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Application Note

How to Perform the Most Commonly Used Measurements from the Cardiac Measurements Package associated with Calculations of Cardiac Function using the Vevo® Lab

Vevo® LAB

Objective

The Vevo LAB offline analysis application has a comprehensive Cardiac Measurements package with measurements and calculations grouped in various protocols for specific imaging planes to support analysis for a complete cardiac exam.
The objective of this document is to review the measurements and calculations available in the various cardiac protocols available in Vevo LAB, as well as some other generic measurements which may be useful when using the Vevo 3100 imaging system.

The Cardiac Measurements and Calculation package has a number of protocols that follow the Imaging Mode - Imaging Plane structure so the calculations correctly correlate with the recommendations from the imaging guide.

B-Mode measurements protocols:

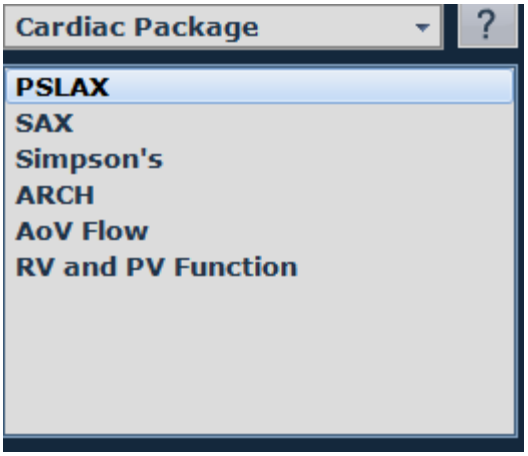

Figure 1 – B-Mode Cardiac package with the list of available protocols

Parasternal Long Axis (PSLAX) Protocol

IVS/LVAW, LVID, LVPW (d-diastole, s-systole) B-Mode Measurements
These measurements involve measuring the thickness of the interventricular septum (IVS) or the left ventricle anterior wall (LVAW), the left ventricular interior diameter (LVID) and the left ventricle posterior wall (LVPW). The software is designed to perform these measurements in the following order IVS/LVAW, LVID, LVPW. Once one measurement is initiated the subsequent measurements are assumed but the cursor position can be moved left or right to compensate for wall asynchronicity.
Diastole - begin the measurement by scrolling through the cine loop and find the frame where the heart is in full diastole. Determine if it is the IVS that appears in the image or the LVAW, this will depend on the imaging plane and rotation of the heart in the thoracic cavity. To begin, select IVS/LVAW;d from the measurement window and move the cursor into the image window and left click on the anterior border of the IVS/LVAW, move the cursor down to the posterior border of the IVS/LVAW (a turquoise line will appear), then move to the posterior wall, first clicking on the anterior portion, and finally the posterior portion. The turquoise line will not appear on the final two segments until the segment is completed.
Systole - Scroll through the cine loop and find the systolic frame and complete the same procedure, starting with the IVS/LVAW;s. Ensure that the completed segments are perpendicular to

the walls, as shown in this image (systole). In this image the IVS was chosen on a portion where the right ventricle is visible. The measurements are shown here in the long axis view; however the same measurement tools are available for a short axis B-Mode image as well.

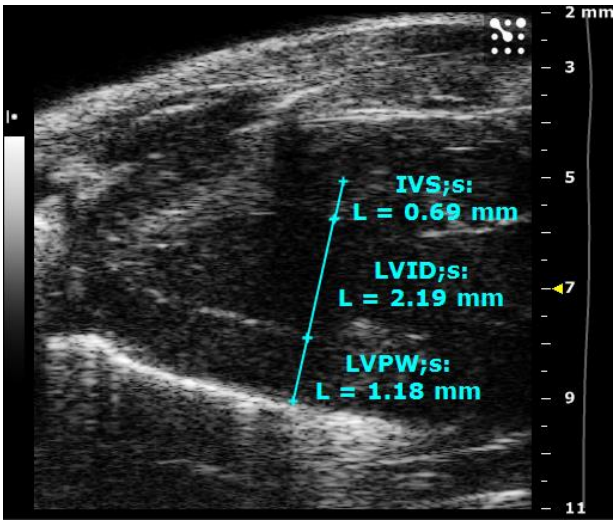

Figure 2 – IVS/LVAW traced measurement at systole, measuring the intraventricular septum (IVS) and left ventricular posterior wall (LVPW) thickness as well as the left ventricular internal diameter (LVID). These measurements are used to generate calculations of cardiac function.

The following calculations are completed and can be viewed in the report:

Volume
Ejection Fraction
Fractional Shortening
LV Mass

LA, Ao Sinus B-Mode Measurements

These measurements are simple linear measurements that can also be traced using the generic measurement on the system and named according to the imaging protocol. There are no calculations associated with these two measurements.

LVEnL (d-diastole, s-systole) B-Mode Measurements

These measurements are simple linear measurements that will be traced at systole and diastole for calculation of the Fractional Shortening based on the length of the left ventricle.
To begin, scroll in the cineloop to the systole and select and trace the LVEnL;s by a left click at the mid-point of the left ventricular outflow tract (LVOT) and move your cursor along the long axis of the heart to the apex, place the second caliper point at the endocardium. Scroll to a frame with the heart in diastole and select and trace the LVEnL;d.

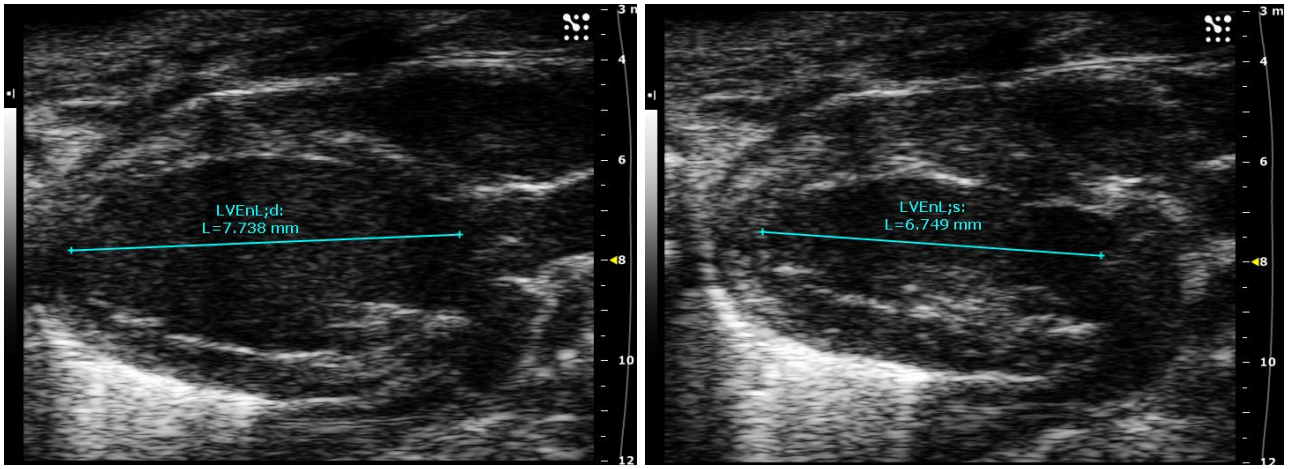

Figure 3 – Left ventricle endocardial length measurements

PSLAX B-Mode

Measurements

Description	Mode	Units	Avg	STD	Instance 1
LVEnL;d - L	B-Mode	mm	7.738		7.738
LVEnL;s - L	B-Mode	mm	6.749		6.749

