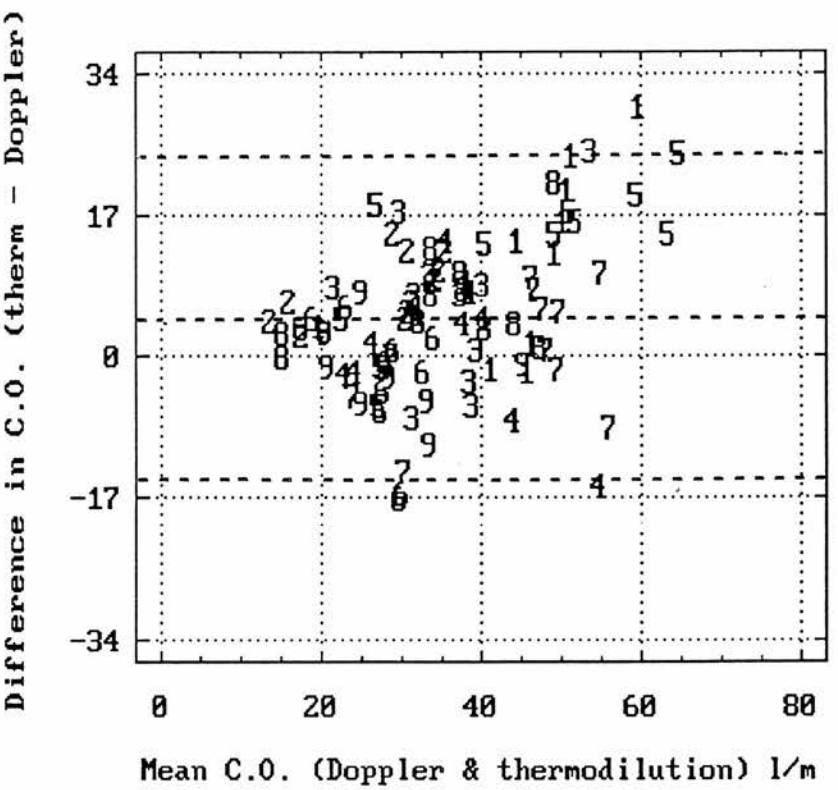
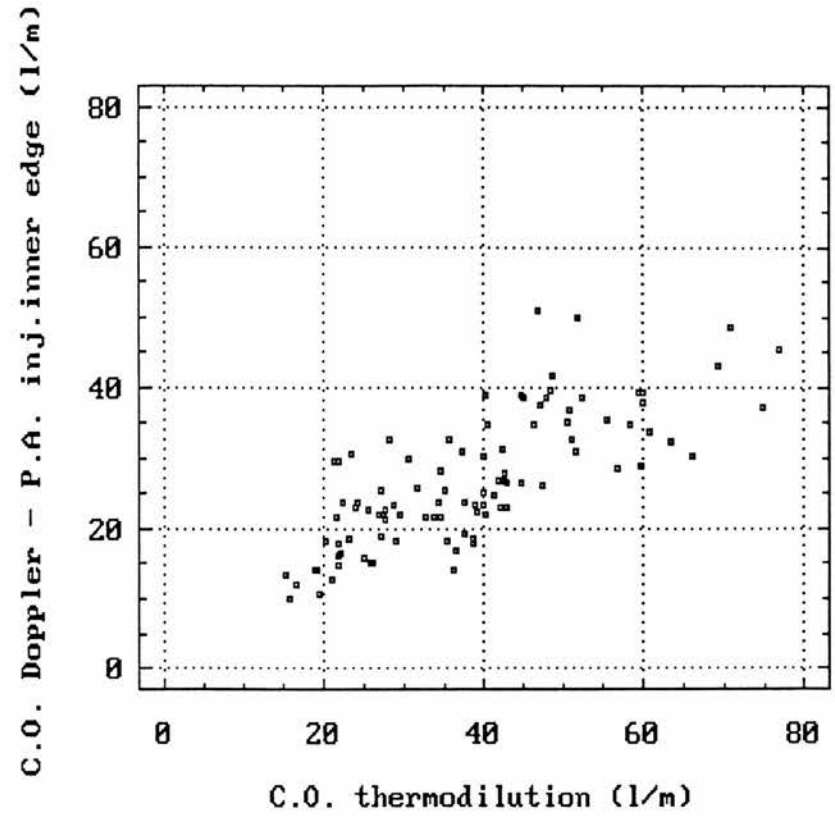

Difference in C.O. (therm - Doppler)
34
17
0
-17
-34
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 64a Scatter plot of cardiac output estimations by Doppler echocardiography against thermodilution. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measurement not including the thickness of the vessel walls. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98. Doppler measurements tend to underestimate cardiac output compared to thermodilution.

Figure 64b Plot of the differences between cardiac output estimations by Doppler echocardiography and thermodilution, against the mean value of the two cardiac output measurements. Doppler waveforms were recorded from the pulmonary artery, with the pulmonary artery diameter measurement not including the thickness of the vessel walls. Doppler waveforms were recorded during the injection of cold indicator, used for thermodilution estimation of cardiac output. Cardiac output measurements are given in litres per minute (l/m). The number of comparisons = 98. Doppler measurements tend to underestimate cardiac output compared to thermodilution. Numbers 1-9 represent cardiac output estimations from individual horses.

Dashed lines represent the mean difference and the limits of agreement between the two techniques. The limits of agreement = the mean difference +/- 1.96 x the standard deviation of the differences.

Mean difference = 11.54 litres per minute.
Limits of agreement = -6.84 to 29.92 litres per minute.


C.O. Doppler - P.A. inj.inner edge (l/m)
80
60
40
20
0
0
20
40
60
80
C.O. thermodilution (l/m)

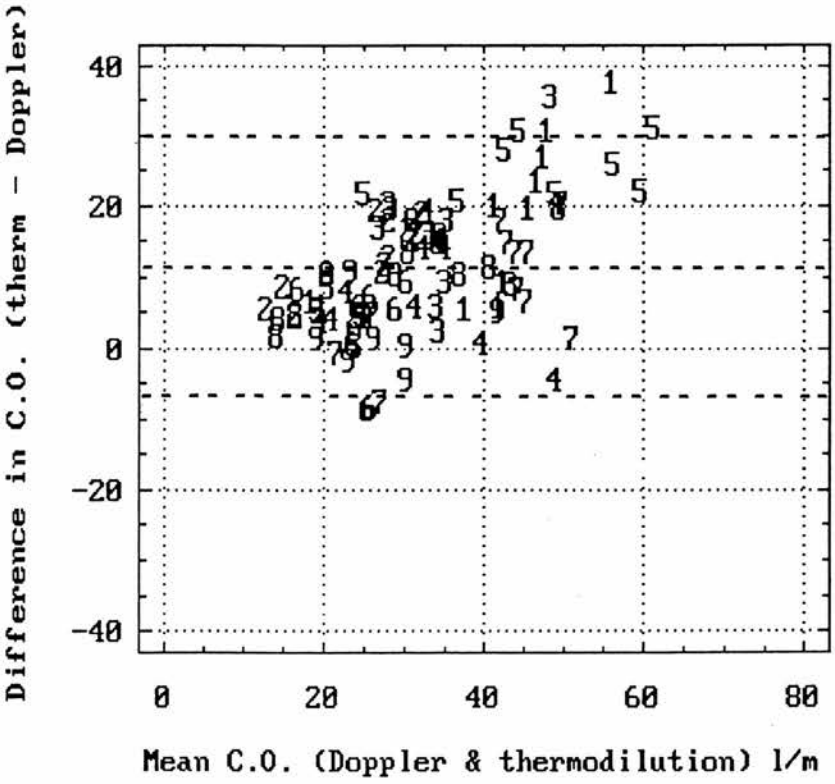

Difference in C.O. (therm - Doppler)
40
20
0
-20
-40
0
20
40
60
80
Mean C.O. (Doppler & thermodilution) l/m

Figure 65 Box and whisker plots displaying the range, interquartile range and mean of aortic peak velocity measurements (VMax) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

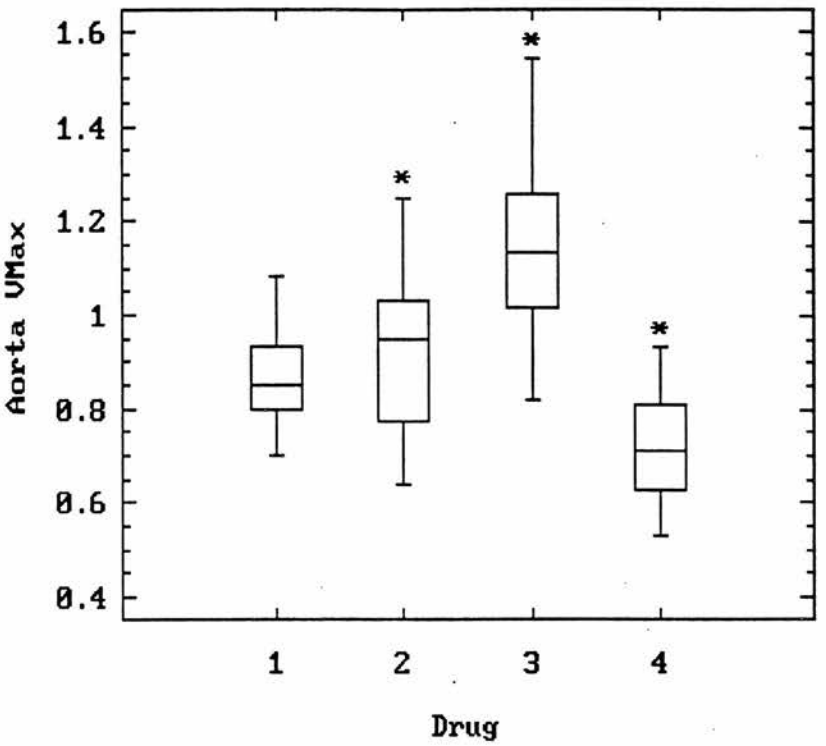
The x axis displays the different study periods
1 = control
2 = during the infusion of 4μg/kg/min dopamine
3 = during the infusion of 4μg/kg/min dobutamine
4 = following the administration of 10μg/kg detomidine and 20μg/kg butorphanol

The y axis displays the aortic peak velocity (VMax). Measurements are given in metres per second.

Figure 66 Box and whisker plots displaying the range, interquartile range and mean of aortic peak acceleration measurements (dv/dt) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

The x axis displays the different study periods
1 = control
2 = during the infusion of 4μg/kg/min dopamine
3 = during the infusion of 4μg/kg/min dobutamine
4 = following the administration of 10μg/kg detomidine and 20μg/kg butorphanol

The y axis displays the aortic peak acceleration (dv/dt). Measurements are given in metres per second^2.


Aorta VMax
1.6
1.4
1.2
1
0.8
0.6
0.4
1
2
3
4
Drug

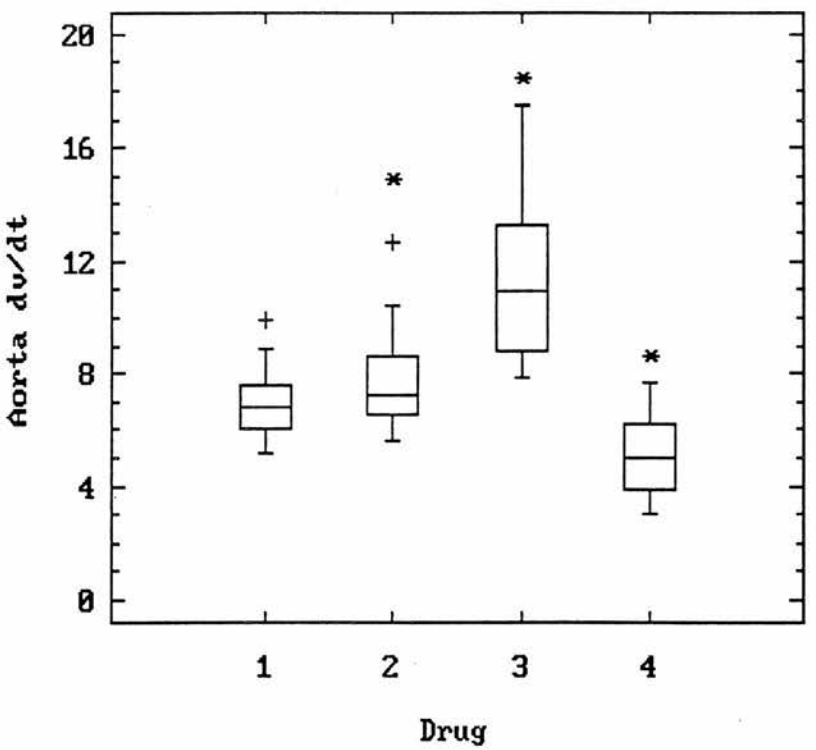

Aorta dv/dt
20
16
12
8
4
0
1
2
3
4
Drug

Figure 67 Box and whisker plots displaying the range, interquartile range and mean of aortic velocity time integral measurements (VTI) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

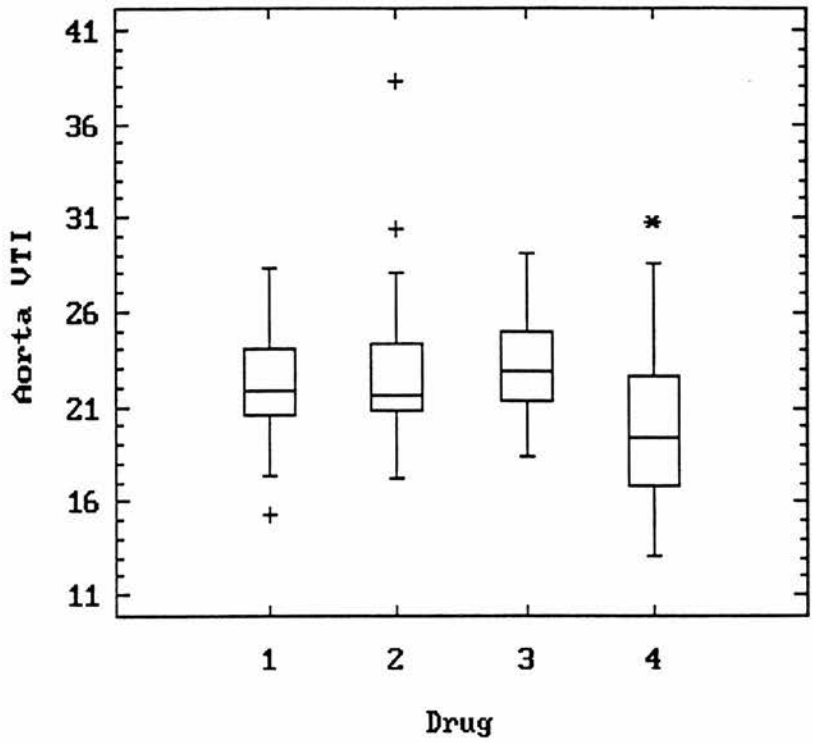
The x axis displays the different study periods
1 = control
2 = during the infusion of 4μg/kg/min dopamine
3 = during the infusion of 4μg/kg/min dobutamine
4 = following the administration of 10μg/kg detomidine and 20μg/kg butorphanol

The y axis displays the aortic velocity time integral (VTI). Measurements are given in centimetres.

Figure 68 Box and whisker plots displaying the range, interquartile range and mean of aortic acceleration time measurements (dt) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

The x axis displays the different study periods
1 = control
2 = during the infusion of 4μg/kg/min dopamine
3 = during the infusion of 4μg/kg/min dobutamine
4 = following the administration of 10μg/kg detomidine and 20μg/kg butorphanol

The y axis displays the aortic acceleration time (dt). Measurements are given in seconds.


Aorta VTI
41
36
31
26
21
16
11
1
2
3
4
Drug

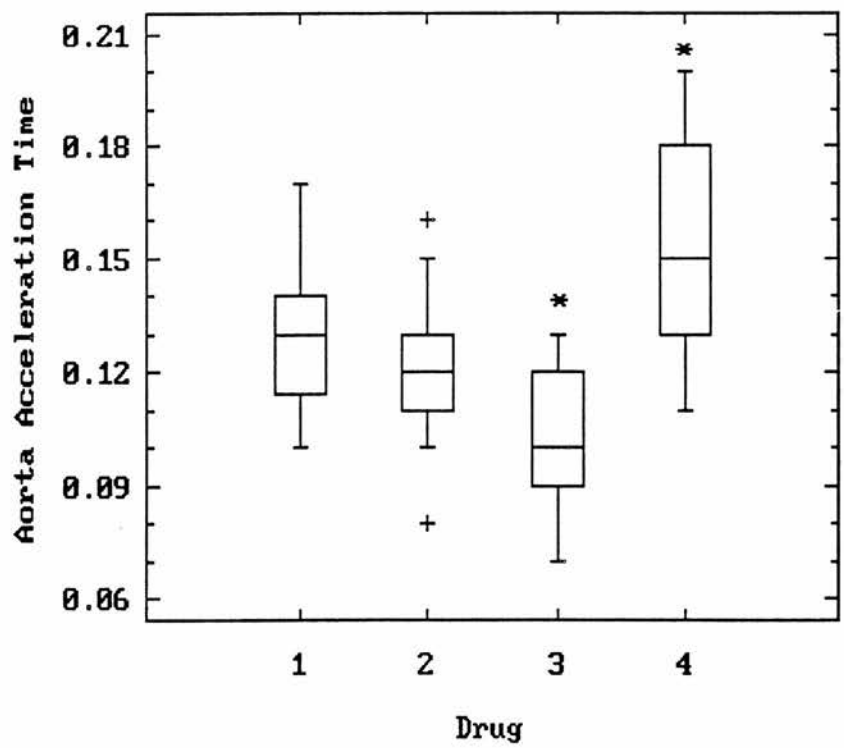

Aorta Acceleration Time
0.21
0.18
0.15
0.12
0.09
0.06
1
2
3
4
Drug

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Figure 69 Box and whisker plots displaying the range, interquartile range and mean of aortic pre-ejection period measurements (PEP) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

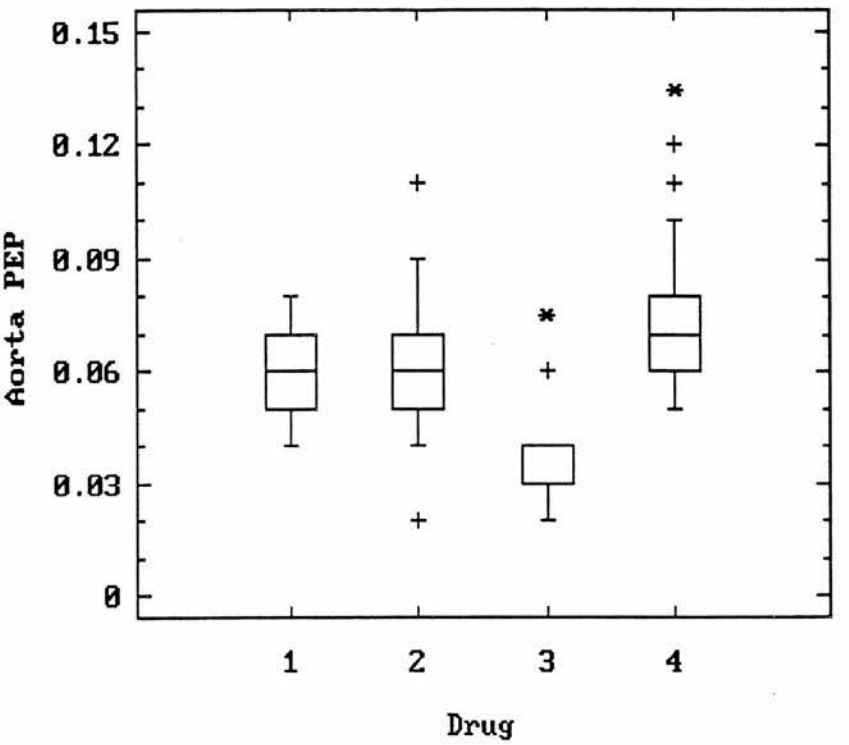
The x axis displays the different study periods
1 = control
2 = during the infusion of 4µg/kg/min dopamine
3 = during the infusion of 4µg/kg/min dobutamine
4 = following the administration of 10µg/kg detomidine and 20µg/kg butorphanol

The y axis displays the aortic pre-ejection period (PEP). Measurements are given in seconds.

Figure 70 Box and whisker plots displaying the range, interquartile range and mean of aortic ejection time measurements (EjT) during different study periods. Doppler waveforms were recorded from a left parasternal long-axis 5-chambered view. * represents significant differences between group 1 and groups 2-4 (Wilcoxon Rank test).

The x axis displays the different study periods
1 = control
2 = during the infusion of 4µg/kg/min dopamine
3 = during the infusion of 4µg/kg/min dobutamine
4 = following the administration of 10µg/kg detomidine and 20µg/kg butorphanol

The y axis displays the aortic ejection time (EjT). Measurements are given in seconds.


