How to Perform the Most Commonly Used Measurements in the Cardiac Measurements Package and the Generated Calculations of Cardiac Function using the Vevo® 2100

VISUALSONICS

Objective

The objective of this application note is to review the measurements and calculations available in the various cardiac protocols as well as some other measurements which may be desired by using the generic tools available within the Vevo 2100 software.

Only the most commonly used measurements will be reviewed, however there are numerous others which are available and if a specific measurement is not defined there are always the generic tools which can be used to perform most necessary measurements.

Parasternal Long Axis (PSLAX) Protocol

PSLAX Trace Tool

This measurement is designed to be used on a parasternal long axis view of the heart acquired in B-Mode.

Ensure that you are in the measurement tab (bottom left of screen), that you are in the Cardiac Package and that the PSLAX protocol is open.
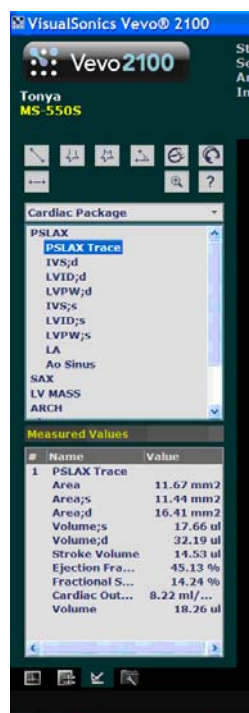

Figure 1 – Cardiac Package with the list of measurements available in the PLAX protocol.

Scroll through the cine loop and find the frame where the heart is in full diastole. To begin the PSLAX trace tool left click on the protocol measurement in the window, then move the cursor into the image window. 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. The image should look like Figure 2, with the diastolic frame outlined in red and systolic frame in green.
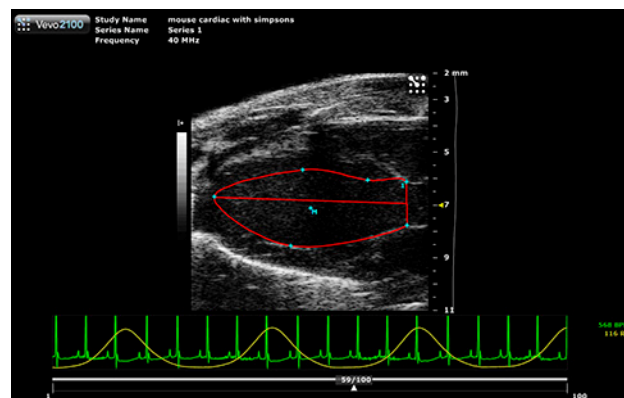

Figure 2 – PSLAX trace tool - outlining the endocardium to yield calculations of cardiac function. Here the diastolic frame is shown with the trace in red.

From this measurement the following calculations are completed:

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

To view the calculations you must go to the Report page. This is accomplished by going into the Study Management window and clicking on the Report button, which will display a page showing all of the measurements completed and the derived calculations for the study.
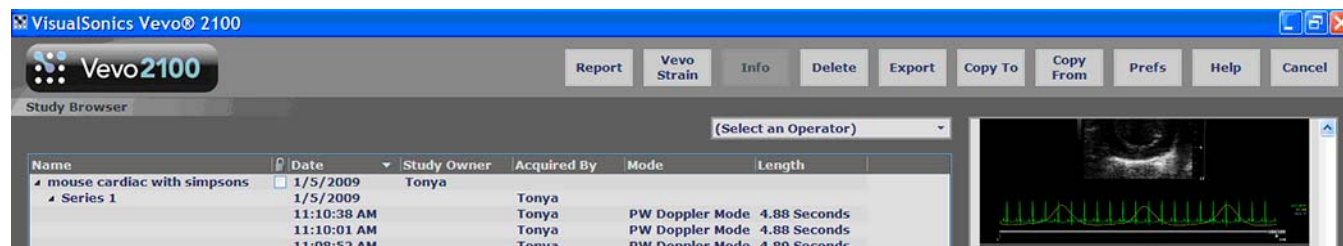

