Vevo® Vasc

User Guide

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Contents

Introduction

Vevo Vasc is a software application designed to measure vessel wall anatomy and motion in small-animal models. Vevo Vasc includes support for a speckle-based vascular wall motion, thickness, strain and stiffness analysis.

This document is designed as a user guide for processing and analyzing clips of B-Mode and EKV 2D images acquired with the Vevo Imaging System.

Vevo Vasc is only available on the Vevo LAB and is not available on the Vevo Imaging Systems.

Data for Vevo Vasc Analysis

Only B-Mode and EKV images (not EKV AM-Mode images) acquired on a Vevo 2100 or Vevo 3100 Imaging System can be analyzed with Vevo Vasc.

The following B-Mode / EKV data is not suitable for Vevo Vasc analysis:

- ECG triggered cine loops.

- Single B-Mode or EKV frames.

- Loops or sub-ranged cine loops with less than 15 frames.

- Loops or sub-ranged cine loops with more than 1000 frames (500 - 750 frames is suggested).

- Cine loops acquired with less than 15 frames per heart cycle.

The following table notes the minimum B-Mode acquisition frame rate required for a set heart rate (BPM).

Heart Rate (BPM)	B-Mode Acquisition Frame Rate
300	83
325	89
350	96
375	103
400	110
425	117

Heart Rate (BPM)	B-Mode Acquisition Frame Rate
450	124
475	131
500	138
525	144
550	151
575	158
600	165

Note: Although cine loops acquired using Respiration Gating can be loaded into Vevo Vasc, the ECG trace will be not be correctly displayed due to the acquisition method used.

Note: For EKV images acquired using V1.5.X builds 5085 or earlier, when the data is loaded into Vevo Vasc, the ECG trace will not be loaded or displayed.

Typical Vevo Vasc Workflow

The following is a quick workflow overview of a Vevo Vasc analysis.

To perform an analysis in Vevo Vasc

1 Select an appropriate B-Mode or EKV cine loop from the Study Browser.

2 Click the **Vevo Vasc** button in the main tool bar of the top of the Study Browser. You can also access Vevo Vasc from the mode window, click Measurements ☑ and then click **Vevo Vasc**.

The application processes the cine loop and then displays it within the Vevo Vasc AM-Mode Selection Window.

3 In the Image area (see ① below):

    a. Use the playback controls below the image to locate the frame you want to work with.
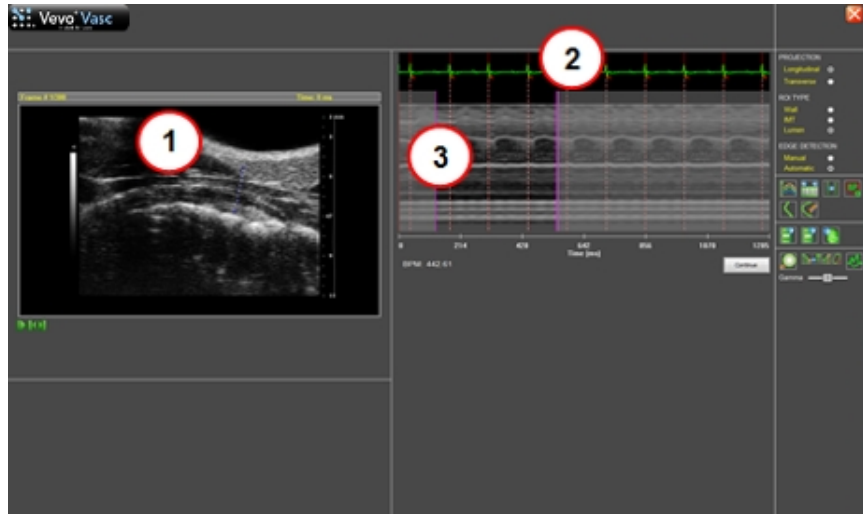
b. Click above the vessel wall, drag the pointer across the vessel to beyond the opposite wall, and then right-click to set the AM-Mode cross-section.

4 In the Physiological Data / AM-Mode Image area (see ② and ③ above):

a. Define the cycle to be analyzed within the Physiological Data (ECG Trace).

    i. On the left side drag the single purple slider to the position where you want the data period to begin (see ③ above).

   ii. On the right side drag the purple slider to the end of the desired data period.