0.15
0.12
0.09
0.06
0.03
0
Aorta PEP
1
2
3
4
Drug

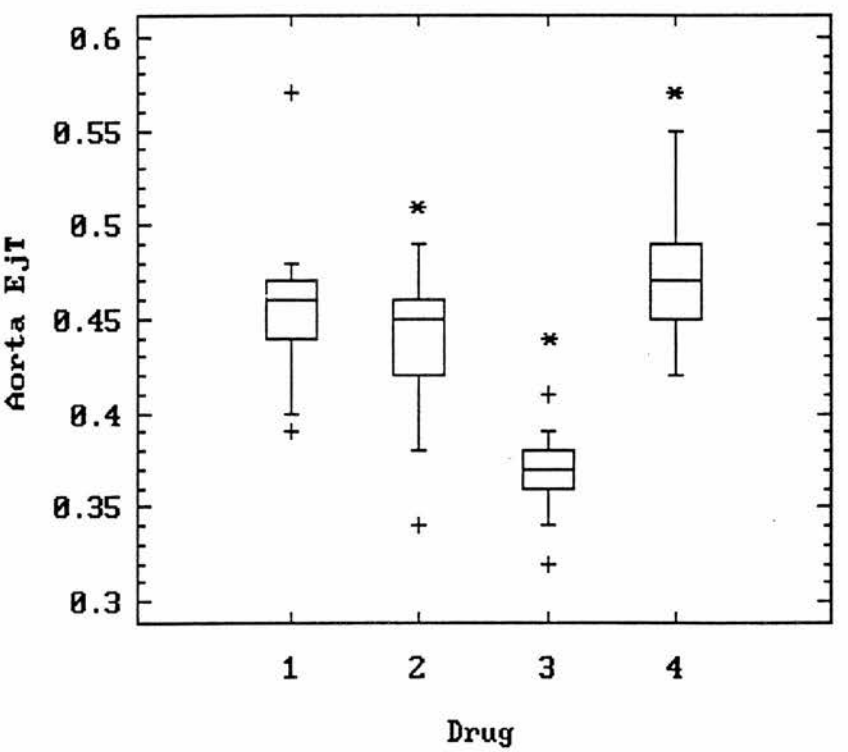
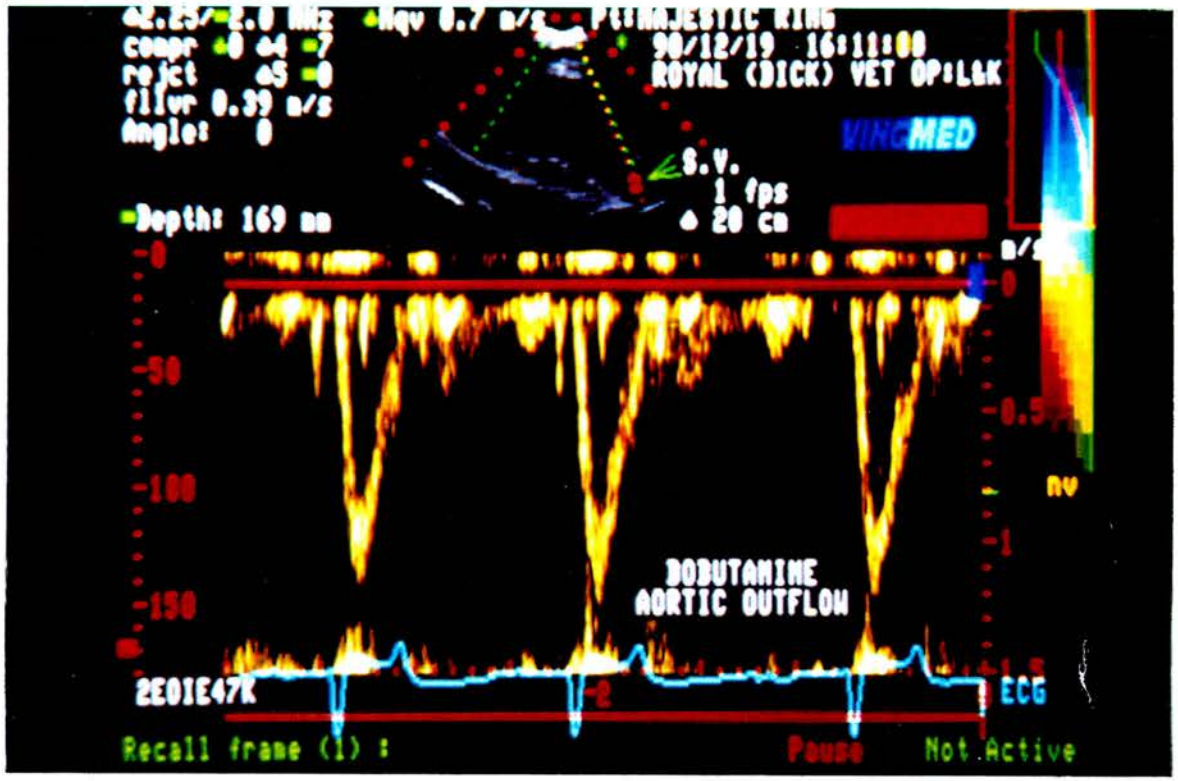
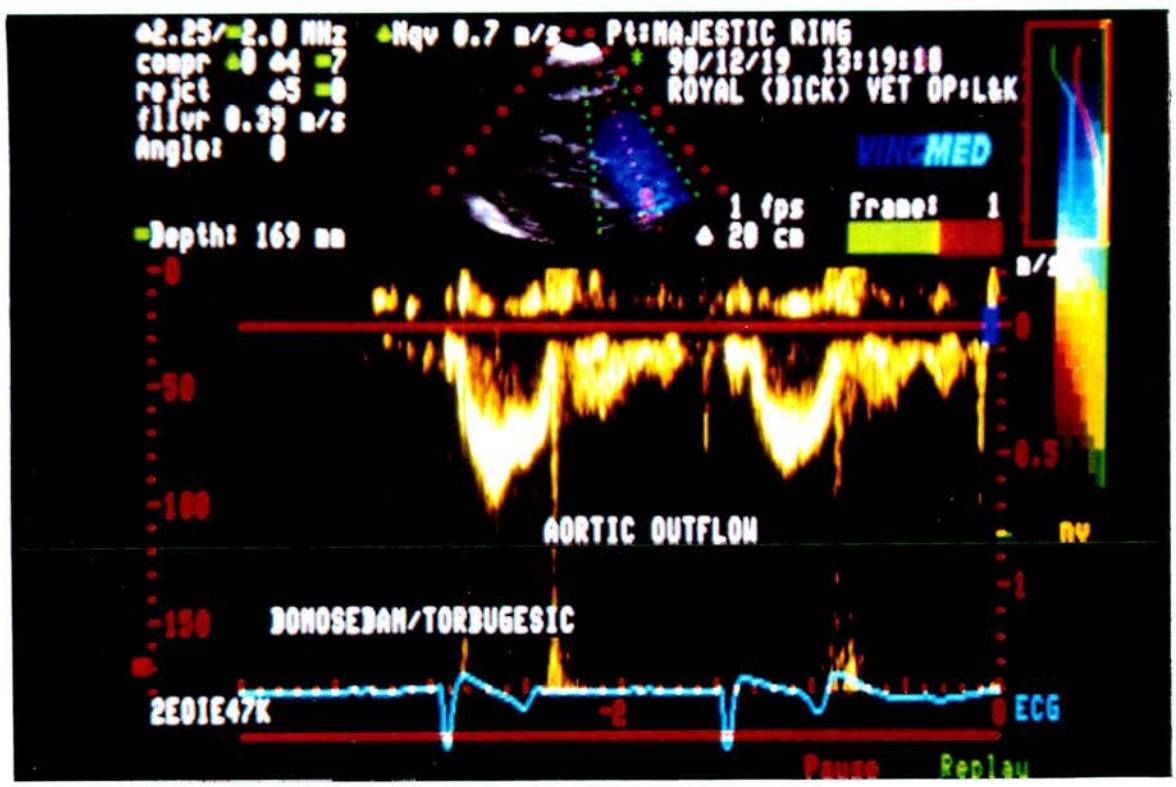

0.6
0.55
0.5
0.45
0.4
0.35
0.3
Aorta EjT
1
2
3
4
Drug

Figure 71 Pulsed wave Doppler study from the aorta, recorded during the infusion of 4µg/kg/min dobutamine. The velocity scale shown on the right of the Doppler display measures up to 1.5 metres per second (m/s). The pulsed wave Doppler sampling site is displayed on the small image sector at the top of the figure.

S.V. = sample volume

Figure 72 Pulsed wave Doppler study from the aorta, recorded after the administration of 10µg/kg detomidine and 20µg/kg butorphanol. The velocity scale shown on the right of the Doppler display measures up to 1.4 metres per second (m/s). The peak velocities of the Doppler spectra are much lower than those in Figure 71. The pulsed wave Doppler sampling site is represented by two red dots which are positioned in the blue colour flow signal shown in the small image sector at the top of the figure.


Pt:MAJESTIC RING
90/12/19 16:11:08
ROYAL (DICK) VET OP:L&K
VINGMED
S.V.
1 fps
Depth: 169 mm
20 cm
DOBUTAMINE
AORTIC OUTFLOW
2E01E47K
ECG
Recall frame (1) :
Pause
Not Active


Pt:MAJESTIC RING
90/12/19 13:19:18
ROYAL (DICK) VET OP:L&K
VINGMED
1 fps
Frame: 1
Depth: 169 mm
20 cm
AORTIC OUTFLOW
DOBOSEDAN/TORBUGESIC
2E01E47K
ECG
Pause
Replay

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APPENDICES

ABBREVIATIONS FOR APPENDICES

APPENDICES 1 AND 2.

HR	Heart rate at rest
WT	Bodyweight in kilograms
MURM	Murmur
EJECT	Ejection murmur
PRESYST L	Presystolic murmur (PMI left hemithorax)
PRESYST R	Presystolic murmur (PMI right hemithorax)
EARLY DIAST L	Early diastolic murmur (PMI left hemithorax)
EARLY DIAST R	Early diastolic murmur (PMI right hemithorax)
MN	Gelding
F	Female
M	Male
RID	Riding horse
NH	National hunt racing
SJ	Showjumping
EVE	Eventing
FL	Flat racing

APPENDIX 3 AND 4.

()	Number of horses studied
LV	Left ventricular
RV	Right ventricular
RVOT	Right ventricular outflow tract
LVOT	Left ventricular outflow tract

APPENDICES 5 TO 7.

- Max	Maximum measurement from five cardiac cycles
- Med	Median measurement from five cardiac cycles
- Min	Minimum measurement from five cardiac cycles
- s	Systolic measurement
- d	Diastolic measurement
LVID	Left ventricular internal diameter
LVW	Left ventricular wall
IVS	Interventricular septum
RVID	Right ventricular internal diameter
EF	Ejection fraction
FS	Fractional shortening
Aod	Aortic diameter in diastole
LIVS	Interventricular septum (left hemithorax)
LLVW	Left ventricular wall (left hemithorax)
LRVW	Right ventricular wall (left hemithorax)
LRVW	Right ventricular wall (left hemithorax)
LLVID	Left ventricular internal diameter (left hemithorax)
LLVID	Left ventricular internal diameter (left hemithorax)
LFS	Fractional shortening (left hemithorax)
LEF	Ejection fraction (left hemithorax)

APPENDICES 8 TO 20.

- Max	Maximum measurement from five cardiac cycles
- Med	Median measurement from five cardiac cycles
- Min	Minimum measurement from five cardiac cycles
RRp	R-R interval preceding measurement
RR	R-R interval during measurement
E	Flow of rapid filling
A	Flow due to atrial contraction
QE	Time to onset of E waveform
QA	Time to onset of A waveform
dt	For mitral inflow tables = deceleration time. For aortic and pulmonary outflow tables = acceleration time
VMax	Peak velocity
dv/dt	Peak acceleration
VTI	Velocity time integral
PEP	Pre-ejection period
EjT	Ejection time

APPENDICES FOR PART 1

Appendix 1. Clinical details of 40 control horses.

HORSE	SEX	AGE	WORK	HR	WT	MURM	TYPE OF FUNCTIONAL MURMUR				
							EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
C1	MN	2	RID	42	502	-	-	-	-	-	-
C2	F	5	RID	44	643	-	-	-	-	-	-
C3	MN	2	RID	40	588	-	-	-	-	-	-
C4	M	2	NH	40	463	+	+	-	-	+	+
C5	M	2	NH	40	487	+	-	+	-	-	+
C6	MN	4	NH	42	475	+	+	-	-	+	-
C7	F	3	NH	44	448	+	+	-	-	+	+
C8	MN	4	NH	40	543	+	+	-	-	+	+
C9	MN	5	NH	36	432	+	+	-	-	+	-
C10	MN	4	NH	35	572	-	-	-	-	-	-
C11	MN	6	SJ	45	525	+	+	-	-	-	-
C12	MN	8	NH	36	648	+	+	-	-	-	+
C13	MN	7	NH	38	604	+	+	-	-	+	-
C14	MN	4	NH	40	477	+	-	-	+	-	-

Appendix 1 (continued). Clinical details of 40 control horses.

HORSE	SEX	AGE	WORK	HR	WT	MURM	TYPE OF FUNCTIONAL MURMUR				
							EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
C15	MN	4	NH	40	504	-	-	-	-	-	-
C16	MN	5	NH	44	517	-	-	-	-	-	-
C17	MN	3	NH	32	510	+	+	+	-	+	-
C18	MN	4	NH	44	475	-	-	-	-	-	-
C19	F	16	RID	44	530	-	-	-	-	-	-
C20	F	10	RID	42	530	-	-	-	-	-	-
C21	F	17	RID	40	440	-	-	-	-	-	-
C22	MN	10	RID	44	542	-	-	-	-	-	-
C23	MN	7	NH	40	520	+	+	-	+	-	+
C24	MN	4	NH	38	486	+	-	-	-	+	-
C25	MN	4	NH	40	453	+	+	-	-	+	-
C26	MN	7	EVE	42	530	-	-	-	-	-	-
C27	F	6	RID	40	520	+	-	+	-	+	+
C28	F	8	RID	38	560	-	-	-	-	-	-

Appendix 1 (continued). Clinical details of 40 control horses.

HORSE	SEX	AGE	WORK	HR	WT	MURM	TYPE OF FUNCTIONAL MURMUR				
							EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
C29	F	4	RID	40	502	-	-	-	-	-	-
C30	F	15	RID	38	532	+	+	-	-	+	-
C31	F	4	RID	42	520	+	-	-	-	+	-
C32	F	6	NH	36	464	-	-	-	-	-	-
C33	F	5	NH	40	509	+	-	-	-	+	-
C34	F	6	NH	40	480	+	-	-	+	-	-
C35	M	3	FL	22	450	+	+	-	+	-	-
C36	F	8	RID	40	530	+	-	+	-	-	-
C37	F	8	NH	40	540	+	+	-	+	-	-
C38	F	3	RID	30	428	+	-	-	-	+	-
C39	MN	12	RID	38	518	-	-	-	-	-	-
C40	MN	14	RID	40	528	-	-	-	-	-	-

Appendix 2. Clinical details of horses in groups 1 to 5.

Group 1.

HORSE	SEX	AGE	WORK	HR	GRADE OF MURMUR	TYPE OF FUNCTIONAL MURMUR				
						EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
M1	MN	8	NH	40	2	+	+	-	+	-
M2	F	4	RID	38	2	+	-	+	-	-
M3	F	10	RID	40	3	-	-	-	-	-
M4	F	6	NH	36	3	-	-	-	-	-
M5	MN	8	RID	38	3	-	-	-	-	-
M6	MN	9	RID	40	4	-	-	+	-	-
M7	M	4	RID	38	4	-	-	-	-	-
M8	F	7	NH	45	5	-	-	-	-	-

Appendix 2 (continued). Clinical details of horses in groups 1 to 5.

Group 2.

HORSE	SEX	AGE	WORK	HR	GRADE OF MURMUR	TYPE OF FUNCTIONAL MURMUR				
						EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
T1	MN	9	RID	38	2	+	-	-	-	+
T2	F	8	RID	32	2	-	-	-	-	-
T3	MN	11	EVE	44	3	+	-	-	-	-
T4	MN	5	NH	40	3	+	-	+	-	+
T5	MN	5	RID	32	3	+	-	-	-	-
T6	F	6	NH	44	4	+	-	+	+	+
T7	MN	5	RID	40	4	-	-	-	-	-
T8	MN	10	NH	32	5	+	-	-	-	-

Appendix 2 (continued). Clinical details of horses in groups 1 to 5.

Group 3.

HORSE	SEX	AGE	WORK	HR	GRADE OF MURMUR	TYPE OF FUNCTIONAL MURMUR				
						EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
T1	MN	9	RID	38	2	+	-	-	-	+
T2	F	8	RID	32	2	-	-	-	-	-
T11	MN	2	NH	38	1	+	-	-	-	-
T12	MN	6	NH	36	2	-	-	-	-	-
T13	MN	5	NH	32	2	+	-	-	-	-
T14	MN	5	NH	36	2	+	-	-	-	-
T15	M	8	RID	38	2	-	-	-	-	-
T16	MN	6	NH	40	2	+	-	-	-	-

Appendix 2 (continued). Clinical details of horses in groups 1 to 5.

Group 4.

HORSE	SEX	AGE	WORK	HR	GRADE OF MURMUR	TYPE OF FUNCTIONAL MURMUR				
						EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
T3	MN	11	EVE	44	3	+	-	-	-	-
T4	MN	5	NH	40	3	+	-	+	-	+
T5	MN	5	RID	32	3	+	-	-	-	-
T6	F	6	NH	44	4	+	-	+	+	+
T7	MN	5	RID	40	4	-	-	-	-	-
T8	MN	10	NH	32	5	+	-	-	-	-
T9	F	9	RID	28	4	+	-	-	-	-
T10	MN	13	NH	44	5	-	+	+	-	-

Appendix 2 (continued). Clinical details of horses in groups 1 to 5.

Group 5.

HORSE	SEX	AGE	WORK	HR	GRADE OF MURMUR	TYPE OF FUNCTIONAL MURMUR				
						EJECT	PRESYST L	PRESYST R	EARLY DIAST L	EARLY DIAST R
A1	MN	7	NH	36	2	+	+	-	-	-
A2	M	2	NH	42	2	+	-	-	-	-
A3	MN	8	NH	40	2	+	-	+	+	-
A4	MN	15	RID	40	3	-	+	+	-	-
A5	F	10	RID	48	3	-	-	+	-	-
A6	F	15	RID	44	3	-	-	-	-	-
A7	F	16	RID	40	4	+	-	-	+	-
A8	MN	17	RID	38	5	+	-	-	-	-

Appendix 3.

Location and approximate sector rotation to obtain standardised two-dimensional images. The number of horses studied is shown in brackets. Figures in italics and underlined represent a clockwise (+) rotation, figures not in italics and not underlined represent an anti-clockwise (-) rotation. The mean rotation used for each view, is printed boldly. Standard location = the reference point (page 81). All other locations are described in relation to this point.

Right parasternal long-axis views.

Location		Approx Sector Rotation.
		0° 10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90°
Reference view.Ventricular inlets.	(14) Standard	**100** - - - - - - - - - - - - - - - - - -
Tipped view. LV inlet / outlet.	(11) Standard/Ventral	- - *18* *18* - ***64*** - - - - - - - - - - - -
Long-axis aorta.	(14) Standard/Dorsal	*14* ***71*** *7* - - - - - - - - - - - - *7*
Dorsal location RV inlet.	(14) Dorsal	*29* *14* *29* *7* *7* *14*
Apical view. Ventricular inlets.	(13) Ventral	*8* 8 *8* - - - - - - - - - - - - - - - - - - **31** *8* *8* *8* *8* *8* *8*

Appendix 3 (Continued).

Right parasternal short-axis views.

	Location	Approx Sector Rotation.																
		0°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
Papillary muscle level.	(12) Standard/Ventral	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	←17→ 17	17	**50**
Chordal level.	(12) Standard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	←25→ 17	8	**50**
Mitral valve level.	(12) Standard	-	-	-	-	-	-	-	-	-	-	-	17	-	17	-	←17→ **50**		
Aortic valve level.	(12) Standard	-	-	-	8	-	**50**	-	-	25	-	-	17	-	-	-	-	-	-
Pulmonary artery level.	(12) Standard	-	-	-	←8→ **25**		←8→ **25**		←17→ 8	-	-	-	8	-	-	-	-	-	-

Right parasternal angled view.

Dorsal location RVOT.	(13) Cranial/Dorsal	←8→ ←8→ 8					←8→ **54**		←15→ 8	-	-	-	-	-	-	-	-	-	-

Appendix 3 (Continued).

	Location	Approx Sector Rotation. 0° 10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90°
Left parasternal long-axis views.		
Reference view. LV inlet.	(11) Standard	**100** - - - - - - - - - - - - - - - - -
Apical view. LV inlet.	(11) Standard/Caudal /Ventral	**64** 9 18 - - - - - - - - - - - - - - - - - (9)
5-chambered.	(9) Standard/Ventral	(11) (11) **22** **22** **22** - - - - - - - - - - - - - - - - - (11)
Left parasternal short-axis views.		
LV Chordal level.	(11) Standard	- - - - - *9* - - (9) *18* *9* *18* - - - *9* - *27*
Right ventricular wall.	(11) Cranial	- - - - - *18* - - *18* (9) *9* - - - *9* - ***36***
Left parasternal angled views.		
RV inlet / outlet.	(7) Cranial/Ventral	- - - - - 29 (14) **57** - - - - - - - - - -
LVOT / Aorta.	(7) Standard/Cranial	-14 - - - ***43*** *(14)* *29* - - - - - - - - - -

Appendix 4.

Approximate sector angulation to obtain standard two-dimensional images. The number of horses studied is shown in brackets. The mean angulation required for each view is printed boldly. 0 = transducer perpendicular to the body wall. 3+ = maximum angulation.

Right parasternal long-axis views.

		Approximate cranial angulation							Approximate caudal angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Reference view ventricular inlets	(14)	**100**	-	-	-	-	-	-	-	29	**64**	7	-	-	-
Tipped view LV inlet / outlet	(11)	**36**	18	27	18	-	-	-	**82**	9	9	-	-	-	-
Long-axis aorta	(14)	21	**43**	36	-	-	-	-	**100**	-	-	-	-	-	-
Dorsal location RV inlet	(14)				**57**				**100**	-	-	-	-	-	-
				29		7									
					7										
Apical view ventricular inlets	(13)	**31**	**31**	8	23	8	-	-	**100**	-	-	-	-	-	-

		Approximate dorsal angulation							Approximate ventral angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Reference view ventricular inlets	(14)	7	**79**	14	-	-	-	-	**100**	-	-	-	-	-	-
Tipped view LV inlet/ outlet	(11)	-	9	9	**45**	36	-	-	**100**	-	-	-	-	-	-
Long-axis aorta	(14)	7	**57**	29	7	-	-	-	**100**	-	-	-	-	-	-
Dorsal location RV inlet	(14)				**71**				**100**	-	-	-	-	-	-
		7				14									
					7										
Apical view ventricular inlets	(13)	-	-	-	-	31	31	**38**	**100**	-	-	-	-	-	-

Appendix 4 (continued).

		Approximate cranial angulation							Approximate caudal angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Right parasternal short-axis views.															
Papillary muscle level	(12)	**100**	-	-	-	-	-	-	25	25	**50**	-	-	-	-
Chordal level	(12)	**92**	-	8	-	-	-	-	33	25	**42**	-	-	-	-
Mitral valve level	(12)	**58**	25	17	-	-	-	-	**75**	-	25	-	-	-	-
Aortic valve level	(12)	25	-	**42**	17	17	-	-	**100**	-	-	-	-	-	-
Pulmonary artery level	(12)	-	-	-	8	**75**	17	-	**100**	-	-	-	-	-	-
Right parasternal angled view.															
Dorsal location RVOT	(13)	15	-	23	23	**38**	-	-	**100**	-	-	-	-	-	-

		Approximate dorsal angulation							Approximate ventral angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Right parasternal short-axis views.															
Papillary muscle level	(12)	**75**	17	8	-	-	-	-	**67**	17	17	-	-	-	-
Chordal level	(12)	33	**42**	25	-	-	-	-	**92**	8	-	-	-	-	-
Mitral valve level	(12)	8	17	**50**	17	8	-	-	**100**	-	-	-	-	-	-
Aortic valve level	(12)	-	-	42	**50**	8	-	-	**100**	-	-	-	-	-	-
Pulmonary artery level	(12)	-	-	-	25	**67**	8	-	**100**	-	-	-	-	-	-
Right parasternal angled view.															
Dorsal location RVOT	(13)	-	-	**38**	23	31	8	-	**100**	-	-	-	-	-	-

Appendix 4 (continued).

		Approximate cranial angulation							Approximate caudal angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Left parasternal long-axis views															
Reference view. LV inlet	(11)	**91**	-	9	-	-	-	-	**64**	18	9	9	-	-	-
Apical view. LV inlet	(11)	**73**	9	18	-	-	-	-	**55**	18	18	9	-	-	-
5-chambered	(9)	-	-	11	33	**44**	11	-	**100**	-	-	-	-	-	-
Left parasternal short-axis views.															
LV Chordal level	(11)	**55**	36	-	9	-	-	-	**82**	9	9	-	-	-	-
Right ventricular wall	(11)	**64**	-	36	-	-	-	-	**73**	18	-	9	-	-	-
Left parasternal angled views.															
RV inlet / outlet	(7)	**71**	-	14	-	14	-	-	**43**	29	29	-	-	-	-
LVOT / Aorta	(7)	**29**	-	**29**	**29**	14	-	-	**86**	14	-	-	-	-	-

		Approximate dorsal angulation							Approximate ventral angulation						
		0	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**	**0**	**0/1+**	**1+**	**1-2+**	**2+**	**2-3+**	**3+**
Left parasternal long-axis views															
Reference view. LV inlet	(11)	-	**55**	45	-	-	-	-	**100**	-	-	-	-	-	-
Apical view. LV inlet	(11)	-	-	-	-	18	**73**	9	**100**	-	-	-	-	-	-
5-chambered	(9)	-	11	**33**	**33**	22	-	-	**100**	-	-	-	-	-	-
Left parasternal short-axis views.															
LV Chordal level	(11)	-	**45**	**45**	9	-	-	-	**100**	-	-	-	-	-	-
Right ventricular wall	(11)	**100**	-	-	-	-	-	-	-	18	**73**	9	-	-	-
Left parasternal angled views.															
RV inlet / outlet	(7)	-	-	**57**	14	29	-	-	**100**	-	-	-	-	-	-
LVOT / Aorta	(7)	-	-	-	-	29	**57**	14	**100**	-	-	-	-	-	-

Appendix 5. Correlation coefficients (r) and probability values (p) for correlation of median two-dimensional and M-mode measurements against bodyweight (kg) and age (years). Values are considered significant (*) when $p < 0.05$.

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
LVIDs Max	-0.127	0.437	-0.269	0.093
LVIDs Med	-0.099	0.544	-0.274	0.087
LVIDs Min	-0.091	0.577	-0.261	0.104
LVIDd Max	0.019	0.917	-0.174	0.325
LVIDd Med	0.003	0.984	-0.199	0.258
LVIDd Min	0.102	0.567	-0.198	0.261
LVWs Max	0.251	0.349	0.088	0.747
LVWs Med	**0.513**	**0.042***	0.007	0.979
LVWs Min	**0.520**	**0.039***	-0.065	0.811
LVWd Max	Insufficient data		Insufficient data	
LVWd Med	Insufficient data		Insufficient data	
LVWd Min	Insufficient data		Insufficient data	
IVSs Max	**0.354**	**0.025***	-0.015	0.929
IVSs Med	**0.394**	**0.012***	0.011	0.944
IVSs Min	**0.400**	**0.011***	0.071	0.662
IVSd Max	0.219	0.175	0.183	0.257
IVSd Med	0.183	0.258	0.162	0.317
IVSd Min	0.118	0.470	0.128	0.431
RVIDs Max	0.108	0.517	0.045	0.790
RVIDs Med	0.176	0.290	0.090	0.592
RVIDs Min	0.036	0.828	0.079	0.636
RVIDd Max	0.214	0.192	0.026	0.876
RVIDd Med	0.255	0.117	0.049	0.767
RVIDd Min	**0.319**	**0.048***	0.122	0.496
EF Max	0.338	0.051	0.289	0.098
EF Med	0.272	0.120	0.233	0.185
EF Min	0.267	0.127	0.315	0.069

Appendix 5 (continued).