Figure 3 – Study Management Window - from this window a study Report can be generated to view all of the measurements and calculations performed for a given study or series.
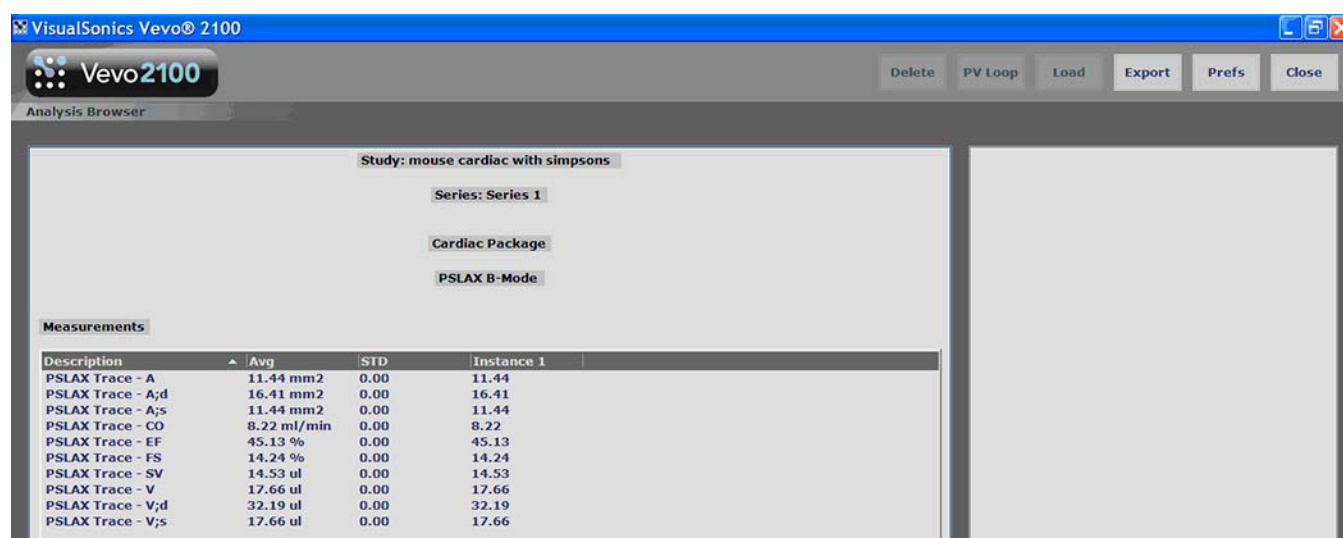

Figure 4 – Report Window - this window shows all the measurements and calculations formed performed within the selected study or series.

IVS/LVAW, LVID, LVPW B-Mode Measurements

These measurements are designed to be used on a parasternal long axis view or a short axis view of the heart acquired in B-Mode. The images below are from a long axis view only.

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 dyssynchrony.

To begin the measurement scroll 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.

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.
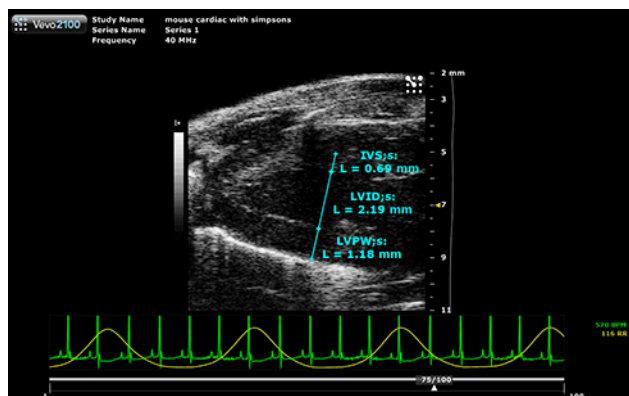

Figure 5 – IVS/LVAW tool - measuring the intraventricular septum (IVS) and left ventricular posterior wall (LVPW) thickness as well as the left ventricular internal diameter (LVID). These measurements are used to generate calculations of cardiac function.

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

> Volume
>
> Ejection Fraction
>
> Fractional Shortening
>
> LV Mass

Short Axis (SAX) Protocol

SAX Trace Tool

This measurement is designed to be used on a short axis view of the heart acquired in B-Mode.

Scroll through the cine loop and find the frame where the heart is in full diastole. To begin the SAX trace tool left click on the protocol measurement in the window, then move the cursor into the image window. 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.6, with the diastolic frame outlined in red and systolic frame in green.
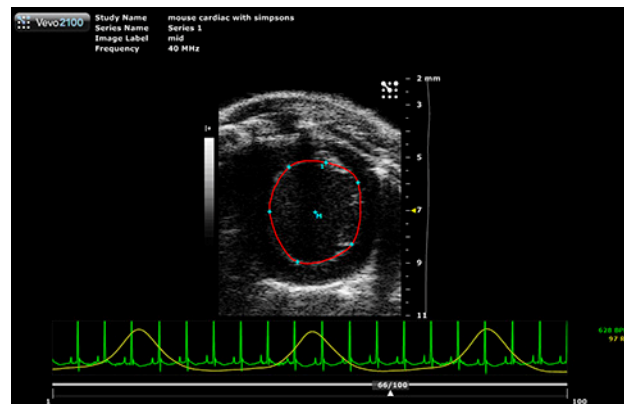

Figure 6 – SAX Trace Tool - outlining the endocardium to yield calculations of cardiac function. Here the diastolic frame is shown with the trace in red.

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

> Area
>
> Fractional Area Change

IVS, LVID, LVPW M-Mode Measurements

This measurement is designed to be used on a parasternal short axis view or a parasternal long axis view of the heart acquired in M-Mode. Images shown here are from a short axis view only.