> **Note:** The period must include at least one complete cardiac cycle.

    b. Define (or redefine) the location of the R-waves within the Physiological Data (ECG trace).

        i. Right click on the R-wave for the first cardiac cycle. The system places a red line with a small red 'R' indicated.

        ii. Right click on the other R-wave locations to add the remainder of your cardiac cycles (see ② above). For best results, create your selection period between one respiration cycle and the next.

        iii. If you want to change the position of a line, right click on it to delete it, and then right click again at the new position.

5 Below the AM-Mode image, click **Continue**. The cine loop now appears in the Vevo Vasc ROI Analysis workspace.
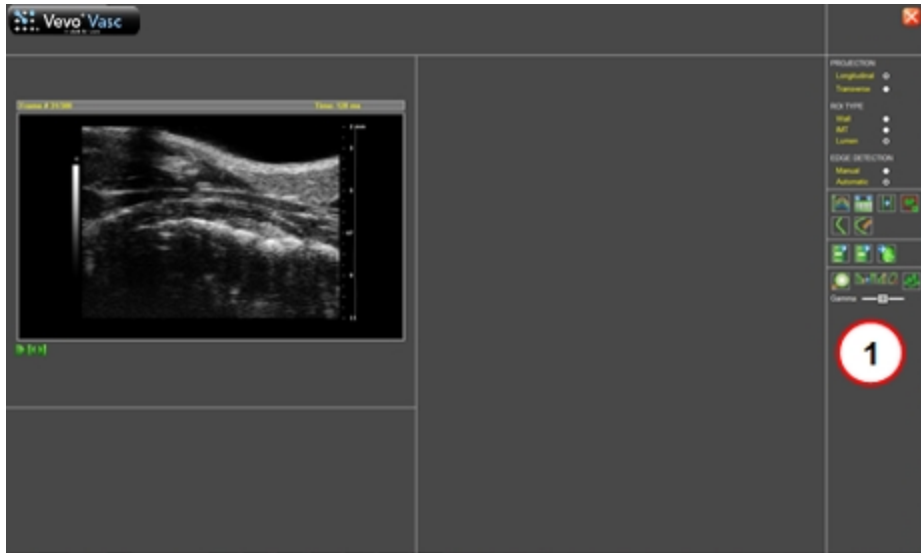
6 In the tool panel (see ① above):

   a. Select the type of Projection to create: Longitudinal, Transverse (see ① below).

   b. Select the type of ROI to be placed: Wall, IMT, Lumen (see ② below).

   c. Select the Edge Detection method to use: Manual, Automatic (see ③ below).
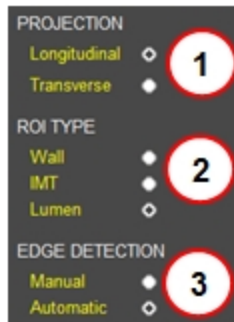
d. Within the image, click and then drag to add points of the ROI. Right-click to complete the ROI trace.

For Automatic Longitudinal / Transverse Projections, and Manual Longitudinal Projections, a floating window is displayed for ROI adjustment.
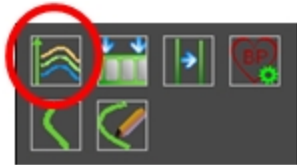
e. If you want to delete the trace and start again, delete the old ROI from the thumbnail context menu and then click the **Trace New ROI** button (see below).
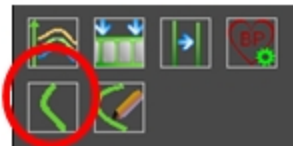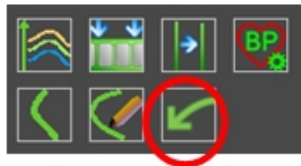

f. If you want to modify the current ROI, click the **Modify ROI** button (see below) and then adjust the ROI displayed.
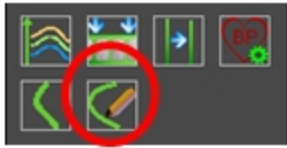
When ROI tracing is complete, click the **Process** button (see below).

g. Once you have edited and processed an ROI, an Undo Editing button is displayed (see below). Click **Undo Editing** to undo the just completed ROI edit.

h. If you want to return to the AM-Mode view to select a new cardiac period, click the Select Sequence/AM-Mode Selection (see below), to create the new period and then click **Continue** again.
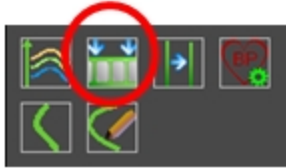
One of two messages will be displayed, dependent on the changes completed within the AM-Mode view:

- If the changes are relatively minor (eg. reducing the range of data to be analyzed), a message is displayed noting that Vevo Vasc will reprocess the data using the updated parameters.