Calculations

Description	Units	Value
FS;length	%	12.782

Figure 4 – Left ventricle Fractional Shortening calculation based on endocardial length measurements

Endocardial and Epicardial Length (d-diastole, s-systole) measurements

These measurements are designed to be used for calculations in combination with area measurements traced on images acquired in the Parasternal Short Axis View which will be detailed in the list of measurements for that specific protocol.

The way to trace them is identical to tracing the LVEnL measurements. To begin, scroll in the cineloop to the systole and select and trace the ENDOmajor;s by a left click at the mid- point of the left ventricular outflow tract (LVOT) and move your cursor along the long axis of the heart to the apex, place the second caliper point at the endocardium. Select the EPImajor;s and left click on the center of the LVOT and then again at the apex on the epicardium. Move now to the subsequent frame showing the heart in full diastole. Complete the same procedure as above using ENDOmajor;d and EPImajor;d.

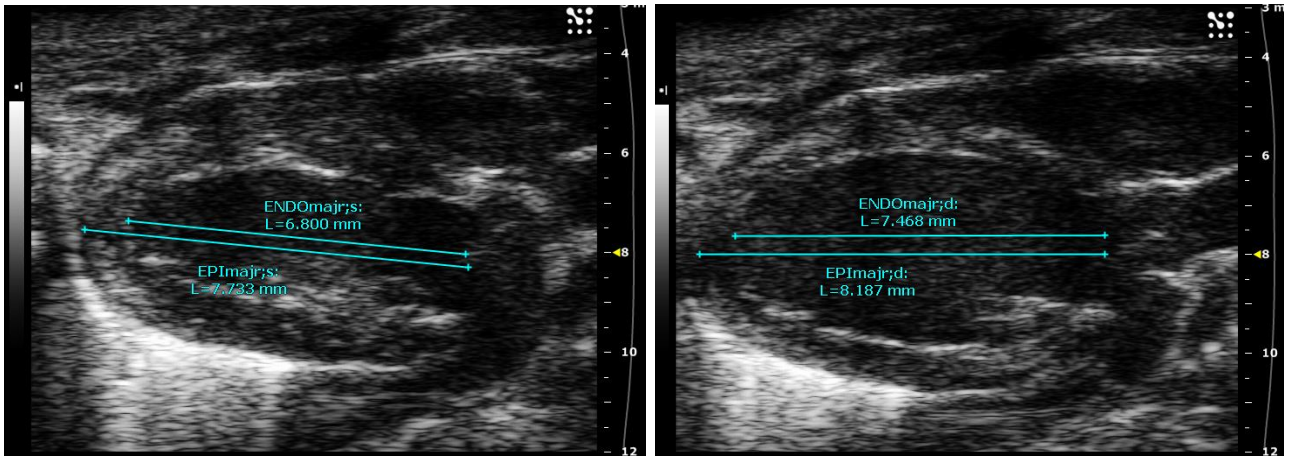

Figure 5 – Left ventricle endocardial length measurements at systole and diastole

LV Trace B-Mode measurement

This measurement is a unique feature introduced on the Vevo systems to improve the workflow and minimize interoperability errors.

Scroll through the cine loop and find the frame where the heart is in full diastole. Select the LV Trace measurement in the PSLAX protocol and start the trace at the left ventricular outflow tract (LVOT) by left clicking at the anterior wall, then the posterior wall, and then drag the cursor out to the apex, left clicking at all 3 locations. Complete the trace of the endocardium by left clicking along the wall to move the trace line to the cursor location. When finished keep the cursor on the endocardium and right click. Scroll through frame by frame, either forward or backwards, until the subsequent systolic frame is located, and complete the above steps to trace the endocardium on this frame. The system will then interpolate the traces between the traced contour, at systole and diastole, throughout a cardiac cycle. Confirm that the system hasn't inserted a false systolic or diastolic value in the cycle through interpolation.

When using the LV Trace measurement on the Vevo 3100 system, select the measurement and place the first point on the anterior wall at the outflow tract and then follow the contour of the endocardium all way on the posterior wall until you complete the contour and release the cursor.

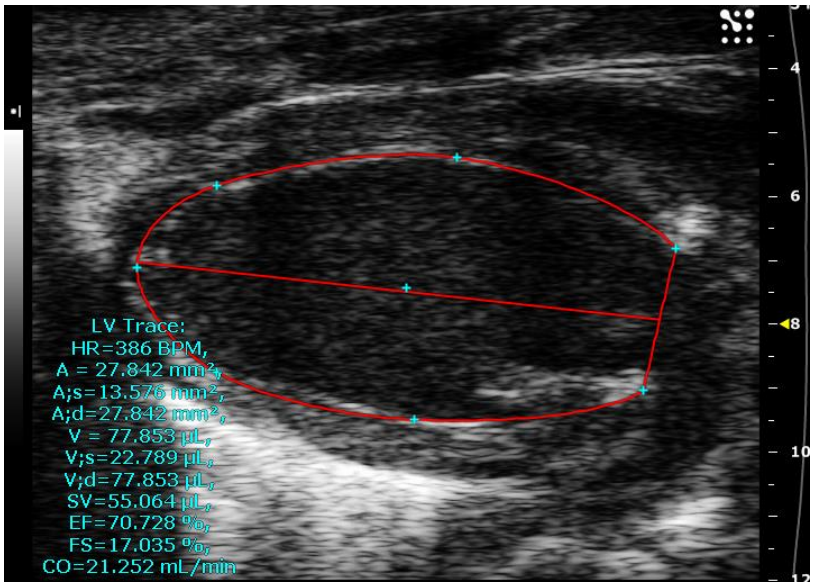

Figure 6 – LV Trace measurement in B-Mode with all the associated calculations available from the automatic tracing, red outline marks diastole

From this measurement the following calculations are completed:

Area
Volume
Fractional Shortening
Ejection Fraction
Stroke Volume
Cardiac Output

To view the calculations open the Report page, from the control bar, and look for the PSLAX B-Mode protocol. All measurements and calculations associated with this protocol will be listed in the report.