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.

To begin the measurement scroll through the cine loop and find a section where the animal was not breathing. 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 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. The images should look similar to this. Here the LVAW was selected as the right ventricle is not visible in the M-Mode spectrum. The measurements are shown here in the short axis view. However the same measurement tools are available for a long axis M-Mode image as well.
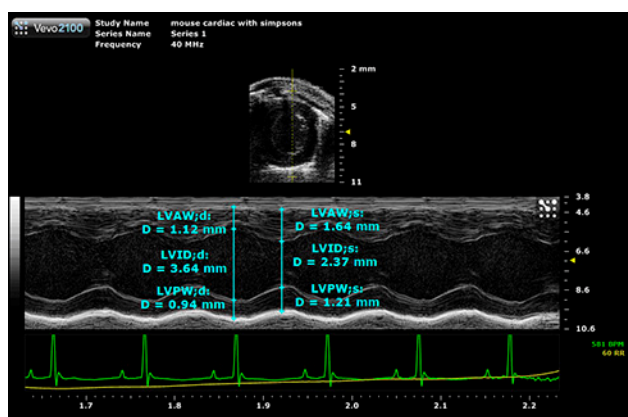

Figure 7 – IVS tool - measuring the thickness of the intraventricular septum (IVS) and left ventricular posterior wall (LVPW) as well as the left ventricular internal diameter (LVID). These measurements are used in calculations of cardiac function.

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

Volume

Ejection Fraction

Fractional Shortening

LV Mass

LV Mass Protocol

LV Trace

This measurement is designed to be used on a parasternal short axis view or a parasternal long axis view of the heart acquired in M-Mode. Images shown here are from a short axis view only.

These measurements involve measuring the thickness of the interventricular septum (IVS) or left ventricular anterior wall (LVAW), depending on which appears in the image. The left ventricle posterior wall as well as the left ventricular interior diameter, over several cardiac cycles.

To begin the measurement scroll through the cine loop and find a section where the animal was not breathing. To begin, select the LV Trace tool from the measurement window and move the cursor into the image window and left click on the posterior border of the IVS/LVAW when the heart is in diastole, then move along the same wall to where the heart is in systole and continue through several cardiac cycles left clicking at systole and diastole. At the last point right click, rather than left clicking. This tells the software that you want to move to the posterior wall. Begin by left clicking on the anterior portion of the posterior wall and do the same as above clicking all the way along. Ensure that you are within the caliper points of the initial trace. If cardiac function is the only requirement when you get to the last point right click twice to finish the measurement. If you desire an LV mass calculation right click only once, then move to the anterior portion of the IVS/LVAW and begin placing points at systole and diastole. At the last point right click and move to the posterior portion of the posterior wall and left click along at systole and diastole. When at the last point right click to finish the measurement.

The images should look similar to this. The measurements are shown here in the short axis view. However the same measurement tools are available for a long axis M-Mode image as well.
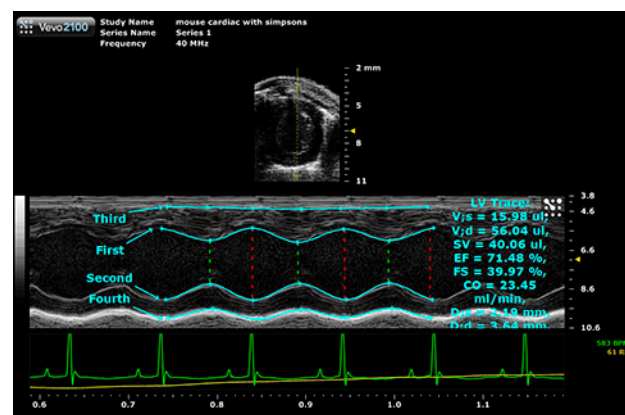

Figure 8 – LV Trace Tool - outlining the left ventricular anterior and posterior walls. These measurements are used for calculations of cardiac function.

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

Diameter

Volume

Stroke Volume

Ejection Fraction

Fractional Shortening

Cardiac Output

Endocardial and Epicardial Area

This measurement is designed to be used on one parasternal long axis view and one parasternal short axis view of the heart acquired in B-Mode.

Start with the long axis view first. To begin the measurement scroll through the cine loop and find a frame where the heart is in full systole. To begin the measurement select the ENDOmajor;s, 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, then select the EPImajor;s, 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.