  Note: While proceeding to the ROI Analysis workspace, the current ROIs will be automatically processed.

- If the changes are more extensive, a message is displayed noting that Vevo Vasc will discard the current ROIs, AM-Mode cross-section and associated data.

  Note: While proceeding to the ROI Analysis workspace, the current ROIs and associated results will be deleted.

In both cases, you will need to either click **Yes** to proceed to the ROI Analysis workspace, or **No** to discard your changes but remain in the AM-Mode view.

7 The software analyses the ROI for all included frames in the cine loop and graphs the results in both the analysis workspace and within the Results Table (see ① and ② below). A thumbnail of the analyzed ROI is displayed at the top of the ROI Analysis Workspace (see ③ below).

At the top of the screen, select the appropriate analysis graphs to be displayed: Velocity, Displacement, Strain or Vessel Analysis (see ④ below).

Note: Strain is only available when Longitudinal ROIs are placed on the image.
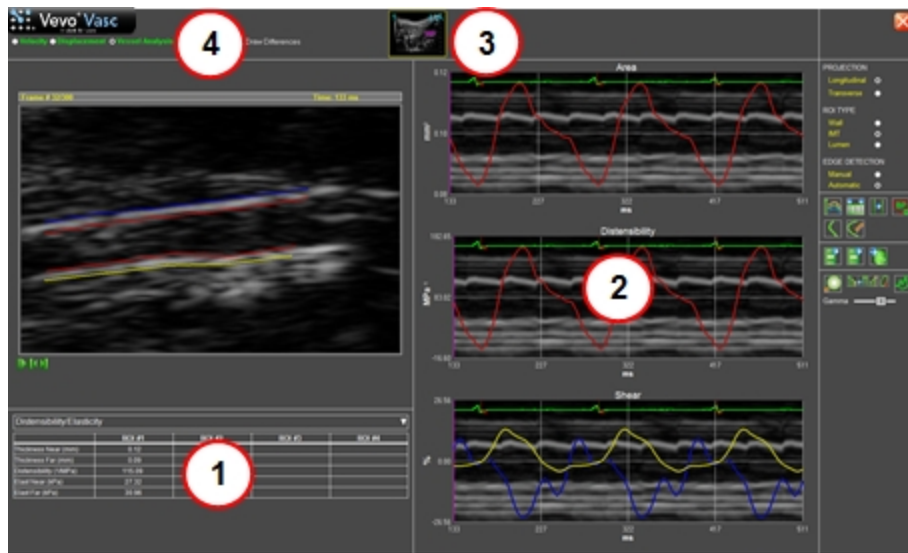
AM-Mode Selection Workspace