PSLAX B-Mode

Measurements

Description	Mode	Units	Avg	STD	Instance 1
ENDOmajr;d - L	B-Mode	mm	7.468		7.468
ENDOmajr;s - L	B-Mode	mm	6.800		6.800
EPImajr;d - L	B-Mode	mm	8.187		8.187
EPImajr;s - L	B-Mode	mm	7.733		7.733
LV Trace - A	B-Mode	mm²	27.842		27.842
LV Trace - A;d	B-Mode	mm²	27.842		27.842
LV Trace - A;s	B-Mode	mm²	13.576		13.576
LV Trace - CO	B-Mode	mL/min	21.252		21.252
LV Trace - EF	B-Mode	%	70.728		70.728
LV Trace - FS	B-Mode	%	17.035		17.035
LV Trace - HR	B-Mode	BPM	386		386
LV Trace - SV	B-Mode	µL	55.064		55.064
LV Trace - V	B-Mode	µL	77.853		77.853
LV Trace - V;d	B-Mode	µL	77.853		77.853
LV Trace - V;s	B-Mode	µL	22.789		22.789

Calculations

Description	Units	Value
Area;d (LV Trace)	mm²	27.842
Area;s (LV Trace)	mm²	13.576
CO (LV Trace)	mL/min	21.252
EF (LV Trace)	%	70.728
Endocardial FS	%	8.950
FS (LV Trace)	%	17.035
SV (LV Trace)	µL	55.064
V;d (LV Trace)	µL	77.853
V;s (LV Trace)	µL	22.789

Figure 7 – Report display of PSLAX B-Mode measurements and calculations

Parasternal Short Axis (PSAX) Protocol

IVS, LVID, LVPW B-Mode, Short Axis, Measurements

These measurements are designed to be used on images acquired in the parasternal short axis view and include measuring the thickness of the interventricular septum (IVS) or the left ventricle anterior wall (LVAW), the left ventricular interior diameter (LVID) and the left ventricle posterior wall (LVPW). The software is designed to perform these measurements in the following order IVS/LVAW, LVID, LVPW; once one measurement is initiated the subsequent measurements are assumed.

To begin, select IVS/LVAW;d from the measurement window and left click on the anterior border of the IVS/LVAW when the heart is in diastole; move the cursor down to the posterior border of the IVS/LVAW (a turquoise line will appear), then move to the posterior wall, first clicking on the anterior border, and finally the posterior border. The turquoise line will not appear on the final two segments until the segment is completed. Ensure when placing the measurement points that you

do not include the papillary muscles in the left ventricular posterior wall thickness, they should only appear in systole.
Select the IVS/LVAW,s and repeat the same procedure as above in an area of systole.
To avoid errors in calculations aim to trace the measurements on subsequent cardiac cycles acquired in between two breaths.

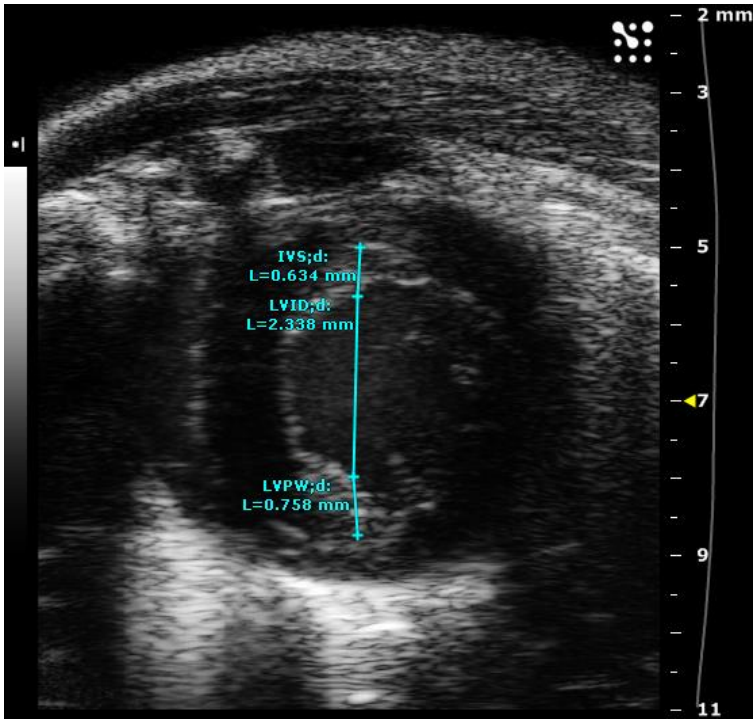

Figure 8 – IVS tool, measuring the thickness of the intraventricular septum (IVS) and left ventricular posterior wall (LVPW), as well as the left ventricular internal diameter (LVID). These measurements are used in calculations of cardiac function.

The following calculations are completed and can be viewed in the report:
Ejection Fraction **LV Mass**
Volume
Fractional Shortening

SAX Trace Measurement
This measurement is designed to be used on a short axis view of the heart acquired in B-Mode and involve tracing the endocardium at systole and diastole.
Scroll through the cine loop and find the frame where the heart is in full diastole and select the SAX trace from the protocol measurement list. Start the trace by left clicking on the endocardium and continue to left click around the myocardium; when finished keep the cursor on the endocardium and right click. Scroll through frame by frame, either forward or reverse, until the subsequent systolic frame is located, and complete the above steps to trace the endocardium on this frame. The image should look like **Fig.9**, with the diastolic frame outlined in red and systolic frame in green.

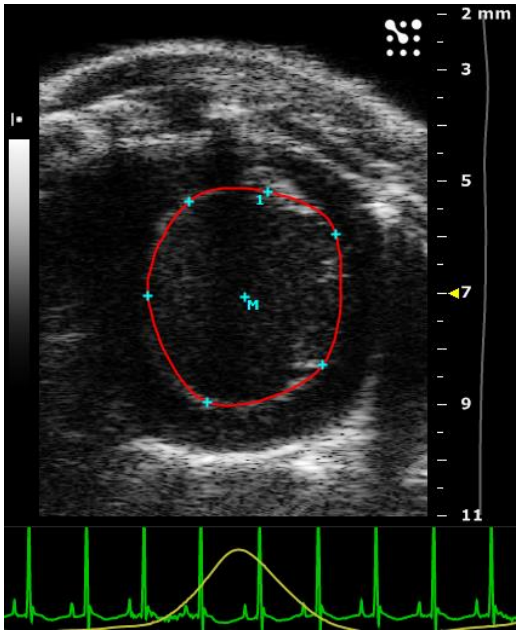

Figure 9 – SAX Trace meausrement, outlining the endocardium to yield calculations of cardiac function, here the diastolic frame is shown with the trace in red

The following calculations are completed and can be viewed in the report:
Area d;s
Fractional Area Change

Endocardial and Epicardial Area Measurements
These measurements are designed to be used in calculations in combination with the Endocardial and Epicardial lengths traced on one parasternal long axis view images also acquired in B-Mode. To trace any the area measurements, i.e. ENDOarea;d, select the measurement in the protocol list, place the cursor on the anterior wall and follow the contour of the endocardium all around the posterior wall and release the cursor. Repeat same steps for the endocardium in diastole and epicardium in systole and diastole.