Now load the short axis view, scroll through the cine loop and find a frame where the heart is in full systole. To begin the measurement select the ENDOarea;s, left click at a location on the endocardium and continue to move the cursor around the myocardium. As the cursor is moved caliper points will be dropped automatically. Once the caliper point gets close to the starting point the area is automatically completed. Then select the EPIarea;s and trace the epicardium just as the endocardium was traced above. Move now to the subsequent frame showing the heart in full diastole. Complete the same procedure as above using ENDOarea;d, EPIarea;d.
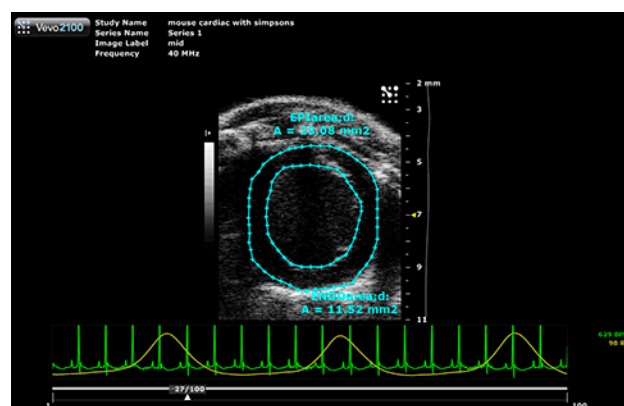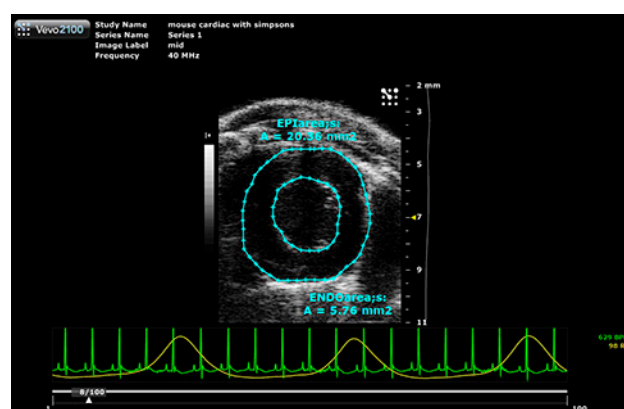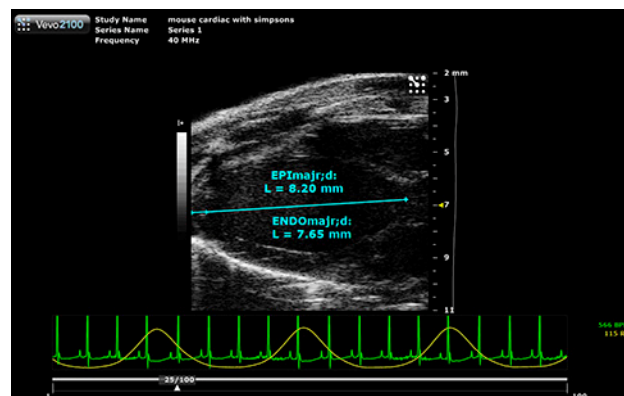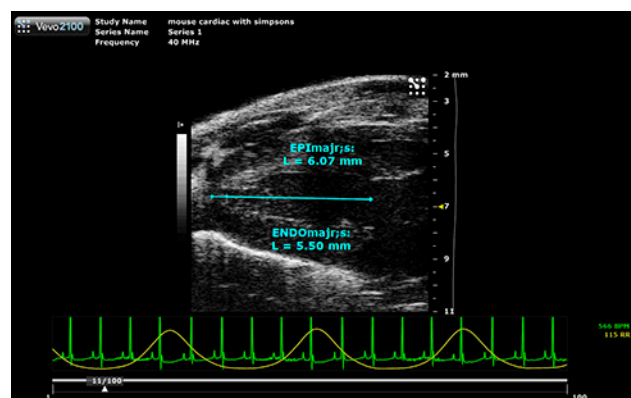

Figure 9 – Endocardial and Epicadial tool - measuring the length of the left ventricle with respect to the endocardium and epicardium in both systole (A) and diastole (B) as well the endocardial and epicardial areas are traced again in systole (C) and diastole (D). These measurements are used for a comprehensive set of cardiac function and LV mass calculations.

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

> Volume
>
> Stroke Volume
>
> Ejection Fraction
>
> Fractional Shortening
>
> Area Change
>
> Fractional Area Change
>
> Cardiac Output
>
> Stroke Volume
>
> LV Mass
>
> Average wall thickness

PV Flow

These measurements are designed to be used on a Pulsed Wave Doppler spectrum of the pulmonary artery acquired just below the pulmonary valve. These measurements involve measuring the velocity and gradient of flow through this vessel.

To begin the measurement scroll through the cine loop and find a section where the animal's breathing is not apparent.

The PV Peak measures the peak velocity of the blood flow. To begin, select the measurement and left click on the peak of the spectrum.