Dimension	Correlation vs bodyweight		Correlation vs age	
FS Max	**0.341**	**0.048 ***	**0.356**	**0.039 ***
FS Med	0.293	0.093	0.206	0.242
FS Min	0.290	0.096	0.286	0.101
Aod Max	0.112	0.497	-0.110	0.504
Aod Med	0.067	0.687	-0.080	0.629
Aod Min	0.075	0.650	-0.040	0.808
LIVSd Max	0.292	0.124	0.021	0.912
LIVSd Med	0.162	0.390	0.082	0.673
LIVSd Min	**0.395**	**0.034 ***	0.003	0.987
LLVWd Max	-0.096	0.620	0.019	0.920
LLVWd Med	-0.065	0.736	0.069	0.721
LLVWd Min	-0.289	0.129	-0.048	0.814
LRVWd Max	-0.009	0.963	-0.126	0.514
LRVWd Med	-0.269	0.159	-0.215	0.263
LRVWd Min	-0.307	0.105	-0.145	0.454
LRVWs Max	0.106	0.585	0.105	0.589
LRVWs Med	0.116	0.551	-0.023	0.905
LRVWs Min	-0.016	0.935	-0.063	0.744
LLVIDs Max	0.092	0.573	-0.244	0.130
LLVIDs Med	0.087	0.593	-0.232	0.149
LLVIDs Min	0.214	0.184	-0.180	0.266
LLVIDd Max	0.233	0.148	-0.269	0.093
LLVIDd Med	0.238	0.139	-0.256	0.110
LLVIDd Min	0.256	0.111	-0.186	0.251
LEF Max	0.010	0.952	-0.010	0.953
LEF Med	0.116	0.477	0.106	0.514
LEF Min	0.112	0.491	0.177	0.274
LFS Max	0.005	0.976	0.021	0.895
LFS Med	0.119	0.496	0.125	0.440
LFS Min	0.104	0.524	0.186	0.252

Appendix 6. Results of Wilcoxon tests performed on measurements from six horses on three consecutive days. * indicates a significant difference ($p<0.05$) between the measurements obtained on the different days.

Dimension	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
LVIDs Max	0.786	0.295	0.106
LVIDs Med	0.584	0.059	0.059
LVIDs Min	0.787	0.201	0.208
LVIDd Max	0.855	0.345	0.584
LVIDd Med	0.584	0.855	1.000
LVIDd Min	0.584	0.201	0.584
LVWs Max	Insufficient data.		
LVWs Med	Insufficient data.		
LVWs Min	Insufficient data.		
LVWd Max	Insufficient data		
LVWd Med	Insufficient data		
LVWd Min	Insufficient data		
IVSs Max	0.281	0.584	0.295
IVSs Med	0.142	0.593	0.138
IVSs Min	0.249	1.000	0.249
IVSd Max	**0.036** *	1.000	0.423
IVSd Med	**0.036** *	0.590	0.106
IVSd Min	0.059	1.000	0.100
RVIDs Max	0.295	0.590	0.059
RVIDs Med	**0.036** *	1.000	**0.036** *
RVIDs Min	0.208	1.000	0.295
RVIDd Max	0.402	0.142	1.000
RVIDd Med	0.675	0.402	0.787
RVIDd Min	0.834	0.893	1.000
EF Max	0.855	0.295	0.142
EF Med	1.000	1.000	1.000
EF Min	1.000	0.100	0.201

Appendix 6 (continued).

Dimension	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
FS Max	1.000	0.345	0.423
FS Med	0.855	1.000	0.787
FS Min	1.000	0.142	0.142
Aod Max	0.686	0.593	0.834
Aod Med	0.675	1.000	0.345
Aod Min	0.529	0.855	0.529
LIVSd Max	0.345	0.855	1.000
LIVSd Med	1.000	0.584	0.345
LIVSd Min	0.201	1.000	0.142
LLVWd Max	0.787	0.584	0.855
LLVWd Med	0.345	1.000	0.584
LLVWd Min	0.201	0.584	0.142
LRVWd Max	0.584	0.855	0.423
LRVWd Med	0.584	1.000	0.142
LRVWd Min	0.584	0.855	0.345
LRVWs Max	0.584	0.593	0.584
LRVWs Med	0.345	1.000	0.201
LRVWs Min	0.463	0.787	0.201
LLVIDs Max	0.100	0.402	1.000
LLVIDs Med	0.059	0.402	0.675
LLVIDs Min	0.059	0.787	0.208
LLVIDd Max	0.059	0.100	0.834
LLVIDd Med	0.463	0.059	0.402
LLVIDd Min	0.100	0.059	0.787
LEF Max	0.201	1.000	0.178
LEF Med	0.075	0.855	0.418
LEF Min	0.686	0.675	0.345
LFS Max	0.201	1.000	0.281
LFS Med	0.075	0.855	0.500
LFS Min	0.686	0.893	0.590

Appendix 7. Median, maximum (Max) and minimum (Min) values for cardiac dimensions of normal horses (C) and horses with cardiac murmurs (groups 1-5). Results from groups 1-5 were compared with the normal group (C) using a Mann-Whitney test. Differences were considered significant (*) when $p<0.05$. N = number of horses.

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
LVIDs Max	C	40	7.840	9.23	6.62	-
	1	8	8.015	9.23	7.06	0.2228
	2	8	8.190	8.80	6.97	0.2925
	3	**8**	**8.410**	**9.23**	**7.93**	**0.0258 ***
	4	8	7.860	8.71	6.97	0.8246
	5	8	8.320	9.41	6.53	0.2342
LVIDs Med	C	40	7.580	9.15	6.18	-
	1	8	7.885	9.06	7.06	0.1537
	2	8	7.795	8.36	6.71	0.7606
	3	8	7.710	8.71	7.14	0.3256
	4	8	7.580	8.19	6.71	0.9228
	5	8	7.710	9.41	6.53	0.2625
LVIDs Min	C	40	7.140	9.06	6.01	-
	1	8	7.315	8.89	6.53	0.3905
	2	8	7.320	8.10	6.53	0.9338
	3	8	7.450	8.54	6.83	0.2026
	4	8	7.015	8.10	6.53	0.5060
	5	8	7.450	9.41	6.45	0.2868
LVIDd Max	C	34	12.195	13.85	10.37	-
	1	6	12.245	13.59	11.50	1.0000
	2	7	12.110	12.98	11.67	0.7156
	3	6	12.460	13.94	12.20	0.0686
	4	7	11.850	12.98	11.67	0.7813
	5	**6**	**12.760**	**14.11**	**12.11**	**0.0146 ***
LVIDd Med	C	34	11.975	13.50	10.02	-
	1	6	12.150	13.16	11.06	0.4039
	2	7	12.020	12.63	11.06	0.8215
	3	6	12.350	13.85	11.85	0.0715
	4	7	11.590	12.63	11.06	0.6148
	5	**6**	**12.590**	**13.50**	**11.93**	**0.0100 ***
LVIDd Min	C	34	11.670	13.15	9.67	-
	1	6	11.930	13.07	10.54	0.4586
	2	7	11.760	12.54	11.06	0.7412
	3	**6**	**12.230**	**13.77**	**11.67**	**0.0318 ***
	4	7	11.410	12.54	11.06	0.7543
	5	**6**	**12.065**	**13.41**	**11.85**	**0.0408 ***
LVWs Max			Insufficient data			
LVWs Med			Insufficient data			
LVWs Min			Insufficient data			

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
LVWd Max			Insufficient data			
LVWd Med			Insufficient data			
LVWd Min			Insufficient data			
IVSs Max	C	40	4.660	5.31	3.92	-
	1	8	4.485	5.66	2.87	0.8029
	2	8	4.575	5.14	4.09	0.9889
	3	8	4.485	4.97	4.09	0.4881
	4	8	4.660	5.14	4.09	0.6669
	5	8	4.705	5.49	4.09	0.4468
IVSs Med	C	40	4.440	5.23	3.75	-
	1	8	4.355	5.40	2.61	0.8673
	2	8	4.360	5.05	3.92	0.9668
	3	8	4.225	4.88	4.01	0.4275
	4	8	4.360	5.05	3.92	0.5973
	5	8	4.530	5.40	3.92	0.3060
IVSs Min	C	40	4.270	5.14	3.31	-
	1	8	4.050	5.23	2.53	0.8135
	2	8	4.180	4.62	3.57	0.9116
	3	8	4.090	4.62	3.32	0.4209
	4	8	4.270	4.88	3.57	0.8568
	5	8	4.400	5.31	3.66	0.3193
IVSd Max	C	40	3.140	3.92	2.44	-
	1	8	3.355	4.18	2.96	0.0899
	2	8	3.265	3.92	2.61	0.5214
	3	8	3.265	3.92	2.61	1.0000
	4	8	3.220	4.44	2.61	0.5582
	5	8	2.960	3.40	2.35	0.0814
IVSd Med	C	40	3.050	3.66	2.35	-
	1	8	3.180	3.92	2.96	0.0643
	2	8	3.180	3.66	2.53	0.2431
	3	8	3.14	3.66	2.20	0.9778
	4	8	3.14	4.36	2.53	0.4121
	5	8	2.83	3.22	2.26	0.0638
IVSd Min	C	40	2.870	3.57	2.18	-
	1	**8**	**3.050**	**3.83**	**2.87**	**0.0365 ***
	2	8	3.050	3.48	2.00	0.5131
	3	8	3.005	3.48	1.83	0.8785
	4	8	2.960	4.27	2.00	0.7175
	5	8	2.745	3.05	2.18	0.3399

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
RVIDs Max	C	38	3.480	4.97	1.31	-
	1	**7**	**4.180**	**4.97**	**2.70**	**0.0132 ***
	2	8	4.050	5.66	1.83	0.0767
	3	8	3.180	5.66	1.65	0.8961
	4	8	3.660	5.23	1.83	0.2458
	5	8	2.355	4.36	1.66	0.1433
RVIDs Med	C	38	3.050	4.88	1.05	-
	1	7	3.750	4.36	2.18	0.0666
	2	8	3.655	5.05	1.66	0.0655
	3	8	2.700	5.05	1.58	0.7061
	4	8	3.395	5.05	1.66	0.1869
	5	8	2.175	4.18	1.48	0.2291
RVIDs Min	C	38	2.570	4.88	0.87	-
	1	**7**	**3.400**	**3.66**	**1.83**	**0.0317 ***
	2	**8**	**3.355**	**4.88**	**1.57**	**0.0245 ***
	3	8	2.395	4.88	1.54	0.9537
	4	8	3.180	4.44	1.57	0.1040
	5	8	2.090	3.92	1.13	0.6325
RVIDd Max	C	39	4.270	6.18	2.26	-
	1	7	4.790	5.25	3.83	0.3746
	2	8	4.790	6.45	3.40	0.0945
	3	8	4.575	6.45	3.14	0.3719
	4	8	4.660	6.36	3.40	0.3212
	5	8	3.835	5.05	2.70	0.1570
RVIDd Med	C	39	3.920	5.92	2.09	-
	1	7	4.270	4.62	3.31	0.6459
	2	8	4.450	6.27	3.22	0.0634
	3	8	4.050	6.27	3.10	0.5708
	4	8	4.225	5.92	3.22	0.2125
	5	8	3.525	4.79	2.00	0.2696
RVIDd Min	C	39	3.660	5.40	1.83	-
	1	7	4.010	4.27	3.14	0.7244
	2	8	3.835	5.92	3.05	0.2014
	3	8	3.920	5.92	2.87	0.5998
	4	8	3.705	4.97	3.05	0.5798
	5	8	3.310	4.70	1.39	0.3576
EF Max	C	34	0.775	0.85	0.66	-
	1	6	0.760	0.82	0.70	0.4823
	2	7	0.770	0.81	0.72	0.8348
	3	6	0.765	0.83	0.72	0.8494
	4	7	0.780	0.81	0.74	0.7543
	5	6	0.795	0.87	0.75	0.1250

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
EF Med	C	34	0.740	0.82	0.64	-
	1	6	0.725	0.81	0.67	0.5688
	2	7	0.740	0.81	0.69	0.6264
	3	6	0.745	0.80	0.69	0.9545
	4	7	0.740	0.81	0.72	0.9445
	5	6	0.775	0.86	0.72	0.0848
EF Min	C	34	0.720	0.81	0.63	-
	1	6	0.685	0.81	0.64	0.2869
	2	7	0.700	0.78	0.61	0.7510
	3	6	0.700	0.76	0.66	0.7034
	4	7	0.700	0.78	0.69	0.9722
	5	6	0.745	0.83	0.67	0.1787
FS Max	C	34	38.5	46	29	-
	1	6	37.0	43	33	0.3719
	2	7	38.0	42	34	0.6637
	3	6	38.0	44	34	0.8343
	4	7	39.0	42	35	0.9168
	5	6	40.5	49	36	0.1555
FS Med	C	34	36	44	28	-
	1	6	35	42	30	0.5812
	2	7	36	42	31	0.4855
	3	7	36	41	31	0.9090
	4	6	36	42	34	0.6753
	5	6	39	47	34	0.0662
FS Min	C	34	34.0	42	28	-
	1	6	31.0	42	28	0.2522
	2	7	33.0	39	30	0.8069
	3	6	32.5	37	30	0.5931
	4	7	33.0	39	32	0.9861
	5	6	35.5	44	30	0.2804
Aod Max	C	39	8.540	9.50	7.23	-
	1	8	8.670	9.41	8.19	0.6810
	2	8	8.495	9.58	8.25	0.9210
	3	7	8.620	9.88	7.84	0.4259
	4	8	8.495	9.06	8.25	0.8096
	5	**8**	**9.320**	**9.49**	**8.36**	**0.0244 ***
Aod Med	C	39	8.280	9.41	6.71	-
	1	8	8.490	9.32	7.40	0.7877
	2	8	8.235	8.97	7.58	0.7551
	3	7	8.540	9.74	7.67	0.5103
	4	8	8.145	8.97	7.58	0.6198
	5	8	9.015	9.41	7.93	0.0745
Aod Min	C	39	8.100	9.32	6.62	-
	1	8	8.055	8.89	7.23	0.8204
	2	8	8.055	8.89	7.32	0.8537
	3	7	8.190	9.34	7.58	0.4907
	4	8	8.010	8.89	7.32	0.6296
	5	8	8.755	9.23	7.75	0.0769

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
LIVSd Max			Insufficient data			
LIVSd Med			Insufficient data			
LIVSd Min			Insufficient data			
LLVWd Max			Insufficient data			
LLVWd Med			Insufficient data			
LLVWd Min			Insufficient data			
LRVWd Max	C	29	1.480	1.92	1.13	-
	1	6	1.480	1.66	1.31	0.8771
	2	**6**	**1.220**	**1.48**	**1.13**	**0.0142 ***
	3	7	1.430	1.83	1.31	0.7166
	4	**5**	**1.220**	**1.66**	**1.13**	**0.0348 ***
	5	5	1.480	1.66	1.13	0.5078
LRVWd Med	C	29	1.220	1.83	1.13	-
	1	6	1.265	1.48	1.22	0.9819
	2	6	1.175	1.48	1.04	0.0523
	3	7	1.310	1.75	1.22	0.2761
	4	5	1.130	1.57	1.04	0.0851
	5	5	1.310	1.57	1.13	1.0000
LRVWd Min	C	29	1.220	1.48	0.96	-
	1	6	1.220	1.39	0.87	0.8243
	2	6	1.050	1.32	0.96	0.0651
	3	7	1.220	1.58	1.05	0.5699
	4	5	1.050	1.31	0.96	0.0884
	5	5	1.220	1.39	0.96	0.8242
LRVWs Max	C	29	2.610	3.53	1.83	-
	1	6	2.485	2.70	1.83	0.2914
	2	6	2.610	2.79	2.00	0.6918
	3	7	2.610	3.28	2.09	0.5077
	4	5	2.440	2.61	2.00	0.2610
	5	5	2.610	2.87	2.00	0.9028
LRVWs Med	C	29	2.260	3.31	1.74	-
	1	6	2.350	2.61	1.83	0.6598
	2	6	2.135	2.53	1.83	0.2513
	3	7	2.270	3.02	1.83	0.9200
	4	5	2.180	2.53	1.83	0.2595
	5	5	2.440	2.70	1.57	0.7504
LRVWs Min	C	29	2.090	2.87	1.48	-
	1	6	2.005	2.26	1.66	0.3126
	2	6	2.045	2.18	1.57	0.1945
	3	7	2.090	2.44	1.57	0.6020
	4	5	2.090	2.18	1.57	0.2218
	5	5	2.090	2.44	1.22	0.7693

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
LLVIDs Max	C	40	8.055	9.76	6.18	-
	1	7	8.450	9.58	8.10	0.0635
	2	7	8.100	8.97	7.10	0.7083
	3	8	8.100	9.15	7.23	0.5606
	4	7	7.930	8.97	7.10	1.0000
	5	7	8.280	8.80	6.53	0.7199
LLVIDs Med	C	40	7.750	9.49	6.10	-
	1	**7**	**8.010**	**9.41**	**7.93**	**0.0347 ***
	2	7	8.010	8.80	7.10	0.5696
	3	8	8.055	8.79	6.88	0.1700
	4	7	7.670	8.80	7.10	0.6973
	5	7	7.580	8.54	6.18	0.7651
LLVIDs Min	C	40	7.360	9.49	6.01	-
	1	7	7.840	9.06	7.32	0.0773
	2	7	7.840	8.62	6.81	0.5102
	3	8	7.885	8.72	6.71	0.0508
	4	7	7.230	8.62	6.81	0.9522
	5	7	7.580	8.28	6.01	0.8930
LLVIDd Max	C	40	12.810	14.46	10.80	-
	1	7	13.150	13.88	11.93	0.3019
	2	7	12.980	13.76	11.79	0.7082
	3	8	13.155	14.46	11.85	0.4800
	4	7	12.450	13.76	11.67	0.3611
	5	7	12.630	14.98	12.11	0.4733
LLVIDd Med	C	40	12.585	14.20	10.54	-
	1	7	12.980	13.76	11.67	0.2432
	2	7	12.380	13.76	11.57	0.8810
	3	8	12.715	14.23	11.32	0.4973
	4	7	12.220	13.76	11.41	0.3234
	5	7	12.540	14.81	12.02	0.3944
LLVIDd Min	C	40	12.280	13.76	10.10	-
	1	7	12.890	13.50	11.50	0.1734
	2	7	12.230	13.68	11.50	0.6321
	3	8	12.500	13.41	11.24	0.5151
	4	7	11.760	13.68	11.24	0.4913
	5	7	12.460	14.37	11.85	0.2500
LEF Max	C	40	0.7825	0.85	0.65	-
	1	7	0.7586	0.82	0.71	0.0761
	2	7	0.7743	0.84	0.72	0.5676
	3	8	0.7650	0.80	0.73	0.2205
	4	7	0.7643	0.84	0.72	0.1856
	5	7	0.8300	0.88	0.75	0.0539
LEF Med	C	40	0.7550	0.84	0.62	-
	1	7	0.7300	0.77	0.68	0.0918
	2	7	0.7400	0.81	0.72	0.4747
	3	8	0.7500	0.79	0.72	0.6461
	4	7	0.7400	0.81	0.69	0.1406
	5	**7**	**0.7900**	**0.88**	**0.75**	**0.0270 ***

Appendix 7 (continued).

Dimension	GROUP	N	MEDIAN	MAX	MIN	p
LEF Min	C	40	0.7200	0.82	0.62	-
	1	7	0.6900	0.75	0.65	0.1453
	2	7	0.7200	0.80	0.69	0.6626
	3	8	0.7250	0.77	0.70	0.9334
	4	7	0.7000	0.80	0.67	0.1447
	5	7	0.7700	0.83	0.71	0.0885
LFS Max	C	40	40.0	46	29	-
	1	7	38.0	43	34	0.0811
	2	7	39.0	45	34	0.1044
	3	8	37.5	41	35	0.2053
	4	7	37.0	45	34	0.2293
	5	7	44.0	50	37	0.0521
LFS Med	C	40	37.0	45	27	-
	1	7	35.0	39	31	0.0522
	2	7	36.0	42	34	0.3994
	3	8	36.5	40	34	0.6660
	4	7	36.0	42	32	0.1140
	5	7	40.0	50	36	0.0558
LFS Min	C	40	34.0	43	27	-
	1	7	32.0	36	29	0.1103
	2	7	34.0	41	32	0.6830
	3	8	33.0	38	33	0.8446
	4	7	34.0	41	30	0.1309
	5	7	38.0	44	34	0.0521

Appendix 8. Comparison of measurements from the pulmonary artery Doppler waveforms and the aortic Doppler waveforms using a Student's t-test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied.

Variable	N	Pulmonary Artery (Mean)	N	Aorta (Mean)	p value	
RRp Max	**40**	**1.738**	**40**	**1.710**	**0.5200**	
RRp Med	**40**	**1.688**	**40**	**1.615**	**0.0034**	*
RRp Min	**40**	**1.649**	**40**	**1.562**	**0.0013**	*
RR Max	**40**	**1.850**	**40**	**1.761**	**0.2700**	
RR Med	**40**	**1.744**	**40**	**1.672**	**0.0016**	*
RR Min	**40**	**1.691**	**40**	**1.561**	**0.0017**	*
VMax Max	40	0.952	**40**	0.979	0.084	
VMax Med	40	0.906	**40**	0.937	0.061	
VMax Min	40	0.866	**40**	0.890	0.160	
dv/dt Max	**40**	**5.032**	**40**	**9.123**	**0.0000**	*
dv/dt Med	**40**	**4.453**	**40**	**8.015**	**0.0000**	*
dv/dt Min	**40**	**4.004**	**40**	**7.047**	**0.0000**	*
dt Max	**40**	**0.231**	**40**	**0.138**	**0.0000**	*
dt Med	**40**	**0.208**	**40**	**0.122**	**0.0000**	*
dt Min	**40**	**0.184**	**40**	**0.107**	**0.0000**	*
VTI Max	40	27.277	40	27.427	0.80	
VTI Med	40	25.740	40	25.369	0.58	
VTI Min	40	24.549	40	23.921	0.33	
PEP Max	**40**	**0.073**	**37**	**0.087**	**0.0003**	*
PEP Med	**40**	**0.061**	**37**	**0.075**	**0.0001**	*
PEP Min	**40**	**0.049**	**37**	**0.064**	**0.0003**	*
EjT Max	**40**	**0.521**	**40**	**0.488**	**0.0000**	*
EjT Med	**40**	**0.501**	**40**	**0.467**	**0.0000**	*
EjT Min	**40**	**0.483**	**40**	**0.449**	**0.0000**	*

Appendix 9. Comparison of tricuspid (long-axis) and mitral inflow measurements using a Student's t-test. Differences were considered significant (*) when $p<0.05$
N = number of horses studied.

Variable	N	Tricuspid Inflow (Mean)	N	Mitral Inflow (Mean)	p value	
RRp Max	40	1.695	39	1.691	0.086	
RRp Med	40	1.646	39	1.633	0.600	
RRp Min	40	1.601	39	1.590	0.650	
RR Max	40	1.751	40	1.751	1.000	
RR Med	40	1.695	40	1.685	0.730	
RR Min	40	1.652	40	1.625	0.370	
E Max	40	0.729	40	0.753	0.4200	
E Med	40	0.650	40	0.697	0.1000	
E Min	40	0.577	40	0.617	0.1200	
A Max	**40**	**0.602**	**40**	**0.481**	**0.0000**	*
A Med	**40**	**0.531**	**40**	**0.417**	**0.0000**	*
A Min	**40**	**0.473**	**40**	**0.348**	**0.0000**	*
E/A Max	**40**	**1.300**	**40**	**1.874**	**0.0000**	*
E/A Med	**40**	**1.305**	**40**	**1.781**	**0.0003**	*
E/A Min	**40**	**1.263**	**40**	**1.662**	**0.0005**	*
dt Max	**40**	**0.291**	**37**	**0.244**	**0.0000**	*
dt Med	**40**	**0.238**	**37**	**0.216**	**0.0130**	*
dt Min	40	0.191	37	0.189	0.9400	
QE Max	**40**	**0.597**	**37**	**0.627**	**0.0087**	*
QE Med	**40**	**0.566**	**37**	**0.608**	**0.0002**	*
QE Min	**40**	**0.542**	**37**	**0.588**	**0.0002**	*
QA Max	**40**	**1.418**	**37**	**1.521**	**0.0040**	*
QA Med	**40**	**1.358**	**37**	**1.442**	**0.0044**	*
QA Min	**40**	**1.310**	**37**	**1.383**	**0.0016**	*

Appendix 10. Comparison of measurements from tricuspid inflow velocity waveforms obtained from the right parasternal long-axis view and the right parasternal angled view using a Student's t-test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied.