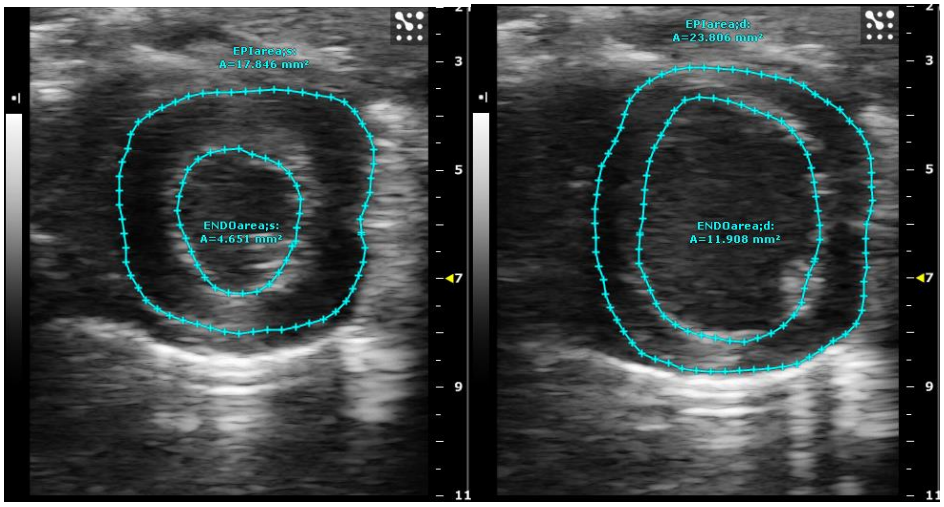

Figure 10 – Endocardial and Epicadial area measurements traced at systole and diastole.

In combination with Endocardial and Epicardial length measurements traced on the Parasternal Long Axis view the following calculations are completed in the report:

Area Change
Volume
Fractional Area Change
Fractional Shortening
Ejection Fraction
Stroke Volume
Cardiac Output

Without tracing the length measurements the report will display calculations for the:
Endocardial Area Change
Endocardial Fractional Area Change

SAX B-Mode

Measurements

Description	Mode	Units	Avg	STD	Instance 1
ENDOarea;d - A	B-Mode	mm²	11.908		11.908
ENDOarea;s - A	B-Mode	mm²	4.651		4.651
EPIarea;d - A	B-Mode	mm²	23.806		23.806
EPIarea;s - A	B-Mode	mm²	17.846		17.846

Calculations

Description	Units	Value
a;d	mm	2.753
b;d	mm	1.947
Endocardial Area Change	mm²	7.257
Endocardial FAC	%	60.943
T;d	mm	0.806

Figure 11 – Endocardial calculations in the report from the PSAX view

Simpson's Protocol

These measurements are designed to be used on B-Mode images of the heart, specifically one long axis view and 3 short axis views evenly spaced around a mid level view at the papillary muscles, one towards the apex, distal plane, and one towards the base, proximal plane.
In the long axis view scroll through the cine loop to find the frame where the heart is in diastole and measure the SimpLength;d. This is done by selecting the measurement and then left clicking on the left ventricular outflow tract (LVOT), and then left clicking at the apical endocardium of the heart. Repeat the same procedure on a systolic frame using SimpLength;s.

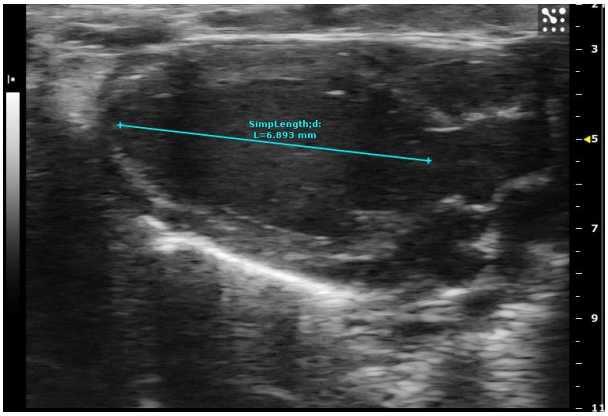

Figure 12 – Simpson's measurements: the length of the ventricle is measured in a long axis view (d)

Then for each of the 3 short axis views the endocardium should be traced in systole and diastole. On the proximal short axis view, for example, scroll through the cine loop to a frame where the heart is in systole and select the SimpAreaProx;s measurement. Begin by left clicking on the endocardium, and then move the cursor around the endocardium, caliper points are dropped as the cursor is moved, and once close to the starting point the area is completed. Repeat this on the proximal short axis view in diastole, as well as on the mid and distal short axis views.

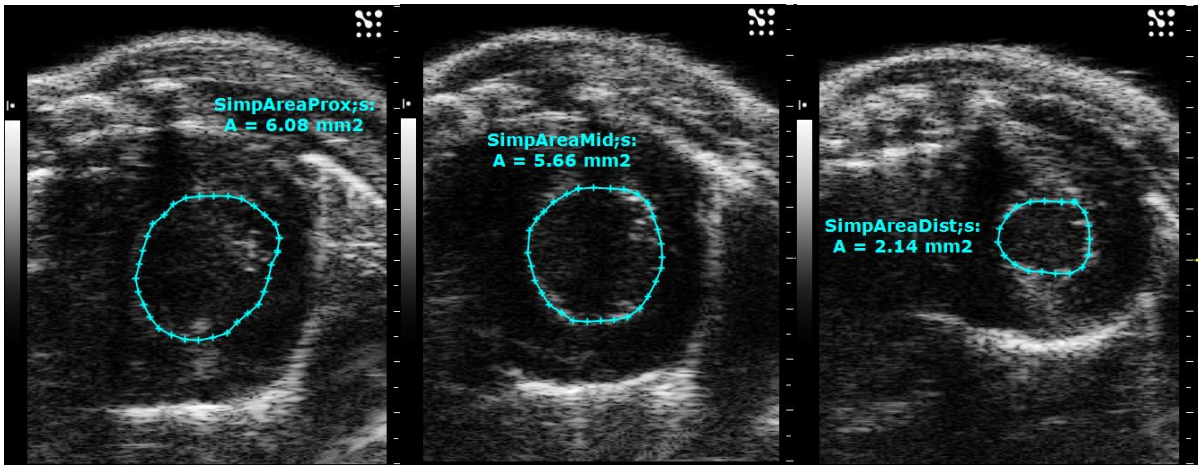

Figure 13 – Simpson's measurements, the endocardial areas must be traced from the proximal short axis view, the mid view, and the distal view, here all measurements are shown in systole.