The PV VTI measures the velocity time interval of the blood flow. To begin, select the measurement and left click at the start of the envelope and move the cursor around the peak and back to where the envelope approaches the baseline level. At this point right click to end the measurement.
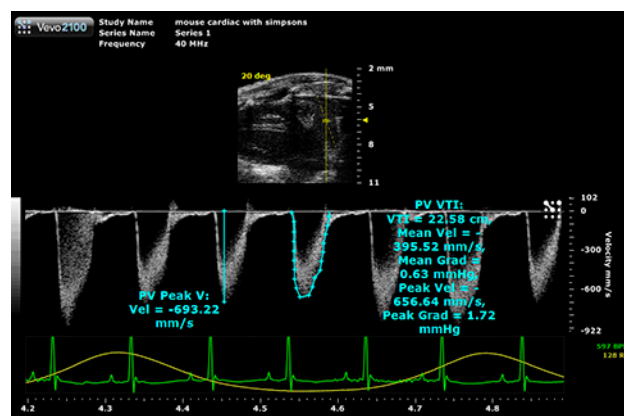

Figure 10 – PV Flow Measurements - here two different tools were used, the pulmonary valve (PV) peak velocity and the PV velocity time interval (PV).

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

> Peak Velocity
>
> Mean Velocity
>
> Peak Gradient
>
> Mean Gradient
>
> Velocity Time Interval

AoV Flow

These measurements are designed to be used on a Pulsed Wave Doppler spectrum and a B-Mode image of the ascending aorta.

These measurements involve measuring the velocity and gradient of flow through this vessel as well as the diameter of the vessel, which combined allow for the calculation of cardiac output.

To begin the measurement scroll through the PW Doppler spectrum and find a section where the animal's breathing is not apparent.

The AoV Peak measures the peak velocity of the blood flow (however is not required for the cardiac output calculation). To begin, select the measurement and left click on the peak of the spectrum.

The AoV VTI measures the velocity time interval of the blood flow. To begin, select the measurement and left click at the start of the envelope and move the cursor around the peak and back to where the envelope approaches the baseline level. At this point right click to end the measurement. This measurement is required for the cardiac output calculation.

Additionally, the left ventricular outflow tract (LVOT) diameter must be measured in the B-Mode image to complete the cardiac output measurement. Ensure that this measurement is done on a frame in the B-Mode cine loop during systole as well that the diameter is measured perpendicular to the aortic wall.
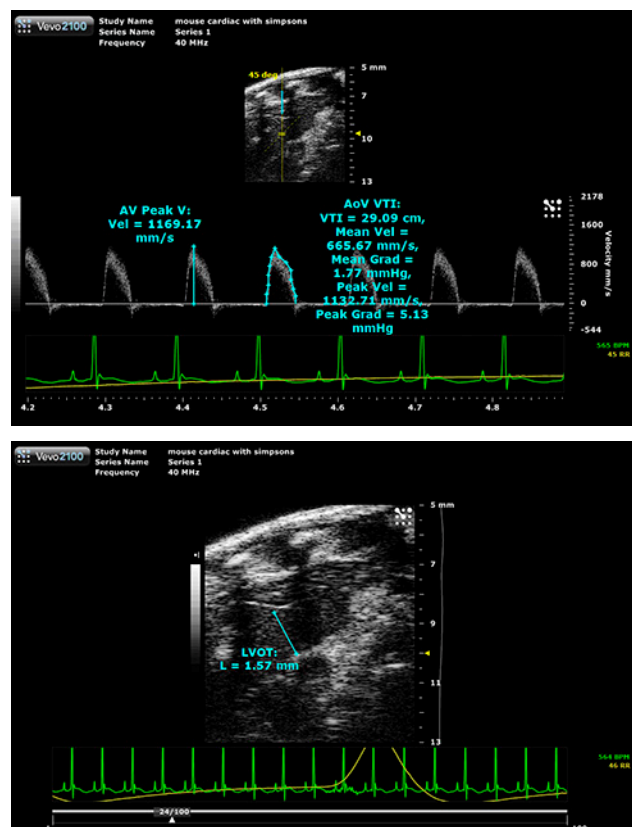

Figure 11 – AoV Flow measurements - here various measurements were made - the aortic valve (Ao/AV) peak velocity as well as the AoV velocity time interval (VTI) (A) and the diameter of the left ventricular outflow (LVOT) tract (B). The last two measurements are required for a calculation of cardiac output.

LV Diastolic Function

These measurements are designed to be used on a Pulsed Wave Doppler spectrum of the mitral valve flow.