When a cine loop is initially loaded into Vevo Vasc, the initial Vevo Vasc workspace displayed is the AM-Mode selection workspace.
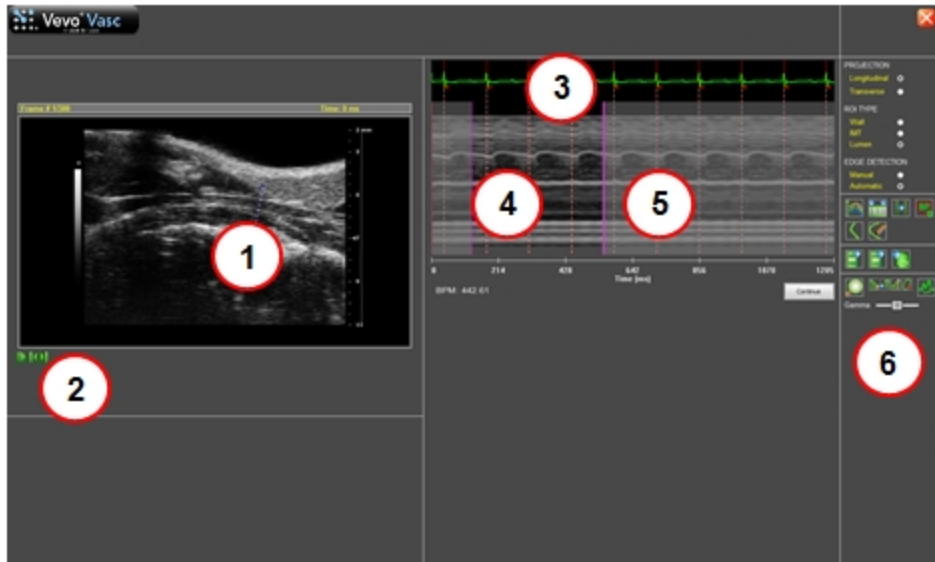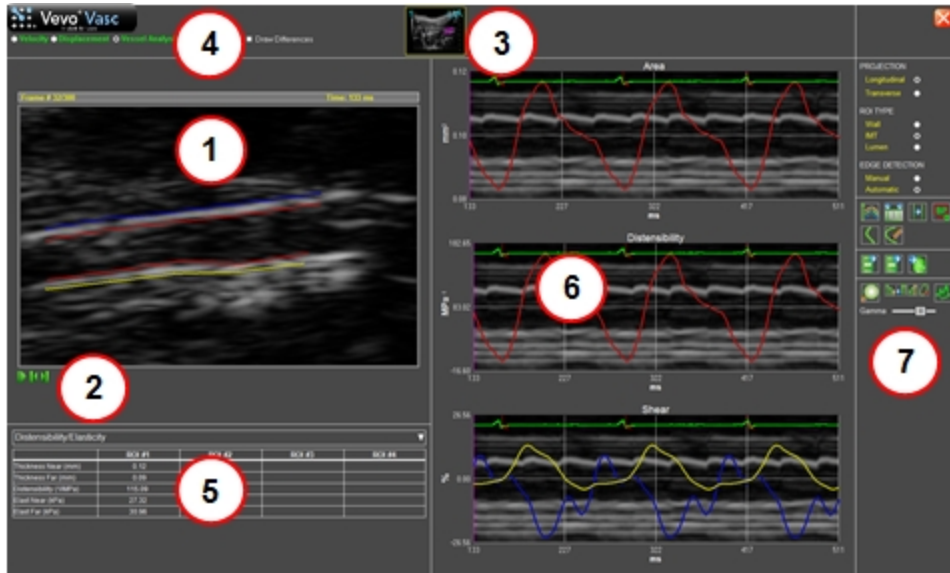

This workspace contains the following:

(1)	Image area. AM-Mode overlay is placed within this image, which generates the AM-Mode image displayed.
(2)	Playback controls. Includes PLAY/STOP, PREVIOUS FRAME, and NEXT FRAME functions.
(3)	Physiological Data. ECG trace with R-wave indicators either manually or automatically applied.
(4)	AM-Mode image - included cycles. Cardiac cycles which have been selected and will be included in the analysis.

(5)	AM-Mode image - excluded cycles. Cardiac cycles which have not been selected for the analysis.
(6)	Tool Panel. Containing ROI, Zoom, and Gamma controls.

ROI Analysis Workspace

Once the R-waves and AM-Mode data have been selected, the next workspace displayed is the ROI Analysis Workspace.

This workspace contains the following:

(1)	The image with the ROI displayed.
(2)	Playback controls. Includes PLAY/STOP, PREVIOUS FRAME, and NEXT FRAME functions.
(3)	ROI thumbnails.
(4)	Analysis graph selector. **Note:** Strain is only available for Longitudinal ROIs.

(5)	Results table.
(6)	Analysis graphs.
(7)	Tool panel. Includes ROI, Export, Zoom, Vector and Gamma controls.

Tool Panel
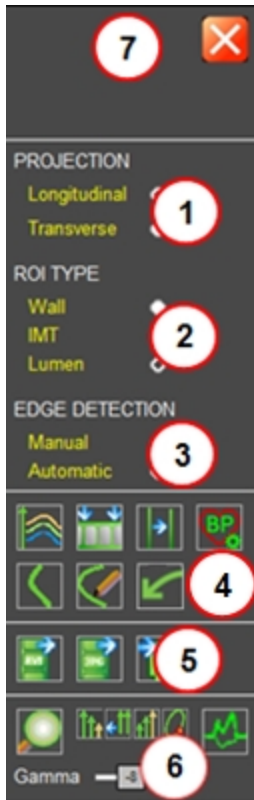
This tool panel contains the following:

①	ROI Projection options: Longitudinal, Transverse.
②	ROI Type options: Wall, IMT, Lumen.
③	ROI Edge Detection options: Manual, Automatic.