The following calculations are completed and can be viewed in the report:

Volume
Fractional Area Change
Fractional Shortening
Ejection Fraction
Stroke Volume
Cardiac Output

Arch Protocol

For the Aortic Arch view in B-Mode there are three measurements that can be traced on the same image. They are independent measurements but can be used for analysis in combination with other available measurements.

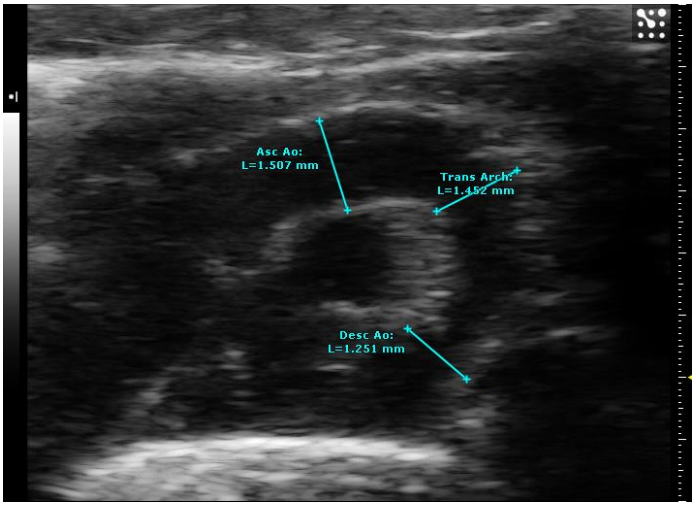

Figure 14 – Aortic Arch measurements

AoV Flow Protocol

The aortic valve flow measurements in B-Mode are linear measurements traced at the outflow tract and aortic valve level and used in calculations in combination with AoV VTI and LVOT VTI measurements traced in corresponding protocols from PW Doppler Mode.

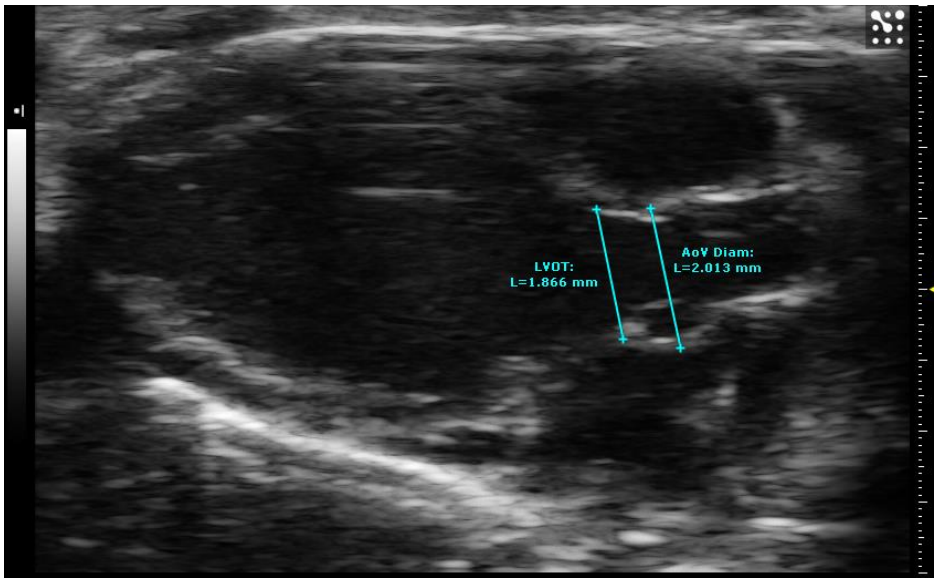

Figure 15 – LVOT and AoV Diam linear measurements

RV and PV Function Protocol

For the right ventricle and pulmonary valve function in B-Mode there are two linear measurements that, similarly to aortic valve flow, are used in combination corresponding VTI measurements in PW Doppler for calculations of cardiac output.

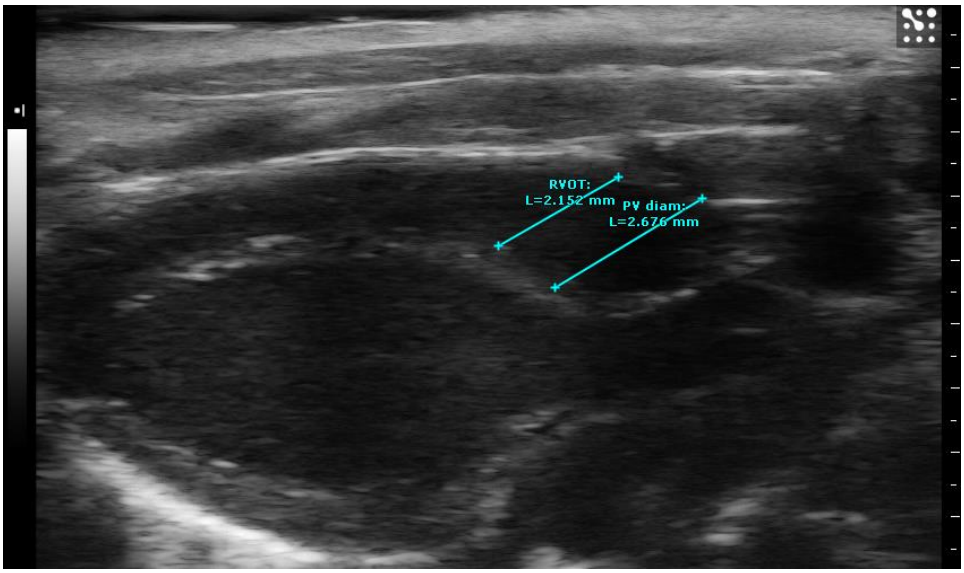

Figure 16 – RVOT and PV Diam linear measurements

M-Mode measurements protocols:

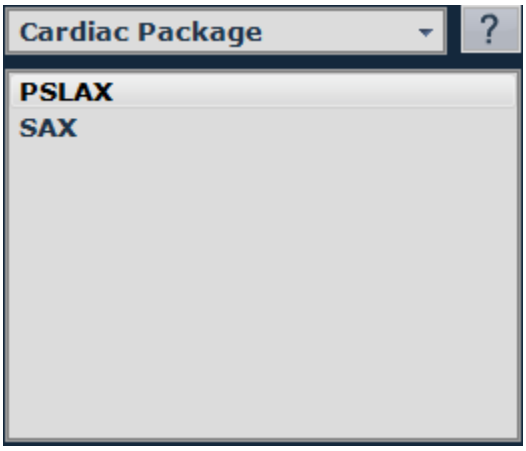

Figure 17 – M-Mode Cardiac package with the list of available protocols

PSLAX Protocol

RVID, IVS, LVID, LVPW M-Mode Measurements
These measurements are designed to be used on M-Mode images acquired from the parasternal long axis view in B-Mode and include measuring the thickness of the interventricular septum (IVS) or the right ventricle wall (RVID), the left ventricular interior diameter (LVID) and the left ventricle posterior wall (LVPW). The software is designed to perform these measurements in the following order IVS/RVID, LVID, LVPW; once one measurement is initiated the subsequent measurements are assumed.
To begin, select IVS;d from the measurement window and left click on the anterior border of the IVS when the heart is in diastole; move the cursor down to the posterior border of the IVS (a turquoise line will appear), then move to the posterior wall of LV and continue to the posterior side of the posterior wall. Ensure when placing the measurement points that you do not include the papillary muscles in the left ventricular posterior wall thickness, they should only appear in systole. To avoid errors in calculations aim to trace the measurements on subsequent cardiac cycles acquired in between two breaths.