There are numerous standard measurements completed to look at diastolic function, typically the mitral valve E and A peaks are measured. The E peak is the "early" peak, while the A peak is the "atrial" peak. Along with these measurements the isovolumic relaxation time (IVRT) and the isovolumic contraction time (IVCT) are measured. Both of these are times when the muscles are contracting. However there is no change in the

volume of the ventricle to cause blood flow, therefore they appear as flat lines on the PW Doppler spectrum. The deceleration of blood flow through the mitral valve can also be measured in terms of the deceleration rate as well as the time. Although not shown in the image below, a velocity time interval (VTI) of the mitral valve inflow can also be completed by tracing the E and A peaks, similar to the VTI trace made in the PV Flow protocol.
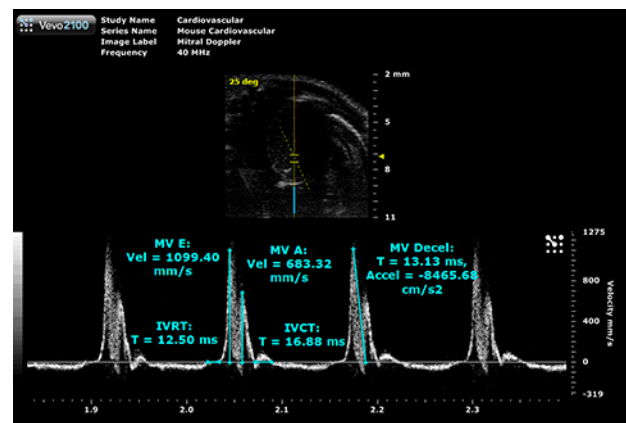

Figure 12 – MV Flow measurements - the above measurements are typically made to assess diastolic function in the left side of the heart through the mitral valve. The peak velocities of the early (E) and atrial (A) peaks are measured, along with the deceleration of the E peak. The isovolumic relaxation and contraction times (IVR/CT) can also be measured.

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

E/A ratio

They Myocardial Performance Index is another calculation preformed on the Mitral Valve PW Doppler spectrum used to assess both systolic and diastolic function of the heart. The "No-Flow Time" (NFT) is measured from the time when the A peak reaches baseline to the time where the next E peak begins, while the aortic ejection time (AET) is measured as the time where the spectrum falls below the baseline, indicating flow out through the aorta.
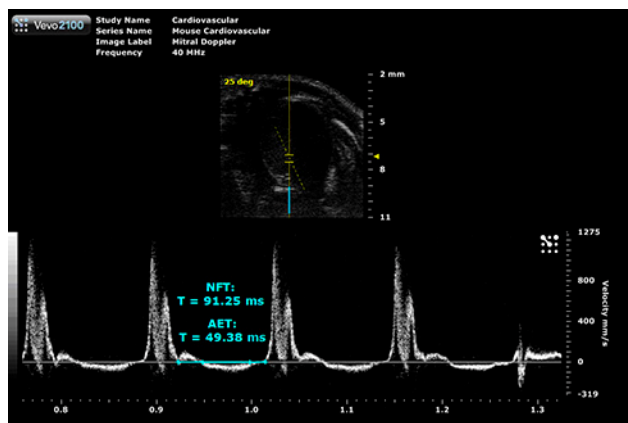
Figure 13 – MV Flow measurements - the No-Flow Time (NFT) through the mitral valve as well as the Aortic Ejection Time (AET) are measured and used in the calculation of the myocardial performance index.

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

Myocardial Performance Index

Tissue Doppler

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

Similar to the Pulsed Wave Doppler spectrum taken and the mitral valve, Tissue Doppler spectrums taken at the mitral valve annulus are also used to look at diastolic function and again, typically the early (E) and atrial (A) peaks are measured. Different than in the PW Doppler spectrum is that the measurements are designated by a ', so the completed measurements are E' and A'.
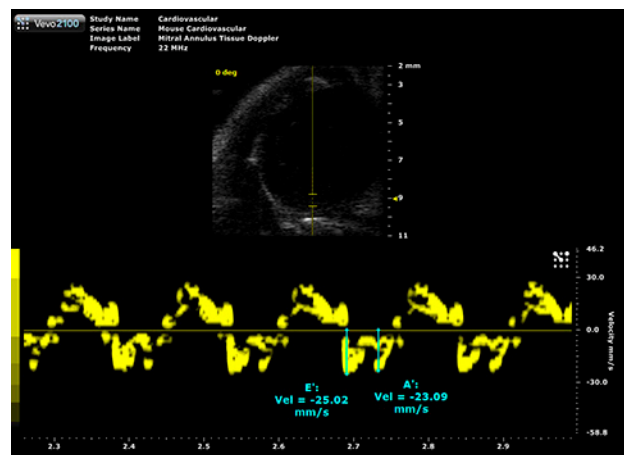

Figure 14 – Tissue Doppler measurements - the above measurements are typically made to assess diastolic function in the left ventricle. The image is taken from the mitral valve annulus. The peak velocities of the early (E') and atrial (A') peaks are measured.

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

The A'/E' velocities ratio

The E'/A' velocities ratio

The MV E/E' velocities ratio

TV Flow

These measurements are designed to be used on a Pulsed Wave Doppler spectrum of the tricuspid valve flow.