Tricuspid Inflow Variable	N	Long-axis (Mean)	N	Angled view (Mean)	p value	
RRp Max	40	1.695	22	1.784	0.088	
RRp Med	40	1.646	22	1.728	0.290	
RRp Min	40	1.601	22	1.669	0.420	
RR Max	40	1.751	23	2.069	0.580	
RR Med	40	1.695	23	1.896	0.089	
RR Min	40	1.652	23	1.781	0.087	
E Max	**40**	**0.728**	**23**	**0.959**	**0.0000**	*
E Med	**40**	**0.650**	**23**	**0.899**	**0.0000**	*
E Min	**40**	**0.577**	**23**	**0.812**	**0.0000**	*
A Max	**40**	**0.602**	**17**	**0.770**	**0.0002**	*
A Med	**40**	**0.531**	**17**	**0.687**	**0.0005**	*
A Min	**40**	**0.473**	**17**	**0.598**	**0.0047**	*
E/A Max	40	1.263	17	1.253	0.8900	
E/A Med	40	1.305	17	1.328	0.8100	
E/A Min	40	1.300	17	1.400	0.3300	
QE Max	**40**	**0.597**	**22**	**0.865**	**0.0000**	*
QE Med	**40**	**0.566**	**22**	**0.831**	**0.0000**	*
QE Min	**40**	**0.542**	**22**	**0.794**	**0.0000**	*
QA Max	**40**	**1.418**	**17**	**1.667**	**0.0000**	*
QA Med	**40**	**1.358**	**17**	**1.606**	**0.0000**	*
QA Min	**40**	**1.310**	**17**	**1.515**	**0.0000**	*

Appendix 11. Comparison of mean tricuspid inflow (long-axis) measurements between males and females using a Student's t-test. Differences were considered significant (*) when $p<0.05$.

Tricuspid inflow (long-axis view).

Dimension	Male (Mean)	Female (Mean)	p
RRp Max	1.680	1.661	0.80
RRp Med	1.631	1.615	0.83
RRp Min	1.592	1.569	0.74
RR Max	1.781	1.668	0.44
RR Med	1.724	1.612	0.43
RR Min	1.682	1.579	0.45
E Max	0.714	0.724	0.81
E Med	0.637	0.648	0.76
E Min	0.563	0.581	0.56
A Max	0.616	0.611	0.88
A Med	0.543	0.537	0.89
A Min	0.490	0.476	0.67
E/A Max	1.193	1.207	0.87
E/A Med	1.270	1.232	0.78
E/A Min	1.204	1.276	0.55
dt Max	0.292	0.290	0.87
dt Med	0.236	0.243	0.63
dt Min	0.196	0.183	0.47
QE Max	0.601	0.596	0.80
QE Med	0.571	0.559	0.46
QE Min	0.551	0.532	0.20
QA Max	1.386	1.407	0.78
QA Med	1.326	1.344	0.81
QA Min	1.291	1.294	0.96

Appendix 11 (continued). Comparison of mean mitral inflow measurements between males and females using a Student's t-test. Differences were considered significant (*) when $p<0.05$.

Mitral inflow.

Dimension	Male (Mean)	Female (Mean)	p	
RRp Max	1.733	1.615	0.15	
RRp Med	1.693	1.559	0.10	
RRp Min	1.650	1.522	0.11	
RR Max	1.827	1.639	0.23	
RR Med	1.787	1.547	0.11	
RR Min	1.740	1.487	0.078	
E Max	0.766	0.730	0.49	
E Med	0.703	0.681	0.66	
E Min	0.637	0.580	0.18	
A Max	0.485	0.489	0.90	
A Med	0.422	0.421	0.96	
A Min	0.357	0.346	0.67	
E/A Max	1.667	1.602	0.75	
E/A Med	1.768	1.742	0.91	
E/A Min	1.893	1.778	0.59	
dt Max	0.252	0.232	0.21	
dt Med	**0.224**	**0.201**	**0.043**	*
dt Min	0.196	0.175	0.12	
QE Max	0.629	0.625	0.87	
QE Med	0.608	0.606	0.92	
QE Min	0.588	0.586	0.93	
QA Max	1.528	1.463	0.48	
QA Med	1.477	1.359	0.16	
QA Min	1.436	1.296	0.97	

Appendix 11 (continued). Comparison of mean pulmonary outflow measurements between males and females using a Student's t-test. Differences were considered significant (*) when $p<0.05$.

Pulmonary outflow.

Dimension	Male (Mean)	Female (Mean)	p
RRp Max	1.736	1.687	0.54
RRp Med	1.692	1.646	0.54
RRp Min	1.658	1.613	0.54
RR Max	1.838	1.699	0.34
RR Med	1.793	1.654	0.31
RR Min	1.732	1.608	0.35
VMax Max	0.956	0.947	0.78
VMax Med	0.908	0.902	0.84
VMax Min	0.866	0.870	0.89
dv/dt Max	4.925	5.190	0.45
dv/dt Med	4.430	4.567	0.60
dv/dt Min	3.915	4.191	0.26
dt Max	0.236	0.222	0.21
dt Med	0.209	0.203	0.57
dt Min	0.187	0.180	0.47
VTI Max	27.740	26.850	0.38
VTI Med	26.730	25.290	0.36
VTI Min	25.110	24.050	0.26
PEP Max	0.075	0.066	0.17
PEP Med	0.064	0.056	0.14
PEP Min	0.052	0.045	0.18
EjT Max	0.521	0.521	0.94
EjT Med	0.503	0.501	0.83
EjT Min	0.483	0.486	0.76

Appendix 11 (continued). Comparison of mean aortic outflow measurements between males and females using a Student's t-test. Differences were considered significant (*) when $p<0.05$.

Aortic outflow.

Dimension	Male (Mean)	Female (Mean)	p	
RRp Max	1.699	1.624	0.30	
RRp Med	1.641	1.581	0.38	
RRp Min	1.590	1.541	0.45	
RR Max	1.871	1.617	0.11	
RR Med	1.741	1.581	0.26	
RR Min	1.594	1.534	0.40	
VMax Max	0.963	1.002	0.19	
VMax Med	0.928	0.949	0.53	
VMax Min	0.886	0.897	0.74	
dv/dt Max	**8.510**	**9.860**	**0.019**	*
dv/dt Med	7.790	8.490	0.14	
dv/dt Min	6.890	7.410	0.29	
dt Max	0.139	0.133	0.51	
dt Med	0.123	0.117	0.43	
dt Min	**0.111**	**0.098**	**0.015**	*
VTI Max	27.620	26.980	0.50	
VTI Med	25.630	24.710	0.38	
VTI Min	24.370	23.260	0.28	
PEP Max	0.093	0.084	0.17	
PEP Med	0.079	0.072	0.23	
PEP Min	0.059	0.069	0.13	
EjT Max	0.487	0.484	0.74	
EjT Med	0.468	0.465	0.79	
EjT Min	0.447	0.451	0.72	

Appendix 12. Probability values (p) for correlation (r) of Doppler measurements against bodyweight (kg) and age (years). Values are considered significant (*) when $p < 0.05$.

Tricuspid inflow (angled view).

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
RR Max	0.154	0.494	0.353	0.107
RR Med	0.194	0.387	0.358	0.102
RR Min	0.270	0.224	0.337	0.125
RR Max	-0.139	0.527	0.145	0.508
RR Med	-0.018	0.936	0.271	0.211
RR Min	0.100	0.651	0.360	0.091
E Max	-0.270	0.213	**-0.555**	**0.006** *
E Med	**-0.463**	**0.026** *	**-0.552**	**0.006** *
E Min	**-0.485**	**0.019** *	**-0.618**	**0.002** *
A Max	-0.000	0.999	-0.200	0.441
A Med	-0.092	0.726	-0.344	0.177
A Min	-0.042	0.873	-0.321	0.209
E/A Max	-0.039	0.881	-0.128	0.624
E/A Med	-0.051	0.846	-0.109	0.678
E/A Min	-0.164	0.529	-0.013	0.960
QE Max	0.379	0.082	**0.494**	**0.019** *
QE Med	0.371	0.090	**0.437**	**0.042** *
QE Min	0.275	0.215	0.351	0.109
QA Max	0.074	0.786	0.195	0.470
QA Med	0.101	0.711	0.210	0.435
QA Min	0.282	0.290	0.127	0.638

Appendix 12 (continued).

Tricuspid inflow (long-axis view).

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
RR Max	-0.223	0.163	0.153	0.345
RR Med	-0.212	0.190	0.143	0.379
RR Min	-0.200	0.216	0.156	0.338
RR Max	-0.091	0.577	**0.317**	**0.046** *
RR Med	-0.091	0.575	0.296	0.063
RR Min	-0.082	0.617	0.301	0.059
E Max	-0.251	0.118	**-0.334**	**0.035** *
E Med	-0.205	0.205	-0.231	0.152
E Min	-0.185	0.252	-0.221	0.170
A Max	-0.210	0.194	0.013	0.936
A Med	-0.219	0.174	0.006	0.973
A Min	-0.128	0.443	0.023	0.889
E/A Max	**-0.336**	**0.034** *	-0.214	0.185
E/A Med	**-0.313**	**0.049** *	-0.122	0.454
E/A Min	-0.182	0.262	-0.111	0.494
dt Max	0.066	0.687	0.135	0.405
dt Med	0.033	0.838	0.249	0.122
dt Min	0.081	0.620	0.078	0.632
QE Max	0.097	0.550	0.201	0.214
QE Med	0.135	0.405	0.203	0.210
QE Min	0.158	0.330	0.188	0.245
QA Max	-0.225	0.163	0.196	0.226
QA Med	-0.226	0.161	0.150	0.355
QA Min	-0.228	0.158	0.151	0.352

Appendix 12 (continued).

Mitral inflow (long-axis).

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
RR Max	-0.169	0.304	0.239	0.143
RR Med	-0.148	0.370	0.285	0.078
RR Min	-0.144	0.382	0.292	0.072
RR Max	0.020	0.904	**0.377**	**0.016** *
RR Med	0.002	0.990	**0.369**	**0.019** *
RR Min	-0.001	0.996	**0.378**	**0.016** *
E Max	-0.131	0.421	**-0.370**	**0.019** *
E Med	-0.172	0.290	-0.318	0.045
E Min	-0.187	0.248	-0.266	0.098
A Max	0.156	0.338	-0.059	0.717
A Med	0.141	0.385	-0.077	0.637
A Min	0.271	0.091	-0.058	0.722
E/A Max	-0.181	0.264	-0.190	0.240
E/A Med	-0.172	0.288	-0.116	0.475
E/A Min	-0.273	0.088	-0.143	0.380
dt Max	0.132	0.436	0.106	0.533
dt Med	0.081	0.632	-0.010	0.955
dt Min	-0.075	0.658	-0.010	0.954
QE Max	0.010	0.955	-0.085	0.617
QE Med	0.050	0.769	0.041	0.810
QE Min	0.048	0.780	0.038	0.822
QA Max	-0.149	0.378	0.189	0.262
QA Med	-0.211	0.210	0.182	0.281
QA Min	-0.211	0.210	0.176	0.298

Appendix 12 (continued).

Pulmonary outflow.

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
RR Max	0.179	0.270	0.152	0.350
RR Med	0.145	0.372	0.174	0.284
RR Min	0.105	0.518	0.156	0.337
RR Max	-0.155	0.340	0.152	0.350
RR Med	-0.057	0.727	0.174	0.284
RR Min	0.052	0.749	0.156	0.337
VMax Max	**0.449**	**0.004** *	0.228	0.158
VMax Med	**0.509**	**0.001** *	0.153	0.345
VMax Min	**0.560**	**0.000** *	0.276	0.085
dv/dt Max	0.053	0.745	0.276	0.084
dv/dt Med	0.192	0.236	0.262	0.102
dv/dt Min	0.204	0.206	0.268	0.094
dt Max	0.054	0.740	-0.192	0.235
dt Med	0.087	0.596	-0.174	0.283
dt Min	0.178	0.271	-0.206	0.201
VTI Max	0.284	0.075	**0.334**	**0.035** *
VTI Med	**0.361**	**0.022** *	**0.383**	**0.015** *
VTI Min	**0.381**	**0.015** *	**0.315**	**0.048** *
PEP Max	0.005	0.978	-0.311	0.051
PEP Med	0.090	0.583	-0.268	0.095
PEP Min	0.092	0.570	-0.234	0.147
EjT Max	-0.114	0.484	0.168	0.300
EjT Med	-0.153	0.344	0.243	0.131
EjT Min	0.023	0.888	0.188	0.245

Appendix 12 (continued).

Aortic outflow.

Dimension	Correlation vs bodyweight		Correlation vs age	
	r	p	r	p
RR Max	-0.079	0.627	-0.286	0.073
RR Med	-0.023	0.888	**0.330**	**0.037** *
RR Min	0.027	0.867	**0.388**	**0.013** *
RR Max	-0.121	0.456	**-0.313**	**0.049** *
RR Med	0.017	0.918	**0.386**	**0.014** *
RR Min	0.047	0.771	**0.392**	**0.012** *
VMax Max	0.108	0.509	-0.104	0.525
VMax Med	0.139	0.394	-0.182	0.262
VMax Min	0.203	0.210	-0.130	0.423
dv/dt Max	0.223	0.167	-0.021	0.896
dv/dt Med	0.278	0.082	0.101	0.536
dv/dt Min	**0.318**	**0.046** *	0.062	0.702
dt Max	-0.252	0.117	-0.206	0.202
dt Med	-0.278	0.083	-0.191	0.237
dt Min	-0.260	0.106	-0.188	0.245
VTI Max	0.052	0.751	0.222	0.168
VTI Med	0.012	0.943	0.219	0.174
VTI Min	-0.045	0.782	0.196	0.225
PEP Max	0.027	0.872	-0.207	0.218
PEP Med	0.098	0.564	-0.122	0.472
PEP Min	0.110	0.517	-0.202	0.231
EjT Max	-0.208	0.198	0.137	0.400
EjT Med	-0.230	0.153	0.171	0.292
EjT Min	-0.232	0.150	0.158	0.330

Appendix 13. Comparison of measurements from the pulmonary artery and aorta in horses with and without systolic ejection murmurs, using a Student's t-test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Mean values of each variable are given.

Aortic Outflow

Variable	N	No Murmur	N	Ejection Murmur	p value	
VMax Max	26	0.979	14	0.980	0.970	
VMax Med	26	0.934	14	0.939	0.860	
VMax Min	26	0.887	14	0.894	0.830	
dv/dt Max	26	9.360	14	8.360	0.054	
dv/dt Med	**26**	**8.430**	**14**	**7.240**	**0.019**	*
dv/dt Min	**26**	**7.510**	**14**	**6.190**	**0.006**	*
dt Max	**26**	**0.128**	**14**	**0.156**	**0.002**	*
dt Med	**26**	**0.115**	**14**	**0.135**	**0.004**	*
dt Min	**26**	**0.101**	**14**	**0.119**	**0.007**	*
VTI Max	26	26.880	**14**	28.440	0.140	
VTI Med	26	24.630	**14**	26.750	0.064	
VTI Min	26	23.260	**14**	25.140	0.100	

Pulmonary Artery

Variable	N	No Murmur	N	Ejection Murmur	p value
VMax Max	26	0.942	14	0.969	0.390
VMax Med	26	0.895	14	0.927	0.260
VMax Min	26	0.850	14	0.895	0.130
dv/dt Max	26	5.050	14	5.000	0.890
dv/dt Med	26	4.486	14	4.390	0.750
dv/dt Min	26	4.032	14	3.953	0.770
dt Max	26	0.225	14	0.244	0.100
dt Med	26	0.202	14	0.218	0.150
dt Min	26	0.179	14	0.194	0.150
VTI Max	26	27.540	14	26.780	0.460
VTI Med	26	25.830	14	25.570	0.790
VTI Min	26	24.480	14	24.670	0.840

Appendix 13 (continued). Comparison of measurements from the mitral and tricuspid inflow in horses with and without early diastolic filling murmurs. Mitral flow velocities were compared in horses with and without left sided murmurs and tricuspid flow velocities were compared in horses with and without right sided murmurs. Measurements were compared using a Student's t-test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Mean values of each variable are given.

Mitral Inflow

Variable	N	No Murmur	N	Filling Murmur	p value	
E Max	**26**	**0.708**	**14**	**0.836**	**0.007**	*
E Med	**26**	**0.649**	**14**	**0.786**	**0.006**	*
E Min	**26**	**0.586**	**14**	**0.676**	**0.004**	*
dt Max	26	0.240	14	0.252	0.440	
dt Med	26	0.213	14	0.223	0.400	
dt Min	26	0.185	14	0.198	0.320	

Tricuspid Inflow (long-axis view)

Variable	N	No Murmur	N	Filling Murmur	P value
E Max	33	0.730	7	0.723	0.870
E Med	33	0.655	7	0.627	0.500
E Min	33	0.585	7	0.540	0.110
dt Max	33	0.293	7	0.286	0.590
dt Med	33	0.240	7	0.231	0.590
dt Min	33	0.191	7	0.192	0.930

Appendix 14. Results of Wilcoxon tests performed on measurements from six horses on three consecutive days. * indicates a significant difference ($p<0.05$) between the measurements obtained on the different days.

Tricuspid Inflow (long-axis view)

Variable	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
RRp Max	0.281	0.059	0.106
RRp Med	0.142	**0.036** *	0.295
RRp Min	0.281	0.059	**0.036** *
RR Max	0.208	**0.036** *	**0.036** *
RR Med	0.208	**0.036** *	**0.036** *
RR Min	0.281	0.059	**0.036** *
E Max	0.917	0.529	0.529
E Med	0.675	0.201	0.142
E Min	1.000	0.787	0.059
A Max	0.529	0.281	1.000
A Med	0.142	0.345	0.675
A Min	0.178	0.059	1.000
E/A Max	0.834	0.675	1.000
E/A Med	1.000	0.142	0.418
E/A Min	0.281	0.059	1.000
dt Max	1.000	0.208	0.463
dt Med	0.917	0.345	0.529
dt Min	0.150	0.550	0.138
QE Max	0.418	0.106	0.590
QE Med	0.787	0.093	0.281
QE Min	0.584	0.361	0.201
QA Max	0.106	**0.036** *	0.281
QA Med	0.138	**0.036** *	0.059
QA Min	0.201	0.059	0.059

Appendix 14 (Continued). Results of Wilcoxon tests performed on measurements from six horses on three consecutive days. * indicates a significant difference ($p<0.05$) between the measurements obtained on the different days.

Mitral Inflow

Variable	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
RRp Max	0.402	0.059	**0.036** *
RRp Med	0.529	0.059	**0.036** *
RRp Min	0.402	**0.036** *	**0.036** *
RR Max	0.402	**0.036** *	**0.036** *
RR Med	1.000	**0.036** *	**0.036** *
RR Min	0.402	**0.036** *	**0.036** *
E Max	0.834	0.834	1.000
E Med	0.600	0.787	0.529
E Min	0.281	1.000	0.834
A Max	0.345	0.463	0.600
A Med	0.208	0.834	0.463
A Min	0.142	0.345	0.834
E/A Max	0.402	0.529	0.834
E/A Med	0.295	1.000	0.402
E/A Min	0.142	0.834	0.142
dt Max	0.361	0.402	0.600
dt Med	0.208	0.753	0.178
dt Min	0.402	0.675	0.465
QE Max	0.893	0.787	0.834
QE Med	0.839	0.584	0.584
QE Min	0.584	0.100	0.675
QA Max	0.590	0.106	**0.036** *
QA Med	0.584	0.281	0.059
QA Min	1.000	0.059	0.059

Appendix 14 (Continued). Results of Wilcoxon tests performed on measurements from six horses on three consecutive days. * indicates a significant difference ($p<0.05$) between the measurements obtained on the different days.

Pulmonary outflow

Variable	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
RRp Max	0.917	0.402	0.075
RRp Med	1.000	0.418	**0.036** *
RRp Min	1.000	0.600	0.295
RR Max	1.000	0.402	0.295
RR Med	1.000	0.529	0.173
RR Min	1.000	0.675	0.834
VMax Max	0.173	0.106	0.059
VMax Med	0.201	0.463	0.059
VMax Min	0.463	0.418	0.173
dv/dt Max	0.093	0.675	0.529
dv/dt Med	0.529	0.463	0.402
dv/dt Min	0.281	0.402	0.834
dt Max	0.402	0.208	0.715
dt Med	0.753	0.463	0.834
dt Min	0.855	1.000	1.000
VTI Max	0.529	0.208	0.295
VTI Med	0.834	0.834	0.402
VTI Min	0.834	0.675	0.295
PEP Max	0.402	0.208	0.930
PEP Med	0.100	0.423	0.273
PEP Min	0.059	0.500	0.529
EjT Max	0.281	0.402	0.345
EjT Med	0.273	1.000	0.500
EjT Min	1.000	0.593	0.917

Appendix 14 (Continued). Results of Wilcoxon tests performed on measurements from six horses on three consecutive days. * indicates a significant difference ($p<0.05$) between the measurements obtained on the different days.

Aortic outflow

Variable	Day 1 vs Day 2	Day 2 vs Day 3	Day 1 vs Day 3
RRp Max	1.000	0.295	0.590
RRp Med	0.834	0.295	0.590
RRp Min	0.834	0.208	0.142
RR Max	0.675	0.208	0.208
RR Med	0.600	0.208	0.093
RR Min	0.402	0.208	0.093
VMax Max	1.000	0.059	0.178
VMax Med	0.787	0.059	0.208
VMax Min	0.787	0.138	0.173
dv/dt Max	0.787	0.093	**0.036** *
dv/dt Med	0.402	0.208	0.142
dv/dt Min	0.295	0.173	0.295
dt Max	0.402	0.917	0.178
dt Med	1.000	0.715	0.402
dt Min	0.590	0.371	0.787
VTI Max	0.675	0.178	0.281
VTI Med	0.675	0.281	0.281
VTI Min	0.834	0.418	0.281
PEP Max	0.590	0.753	0.273
PEP Med	0.917	0.834	1.000
PEP Min	0.787	0.715	0.855
EjT Max	0.295	0.787	0.787
EjT Med	1.000	0.787	0.715
EjT Min	1.000	0.100	0.500

Appendix 15. Comparison of tricuspid inflow measurements recorded at resting and elevated heart rates using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Tricuspid Inflow Measurements	N	Resting Heart Rate	Elevated Heart Rate	p	
RRp Max	**8**	**1.675**	**1.200**	**0.001**	*
RRp Med	**8**	**1.625**	**1.070**	**0.003**	*
RRp Min	**8**	**1.560**	**1.015**	**0.000**	*
RR Max	**8**	**1.670**	**1.165**	**0.001**	*
RR Med	**8**	**1.625**	**1.050**	**0.000**	*
RR Min	**8**	**1.535**	**1.015**	**0.000**	*
E Max	**8**	**0.795**	**0.995**	**0.015**	*
E Med	**8**	**0.670**	**0.890**	**0.017**	*
E Min	**8**	**0.620**	**0.805**	**0.023**	*
A Max	**8**	**0.560**	**0.810**	**0.002**	*
A Med	**8**	**0.510**	**0.740**	**0.007**	*
A Min	**8**	**0.410**	**0.650**	**0.017**	*
E/A Max	**8**	**1.341**	**1.038**	**0.035**	*
E/A Med	**8**	**1.491**	**1.145**	**0.022**	*
E/A Min	8	1.459	1.185	0.151	
dt Max	**8**	**0.305**	**0.260**	**0.014**	*
dt Med	**8**	**0.235**	**0.200**	**0.021**	*
dt Min	**8**	**0.190**	**0.140**	**0.006**	*
QE Max	8	0.590	0.560	0.072	
QE Med	**8**	**0.570**	**0.535**	**0.044**	*
QE Min	**8**	**0.550**	**0.510**	**0.029**	*
QA Max	**8**	**1.360**	**1.030**	**0.005**	*
QA Med	**8**	**1.290**	**0.900**	**0.002**	*
QA Min	**8**	**1.260**	**0.840**	**0.002**	*

Appendix 16. Comparison of aortic outflow measurements recorded at resting and elevated heart rates using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Aortic Measurements	N	Resting Heart Rate	Elevated Heart Rate	p	
RRp Max	**8**	**1.645**	**1.210**	**0.014**	*
RRp Med	**8**	**1.605**	**1.145**	**0.014**	*
RRp Min	**8**	**1.530**	**1.110**	**0.014**	*
RR Max	**8**	**1.660**	**1.180**	**0.014**	*
RR Med	**8**	**1.600**	**1.135**	**0.014**	*
RR Min	**8**	**1.510**	**1.110**	**0.014**	*
VMax Max	**8**	**0.930**	**1.190**	**0.014**	*
VMax Med	**8**	**0.860**	**1.150**	**0.014**	*
VMax Min	**8**	**0.820**	**1.090**	**0.014**	*
dv/dt Max	**8**	**8.410**	**13.760**	**0.014**	*
dv/dt Med	**8**	**7.645**	**11.070**	**0.014**	*
dv/dt Min	**8**	**6.420**	**9.590**	**0.014**	*
dt Max	8	0.135	0.110	0.151	
dt Med	8	0.120	0.100	0.116	
dt Min	8	0.100	0.090	0.052	
VTI Max	8	27.470	30.800	0.107	
VTI Med	8	24.855	27.940	0.107	
VTI Min	8	24.005	25.160	0.529	
PEP Max	8	0.987	0.085	0.234	
PEP Med	8	0.800	0.065	0.141	
PEP Min	8	0.065	0.040	0.076	
EjT Max	**8**	**0.490**	**0.445**	**0.014**	*
EjT Med	**8**	**0.465**	**0.415**	**0.014**	*
EjT Min	**8**	**0.455**	**0.390**	**0.014**	*

Appendix 16 (continued). Comparison of pulmonary outflow measurements recorded at resting and elevated heart rates using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Pulmonary artery Measurements	N	Resting Heart Rate	Elevated Heart Rate	p	
RRp Max	**6**	**1.705**	**1.240**	**0.036**	*
RRp Med	**6**	**1.420**	**1.150**	**0.036**	*
RRp Min	**6**	**1.480**	**1.070**	**0.036**	*
RR Max	**6**	**1.705**	**1.270**	**0.036**	*
RR Med	**6**	**1.490**	**1.190**	**0.036**	*
RR Min	**6**	**1.495**	**1.135**	**0.036**	*
VMax Max	**6**	**0.945**	**1.080**	**0.036**	*
VMax Med	**6**	**0.855**	**1.035**	**0.036**	*
VMax Min	**6**	**0.795**	**0.980**	**0.036**	*
dv/dt Max	**6**	**4.715**	**6.355**	**0.036**	*
dv/dt Med	6	4.165	5.565	0.059	
dv/dt Min	6	3.735	5.075	0.059	
dt Max	6	0.230	0.205	0.295	
dt Med	6	0.200	0.185	0.138	
dt Min	6	0.195	0.170	0.093	
VTI Max	6	27.440	28.51	0.208	
VTI Med	6	25.440	26.42	0.402	
VTI Min	6	23.550	25.06	0.839	
PEP Max	6	0.080	0.070	0.208	
PEP Med	6	0.060	0.070	0.402	
PEP Min	6	0.055	0.450	0.173	
EjT Max	6	0.500	0.470	0.059	
EjT Med	**6**	**0.480**	**0.455**	**0.036**	*
EjT Min	**6**	**0.470**	**0.445**	**0.036**	*

Appendix 17. Comparison of tricuspid inflow long-axis measurements before and immediately following second degree atrioventricular block using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$.
N = number of horses studied. Median values of each variable are given.