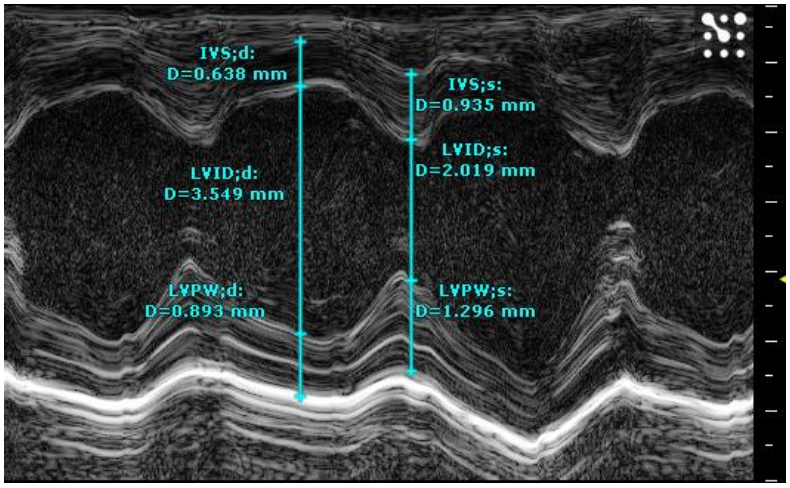

Figure 18 – M-Mode IVS, LVID, LVPW chain measurements

All these linear measurements on the M-Mode image are ideal for a quick cardiac assessment with the following calculations:

Ejection Fraction
Fractional Shortening
Volume
LV Mass
LV Mass (Corrected)

PSLAX M-Mode

Measurements

Description	Mode	Units	Avg
IVS;d - D	M-Mode	mm	0.637
IVS;s - D	M-Mode	mm	0.935
LVID;d - D	M-Mode	mm	3.549
LVID;s - D	M-Mode	mm	2.019
LVPW;d - D	M-Mode	mm	0.892
LVPW;s - D	M-Mode	mm	1.296

Calculations

Description	Units	Value
EF	%	75.217
FS	%	43.114
LV Mass	mg	90.882
LV Mass (Corrected)	mg	72.706
LV Vol;d	µL	52.589
LV Vol;s	µL	13.033

Figure 19 – M-Mode calculations from the PSLAX protocol using the linear measurements

LV Trace
The LV trace for M-Mode has two components, the anterior and posterior traces. The traces have to be done following a sequence in order to obtain the correct results; also it is required that the measurement contain at least to two points of diastole.
Start on the endocardial border on the anterior wall at any point on the cardiac cycle and left click at the systole and diastole for at least two cardiac cycles. When done with the anterior wall right click and the cursor will move to the posterior wall where points for the systole and diastole will be traced using left clicks for all the corresponding points from the anterior wall.
For calculations of the LV Mass repeat the trace on the epicardial contour.

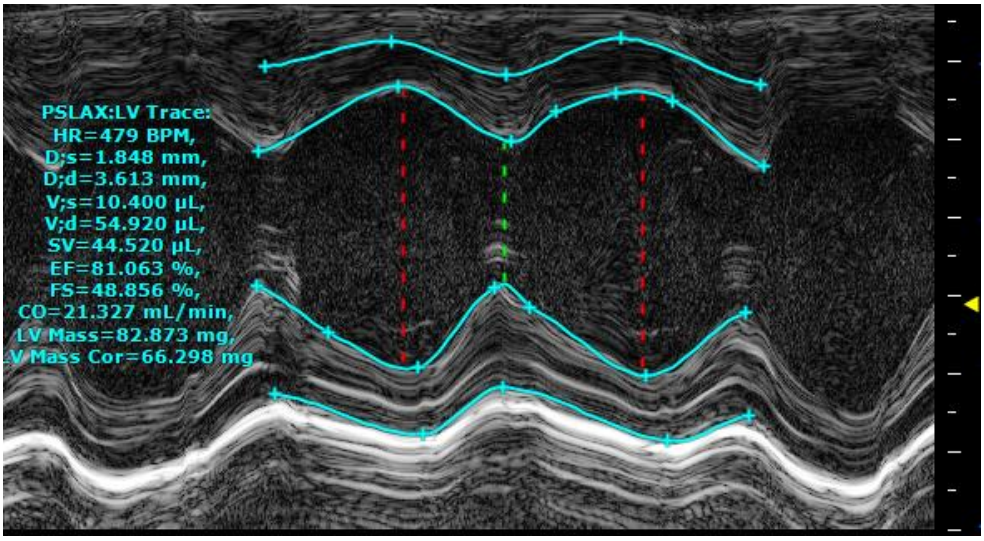

Figure 20 – M-Mode PSLAX trace measurements and derived calculations

SAX Protocol

IVS/LVAW, LVID, LVPW M-Mode Measurements

These measurements are designed to be used on M-Mode images acquired from the parasternal short axis view in B-Mode and include measuring the thickness of the interventricular septum (IVS) or left ventricle anterior wall depending on the orientation of the transducer, the left ventricular interior diameter (LVID) and the left ventricle posterior wall (LVPW). The software is designed to perform these measurements in the following order IVS/LVAW, LVID, LVPW; once one measurement is initiated the subsequent measurements are assumed.

To begin, select IVS;d from the measurement window and left click on the anterior border of the IVS when the heart is in diastole; move the cursor down to the posterior border of the IVS (a turquoise line will appear), then move to the posterior wall of LV and continue to the posterior side of the posterior wall. Ensure when placing the measurement points that you do not include the papillary muscles in the left ventricular posterior wall thickness, they should only appear in systole. To avoid errors in calculations aim to trace the measurements on subsequent cardiac cycles acquired in between two breaths.