In the tricuspid valve typically the E and A peaks are measured. The E peak is the "early" peak, while the A peak is the "atrial" peak.
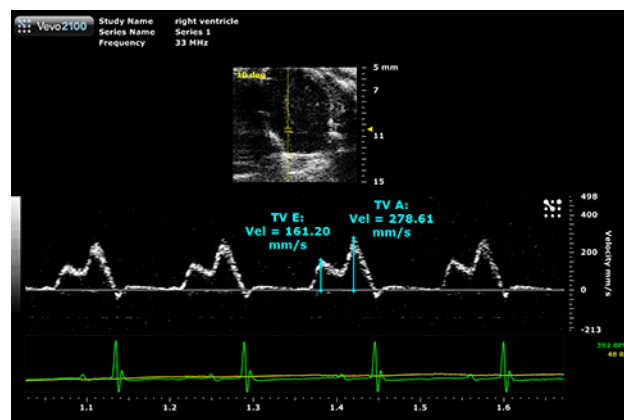

Figure 15 – TV Flow measurements - the above measurements are typically made to assess diastolic function in the right side of the heart through the tricuspid valve. The peak velocities of the early (E) and atrial (A) peaks are measured.

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

The Tricuspid Valve E/A velocities ratio

The Tricuspid Valve Peak Pressure

Simpson's

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 or distal portion of the heart and one towards the base or proximal portion of the heart. This allows for more precision when the cardiac geometry isn't typical or changing over time.

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.
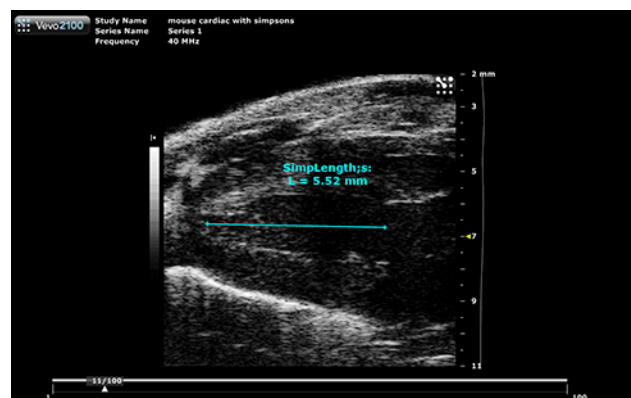

Figure 16 – Simpson's measurements - the length of the ventricle is measured in a long axis view, here shown in systole.

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.
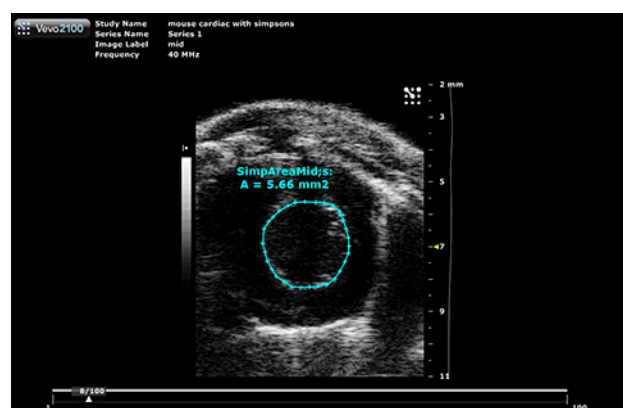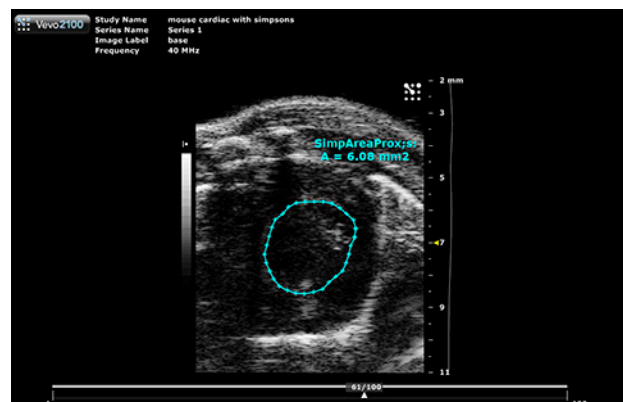

Figure 17 – Simpson's measurements - the endocardial areas must be traced from the proximal short axis view (A), the mid view (B) and the distal view (C), here all measurements are shown in systole.

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

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

Generic Measurement Tools

Right Ventricle

Currently the Vevo 2100 software does not include a complete protocol for right ventricle measurements. However the generic measurement tools can be used to make any desired measurement, the results of which are also included in the data export file. These measurements can be given an appropriate label to identify them in the report.

In a modified parasternal long axis view the right ventricle can be visualized in B-Mode. Scroll to a frame where the right ventricle is in diastole. The wall thickness and ventricle diameter can be measured using the generic linear measurement tool.