Tricuspid Inflow Measurements	N	Post block beats	Preceding beats	p value	
RRp Max	**6**	**3.395**	**1.475**	**0.036**	*
RRp Med	**6**	**3.000**	**1.375**	**0.036**	*
RRp Min	**6**	**2.950**	**1.340**	**0.036**	*
RR Max	6	1.445	3.375	0.059	
RR Med	6	1.395	1.740	0.834	
RR Min	6	1.360	1.290	0.834	
E Max	**6**	**0.840**	**0.745**	**0.036**	*
E Med	6	0.770	0.670	0.059	
E Min	6	0.725	0.625	0.093	
A Max	6	0.700	0.610	0.402	
A Med	6	0.625	0.540	0.402	
A Min	6	0.495	0.490	0.402	
E/A Max	6	1.054	1.105	0.208	
E/A Med	6	1.068	1.109	0.295	
E/A Min	6	1.168	1.162	0.834	
dt Max	6	0.230	0.270	0.249	
dt Med	6	0.220	0.200	1.000	
dt Min	6	0.210	0.160	0.273	
QE Max	6	0.585	0.595	0.584	
QE Med	6	0.565	0.575	0.059	
QE Min	6	0.550	0.570	0.100	
QA Max	6	1.140	1.185	0.402	
QA Med	**6**	**1.115**	**1.135**	**0.036**	*
QA Min	6	1.090	1.115	1.000	

Appendix 17 (continued). Comparison of mitral inflow measurements before and immediately following second degree atrioventricular block using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Mitral Inflow Measurements	N	Post block beats	Preceding beats	p value	
RRp Max	**8**	**3.595**	**1.760**	**0.036**	*
RRp Med	**8**	**3.585**	**1.725**	**0.036**	*
RRp Min	**8**	**3.550**	**1.660**	**0.036**	*
RR Max	**8**	**1.700**	**3.010**	**0.036**	*
RR Med	8	1.640	1.730	0.093	
RR Min	8	1.635	1.710	0.142	
E Max	8	0.640	0.750	0.281	
E Med	8	0.570	0.685	0.402	
E Min	8	0.510	0.585	0.418	
A Max	8	0.380	0.410	0.893	
A Med	8	0.365	0.360	0.142	
A Min	8	0.300	0.310	0.529	
E/A Max	8	1.453	1.691	0.295	
E/A Med	8	1.740	2.027	0.183	
E/A Min	8	1.367	2.017	0.059	
dt Max	8	0.225	0.255	0.402	
dt Med	8	0.175	0.225	0.173	
dt Min	8	0.170	0.190	0.295	
QE Max	8	0.630	0.640	1.000	
QE Med	8	0.620	0.620	0.834	
QE Min	8	0.590	0.600	1.000	
QA Max	8	1.435	1.495	0.106	
QA Med	8	1.420	1.460	0.142	
QA Min	8	1.385	1.385	0.834	

Appendix 18. Comparison of aortic outflow measurements before and immediately following second degree atrioventricular block using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Aortic Measurements	N	Post block beats	Preceding beats	p	
RRp Max	**7**	**4.110**	**1.960**	**0.022**	*
RRp Med	**7**	**3.840**	**1.710**	**0.022**	*
RRp Min	**7**	**3.610**	**1.650**	**0.022**	*
RR Max	**7**	**1.760**	**3.110**	**0.022**	*
RR Med	7	1.690	2.100	0.076	
RR Min	7	1.680	1.650	0.800	
VMax Max	**7**	**1.000**	**0.950**	**0.035**	*
VMax Med	**7**	**0.930**	**0.860**	**0.035**	*
VMax Min	**7**	**0.910**	**0.790**	**0.036**	*
dv/dt Max	7	11.590	9.080	0.076	
dv/dt Med	7	8.250	7.520	0.205	
dv/dt Min	7	7.355	6.560	0.093	
dt Max	7	0.130	0.140	1.000	
dt Med	7	0.110	0.110	0.855	
dt Min	7	0.090	0.100	0.600	
VTI Max	7	26.010	24.410	0.076	
VTI Med	**7**	**25.170**	**22.520**	**0.022**	*
VTI Min	**7**	**22.760**	**22.130**	**0.036**	*
PEP Max	7	0.080	0.110	0.075	
PEP Med	7	0.060	0.090	0.075	
PEP Min	7	0.065	0.070	0.787	
EjT Max	7	0.500	0.490	0.787	
EjT Med	7	0.490	0.450	0.789	
EjT Min	7	0.460	0.440	0.787	

Appendix 18 (continued). Comparison of pulmonary outflow measurements before and immediately following second degree atrioventricular block using a Wilcoxon test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied. Median values of each variable are given.

Pulmonary artery Measurements	N	Post block beats	Preceding beats	p	
RRp Max	**8**	**3.700**	**1.605**	**0.014**	*
RRp Med	**8**	**3.610**	**1.545**	**0.014**	*
RRp Min	**8**	**3.400**	**1.450**	**0.014**	*
RR Max	**8**	**1.530**	**3.660**	**0.021**	*
RR Med	**8**	**1.520**	**1.700**	**0.030**	*
RR Min	8	1.495	1.520	0.091	
VMax Max	8	1.010	0.915	0.069	
VMax Med	8	0.960	0.855	0.363	
VMax Min	8	0.860	0.820	0.363	
dv/dt Max	8	3.320	4.705	0.726	
dv/dt Med	8	3.230	4.145	0.529	
dv/dt Min	8	2.295	3.690	0.944	
dt Max	8	0.290	0.225	0.554	
dt Med	8	0.260	0.210	1.000	
dt Min	**8**	**0.245**	**0.185**	**0.043**	*
VTI Max	8	23.76	26.780	0.234	
VTI Med	8	21.68	24.960	0.234	
VTI Min	8	21.03	22.650	0.529	
PEP Max	8	0.050	0.0671	0.076	
PEP Med	8	0.040	0.0543	0.272	
PEP Min	8	0.040	0.0329	0.787	
EjT Max	8	0.530	0.5288	1.000	
EjT Med	8	0.500	0.5037	0.866	
EjT Min	8	0.495	0.4787	0.735	

Appendix 19. Median, maximum and minimum values for median measurements from normal horses (C) and horses with cardiac murmurs (groups 1-5). Results from groups 1-5 were compared with the normal group (C) using a Mann-Whitney test. Differences were considered significant (*) when $p<0.05$. N = number of horses studied.

Tricuspid inflow

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RRp Max	C	40	1.670	2.63	1.27	-	
	1	8	1.740	2.23	1.43	0.5108	
	2	8	1.730	1.96	1.31	0.5427	
	3	8	1.885	2.13	1.34	0.1665	
	4	7	1.660	2.13	1.34	0.5108	
	5	8	1.590	1.84	1.51	0.7190	
RRp Med	C	40	1.610	2.49	1.24	-	
	1	8	1.600	2.15	1.35	0.1000	
	2	8	1.700	1.96	1.27	0.3833	
	3	8	1.815	1.96	1.27	0.1795	
	4	7	1.64	1.81	1.27	0.7086	
	5	8	1.575	1.80	1.47	0.8248	
RRp Min	C	40	1.565	2.35	1.20	-	
	1	8	1.590	2.13	1.30	0.9285	
	2	8	1.675	1.84	1.15	0.3326	
	3	8	1.745	1.84	1.23	0.2866	
	4	7	1.63	1.73	1.15	0.8110	
	5	8	1.550	1.77	1.47	0.9890	
RR Max	C	40	1.665	4.27	1.30	-	
	1	7	1.810	3.71	1.50	0.0856	
	2	**8**	**1.840**	**3.04**	**1.57**	**0.0342**	*
	3	**8**	**1.955**	**4.40**	**1.76**	**0.0080**	*
	4	7	1.750	3.04	1.35	0.3313	
	5	8	1.640	1.84	1.52	0.8790	
RR Med	C	40	1.600	4.14	1.25	-	
	1	7	1.690	2.15	1.40	0.5012	
	2	8	1.750	1.95	1.31	0.2233	
	3	8	1.805	2.00	1.45	0.1085	
	4	7	1.700	1.95	1.31	0.9881	
	5	8	1.575	1.81	1.50	0.9228	
RR Min	C	40	1.560	4.05	1.17	-	
	1	7	1.560	2.10	1.20	0.4548	
	2	8	1.715	1.90	1.19	0.1979	
	3	8	1.745	1.82	1.23	0.5704	
	4	7	1.650	1.90	1.19	0.9166	
	5	8	1.555	1.78	1.42	1.0000	

Appendix 19 (continued). Tricuspid inflow (long-axis view).

Variable	GROUP	N	MEDIAN	MAX	MIN	p
E Max	C	40	0.715	1.01	0.51	-
	1	7	0.610	0.93	0.40	0.2747
	2	8	0.750	0.84	0.57	0.9338
	3	8	0.675	0.74	0.57	0.1141
	4	7	0.760	0.84	0.51	0.7647
	5	8	0.720	0.77	0.48	0.3391
E Med	C	40	0.615	0.87	0.44	-
	1	7	0.570	0.82	0.36	0.3460
	2	8	0.630	0.75	0.54	0.8462
	3	8	0.565	0.69	0.53	0.1208
	4	7	0.630	0.75	0.47	0.5697
	5	8	0.635	0.87	0.44	0.8462
E Min	C	40	0.570	0.78	0.43	-
	1	7	0.560	0.74	0.36	0.7762
	2	8	0.530	0.72	0.48	0.5422
	3	8	0.510	0.62	0.46	0.1207
	4	7	0.530	0.72	0.36	0.3856
	5	8	0.550	0.78	0.44	1.0000
A Max	C	40	0.580	0.86	0.32	-
	1	7	0.560	0.65	0.46	0.2815
	2	8	0.670	0.77	0.37	0.8032
	3	8	0.680	0.82	0.33	0.2563
	4	7	0.510	0.77	0.37	0.5699
	5	8	0.720	0.80	0.44	1.0000
A Med	C	40	0.530	0.79	0.25	-
	1	7	0.490	0.55	0.32	0.2091
	2	8	0.520	0.69	0.28	0.9338
	3	8	0.530	0.67	0.30	0.9779
	4	7	0.490	0.69	0.34	0.7994
	5	8	0.530	0.70	0.31	1.0000
A Min	C	40	0.480	0.72	0.25	-
	1	7	0.390	0.51	0.32	0.1509
	2	8	0.430	0.55	0.28	0.6878
	3	8	0.435	0.63	0.24	0.5987
	4	7	0.430	0.55	0.28	0.7195
	5	8	0.480	0.62	0.31	0.8572
E/A Max	C	40	1.244	3.16	0.77	-
	1	7	1.261	1.66	0.70	0.8930
	2	8	1.112	1.65	0.87	1.0000
	3	8	1.053	1.85	0.75	0.1117
	4	7	1.143	1.65	0.87	0.8111
	5	8	1.147	1.75	0.67	0.7295
E/A Med	C	40	1.184	3.19	0.76	-
	1	7	1.218	1.86	0.71	0.8460
	2	8	1.203	1.62	0.91	0.8356
	3	8	1.165	1.83	0.81	0.6283
	4	7	1.200	1.62	0.91	0.6404
	5	8	1.239	2.23	0.63	0.8573

Appendix 19 (continued). Tricuspid inflow (long-axis view).

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
E/A Min	C	40	1.216	3.12	0.78	-	
	1	7	1.383	2.00	0.72	0.3944	
	2	8	1.151	1.89	0.98	0.9449	
	3	8	1.183	2.12	0.76	0.7295	
	4	7	1.057	1.89	0.90	0.7311	
	5	8	1.283	2.25	0.71	0.9449	
dt Max	C	40	0.290	0.37	0.23	-	
	1	8	0.350	0.44	0.19	0.0847	
	2	8	0.290	0.39	0.26	0.2546	
	3	8	0.275	0.37	0.20	0.8677	
	4	7	0.290	0.39	0.29	0.3216	
	5	8	0.270	0.46	0.22	0.3525	
dt Med	C	40	0.230	0.34	0.16	-	
	1	8	0.240	0.37	0.15	0.5686	
	2	8	0.220	0.37	0.20	0.4362	
	3	8	0.205	0.29	0.17	0.2104	
	4	7	0.250	0.37	0.21	0.2072	
	5	8	0.230	0.40	0.18	0.7808	
dt Min	C	40	0.190	0.32	0.11	-	
	1	8	0.220	0.32	0.11	0.5192	
	2	8	0.195	0.34	0.13	0.3968	
	3	8	0.190	0.24	0.15	0.9889	
	4	7	0.200	0.34	0.13	0.3297	
	5	8	0.185	0.37	0.16	0.5692	
QE Max	C	40	0.590	0.77	0.51	-	
	1	7	0.610	0.80	0.53	0.5490	
	2	**8**	**0.615**	**0.77**	**0.59**	**0.0428**	*
	3	8	0.600	0.67	0.56	0.4371	
	4	**7**	**0.610**	**0.77**	**0.59**	**0.0415**	*
	5	**8**	**0.650**	**0.80**	**0.57**	**0.0210**	*
QE Med	C	40	0.560	0.67	0.46	-	
	1	7	0.570	0.74	0.51	0.7757	
	2	**8**	**0.595**	**0.71**	**0.56**	**0.0470**	*
	3	8	0.580	0.63	0.50	0.6075	
	4	**7**	**0.600**	**0.71**	**0.56**	**0.0444**	*
	5	8	0.590	0.70	0.55	0.1415	
QE Min	C	40	0.550	0.62	0.43	-	
	1	7	0.560	0.70	0.49	0.6638	
	2	8	0.565	0.67	0.52	0.1038	
	3	8	0.555	0.62	0.50	0.4367	
	4	7	0.580	0.67	0.52	0.0899	
	5	8	0.570	0.68	0.52	0.1189	
QA Max	C	40	1.385	2.32	1.05	-	
	1	7	1.380	2.07	1.17	0.9048	
	2	8	1.495	1.76	1.04	0.3832	
	3	8	1.515	1.76	1.04	0.2865	
	4	8	1.420	1.66	1.18	0.9761	
	5	8	1.390	1.53	1.22	0.8342	

Appendix 19 (continued). Tricuspid inflow (long-axis).

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
QA Med	C	40	1.310	2.29	0.96	-	
	1	7	1.350	1.98	1.11	0.8226	
	2	8	1.455	1.64	0.99	0.3258	
	3	8	1.470	1.66	0.98	0.4222	
	4	8	1.400	1.64	0.99	0.8459	
	5	8	1.310	1.49	1.14	0.9285	
QA Min	C	40	1.295	2.00	0.94	-	
	1	7	1.240	1.95	1.10	0.6647	
	2	8	1.385	1.63	0.90	0.3060	
	3	8	1.365	1.52	0.91	0.5895	
	4	8	1.370	1.63	0.90	0.8460	
	5	8	1.280	1.43	1.11	0.7650	

Mitral inflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RRp Max	C	40	1.660	2.70	1.10	-	
	1	6	1.800	2.11	1.42	0.2850	
	2	8	1.665	2.57	1.28	0.6504	
	3	7	1.905	2.13	1.32	0.1415	
	4	8	1.665	2.57	1.28	1.0000	
	5	6	1.560	1.82	1.31	0.3645	
RRp Med	C	40	1.640	2.30	1.08	-	
	1	6	1.775	2.06	1.41	0.3004	
	2	8	1.645	2.28	1.23	0.6004	
	3	7	1.830	2.12	1.26	0.4536	
	4	8	1.635	2.28	1.23	0.9774	
	5	6	1.485	1.80	1.25	0.2777	
RRp Min	C	40	1.630	2.23	1.06	-	
	1	6	1.695	1.98	1.40	0.3083	
	2	8	1.625	2.03	1.19	0.6108	
	3	7	1.750	2.06	1.23	0.2632	
	4	8	1.620	2.03	1.23	0.9323	
	5	6	1.490	1.79	1.12	0.4707	
RR Max	C	40	1.660	4.20	1.10	-	
	1	**7**	**1.920**	**3.51**	**1.40**	**0.0280**	*
	2	8	1.780	3.06	1.44	0.2079	
	3	7	1.980	2.54	1.45	0.0638	
	4	8	1.755	3.06	1.34	0.4466	
	5	6	1.510	1.82	1.25	0.2602	
RR Med	C	40	1.625	4.16	1.06	-	
	1	7	1.716	2.06	1.35	0.3943	
	2	8	1.696	2.28	1.28	0.5612	
	3	7	1.810	2.12	1.30	0.4196	
	4	8	1.635	2.28	1.28	0.9559	
	5	6	1.460	1.80	1.23	0.2816	

Appendix 19 (continued). Mitral inflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RR Min	C	40	1.610	3.98	1.10	-	
	1	7	1.630	1.98	1.31	0.5700	
	2	8	1.620	2.12	1.23	0.5519	
	3	7	1.750	2.06	1.24	0.2337	
	4	8	1.615	2.12	1.23	0.8790	
	5	6	1.430	1.77	1.12	0.3524	
E Max	C	40	0.765	1.12	0.41	-	
	1	7	0.740	1.18	0.56	0.9285	
	2	8	0.680	0.80	0.55	0.1146	
	3	7	0.760	0.87	0.62	0.9048	
	4	**8**	**0.650**	**0.80**	**0.42**	**0.0419**	*
	5	6	0.680	0.90	0.56	0.3780	
E Med	C	40	0.690	1.12	0.41	-	
	1	7	0.630	1.12	0.52	0.8810	
	2	8	0.585	0.75	0.54	0.0557	
	3	7	0.690	0.79	0.49	0.8810	
	4	**8**	**0.560**	**0.75**	**0.39**	**0.0305**	*
	5	6	0.620	0.86	0.41	0.1415	
E Min	C	40	0.600	0.88	0.33	-	
	1	7	0.590	1.01	0.46	0.8693	
	2	8	0.550	0.64	0.41	0.0762	
	3	7	0.640	0.76	0.47	0.8108	
	4	**8**	**0.535**	**0.65**	**0.37**	**0.0492**	*
	5	6	0.560	0.79	0.41	0.2397	
A Max	C	40	0.470	0.71	0.27	-	
	1	7	0.460	0.76	0.27	0.7086	
	2	8	0.440	0.52	0.37	0.3057	
	3	7	0.390	0.56	0.33	0.1785	
	4	8	0.395	0.52	0.31	0.1115	
	5	6	0.435	0.50	0.37	0.3780	
A Med	C	40	0.405	0.63	0.24	-	
	1	7	0.370	0.53	0.23	0.7306	
	2	8	0.365	0.46	0.35	0.2859	
	3	7	0.350	0.48	0.30	0.0938	
	4	8	0.360	0.46	0.30	0.1702	
	5	6	0.380	0.63	0.28	0.2396	
A Min	C	40	0.345	0.59	0.20	-	
	1	7	0.330	0.49	0.20	0.9642	
	2	8	0.340	0.43	0.29	0.7605	
	3	7	0.290	0.39	0.24	0.1507	
	4	8	0.335	0.43	0.27	0.4973	
	5	6	0.345	0.37	0.26	0.7193	
E/A Max	C	40	1.506	3.41	0.80	-	
	1	7	1.609	2.93	1.08	0.8695	
	2	8	1.567	1.85	1.10	0.9890	
	3	8	1.838	2.24	1.39	0.2150	
	4	7	1.544	2.29	1.10	0.9009	
	5	8	1.628	1.96	1.37	0.7076	

Appendix 19 (continued). Mitral inflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p
E/A Med	C	40	1.616	3.56	0.95	-
	1	7	1.750	3.30	1.43	0.6115
	2	8	1.671	1.92	1.74	0.8141
	3	8	1.917	2.44	1.54	0.2500
	4	7	1.558	2.30	1.17	0.6580
	5	8	1.753	2.05	0.95	0.6479
E/A Min	C	40	1.795	3.39	0.89	-
	1	7	1.714	3.50	1.39	0.7995
	2	8	1.672	1.90	1.21	0.3686
	3	8	1.958	2.59	1.82	0.2320
	4	7	1.503	2.41	1.21	0.3193
	5	8	1.772	2.13	1.14	0.6362
dt Max	C	37	0.240	0.34	0.15	-
	1	7	0.270	0.32	0.21	0.1662
	2	8	0.215	0.32	0.18	0.4385
	3	7	0.220	0.26	0.19	0.2207
	4	8	0.235	0.32	0.18	0.9762
	5	5	0.260	0.30	0.16	-
dt Med	C	37	0.210	0.27	0.14	-
	1	7	0.230	0.25	0.17	0.7465
	2	8	0.200	0.25	0.14	0.2095
	3	7	0.210	0.23	0.19	0.0617
	4	8	0.205	0.26	0.14	0.5301
	5	5	0.230	0.29	0.14	-
dt Min	C	37	0.190	0.26	0.10	-
	1	7	0.190	0.23	0.17	0.6403
	2	8	0.170	0.25	0.14	0.4841
	3	7	0.190	0.22	0.17	0.8090
	4	8	0.170	0.25	0.14	0.4213
	5	5	0.170	0.28	0.13	-
QE Max	C	37	0.620	0.90	0.54	-
	1	7	0.620	0.65	0.57	0.7229
	2	8	0.645	0.69	0.57	0.1799
	3	7	0.610	0.65	0.57	0.4588
	4	8	0.655	0.69	0.57	0.2055
	5	5	0.580	0.67	0.54	-
QE Med	C	37	0.610	0.89	0.52	-
	1	7	0.600	0.64	0.55	0.8465
	2	8	0.630	0.67	0.54	0.1994
	3	7	0.590	0.64	0.56	0.7470
	4	8	0.625	0.67	0.54	0.2893
	5	5	0.540	0.63	0.49	-
QE Min	C	37	0.580	0.86	0.50	-
	1	7	0.570	0.62	0.55	0.8091
	2	8	0.610	0.67	0.52	0.1041
	3	7	0.590	0.63	0.54	0.9615
	4	8	0.610	0.67	0.52	0.1566
	5	5	0.520	0.62	0.48	-

Appendix 19 (continued). Mitral inflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
QA Max	C	37	1.480	2.45	0.96	-	
	1	7	1.450	2.02	1.17	0.7360	
	2	8	1.495	2.23	1.29	0.6136	
	3	7	1.500	1.83	1.04	1.0000	
	4	8	1.470	2.23	1.17	0.7104	
	5	5	1.235	1.57	1.11	-	
QA Med	C	37	1.450	2.23	0.92	-	
	1	7	1.420	1.91	1.14	0.9360	
	2	8	1.440	1.94	1.07	0.9882	
	3	7	1.450	1.78	1.00	0.9616	
	4	8	1.430	1.94	1.07	1.0000	
	5	5	1.200	1.55	0.99	-	
QA Min	C	37	1.420	1.99	0.89	-	
	1	7	1.370	1.81	1.12	1.0000	
	2	8	1.415	1.84	1.02	0.8703	
	3	7	1.380	1.73	0.94	1.0000	
	4	8	1.405	1.84	1.02	0.8703	
	5	5	1.095	1.54	0.93	-	