(4)	ROI Control options: Process, Sequence/AM-Mode Selection, Pulse Propagation Velocity, Blood Pressure Modification, Trace New ROI, Modify Existing ROI, Undo Editing. **Note:** The PPV button is only available for Longitudinal ROIs.
(5)	Export options: Export Video, Export Images, Export Data.
(6)	Image, Trace and Analysis Graphs options: Zoom/Restore, Decrease Vector Size, Reset Vectors Size, Increase Vector Size, Toggle Border/Velocity Vectors/Trajectory, Toggle AM-Mode Background, Gamma Slider.
(7)	Exit Vevo Vasc button.

Defining and Modifying ROIs

Longitudinal projections

Once Longitudinal has been selected on the tool panel, three different longitudinal ROIs can be traced:

- Wall ROI. Composed of four borders placed on the two sides of a vessel, defining the internal and external boundaries of the vessel.

- IMT ROI. Composed of four borders placed on the two sides of a vessel, defining the internal boundaries and the IMT.

- Lumen (vessel diameter) ROI. Composed of two borders that define the internal dimension of a vessel without IMT thickness.

To place a longitudinal ROI

1 Within the tool panel, click **Longitudinal**.

> **Note:** Only one type of projection can be placed on an image. Once a Longitudinal ROI exists on the image, the user will be unable to select or place a Transverse ROI.

2 Select the edge detection method to be used: Manual, Automatic.

3 Select the type of ROI to be traced: Wall, IMT, Lumen.

4 Within the image displayed, use the cine loop review buttons to select a reference frame to be used for ROI placement.

5 To start tracing the ROI within the image, click **Trace New ROI**, or click within the image when no other ROI has been previously placed. When placing a manual drawn ROI, a floating window will appear.

6 First and subsequent points are placed by left clicking on the image during manual tracing. The last point and the ROI are committed by a final right click.

7 Place your ROI.

a. Manual edge detection

Manual IMT or Wall ROIs are placed by defining the FAR inner wall (labeled as 'F') first (see ① below). The other three contours are then automatically traced. Each wall can be moved and defined, however, if the inner wall of the ROI is moved, the external wall moves with it.

> **Note:** ROI labels within the image can be enabled via the 'Toggle ID Numbers on ROIs' context menu option. When this option is enabled for a Wall or IMT ROI, the ROI ID, 'N' near and 'F' far walls are identified.
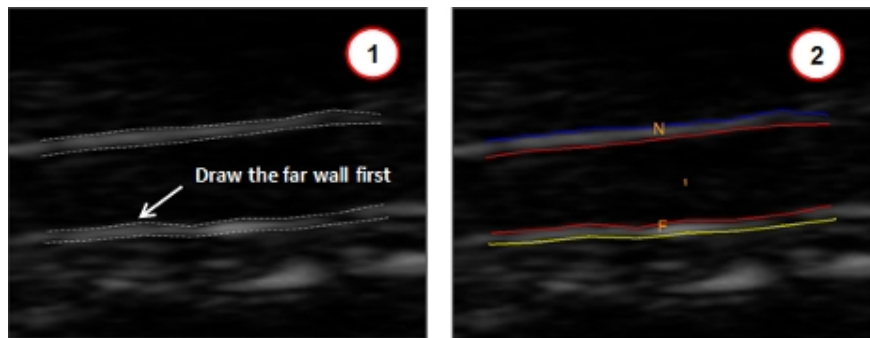

The number of points within the new ROI can be increased or decreased using the Increase Sampling and Reduce Sampling context menu option. The user is able to zoom into the image via the Zoom In and Zoom Out context menu options.