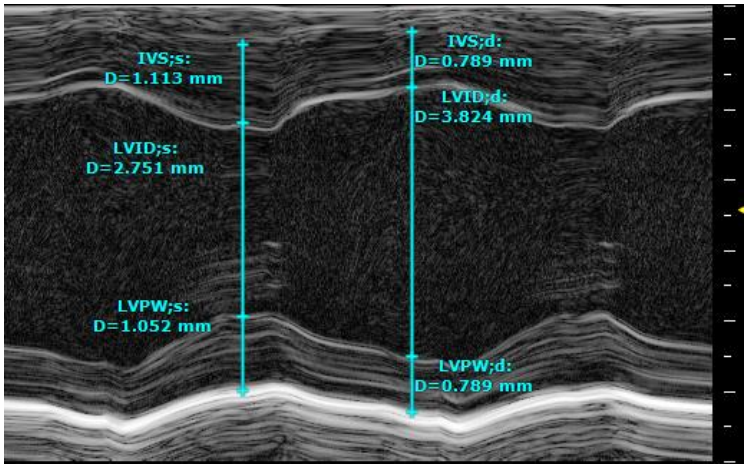

Figure 20 – M-Mode SAX IVS, LVID,LVPW measurements

Linear chained measurements in M-Mode from the short axis view are used for calculations of the following parameters:

Ejection Fraction
Fractional Shortening
Volume
LV Mass
LV Mass (Corrected)

SAX M-Mode

Measurements

Description	Mode	Units	Avg
IVS;d - D	M-Mode	mm	0.789
IVS;s - D	M-Mode	mm	1.113
LVID;d - D	M-Mode	mm	3.824
LVID;s - D	M-Mode	mm	2.751
LVPW;d - D	M-Mode	mm	0.789
LVPW;s - D	M-Mode	mm	1.052

Calculations

Description	Units	Value
EF	%	54.986
FS	%	28.042
LV Mass	mg	107.107
LV Mass (Corrected)	mg	85.686
LV Vol;d	µL	62.881
LV Vol;s	µL	28.306

Figure 21 – M-Mode SAX IVS, LVID,LVPW measurements and derived calculations in the report

LV Trace
Similarly to the LV trace measurements from the long axis view protocol the one for M-Mode SAX protocol has also two components for the anterior and posterior walls. The traces have to be done following the same sequence in order to obtain the correct results; also it is required that the measurement contain at least to two points of diastole.
Start on the endocardial border on the anterior wall at any point on the cardiac cycle and left click at the systole and diastole for at least two cardiac cycles. When done with the anterior wall right click and the cursor will move to the posterior wall where points for the systole and diastole will be traced using left clicks for all the corresponding points from the anterior wall. For calculations of the LV Mass repeat the trace on the epicardial contour.

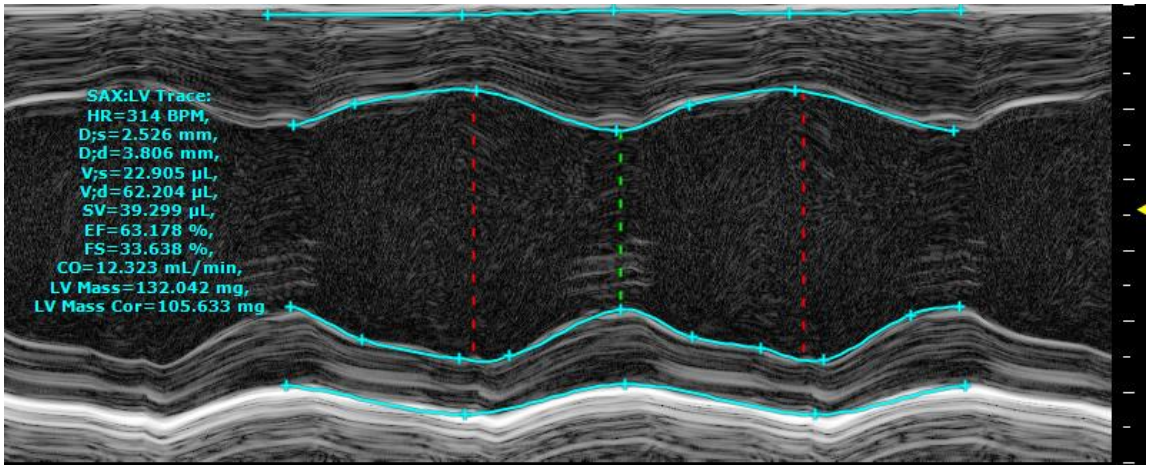

Figure 22 – M-Mode SAX trace measurements and derived calculations

PW Doppler Mode measurements protocols:

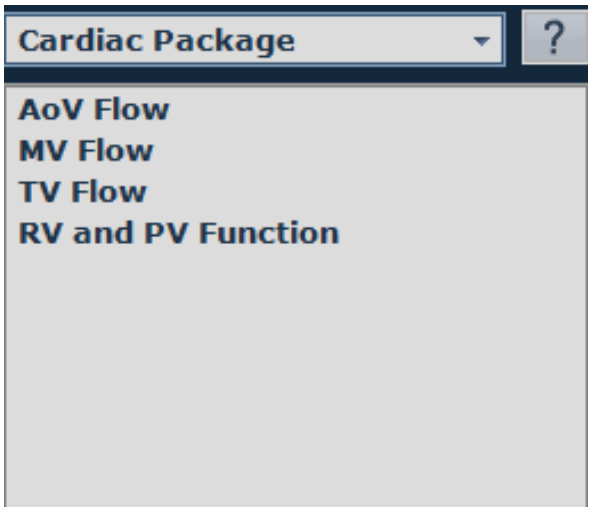

Figure 23 – PW Doppler Cardiac package with the list of available protocols

AoV Flow, MV Flow, TV and RV and PV Function Protocols

The measurements that are part of the AoV, MV, TV, RV and RV protocols are primarily velocity or velocity derivative measurements and can be used for analysis on their own or as part of the calculations available on the system for the Cardiac Output.

LVOT VTI, AoV VTI, RVOT VTI, MV VTI and TV VTI Measurements

These velocity time integral measurements are best traced using the auto-trace feature. With the auto-trace feature enabled on the image start the measurement with a left click at the beginning of the cycle and finish with a right click at the end of the cycle. For measurements of subsequent cycles left click at the beginning and end of cycles until the last cycle when you end with a right click.