Pulmonary outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RRp Max	C	40	1.730	2.94	1.32	-	
	1	7	1.690	2.10	1.43	0.9523	
	2	8	1.765	1.95	1.22	0.6983	
	3	8	1.875	2.18	1.28	0.2804	
	4	8	1.695	2.10	1.22	0.7398	
	5	8	1.670	1.78	1.55	0.3698	
RRp Med	C	40	1.730	2.53	1.31	-	
	1	7	1.690	2.05	1.42	0.9048	
	2	8	1.765	1.88	1.16	0.7714	
	3	8	1.835	2.01	1.22	0.3328	
	4	8	1.625	2.09	1.16	0.7820	
	5	8	1.485	1.74	1.24	0.3397	
RRp Min	C	40	1.590	2.32	1.31	-	
	1	7	1.580	1.97	1.35	0.6865	
	2	8	1.685	1.81	1.13	0.8033	
	3	8	1.745	1.95	1.18	0.6087	
	4	8	1.605	2.02	1.13	0.7190	
	5	8	1.580	1.70	1.51	0.6324	
RR Max	C	40	1.730	5.07	1.32	-	
	1	**7**	**2.880**	**3.68**	**1.67**	**0.0131**	*
	2	8	1.730	1.95	1.23	0.8681	
	3	**8**	**1.955**	**4.47**	**1.71**	**0.0040**	*
	4	8	1.680	2.10	1.23	0.5895	
	5	8	1.670	1.81	1.55	0.4370	

Appendix 19 (continued). Pulmonary outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RR Med	C	40	1.680	4.09	1.31	-	
	1	7	1.680	2.10	1.43	0.9642	
	2	8	1.705	1.89	1.15	0.7926	
	3	**8**	**1.875**	**4.03**	**1.42**	**0.0479**	*
	4	8	1.655	2.09	1.15	0.7608	
	5	8	1.460	1.74	1.54	0.6086	
RR Min	C	40	1.585	3.94	1.31	-	
	1	7	1.650	1.97	1.35	0.9642	
	2	8	1.690	1.81	1.08	0.6780	
	3	8	1.735	1.96	1.22	0.5799	
	4	8	1.610	2.02	1.08	0.9118	
	5	8	1.460	1.73	1.46	0.7764	
VMax Max	C	40	0.970	1.11	0.81	-	
	1	7	0.920	1.05	0.76	0.7762	
	2	8	0.900	1.12	0.77	0.5890	
	3	8	0.875	1.04	0.77	0.0909	
	4	8	0.900	1.12	0.70	0.7500	
	5	8	0.900	1.08	0.74	0.3019	
VMax Med	C	40	0.910	1.04	0.78	-	
	1	7	0.850	0.98	0.74	0.6106	
	2	8	0.845	1.06	0.76	0.3903	
	3	8	0.830	1.01	0.74	0.1341	
	4	8	0.845	1.06	0.69	0.5060	
	5	8	0.855	1.06	0.71	0.2500	
VMax Min	C	40	0.880	1.01	0.73	-	
	1	7	0.810	0.94	0.70	0.1732	
	2	8	0.790	1.01	0.76	0.2073	
	3	8	0.790	0.93	0.72	0.1142	
	4	8	0.800	1.01	0.60	0.2228	
	5	8	0.820	1.03	0.70	0.2950	
dv/dt Max	C	40	4.820	8.51	3.40	-	
	1	7	4.820	6.60	3.20	1.0000	
	2	8	4.855	5.51	3.57	0.7295	
	3	8	4.660	6.03	3.44	0.1316	
	4	8	4.640	5.51	3.29	0.4304	
	5	8	5.290	6.35	3.61	0.5601	
dv/dt Med	C	40	4.453	6.71	2.99	-	
	1	7	4.421	5.68	3.15	0.9762	
	2	8	4.199	4.88	3.24	0.9762	
	3	8	3.760	5.11	2.71	0.1502	
	4	8	4.020	4.88	3.14	0.2081	
	5	8	4.453	4.98	3.31	0.9339	
dv/dt Min	C	40	3.870	6.31	2.89	-	
	1	7	4.170	4.62	2.58	0.9523	
	2	8	3.895	4.30	2.82	0.4223	
	3	8	3.205	4.79	2.52	0.1582	
	4	8	3.805	4.30	2.88	0.1734	
	5	8	3.760	4.74	2.89	0.6219	

Appendix 19 (continued). Pulmonary outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p
dt Max	C	40	0.235	0.29	0.16	-
	1	7	0.220	0.29	0.19	0.7177
	2	8	0.220	0.33	0.19	0.9555
	3	8	0.255	0.34	0.19	0.3155
	4	8	0.230	0.33	0.21	0.8889
	5	8	0.230	0.28	0.20	1.0000
dt Med	C	40	0.208	0.27	0.16	-
	1	7	0.204	0.27	0.17	0.5180
	2	8	0.211	0.29	0.17	0.9002
	3	8	0.225	0.32	0.17	0.2533
	4	8	0.200	0.29	0.17	0.8892
	5	8	0.203	0.24	0.17	0.5964
dt Min	C	40	0.185	0.25	0.13	-
	1	7	0.160	0.25	0.15	0.6735
	2	8	0.175	0.24	0.14	0.9889
	3	8	0.195	0.24	0.16	0.4948
	4	8	0.185	0.24	0.14	0.9889
	5	8	0.180	0.22	0.13	0.3744
VTI Max	C	40	27.130	37.58	22.26	-
	1	7	26.080	31.27	21.89	0.5109
	2	8	25.915	31.32	23.04	0.2995
	3	8	25.910	31.52	23.04	0.3988
	4	8	26.300	31.32	17.91	0.5520
	5	8	27.020	29.32	22.16	0.4461
VTI Med	C	40	25.740	36.71	20.37	-
	1	7	25.230	29.90	21.35	0.8460
	2	8	24.805	29.59	22.31	0.3126
	3	8	24.685	28.41	22.31	0.7088
	4	8	24.970	29.59	17.01	0.5520
	5	8	25.066	27.43	20.13	0.3835
VTI Min	C	40	24.315	33.93	19.54	-
	1	7	23.870	27.52	18.97	0.5402
	2	8	23.170	28.11	20.99	0.2868
	3	8	23.675	25.93	18.99	0.3835
	4	8	23.900	28.11	16.54	0.4468
	5	8	23.160	26.17	18.98	0.2754
PEP Max	C	40	0.070	0.12	0.04	-
	1	7	0.060	0.09	0.05	0.3388
	2	8	0.080	0.12	0.05	0.2572
	3	6	0.075	0.11	0.07	0.2820
	4	8	0.075	0.16	0.05	0.5476
	5	5	0.080	0.12	0.08	0.0798
PEP Med	C	40	0.061	0.10	0.02	-
	1	7	0.053	0.06	0.04	0.1649
	2	8	0.069	0.09	0.05	0.2846
	3	6	0.065	0.08	0.05	0.4847
	4	8	0.065	0.14	0.05	0.3384
	5	5	0.071	0.11	0.06	0.2113

Appendix 19 (continued). Pulmonary outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p
PEP Min	C	40	0.050	0.09	0.01	-
	1	7	0.040	0.06	0.03	0.2378
	2	8	0.050	0.08	0.03	0.8987
	3	6	0.055	0.07	0.04	0.3230
	4	8	0.045	0.12	0.03	0.9438
	5	5	0.050	0.07	0.03	0.9330
EjT Max	C	40	0.520	0.60	0.46	-
	1	7	0.520	0.55	0.48	0.8094
	2	7	0.520	0.55	0.50	0.6730
	3	7	0.530	0.57	0.50	0.2058
	4	8	0.525	0.55	0.48	0.8125
	5	7	0.515	0.53	0.44	0.4891
EjT Med	C	40	0.501	0.58	0.45	-
	1	7	0.500	0.53	0.45	0.6947
	2	7	0.500	0.52	0.47	0.8918
	3	7	0.510	0.56	0.48	0.1789
	4	8	0.510	0.52	0.41	0.9220
	5	7	0.479	0.53	0.42	0.2001
EjT Min	C	40	0.470	0.55	0.43	-
	1	7	0.490	0.51	0.42	0.8681
	2	7	0.490	0.50	0.45	0.8677
	3	7	0.500	0.54	0.45	0.4756
	4	8	0.490	0.51	0.39	0.9219
	5	7	0.455	0.50	0.40	0.1283
Aortic outflow.						
RRp Max	C	40	1.670	3.16	1.31	-
	1	6	1.730	2.11	1.38	0.8342
	2	8	1.730	2.20	1.31	0.4063
	3	7	1.820	2.10	1.43	0.1664
	4	8	1.665	2.21	1.21	0.8463
	5	6	1.630	1.98	1.38	0.6477
RRp Med	C	40	1.600	2.08	1.30	-
	1	6	1.670	2.04	1.37	0.6281
	2	8	1.700	1.98	1.21	0.3259
	3	7	1.725	1.84	1.30	0.4633
	4	8	1.640	1.98	1.21	1.0000
	5	6	1.610	1.86	1.37	0.9091
RRp Min	C	40	1.550	1.27	2.03	-
	1	6	1.660	1.34	1.99	0.5905
	2	8	1.665	1.18	1.96	0.2233
	3	7	1.660	1.81	1.21	0.5799
	4	8	1.545	1.96	1.00	0.6380
	5	6	1.570	1.27	1.80	0.9220

Appendix 19 (continued). Aortic outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
RR Max	C	40	1.675	4.26	1.31	-	
	1	7	1.750	3.00	1.41	0.2688	
	2	8	1.815	3.11	1.62	0.0721	
	3	**7**	**1.860**	**4.61**	**1.48**	**0.0128**	*
	4	8	1.735	3.11	1.39	0.3059	
	5	7	1.690	1.89	1.39	0.9642	
RR Med	C	40	1.610	4.17	1.06	-	
	1	7	1.715	2.97	1.35	0.1541	
	2	8	1.705	2.10	1.28	0.2624	
	3	7	1.765	2.10	1.30	0.2508	
	4	8	1.635	2.10	1.21	0.8790	
	5	7	1.630	1.85	1.23	0.7650	
RR Min	C	40	1.540	2.12	1.27	-	
	1	7	1.680	2.04	1.34	0.4730	
	2	8	1.670	1.96	1.18	0.2682	
	3	7	1.660	1.83	1.21	0.6379	
	4	8	1.530	1.96	1.02	0.6579	
	5	7	1.580	2.12	1.22	1.0000	
VMax Max	C	40	0.985	1.16	0.79	-	
	1	7	0.930	1.21	0.79	0.2618	
	2	8	0.900	1.19	0.81	0.3055	
	3	7	0.945	1.15	0.84	0.3830	
	4	8	0.880	1.19	0.81	0.3255	
	5	**7**	**1.190**	**1.42**	**0.87**	**0.0078**	*
VMax Med	C	40	0.935	1.15	0.78	-	
	1	7	0.890	1.11	0.76	0.2447	
	2	8	0.850	1.18	0.76	0.3536	
	3	7	0.905	0.97	0.82	0.2740	
	4	8	0.820	1.18	0.74	0.3325	
	5	**7**	**1.100**	**1.28**	**0.86**	**0.0068**	*
VMax Min	C	40	0.885	1.10	0.72	-	
	1	7	0.850	1.08	0.70	0.4219	
	2	8	0.815	1.09	0.72	0.3830	
	3	7	0.860	0.89	0.75	0.1347	
	4	8	0.770	1.09	0.72	0.3534	
	5	**7**	**1.070**	**1.23**	**0.84**	**0.0035**	*
dv/dt Max	C	40	9.090	13.16	5.32	-	
	1	7	10.69	14.92	6.25	0.2031	
	2	8	9.640	14.60	7.68	0.4719	
	3	7	8.755	9.87	7.56	0.3988	
	4	8	9.640	16.82	7.68	0.2567	
	5	**7**	**11.360**	**22.95**	**7.55**	**0.0206**	*

Appendix 19 (continued). Aortic outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
dv/dt Med	C	40	7.850	10.83	5.19	-	
	1	7	8.340	10.03	5.40	0.9559	
	2	8	8.070	13.22	7.44	0.2868	
	3	7	7.375	9.23	5.87	0.2995	
	4	8	8.260	13.22	6.52	0.4144	
	5	**7**	**9.390**	**12.27**	**6.41**	**0.0241**	*
dv/dt Min	C	40	7.155	9.81	4.66	-	
	1	7	7.055	9.71	4.92	0.8573	
	2	8	7.735	10.88	6.35	0.0528	
	3	7	6.655	8.48	5.27	0.5706	
	4	8	7.360	10.88	5.96	0.2684	
	5	7	7.910	10.66	6.14	0.0942	
dt Max	C	40	0.130	0.21	0.10	-	
	1	7	0.140	0.17	0.10	0.8780	
	2	**8**	**0.115**	**0.14**	**0.09**	**0.0188**	*
	3	7	0.130	0.18	0.11	0.7261	
	4	7	0.120	0.17	0.09	0.2521	
	5	7	0.130	0.16	0.10	0.9278	
dt Med	C	40	0.120	0.17	0.09	-	
	1	7	0.115	0.14	0.09	0.6134	
	2	8	0.110	0.12	0.08	0.0935	
	3	7	0.120	0.15	0.10	0.9776	
	4	7	0.110	0.12	0.08	0.1511	
	5	7	0.100	0.15	0.09	0.2823	
dt Min	C	40	0.100	0.16	0.08	-	
	1	**7**	**0.090**	**0.13**	**0.07**	**0.0357**	*
	2	8	0.100	0.11	0.08	0.3722	
	3	7	0.100	0.14	0.09	1.0000	
	4	7	0.100	0.11	0.06	0.2647	
	5	7	0.090	0.12	0.05	0.1968	
VTI Max	C	40	27.335	35.61	22.76	-	
	1	7	25.580	30.98	20.87	0.1666	
	2	8	25.140	33.42	22.88	0.3835	
	3	8	25.275	29.16	23.16	0.1624	
	4	8	25.140	17.06	17.06	0.2509	
	5	**7**	**30.600**	**37.42**	**24.08**	**0.0241**	*
VTI Med	C	40	24.850	32.90	20.61	-	
	1	7	24.720	30.20	19.42	0.6681	
	2	8	24.220	30.51	20.97	0.6580	
	3	8	23.785	27.54	20.21	0.3613	
	4	8	24.220	30.51	16.51	0.4635	
	5	**7**	**29.590**	**36.52**	**21.70**	**0.0175**	*

Appendix 19 (continued). Aortic outflow.

Variable	GROUP	N	MEDIAN	MAX	MIN	p	
VTI Min	C	40	23.330	32.55	19.61	-	
	1	7	23.860	28.31	18.57	0.8248	
	2	8	22.770	27.72	20.68	0.8573	
	3	8	21.910	26.67	18.24	0.2131	
	4	8	22.770	27.72	15.71	0.6481	
	5	**7**	**28.450**	**33.53**	**20.53**	**0.0383**	*
PEP Max	C	40	0.080	0.12	0.05	-	
	1	7	0.110	0.12	0.07	0.1242	
	2	**8**	**0.115**	**0.16**	**0.07**	**0.0315**	*
	3	**8**	**0.100**	**0.16**	**0.09**	**0.0207**	*
	4	**8**	**0.115**	**0.18**	**0.07**	**0.0315**	*
	5	6	0.080	0.12	0.02	0.3263	
PEP Med	C	40	0.080	0.11	0.04	-	
	1	7	0.090	0.10	0.04	0.1552	
	2	**8**	**0.100**	**0.15**	**0.07**	**0.0064**	*
	3	**8**	**0.090**	**0.15**	**0.07**	**0.0300**	*
	4	**8**	**0.100**	**0.16**	**0.06**	**0.0270**	*
	5	6	0.062	0.11	0.01	0.3015	
PEP Min	C	40	0.070	0.10	0.03	-	
	1	7	0.090	0.10	0.04	0.0546	
	2	**8**	**0.085**	**0.13**	**0.05**	**0.0261**	*
	3	8	0.070	0.13	0.05	0.2778	
	4	8	0.040	0.15	0.05	0.1010	
	5	6	0.062	0.10	0.01	0.0648	
EjT Max	C	40	0.485	0.60	0.42	-	
	1	7	0.480	0.50	0.46	0.4355	
	2	8	0.480	0.50	0.43	0.3229	
	3	8	0.480	0.53	0.44	0.8238	
	4	8	0.461	0.50	0.36	0.1768	
	5	6	0.485	0.51	0.45	0.7408	
EjT Med	C	40	0.465	0.55	0.41	-	
	1	7	0.465	0.48	0.44	0.6763	
	2	8	0.440	0.49	0.43	0.2198	
	3	8	0.465	0.52	0.41	0.6161	
	4	8	0.445	0.49	0.35	0.0745	
	5	6	0.460	0.51	0.44	0.5986	
EjT Min	C	40	0.450	0.53	0.39	-	
	1	7	0.445	0.47	0.43	0.6758	
	2	8	0.430	0.47	0.40	0.1861	
	3	8	0.445	0.49	0.35	0.7174	
	4	8	0.425	0.47	0.32	0.0845	
	5	6	0.460	0.58	0.44	0.3006	

APPENDICES FOR PART 2

Appendix 20. Results of Kruskal-Wallace tests and subsequent Wilcoxon tests on Doppler variables recorded from the aortic and pulmonary outflow of nine horses during different study periods. 1 = control, 2 = dopamine infusion, 3 = dobutamine infusion, 4 = detomidine/butorphanol administration. Significant ($p < 0.05$) values are printed boldly. P values in column 1 VS represent comparisons between group 1 (the vertical column) and the groups in rows. P values in column 2 VS represent comparisons between group 2 (the vertical column) and the groups in rows and p values in column 3 VS represent comparisons between groups 3 and 4. N = number measurements.

Aortic Outflow.

	STUDY PERIOD	N	MEDIAN	KRUSKAL-WALLACE	WILCOXON TEST 1 VS	2 VS	3 VS
HR	**1**	26	36	**0.000**	-	-	-
	2	25	44		**0.002**	-	-
	3	24	36		0.394	**0.003**	-
	4	27	24		**0.000**	**0.000**	**0.000**
VMax	**1**	26	0.85	**0.000**	-	-	-
	2	25	0.95		**0.027**	-	-
	3	24	1.13		**0.000**	**0.000**	-
	4	27	0.71		**0.000**	**0.000**	**0.000**
dv/dt	**1**	26	6.77	**0.000**	-	-	-
	2	25	7.27		**0.021**	-	-
	3	24	10.95		**0.000**	**0.000**	-
	4	27	4.98		**0.000**	**0.000**	**0.000**
dt	**1**	26	0.13	**0.000**	-	-	-
	2	25	0.12		0.267	-	-
	3	24	0.10		**0.000**	**0.002**	-
	4	27	0.15		**0.006**	**0.000**	**0.000**
VTI	**1**	26	21.83	**0.002**	-	-	-
	2	25	21.64		0.502	-	-
	3	24	22.83		0.230	0.595	-
	4	27	19.43		**0.010**	**0.000**	**0.000**
PEP	**1**	26	0.06	**0.000**	-	-	-
	2	25	0.06		1.000	-	-
	3	24	0.03		**0.000**	**0.000**	-
	4	27	0.07		**0.015**	**0.030**	**0.000**
EjT	**1**	26	0.46	**0.000**	-	-	-
	2	25	0.45		**0.048**	-	-
	3	24	0.37		**0.000**	**0.000**	-
	4	27	0.47		**0.002**	**0.000**	**0.000**

Appendix 20 (Continued).

Pulmonary Outflow.

	STUDY PERIOD	N	MEDIAN	KRUSKAL-WALLACE	WILCOXON TEST 1 VS	2 VS	3 VS
HR	**1**	27	37.38	**0.000**	-	-	-
	2	24	44.54		**0.003**	-	-
	3	25	36.00		**0.004**	**0.000**	-
	4	25	24.00		**0.000**	**0.000**	**0.001**
VMax	**1**	26	0.88	**0.000**	-	-	-
	2	24	0.89		0.681	-	-
	3	23	1.06		**0.003**	**0.001**	-
	4	22	0.74		**0.000**	**0.000**	**0.000**
dv/dt	**1**	26	4.07	**0.000**	-	-	-
	2	24	4.51		0.370	-	-
	3	23	6.34		**0.000**	**0.000**	-
	4	22	3.14		**0.000**	**0.000**	**0.000**
dt	**1**	26	0.22	**0.000**	-	-	-
	2	24	0.21		0.281	-	-
	3	23	0.17		**0.000**	**0.001**	-
	4	22	0.22		**0.011**	**0.014**	**0.000**
VTI	**1**	26	23.42	0.137	-	-	-
	2	24	24.23		-	-	-
	3	23	23.70		-	-	-
	4	22	21.26		-	-	-
PEP	**1**	26	0.05	**0.000**	-	-	-
	2	24	0.05		0.320	-	-
	3	23	0.03		**0.006**	**0.001**	-
	4	22	0.06		**0.002**	**0.010**	**0.000**
EjT	**1**	26	0.47	**0.000**	-	-	-
	2	24	0.48		0.230	-	-
	3	23	0.39		**0.000**	**0.000**	-
	4	22	0.51		**0.009**	**0.002**	**0.000**

APPENDIX 21

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Standardised imaging technique for guided M-mode and Doppler echocardiography in the horse

KAREN J. LONG, J. D. BONAGURA* and P. G. G. DARKE†

Department of Veterinary Clinical Studies, University of Edinburgh, Royal (Dick) School of Veterinary Studies, Veterinary Field Station, Easter Bush, Roslin, Midlothian EH25 9RG, UK.

Summary

Eighteen echocardiographic images useful for diagnostic imaging, M-mode echocardiography, and Doppler echocardiography of the equine heart were standardised by relating the position of the axial beam to various intracardiac landmarks. The transducer orientation required for each image was recorded in 14 adult horses by describing the degree of sector rotation and the orientation of the axial beam relative to the thorax. Repeatable images could be obtained within narrow limits of angulation and rotation for 14 of the 18 standardised images evaluated.

Twenty-seven National Hunt horses were subsequently examined using this standardised technique. Selected cardiac dimensions were measured from two-dimensional and guided M-mode studies. Satisfactory results were achieved in 26 of the 27 horses. There was no linear correlation between any of the measured cardiac values and bodyweight. There was no significant difference between measurements taken from the left and the right hemithorax. Six horses were imaged on three consecutive days to assess the repeatability of the measurements. No significant difference was found between measurements obtained on different days.

This study demonstrates a method for standardised echocardiographic evaluation of the equine heart that is repeatable, valuable for teaching techniques of equine echocardiography, applicable for diagnostic imaging and quantification of cardiac size, and useful for the evaluation of blood-flow patterns by Doppler ultrasound.

Introduction

ECHOCARDIOGRAPHY is a well established non-invasive technique which allows real time imaging of cardiac structures (Feigenbaum 1986). The first report of its use in the horse described the technique of M-mode echocardiography (Pipers and Hamlin 1977). The authors described a systematic examination using an unguided M-mode transducer. Various cardiac parameters were recorded in 25 normal sedated horses. Other workers have since used this same technique to describe various normal cardiac parameters for foals (Lombard, Evans, Martin and Tehrani 1984; Stewart, Rose and Barko 1984) and unsedated horses (Lescure and Tamzali 1984; Paull, Wingfield, Bertone and Boon 1987). M-mode echocardiography has proved to be a valuable diagnostic aid in equine cardiology for which conventional radiographic techniques are of limited value (Pipers, Hamlin and Reef 1979; Wingfield *et al* 1980; Bonagura and Pipers 1983; Lombard, Scarratt and Buergelt 1983).

With advances in ultrasound technology, it has become possible to obtain two-dimensional (2-D) images of the equine heart (Bonagura, Herring and Welker 1985). The diagnostic value of this technique has also been reported (Rantanen, Byars, Hauser and Gaines 1984; Pipers, Reef and Wilson 1985; Freestone, Thomas, Carlson and Brumbaugh 1987; Reef and Spencer 1987; Reef, Mann and Orsini 1987; Reef 1987).

Carlsten (1987) described standard transducer locations at which both long- and short-axis images of the heart could be obtained. However, the disadvantage of using standard transducer locations to derive 2-D images is that there is considerable variation in the thoracic conformation and the images obtained from individual horses. Voros, Holmes and Gibbs (1990) have described a method for 2-D imaging using intracardiac structures as reference points and have validated these anatomical studies using an *in vitro* model. None of these studies has specifically addressed image planes that are useful for guided M-mode and Doppler studies.

Two-dimensional images can be recorded in an infinite number of planes. If the results of different workers are to be compared accurately it is important to standardise image planes and to detail standard views, as has already been reported for other species (Henry *et al* 1980; Thomas 1984; O'Grady, Bonagura, Powers and Herring 1986).

Modern equipment now enables M-mode, 2-D and Doppler echocardiography to be performed simultaneously. Two-dimensional images can be used to provide the spatial information by which M-mode studies can be guided. They can also be used to guide the placement of Doppler sampling gates (Reef *et al* 1989) and may be overlaid by Doppler colour flow maps.