Figure 18 – Generic Linear Measurement Tool - this tool can be used to perform any desired linear measurement which is not defined within a protocol

To measure the anterior wall of the right ventricle select the linear measurement tool, move the cursor to the anterior border of the wall and left click to start the measurement, move to the opposing edge of the wall and left click. Ensure that the measurement was made perpendicular to the edge of the wall. The ventricle diameter can also be made using the same technique. You must

reselect the generic linear measurement tool. To give the measurement an appropriate name, right click on the line and choose Properties. Within this window the generic name can be changed to a more appropriate one.
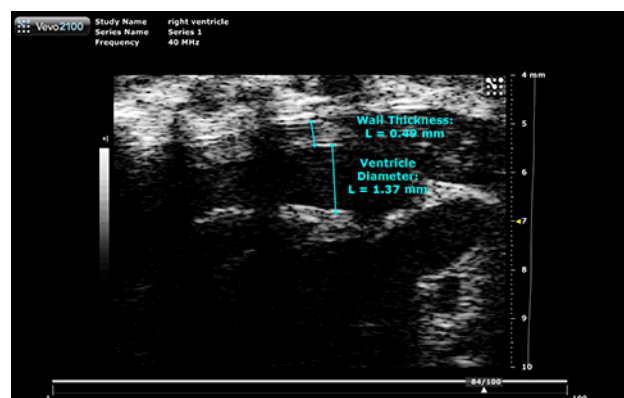

Figure 19 – Right Ventricle measurements - generic linear measurement tool was used to measure the right ventricle wall thickness and ventricle diameter in B-Mode.

The right ventricle can also be imaged using M-Mode. The wall thickness and ventricle diameter can also be measured in this mode. Again use the generic depth measurement tool: select an area in the M-Mode spectrum where the ventricle is in diastole and ensure that the measurement is not done during a respiration. To give the measurement an appropriate name, right click on the line and choose Properties. Within this window the generic name can be changed to a more appropriate one.
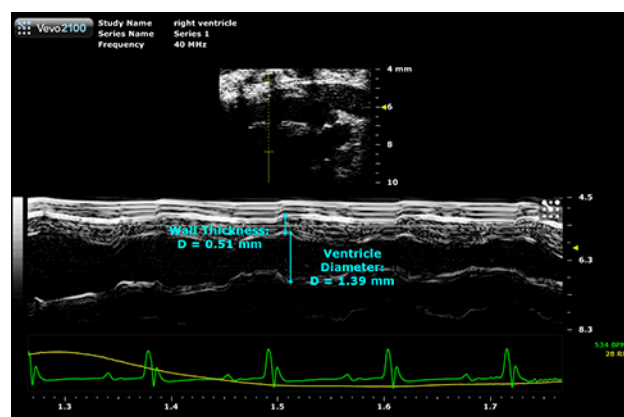

Figure 20 – Right Ventricle measurements - generic linear measurement tool was used to measure the right ventricle wall thickness and ventricle diameter in M-Mode.

Pulmonary Vein

Currently the Vevo 2100 software does not include a protocol for pulmonary vein measurements. However the generic measurement tools can be used to make any desired measurement, the results of which are also included in the data export file. These measurements can be given an appropriate label to identify them in the report.

Pulsed Wave Doppler can be completed on the pulmonary vein in a modified parasternal long axis view. Color Doppler aids in obtaining the best PW Doppler spectrum. The velocities can be measured for the atrial, systolic and diastolic peaks using the generic velocity measurement tool.

Figure 22 – Pulmonary Vein measurements - the atrial, systolic and diastolic peaks can be traced in the Pulsed Wave Doppler spectrum using the generic velocity measurements.

Figure 21 – Generic Velocity Measurement Tool - this tool can be used to perform any desired velocity measurement which is not defined within a protocol.

To measure the peak velocities select the generic velocity measurement and move the cursor to the peak to be measured and left click. A straight line will be placed connecting this point to the baseline, providing the velocity measurement. This procedure can be completed for the atrial, systolic and diastolic peaks. The generic velocity tool will have to be reselected every time. To give the measurement an appropriate name, right click on the line and choose Properties. Within this window the generic name can be changed to a more appropriate one.
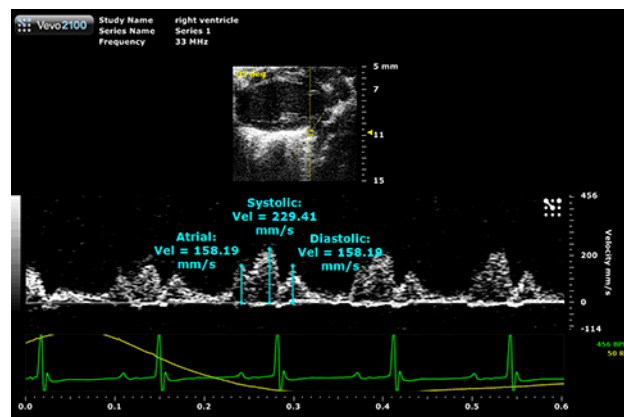
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