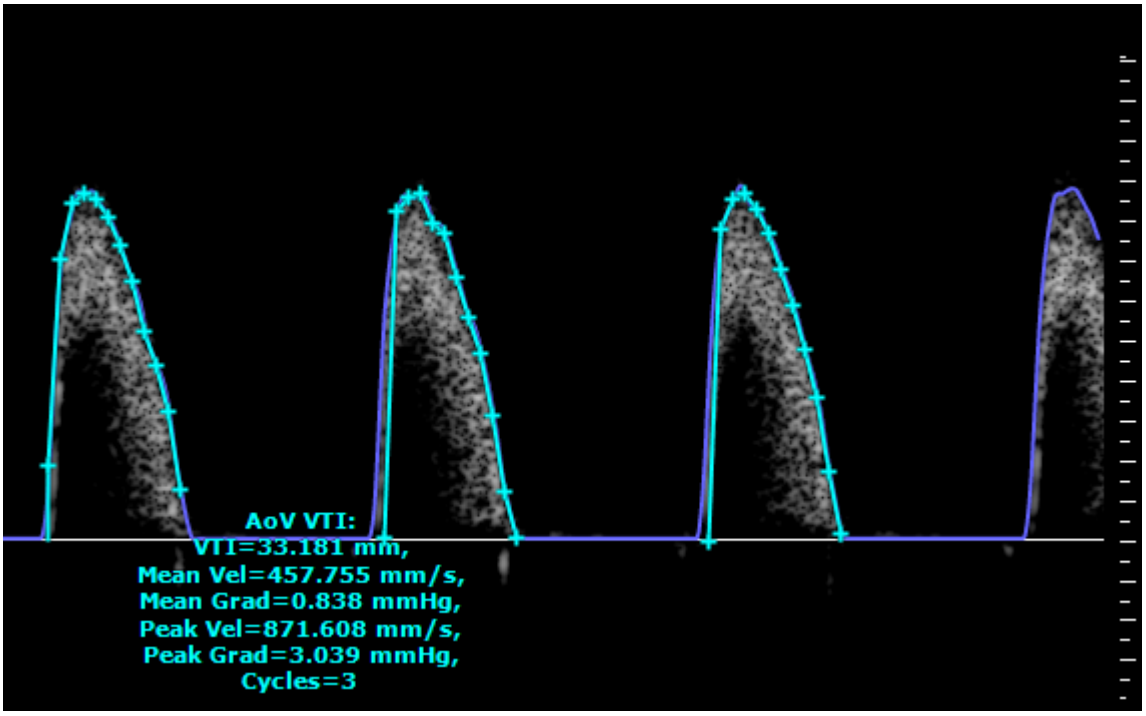

Figure 24 – VTI measurements for the AoV flow

Calculations

Description	Units	Value
PV CO	mL/min	22.205
PV SV	µL	54.781
PVA	mm²	1.820
RVOT CO	mL/min	11.641
RVOT SV	µL	28.718

AoV Flow

Measurements

Description	Mode	Units	Avg	STD	Instance 1	Instance 2	Instance 3
AoV Diam - L	B-Mode	mm	2.013		2.013		
AoV VTI - Cycles	PW Doppler Mode		2	1	1	3	1
AoV VTI - Mean Grad	PW Doppler Mode	mmHg	1.251	0.359	1.488	0.838	1.427
AoV VTI - Mean Vel	PW Doppler Mode	mm/s	555.019	84.471	609.982	457.755	597.320
AoV VTI - Peak Grad	PW Doppler Mode	mmHg	2.964	0.067	2.909	3.039	2.943
AoV VTI - Peak Vel	PW Doppler Mode	mm/s	860.739	9.741	852.796	871.608	857.813
AoV VTI - VTI	PW Doppler Mode	mm	34.627	1.572	34.400	33.181	36.300
LVOT - L	B-Mode	mm	1.821	0.064	1.775	1.866	
LVOT VTI - Cycles	PW Doppler Mode		1		1		
LVOT VTI - Mean Grad	PW Doppler Mode	mmHg	1.240		1.240		
LVOT VTI - Mean Vel	PW Doppler Mode	mm/s	556.689		556.689		
LVOT VTI - Peak Grad	PW Doppler Mode	mmHg	2.310		2.310		
LVOT VTI - Peak Vel	PW Doppler Mode	mm/s	759.992		759.992		
LVOT VTI - VTI	PW Doppler Mode	mm	29.741		29.741		

Calculations

Description	Units	Value
AoV CO	mL/min	46.211
AoV SV	µL	110.184
LVOT CO	mL/min	32.665
LVOT SV	µL	77.389

Figure 25 – Measurements and Calculations listed in the Report for various flow measurements protocols

PW Doppler Tissue measurements protocols:

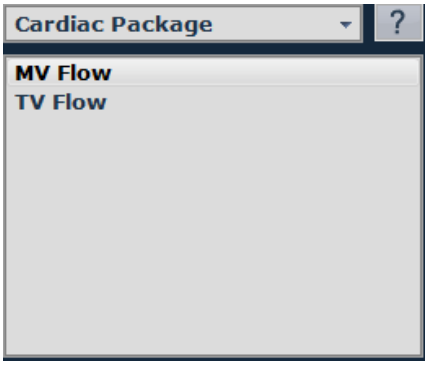

Figure 26 – PW Tissue Doppler Cardiac package with the list of available protocols

MV Flow and TV Protocol

These measurements are designed to be used on a Tissue Doppler spectrum of the mitral or tricuspid valve annulus.

Similar to the Pulsed Wave Doppler spectrum taken in the flow at the mitral valve level, the Tissue Doppler spectrum measured on the tissue of the mitral valve annulus are used to assess the diastolic function. The difference from the PW Doppler assessment is that the measurements are taken on the tissue spectrum and defined as measurements are E' and A'.

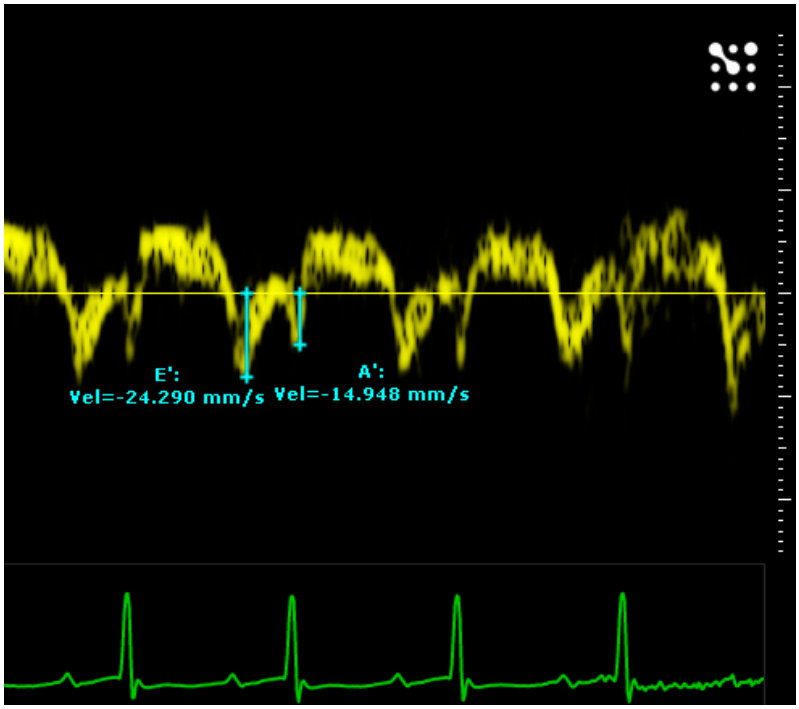

Figure 26 – PW Tissue Doppler Cardiac package with the list of available protocols

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