The aims of this work were (1) to detail standard image planes for 2-D, M-mode and Doppler echocardiography in the horse: (2) to describe the methods used to obtain the standard views; (3) to describe the technique of guided M-mode echocardiography in the horse; and (4) to use the standard views to measure selected cardiac parameters in a group of normal horses.

*Dr Bonagura's present address is: The Ohio State University College of Veterinary Medicine, Veterinary Teaching Hospital, 1935 Coffey Road, Columbus, Ohio 43210-1089, USA.
†Dr. Darke's present address is: Department of veterinary of Edinburgh, Royal (Dick) School of Veterinary Studies, Summerhall, EH9 1QH, UK.

TABLE 1: Standardised images obtained from the right hemithorax of the horse

View	Structures imaged	Location of axial beam	Comments	Fig
Right parasternal long-axis views				
Reference view Ventricular inlets	RA, RV, TV, IVS, LA, LV, MV, LVW	RV, IVS, CT of MV	The LVOT is not included in this view. The IVS crosses the axial beam at right angles. The LA and LV size are maximised	1a
Tipped view LV inlet/outlet	RA, RV, TV, LV, IVS, Ao, AOV, LVOT CT of MV. LA in systole	RV, CT of TV. In diastole: junction of Ao root and MV annulus. In systole: AOV	The long-axis of the heart crosses the axial beam at an angle of 40-60°. The cardiac apex is tipped dorsally towards the transducer	1b
Long-axis aorta	LVOT, Ao, AOV, RA, RV, TV, LV, LA, CT of MV	CT of TV or valve tips. In diastole: LVOT and CT of MV. In systole: AOV, TV	The long-axis of the aorta is perpendicular to the axial beam	1c
Dorsal location RV inlet	RA, TV, RV, Ao (RVOT or LVOT)	TV, Ao	From this view it is possible to sweep through a wide range of rotations and cranial and dorsal angulations. The aorta will appear in short-axis, long-axis or obliquely depending on the rotation of the transducer	1d
Apical view Ventricular inlets	RA, TV, RV, IVS, LV, MV, LA	RV, TV, RA	The long-axis of the heart is displayed as vertically as possible	1e
Right parasternal short-axis views				
Papillary muscle level	PMs, RV RVW, IVS, LV, LVW	Junction of the IVS and LV lateral wall	This is a true short-axis view with papillary muscles evenly displayed	2a
Chordal level	RV, RVW, IVS, LV, LVW, CT	Junction of the IVS and LV lateral wall	This level is immediately above the PM level and immediately below the MV level. The LV lumen is as large as possible without imaging the MV The view is a true short-axis of the LV	2b
Mitral valve level	TV, IVS, MV	TV and lateral edge of anterior mitral valve leaflet	The MV leaflets are visualised in systole and diastole	2c
Aortic valve level	Ao, TV, RA, RV RVOT, LA	TV, Ao	The axial beam bisects the aorta. The valve leaflets are obvious during diastole	2d
Pulmonary artery level	Ao, SV crest, PA, coronary artery, RVOT	SV crest in systole. Ao in diastole	The SV crest and Ao move in and out of the axial beam during the cardiac cycle	2e
Right parasternal angled view				
Dorsal location RVOT	PA, PV, RVOT, Ao, TV, RV, SV crest, coronary artery	RV inflow tract. SV crest in diastole. RVOT and PA in systole	The SV crest and PA move in and out of the beam as the heart contracts and relaxes The RVOT, PV and PA are in long-axis	3

TABLE 2: Standardised images obtained from the left hemithorax of the horse

View	Structures imaged	Location of axial beam	Comments	Fig
Left parasternal long-axis views				
Reference view LV inlet	LA, LV, CT of MV, RV, RA, TV	CT of MV, IVS, RV	The long-axis of the heart crosses the axial beam at right angles	4a
Apical view LV inlet	LV, LA, MV, RV, RA,	LV, MV	The long-axis of the heart is displayed as vertically as possible	4b
5-chambered	LV, LVOT, AOV, RV, TV, RA	LV, AOV, Ao	The Ao and AOV are in long-axis	4c
Left parasternal short-axis views				
LV chordal level	RV, IVS, LV	LV. Junction of the LV wall and IVS	This is a true short-axis view of the LV. The LV lumen is as large as possible without including the MV. The posterior PM and the LVOT are not included in this view	5a
Right ventricular wall	RVW, RV, IVS, LV	IVS, RVW	The LV is in short axis	5b
Left parasternal angled views				
RV inlet/outlet	TV, RA, PA	RV, TV, RA	The PV and PA are in long-axis	6a
LVOT/Aorta	AOV, LVOT, Ao	LV, LVOT, AOV, Ao	The LVOT and AOV are in long-axis	6b

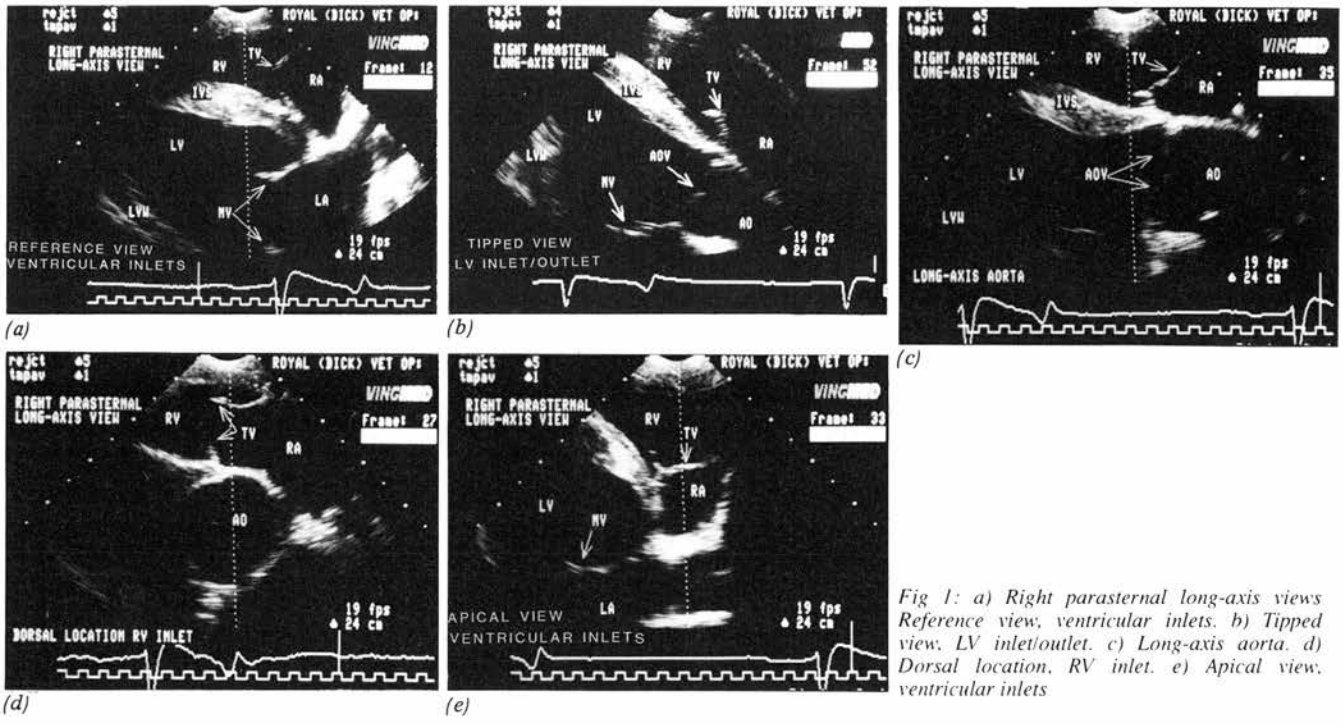


Fig 1: a) Right parasternal long-axis views Reference view, ventricular inlets. b) Tipped view, LV inlet/outlet. c) Long-axis aorta. d) Dorsal location, RV inlet. e) Apical view, ventricular inlets

Materials and Methods

Phase 1

Images were taken of 14 clinically normal Thoroughbred or Thoroughbred-cross horses to develop standard imaging planes. Eighteen standard views were defined which were considered useful to evaluate cardiac structures and to perform M-mode and Doppler studies (Tables 1 and 2). The views were standardised by relating sector rotations and the position of the axial beam relative to various intracardiac landmarks.

Images were recorded from the right and left sides of the thorax. The hair coat was clipped and acoustic coupling was achieved using ultrasound gel (Euro Diffusion Medicale, Rosney, St Bois, France). The horse was positioned with the appropriate foreleg slightly abducted so that the olecranon process was free of the thoracic wall. This could be achieved by standing the horse alongside the operator and pushing the hindquarters away slightly. To obtain some views the foreleg was placed slightly cranial and lateral.

The images were obtained using a Vingmed CFM 700 ultrasound machine linked to a Vingmed 2.25 MHz annular array transducer (Diasonics Sonotron, Bedford, Beds, UK). The maximum imaging depth of the equipment was 24 cm with a maximum sector angle of 90°. The frame rate in the 2-D imaging mode varied with angle and depth from 19 frames/sec to 55 frames/sec. The equipment allowed simultaneous 2-D and M-mode imaging.

Detailed notes were made of the location, sector rotation and axial (central) beam angulation of the transducer required to obtain each view as noted below.

The *location* of the transducer describes the position of the transducer on the body wall relative to a long-axis reference image. Imaging was started from the right hemithorax using a long-axis view of the ventricular inlets as a reference image (Table 1, Fig 1a). This image was obtained by placing the transducer at the 4th or 5th intercostal space just dorsal to the olecranon process. The sector edge was rotated dorsad (0°) and the axial beam was then adjusted to image the ventricular inlets and the interventricular septum (IVS). The image was considered acceptable when the axial beam crossed the left ventricle (LV) at the level of the chordae tendineae and the IVS was orientated almost horizontally across the sector. The reference image from the left hemithorax was obtained by placing the transducer caudal to the olecranon process and dorsal to the left apical impulse with the sector edge rotated dorsad (0°). This generated a long-axis view of the left atrium and ventricle optimised to view the mitral valve and left ventricular inlet (Table 2, Fig 4a). The axial beam was adjusted to cross the LV at the level of the chordae tendineae. Once again the IVS was orientated almost horizontally across the sector. Thus the location of the transducer required to obtain the reference images provided the reference point from which the other standardised views could be obtained. Placement of the transducer away from these points was described as cranial, caudal, dorsal or ventral.

The sector *rotation* of the transducer was defined as "+" when rotated in a clockwise direction (as viewed from the handle) and "-" when rotated in an anti-clockwise direction. Zero was defined as "no rotation", ie when the index mark was in the dorsal 12 o'clock position. The approximate sector rotation required for each view was assessed visually by two observers.

Angulation was achieved by pivoting the transducer about a fixed location on the body wall in a cranial, caudal, dorsal or ventral direction. The angulation of the transducer was defined as "0" when the transducer was held perpendicular to the body wall. An angulation of "+3" corresponded to the maximum angulation that could be achieved between the transducer and the body wall without loss of contact at the body surface. The maximum angulation achieved with the Vingmed 2.25 MHz transducer was approximately 65° from the perpendicular position. Transducer angulation between these limits was assessed as "+1" (slight) or "+2" (moderate).

The nomenclature and standards used in this sudy followed the proposals of Henry *et al* (1980) for human echocardiography. However, due to the lateral compression of the thorax in the horse the transducer placement required to obtain the parasternal views in this species could be more accurately described as left and right intercostal. This has also been reported in canine echocardiography (Thomas 1984). Whilst accepting these observations, the human nomenclature has been adopted for this work as the images obtained from the intercostal locations in the

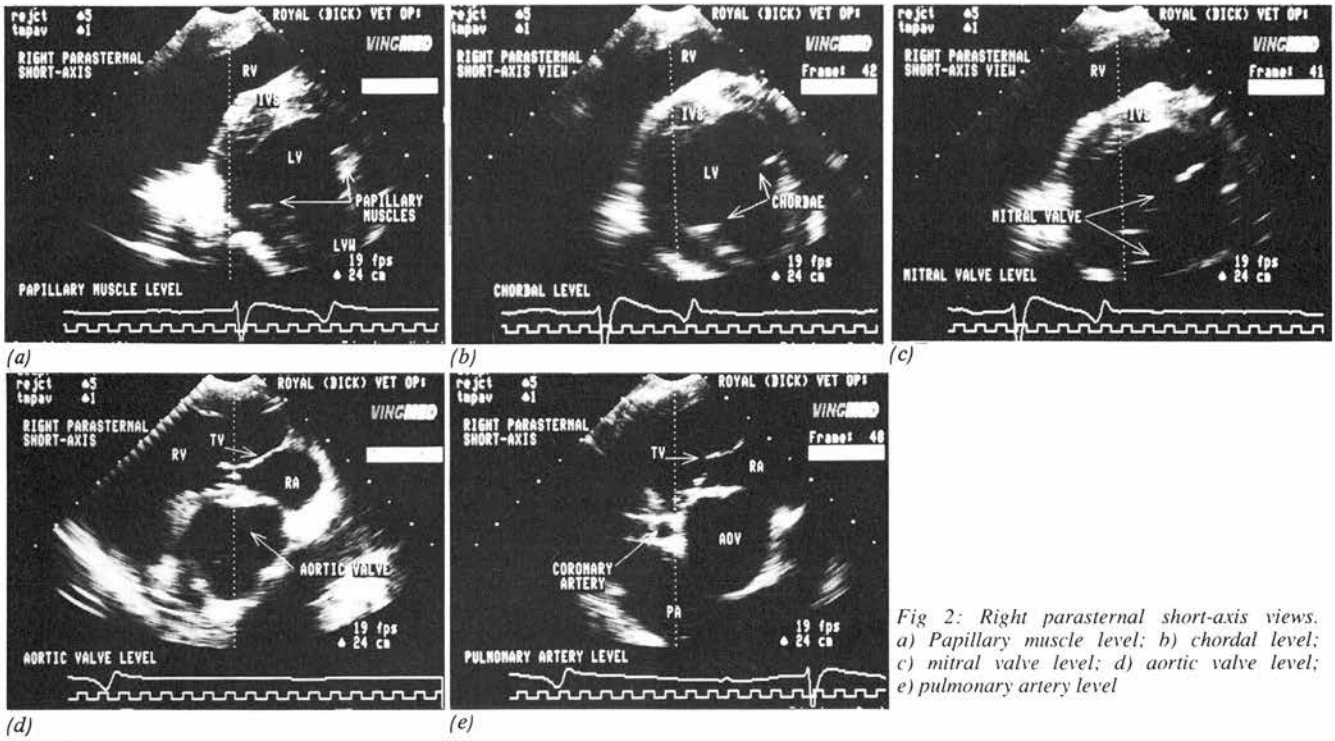


Fig 2: Right parasternal short-axis views. a) Papillary muscle level; b) chordal level; c) mitral valve level; d) aortic valve level; e) pulmonary artery level

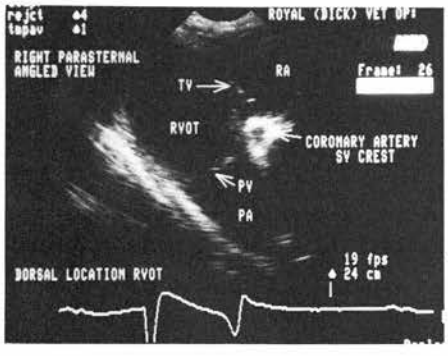


Fig 3: Right parasternal angled view. Dorsal location RVOT

horse were similar to the images obtained from the parasternal location in man. Long-axis images were displayed with the apex to the left of the screen and the atria to the right. The index mark of the transducer indicating the edge of the imaging plane corresponded to the edge which appeared on the right of the image display. The transducer was held with the index mark under the thumb of the left hand when imaging the right hemithorax and the right hand when imaging the left hemithorax. Sagittal images are referred to as "long-axis", coronal images as "short-axis", views obtained with the transducer in a ventral thoracic location as "apical" and the term "angled view" is used to describe images in which some structures are visualised in long-axis and others in short-axis (Weyman 1982).

Phase 2

The standardised views were used to obtain 2-D, M-mode and Doppler derived velocity measurements from a group of 27 normal National Hunt horses. The methods used to obtain the Doppler-derived velocity measurements and the subsequent results are not reported in this work. The group consisted of Thoroughbred or Thoroughbred-cross horses: 3 stallions, 5 mares and 19 geldings aged 2 to 17 years. Weight ranged from 432 to 648 kg with a mean of 517 kg. The horses had no evidence of cardiovascular dysfunction on clinical or electrocardiograph (ECG) examination. Horses with the following functional murmurs were included as normals: early systolic ejection murmurs with the point of maximum intensity (PMI) over the aortic valve; presystolic murmurs (murmur audible between the fourth and first heart sounds); early diastolic murmurs (murmur audible betweent he second and third heart sounds).

Two-dimensional images from both the left and right hemithoraces were used to guide the placement of a cursor to obtain accurate M-mode recordings. A simultaneous ECG permitted

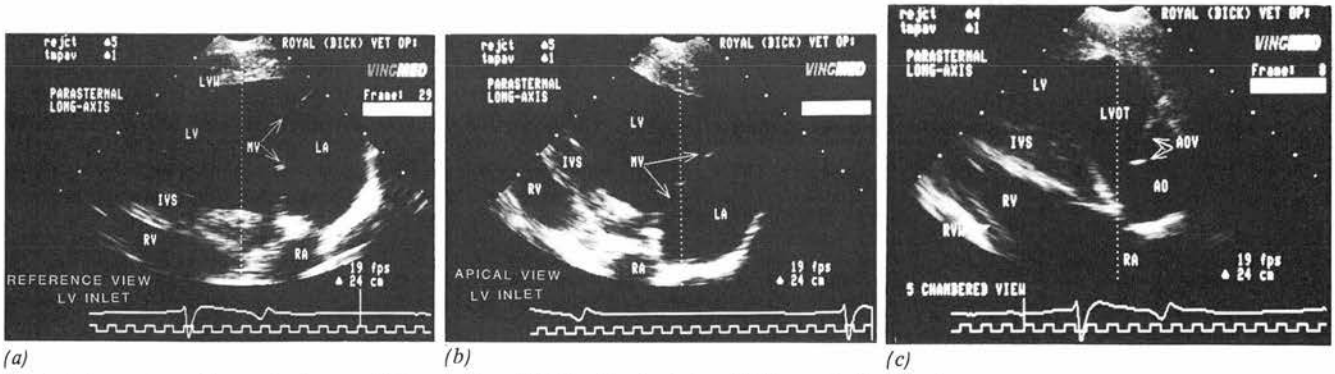


Fig 4: Left parasternal long-axis views. a) Reference view, LV inlet; b) apical view, LV inlet; c) 5-chambered

TABLE 3: Summary of the potential uses of each standardised view and the transducer orientation required to obtain them

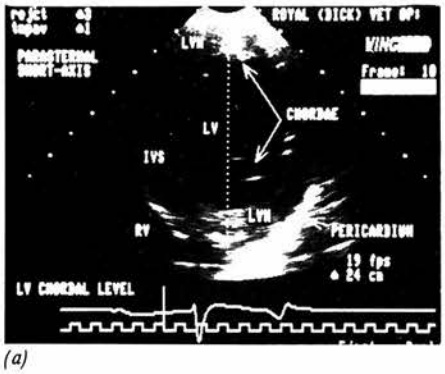
	Transducer orientation (location, rotation, CR/CD D/V angulation)	Comments	Typical uses
Right parasternal long-axis views			
Reference view. Ventricular inlets	Standard 0° (CD) (D)	–	Imaging, colour flow mapping (ventricularseptal defect, MR, TR)
Tipped view. LV inlet/outlet	Standard/ventral +30° (CR) D	–	Imaging, colour flow mapping (ventricularseptal defect, aortic insufficiency, MR, TR)
Long-axis aorta	Standard/dorsal +30° (CR) (D)	Can alter rotation up to 45° also CR angulation to image more aorta in long-axis	Imaging, colour flow mapping (ventricularseptal defect, aortic insufficiency)
Dorsal location RV inlet	Dorsal 0° to +90° (CR) to CR* (D) to D*	Can alter rotation, cranial and dorsal angulation through complete range to image RA	Imaging, colour flow mapping, spectral Doppler (RV inflow, TR)
Apical view. Ventricular inlets	Ventral 0° (CR) D*	Can alter rotation up to 45°, can also add CR angulation to image more RA	Imaging, colour flow mapping, spectral Doppler (RV inflow)
Right parasternal short-axis views			
Papillary muscle level	Standard/ventral -90° (CD) (D) (V)	Adjust rotation through -80° to -90° to obtain true short-axis	Imaging
Chordal level	Standard -90° (CD) (D)	Adjust rotation through -80° to -90° to obtain true short-axis	Imaging, LV measurements (M-mode and 2-D)
Mitral valve level	Standard -80° (CR) (CD) D	Adjust rotation through -60° to -80° to obtain true short-axis	Imaging, M-mode (MV motion), colour flow mapping (MR)
Aortic valve level	Standard -30° CR D	Adjust rotation through -20° to -60° to obtain true short-axis	Imaging, M-mode (aortic diameter, AV motion), colour flow mapping (aortic insufficiency)
Pulmonary artery level	Standard -20° to -30° CR* D	Adjust rotation through -20° to -60°	Imaging, spectral Doppler, colour flow mapping (RV inflow, pulmonary insufficiency)
Right parasternal angled view			
Dorsal location RVOT	Cranial/dorsal -30° CR D	–	Imaging, spectral Doppler, colour flow mapping (RV inflow, pulmonary insufficiency, TR pulmonary outflow, sub-pulmonic VSD)
Left parasternal long-axis views			
Reference view. LV inlet	Standard 0° (CD) (D)	–	Imaging, colour flow mapping (ventricularseptal defect, MR)
Apical view. LV inlet	Standard/caudal/ventral 0° (CR) (CD) D*	Can alter rotation up to -40° to image more LA	Imaging, colour flow mapping, spectral Doppler (LV inflow, MR)
5-chambered	Standard/ventral 0° to -30° CR D	Slide transducer to caudal edge of intercostal space and angle cranially	Imaging, colour flow mapping, spectral Doppler (aortic outflow, aortic insufficiency)
Left parasternal short-axis views			
LV chordal level	Standard +90° (CR) (D)	In a small number of cases caudal angulation is necessary. Adjust rotation from +30° to +90° to obtain true short-axis	Imaging. LV measurements (M-mode and 2-D)
Right ventricular wall	Cranial +90° (CR) (CD) (V)	In a small number of cases caudal angulation is necessary. Adjust rotation from +30° to +90° to obtain true short-axis	RV wall measurement (M-mode)
Left parasternal angled views			
RV inlet/outlet	Cranial/ventral -45° (CD) D	Position as cranially and ventraly as possible. Try to angle caudally and dorsally	Imaging, spectral Doppler, colour flow mapping (RV inflow, TR, pulmonary insufficiency)
LVOT/aorta	Standard/ventral +30° (CR) D*	Some cases may require (CD) or CR angulation to obtain the LVOT and aorta in long-axis	Imaging, colour flow mapping, spectral Doppler (aortic outflow, aortic insufficiency)

CR = a cranial angulation of + or ++; CD = a caudal angulation of + or ++; D = a dorsal angulation of + or ++; V = a ventral angulation of + or ++; *angulation of ++ or +++; ( ) = angulation of 0 to +

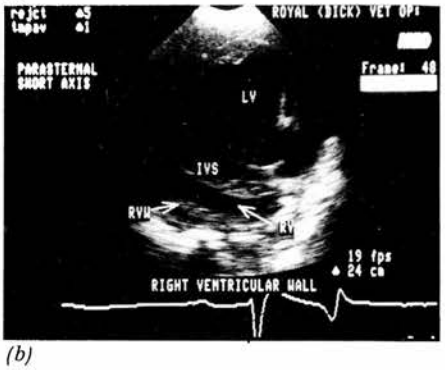
TABLE 4: Comparison of results of the present study with selected cardiac measurements obtained by previous workers using unguided M-mode echocardiography

	Present study						O'Callaghan (1985)	Lescure and Tamzali (1984)	Pipers and Hamlin (1977)
	N	Min.	Max.	cv	Mean	sd	Mean	Mean + sd	Mean + sd
LVIDs	26	6.1	8.7	9.79	7.35	0.72	6.8	6.11 + 0.91	5.7 + 0.23
LVIDd	21	10.5	13.4	5.96	11.90	0.71	9.8	11.06 + 1.34	9.3 + 0.30
LVWs	9	3.0	5.4	15.91	3.96	0.63	2.8	–	–
IVSs	26	3.3	5.6	12.09	4.55	0.55	3.6	4.81 + 0.71	–
IVSd	26	2.4	3.7	12.91	3.02	0.39	2.4	3.06 + 0.6	–
RVIDs	25	1.0	4.9	36.90	2.71	1.00	–	–	–
RVIDd	26	2.2	5.4	23.76	3.83	0.91	–	–	–
FS	21	29.0	47.0	11.84	38.76	4.59	–	44.1 + 6.4	38.6 + 1.6
Aod	24	7.7	9.5	6.00	8.50	0.51	–	7.31	7.7
LIVSd	19	2.4	3.3	8.68	2.88	0.26	–	–	–
LLVWd	20	1.8	2.9	11.25	2.39	0.26	–	–	–
LRVWd	16	1.1	2.0	16.67	1.44	0.24	–	–	–
LRVWs	16	1.4	3.2	19.25	2.39	0.46	–	–	–
LLVIDs	26	6.2	8.7	6.74	7.71	0.52	–	–	–
LLVIDd	26	10.4	13.5	5.88	12.25	0.72	–	–	–
LFS	26	27.0	45.0	10.56	37.01	3.91	–	–	–
Bodyweight					517 kg			445 kg	300 kg

All measurements are given in cm. N = no. of horses. Min. = minimum value. Max. = maximum value. cv = coefficient of variation (as %). sd = standard deviation



(a)



(b)

Fig 5: Left parasternal short-axis views. a) LV chordal level; b) RV wall

accurate timing of measurements within the cardiac cycle. All images were recorded on videotape for later analysis. Selected cardiac dimensions were measured using electronic callipers within the equipment software. The callipers measured to the nearest 1 mm. All measurements were taken at resting heart rates.

The recommendations of the American Society of Echocardiography were followed for all M-mode measurements (Sahn, DeMaria, Kisslo and Weyman 1978). The "leading edge method" was used for all M-mode measurements. End diastolic measurements were taken at the onset of the QRS complex. Systolic measurements were taken during the maximum excursion of the ventricular septum. Measurements were obtained from 2-D images using the "leading edge method" (Feigenbaum 1986) when tissue interfaces were perpendicular to the axial beam and using the "leading edge trailing edge method" (Wyatt, Haendchen, Meerbaum and Corday 1983) when tissue interfaces were aligned parallel to the axial beam, eg the IVS when measured from a left parasternal short-axis view of the right ventricular wall.

The following views were used to guide M-mode studies.

(1) The right parasternal short-axis view at the chordal level (Fig 2b): The M-mode cursor was placed across the LV. The IVS and left ventricular wall (LVW) were intersected at right angles. The image of the LV had to be placed at the far right of the sector display for the cursor to bisect the left ventricle (Fig 7). This was achieved by angling the transducer cranially. The following M-mode measurements were taken: LV internal diameter in systole (LVIDs) and diastole (LVIDd); LV wall thickness in systole (LVWs) and diastole (LVWd); interventricular septal thickness in systole (IVSs) and diastole (IVSd); right ventricular internal diameter in systole (RVIDs) and diastole (RVIDd).

Left ventricular measurements were used to calculate the fractional shortening using the following equation:

$$FS = \frac{LVIDd - LVIDs \times 100}{LVIDd}$$

(2) The right parasternal short-axis view at the aortic valve level (Fig 2d): The cursor was positioned to bisect the aorta. The M-mode image was considered acceptable if one of the valve cusps could be seen clearly during systole and diastole. The aortic diameter was measured in diastole (Aod).

(3) The left parasternal short-axis view at the chordal level (Fig 5a): The cursor was positioned to cross the ventricular free wall and the junction of the LVW and IVS, at right angles, thus dividing the left ventricle in half. The posterior papillary muscle and the left ventricular outflow tract (LVOT) were not included in this image. The left ventricular internal diameter was measured from the M-mode image in systole (LLVIDs) and diastole (LLVIDd). The fractional shortening was calculated from these measurements (LFS) as previously described for measurements obtained from the right hemithorax.

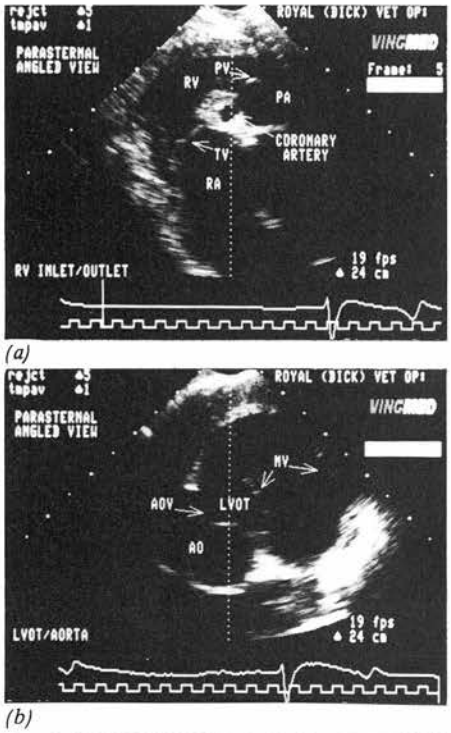


Fig 6: Left parasternal angled views. a) RV inlet/outlet; b) LVOT/aorta

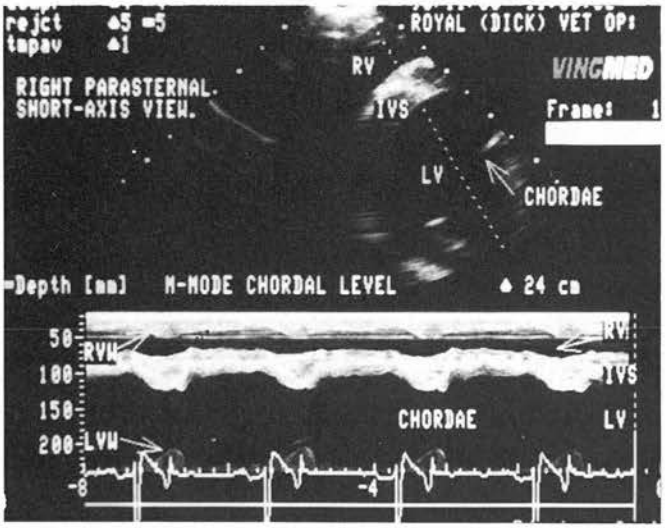


Fig 7: M-mode taken from the right parasternal short-axis view chordal level

(4) The left parasternal short-axis view of the right ventricular wall (Fig 5b): The M-mode cursor crossed the right ventricular wall perpendicularly (Fig 8). The thickness of the right ventricular wall was measured in systole (RVWs) and diastole (RVWd). Measurements of the LVW and IVS were obtained in diastole from the 2-D image.

Phase 3

Six horses were imaged on three consecutive days to assess the repeatability of selected cardiac measurements.

Statistical analysis of results

For each dimension the average value from three consecutive cardiac cycles was calculated. Summary statistics for each

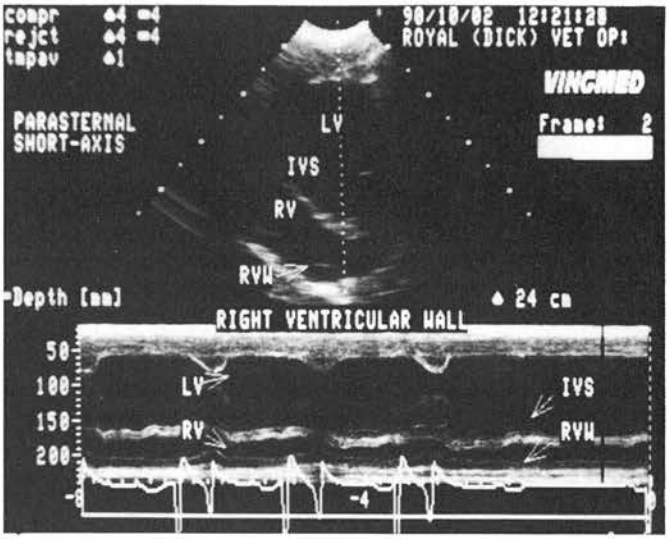


Fig 8: M-mode taken from the left parasternal short-axis view RV wall

dimension were determined including the range, mean, standard deviation and coefficient of variation. Least squares linear regression analysis was used to evaluate any relationship between measured variables and bodyweight. Differences between mean values were compared using a Student's *t* test for the measurements of LVIDs and LLVIDs; LVIDd and LLVIDd; FS and LFS; and LIVSd and IVSd. Repeatability for each dimension was assessed using a two-way analysis of variance for repeated measures. Statistical analysis was performed using a minitab statistical package (Ryan, Joiner and Ryan 1985) according to the methods described by Snedecor and Cochran (1980).

Results

The transducer location, sector rotation and axial beam angulation required to obtain each view are summarised in Table 3.

Clockwise (positive) rotation of the transducer was required to image the aorta in the right parasternal long-axis views (Figs 1b and 1c). In the right parasternal short-axis views there was a progressive decrease in the degree of negative rotation as the transducer was moved from the papillary muscle level to the pulmonary artery level (Figs 2a to 2e). Two right parasternal long-axis views of the RV inlet (Figs 1d and 1e) were obtained from dorsal and apical locations, using a wide range of transducer rotation.

Ventral angulation was only required for two of the 18 standardised views. The left parasternal short-axis view of the right ventricular wall (Fig 5b) was the only view that required ventral angulation in all horses. Slight cranial and dorsal angulation was required in most horses to image the aorta from both the left and right parasternal long-axis views (Figs 1c and 4c). As the transducer was moved through the right parasternal short-axis images from the papillary muscle level to the pulmonary artery level (Figs 2a to 2e), increasing dorsal and cranial angulation was required. The two right parasternal long-axis views of the RV inlet (Figs 1d and 1e) were imaged with the full range of cranial and dorsal angulation.

Potential uses of each view and comments to aid the reader in obtaining these standardised views are given in Table 3.

Of the 27 horses studied, 26 were imaged successfully: the remaining horse could not be imaged safely, due to its temperament. Summary statistics of the selected cardiac dimensions are given in Table 4. Five cardiac measurements had a coefficient of variation greater than 15 per cent. These were the right ventricular wall thickness in systole (LRVWs) and diastole

(LRVWd), the right ventricular internal diameter in systole (RVIDs) and diastole (RVIDd) and the left ventricular wall thickness in systole (LVWs). The limitation of imaging depth when scanning from the right hemithorax prevented measurement of the left ventricular wall thickness in systole (LVWs) and diastole (LVWd), the left ventricular internal dimension in diastole (LVIDd) and the aortic diameter (Aod) in a number of horses. It was only possible to measure the left ventricular wall thickness in diastole (LVWd) in three horses from the right parasternal short-axis view at the chordal level.

No linear correlation was found between the measurements taken and bodyweight. No significant difference could be found between the following values when measured from the right and left parasternal short-axis views: the left ventricular internal diameter in diastole, the left ventricular internal diameter in systole, the interventricular septum in diastole and the fractional shortening. There was no significant difference in the mean values obtained from six horses when imaged on consecutive days.

Discussion

The 18 standardised images could be obtained in all horses examined. Most of the standardised images were recorded with a narrow range of transducer location, rotation and angulation; however, some exceptions were noted. Two right parasternal views of the RV inlet (Figs 1d and 1e) could be obtained from a wide range of sector rotations and cranial/caudal angulations. This was due to a lack of precision in fully defining these views. It was possible to alter the rotation and cranial angulation to view a large area of the right atrium yet still maintain the available intracardiac landmarks within the axial beam. A wide range of sector rotation could also be used to image the RVOT from the right parasternal dorsal location (Fig 3), and the parasternal short-axis views at the aortic (Fig 2d) and pulmonary artery levels (Fig 2e). Because these views were specifically defined, the variation in sector rotation is probably either a reflection of differences between subjects or in the initial placement of the transducer.

This systematic method of standardisation of equine echocardiographic images differs somewhat from those in previous studies. Carlsten (1987) used standardised intercostal locations to obtain long-axis and short-axis images from the left and right hemithoraces. The disadvantage of using standard transducer placement rather than standard views is that there is considerable variation between individual horses. In some horses an initial cranial placement of the transducer was required to obtain the reference views; whereas in other horses these were obtained from more caudal positions. Once the reference views were achieved in each horse it was possible to relate all subsequent views to these original transducer placements.

Voros *et al* (1990) used intracardiac landmarks to standardise specific image planes of the equine heart. Anatomical validation of intracardiac structures was achieved using *in vivo* and *in vitro* techniques. The exact positioning of the transducer required to obtain specific views was not addressed.

The concept of recording transducer rotation and beam angulation was considered by Stadler, D'Agostino and Deegan (1988) in their work using the method of Carlsten (1987) to obtain 2-D images of the equine heart. Whilst this study was not as detailed as the present study the results are in general agreement. The approximate transducer rotation and angulation required to achieve each image were detailed although the relationship of the axial beam to the intracardiac landmarks was not described.

The position of the axial beam in relation to intracardiac structures can be used to identify the location and angulation of the transducer. It is therefore possible to determine the transducer position required to obtain a subsequent view from any given image. The reference image can be used to illustrate this point. If, for example the axial beam is cranial to the aorta more caudal placement or angulation of the transducer is required to obtain the reference image. If the LVOT appears in the reference image then either excessive positive rotation or cranial angulation of the transducer must be present. If the septum is not orientated perpendicular to the axial beam, ventral transducer placement with dorsal beam angulation must be present. When the transducer is held perpendicularly to the thoracic wall, with the sector angulation at 0, ventral placement of the transducer results in the axial beam crossing the reference image towards the apex of the heart. A dorsal location of the transducer results in the axial beam crossing the image at the level of the atrioventricular valves or atria. Whilst the method of estimating the angulation and rotation in this study was subjective, this standardised technique of imaging the equine heart has proved to be repeatable and is definitely effective in our experience for teaching and learning echocardiography in this species.

Correct positioning of the horse was essential to obtain good images. The more cranial transducer placements were poorly tolerated by most horses and advancement of the appropriate forelimb was necessary to obtain these views. No advantage was achieved by holding the leg up as this merely flexed the leg at the elbow and produced more caudal placement of the triceps muscle mass. Broad-chested animals and overweight animals produced images of poorer quality. Images obtained from the left side were sometimes of poorer quality than those obtained from the right. This is in agreement with comments by Stadler *et al* (1988) but is in contrast to the observations of Carlsten (1987).

The recommendations of the American Society of Echocardiography were followed for all M-mode measurements (Sahn, De Maria, Kisslo and Weyman 1978). The "leading edge method" has been shown to be more accurate than the "leading trailing" or the "trailing leading" method for measurement of myocardial thickness (Wyatt *et al* 1983). The "leading edge trailing edge" method was used for tissue interfaces which were parallel to the axial beam, such as the IVS when measured from a left parasternal short-axis view of the right ventricular wall. Although this may theoretically lead to over-estimation of the true width of the structure, it was difficult to determine the width of the endocardium due to the poor lateral resolution of ultrasound equipment.

Measurements were taken from M-mode studies where possible rather than the 2-D image, as M-mode studies are not limited by frame rates. This enables more accurate timing of measurements within the cardiac cycle. The guided M-mode technique allows the M-mode cursor to be placed accurately. Incorrect angulation of the M-mode cursor on the 2-D image can be appreciated and corrected. It was possible to achieve a true minor axis of the left ventricle in all horses using this technique. The M-mode studies were taken from the short-axis view as the cursor could be placed accurately across the maximum diameter of the chamber. In this view it was also easy to ensure that the M-mode cursor was not placed obliquely across the septum and ventricular walls. It was helpful firstly to orientate the cursor in the long-axis view. This ensured that the cursor was at the chordal level and crossed the long-axis perpendicularly, before turning to the short-axis view.

The thickness of the right ventricular wall was difficult to measure from the right parasternal short-axis view due to poor resolution of near field structures by the low frequency transducer. It could be clearly imaged from the left parasternal short-axis view (Fig 5b) and measured from the derived M-mode study (Fig 8). The coefficient of variation for the systolic and diastolic measurements was >15% which indicates that these measurements may be of limited clinical value. This high coefficient of variation may be due to difficulty in aligning the M-mode cursor perpendicularly to the endocardial surface or may be due to variability in the thickness of the right ventricular wall (Dixon *et al* 1982). High variability was also found in the

measurements of the RVID, both in systole and diastole this is probably due to the non-circular geometry of the RV. The other cardiac measurements showed limited variation and are likely to be of greater value in the assessment of cardiovascular dysfunction. The left ventricular internal dimension could be obtained with limited variability from both sides of the thorax. This may be useful in assessing the response of the heart to valvular disorders such as aortic insufficiency and mitral regurgitation and may be helpful in evaluating LV mass in performance horses.

No attempt was made to measure the atria. The entire atrium could not be imaged in any view. In the right and left parasternal long-axis views echo dropout in the near field and lung interference laterally prevented the measurement of the major or minor diameter of the atria. Measuring the atria at the level of the atrioventricular valves would give a measure of the valve annulus rather than a true atrial diameter. The ideal method of measuring both atria would be from an apical 4-chambered plane. This plane lies mutually perpendicular to the long-axis and short-axis planes. Schnittger, Gordon, Fitzgerald and Popp (1983) have shown in man that the minor axis of the left atrium measured from the left parasternal long-axis view is equal to that obtained from the left parasternal short-axis view at the level of the aorta and only 0.9% larger than that obtained from the apical 4-chambered plane. The left parasternal long-axis view in man corresponds to the right parasternal long-axis view of the aorta in the horse (Fig 1c). Unfortunately the depth limitations of the ultrasound equipment made it impossible to image the far wall of the left atrium in this group of horses and the measurement could not be made. This was also true for the left parasternal short-axis view. More recent equipment has a maximum imaging depth of 30 cm (Vingmed CFM 750). When imaging at this depth accurate measurement of the left atrium may be possible.

The apical 4-chambered plane is used to measure right atrial dimensions in man. This could not be achieved in the adult horse due to the width of the sternum, although this plane can be obtained in small foals. In the adult horse the apical long-axis views (Figs 1e and 4b) allow visualisation of the RA, RV, LA and LV. However, these views are inferior to the 4-chambered plane for measurement of the atria as the atria are not truly bisected. It would be beneficial to record a range of atrial dimensions in normal horses, as atrioventricular valve regurgitation is a common finding in the horse, with atrial enlargement a common sequel.

The results of this study are in agreement with those of Lescure and Tamzali (1984) except for the measurement of the Aod and LVIDs. The greater aortic diameter recorded in this study may be a reflection of the larger horses used (Table 4). Lescure and Tamzali (1984) used the "trailing edge" method for measuring the Aod. This will result in smaller values than would be obtained with the "leading edge leading edge" method. The measurements recorded in the present study are greater than those obtained by the unguided M-mode studies of O'Callaghan (1985) and Pipers and Hamlin (1977) (Table 4). Again this may be attributed to the larger bodyweights of horses in this study or more accurate placement of the M-mode cursor using 2-D guidance. The average weight of the horses in the study by Pipers and Hamlin (1977) was 300 kg and the horses imaged by O'Callaghan (1985) ranged from Welsh ponies to adult Thoroughbreds.

There was no linear correlation of any of the cardiac measurements to bodyweight, as found by Lescure and Tamzali (1984). Lombard *et al* (1984) and Stewart *et al* (1984) have shown a correlation between echocardiographic variables and bodyweight in studies of the growing pony foal. This appears to be contrary to the findings in the adult horse. However, other transformations of the data and variations in cardiac size between different breeds of horses were not investigated. The repeatability study in this work was a single observer repeatability and did not test for differences that might be obtained between different examiners. However, this study demonstrates that it is possible to obtain standardised echocardiographic views in the horse. These can be used for routine imaging, to guide M-mode studies and to guide the placement of sampling gates for colour flow and spectral Doppler. The adoption of a standardised method of examining the heart will facilitate the comparison of results from different workers. The method has advantages over standardised transducer positions as it will allow more accurate comparisons to be made. New images are described and measurements obtained from guided M-mode echocardiography in a group of normal horses are reported.

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Appendix: List of abbreviations

Aod	Aortic diameter in diastole
AOV	Aortic valve
ECG	Electrocardiograph
FS	Fractional shortening calculated from measurements obtained from the right hemithorax
IVS	Interventricular septum
IVSs	Interventricular septum in systole
LA	Left atrium
LFS	Fractional shortening calculated from measurements obtained from the left hemithorax
LIVSd	Interventricular septum in diastole measured from the left hemithorax
LLVIDd	Left ventricular internal diameter in diastole measured from the left hemithorax
LLVIDs	Left ventricular internal diameter in systole measured from the left hemithorax
LLVWd	Left ventricular wall in diastole measured from the left hemithorax
LRVWd	Right ventricular wall in diastole measured from the left hemithorax
LRVWs	Right ventricular wall in systole measured from the left hemithorax
LV	Left ventricle
LVIDd	Left ventricular internal diameter in diastole
LVIDs	Left ventricular internal diameter in systole
LVOT	Left ventricular outflow tract
LVWs	Left ventricular wall in systole
MV	Mitral valve
PA	Pulmonary artery
PM	Papillary muscle
PV	Pulmonary valve
RA	Right atrium
RV	Right ventricle
RVIDd	Right ventricular internal diameter in diastole
RVIDs	Right ventricular internal diameter in systole
RVOT	Right ventricular outflow tract
TV	Tricuspid valve

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Short Communications

Amniotic fluid analysis for ante-partum foetal assessment in the horse

M. A. WILLIAMS*, A. R. SCHMIDT, C. L. CARLETON, B. J. DARIEN, G. L. GOYERT, R. J. SOKOL and F. J. DERKSEN

Michigan State University, College of Veterinary Medicine, Department of Large Animal Clinical Sciences, East Lansing, MI 48824, USA.

Introduction

RELIABLE methods to evaluate the stressed foetus or to predict foetal maturity have not been fully developed for horses. At present, only a few of the increasingly sophisticated techniques used for man (Evans and Schulman 1987; Phelan 1988) have been adapted for equine foetal assessment (Adams-Brendemuehl and Pipers 1987; Williams, Goyert, Goyert and Sokol 1988; Schmidt *et al* 1991).

In human infants, fetal pulmonary maturity can be predicted by determining the percentage phosphatidylglycerol and lecithin:sphingomyelin ratio (L:S) from amniotic fluid phospholipids (Gabbe 1986). Additionally, there is evidence to suggest that fetal cortisol production is associated with foetal lung maturation and that fetal creatinine excretion parallels kidney maturation and function (McCarthy and Saunders 1978; Stahlman 1987). In horses, little is known about amniotic fluid concentrations of phospholipids, cortisol and creatinine, or associations of these substances with foetal development (Paradis 1987; Schott and Mannsman 1988; Williams *et al* 1988). The purpose of this study was to evaluate equine amniotic fluid for percentage phosphatidylglycerol, lecithin:sphingomyelin (L:S) ratio, cortisol and creatinine concentrations as a means of ante-partum foetal assessment in the horse.

Materials and methods

FIFTEEN pregnant mares with known mating dates were used. In 6 mares (Group 1) amniotic fluid (AF) was collected 4 times during the last third of gestation, at approximately 2-week intervals. Except at foaling, AF was collected by ultrasound-guided transabdominal amniocentesis, as described by Schmidt *et al* (1991). Ultrasonography was accomplished with mares restrained in stocks and sedated with xylazine (0.6 mg/kg bwt) and butorphanol (0.02 mg/kg bwt) using a 5-MHz or 3-MHz sector scanner (Advanced Technologies Laboratories Ultramark 8; ALT, Bellevue, WA, USA). The abdomen was scanned until a pocket of AF was located and the site was surgically prepared and locally infiltrated with an anaesthetic (2% mepivacaine). A biopsy guide and a 22-cm 18-gauge spinal needle were attached to the transducer and the needle was advanced until AF could be aspirated (Schmidt *et al* 1991). At parturition, AF was collected by direct needle aspiration before rupture of the amnion. To ascertain that repeat amniocentesis did not affect the AF composition, AF was collected from an additional 9 mares (Group 2) at foaling only. All parturitions were observed and the foals were evaluated using physical examination, haematology, and measurement of plasma cortisol and glucose concentrations (Rossdale, Ousey, Silver and Fowden 1984). All placentae were evaluated grossly at parturition and samples

TABLE 1: % Measurements of phosphatidylglycerol (%P), lecithin:sphingomyelin (L:S) value, cortisol concentration and creatinine concentration in amniotic fluid collected at delivery from 4 clinical mares with induced and/or prolonged gestation

Mare	Gestation (days)	History	Birth status	Outcome	L:S	%P	Cortisol (nmol/l)	Creatinine (μmol/l)
1	338	Induced parturition	Normal	Lived	> 4.0:1	6.1	66	1140.4
2	360	Induced parturition	Normal	Lived	> 4.0:1	16.8	13	2254.2
3	360	Spontaneous parturition	Dysmature	Died	> 4.0:1	9.1	0	1458.6
4	180	Elective abortion	Immature	Died	3.2:1	0.0	1	203.3

*Dr William's present address is: Department of Large Animal Surgery and Medicine, College of Veterinary Medicine, Auburn University, Alabama 36849-5522, USA.