Once the ROI is initially placed, its walls and points can be adjusted as required.
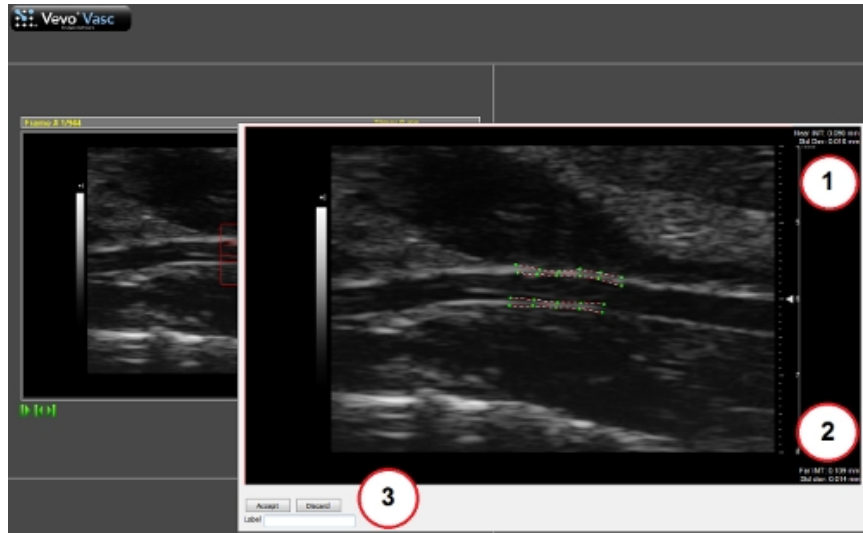
Once the ROI is correctly placed, three options are available on the bottom of the window: Discard (select if you want to delete the newly placed ROI), Accept (select if you want to process the newly placed ROI), Label (type text to label the ROI). See ③ below.

b. Automatic edge detection

Automatic ROIs are traced by drawing a horizontal rectangle by pressing the left mouse button and releasing it on the last point (see ① below).
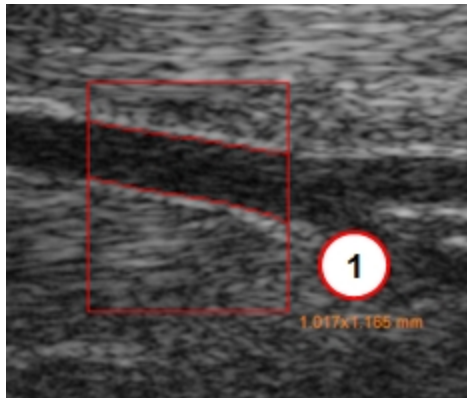
When the left mouse button is released, a floating window appears (see below).

When an IMT ROI is being placed, IMT measurements are displayed within the floating window for both near (Near IMT see ① above) and far (Far IMT, see ② above) regions.

Once the ROI is initially placed, its walls and points can be adjusted separately, to correctly define shape and distance. The image in the floating window can be zoomed in/out, and points can be increased and decreased by acting on the ROIs context menu.

Once the ROI is correctly placed, three options are available: Discard (select if you want to delete the newly placed ROI), Accept (select if you want to process the newly placed ROI), and Label (type text to label the ROI). See ③ above.

8 Once a ROI is committed on an image, the ROIs thumbnail is displayed on the top of the Vevo Vasc screen. Text on the top right corner of the ROI

thumbnail indicates the Projection, ROI Type and Edge Detection used to create it (see below).

- The first letter indicates the Projection: **L**ongitudinal or **T**ransverse.

- The second letter indicates the ROI Type: **W**all, **I**MT, or **L**umen.

- The third letter indicates the Edge Detection used: **M**anual or **A**utomatic.
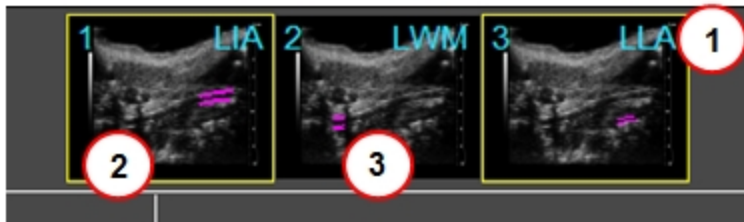
9 The user is able to select which ROI data to be displayed, by toggling the available ROI thumbnails. An ROI thumbnail with a yellow border is toggled on (see ② above). An ROI thumbnail without a border is toggled off (see ③ above).

10 (Optional) More than one ROI can be placed on an image. To add another ROI, click **Trace New ROI**.

11 (Optional) An ROI can be further modified, even after processing. Click **Modify Existing ROI** and then click **Process**. To cancel the editing mode without applying changes, click **Esc** on your keyboard.

12 (Optional) Click **Undo Editing** to undo the just completed ROI edit.

Transverse projections

Once Transverse has been selected on the tool panel, two different Transverse ROIs can be traced:

- Lumen ROI. Composed of one ellipse placed along the internal vessel wall.

- IMT ROI. Composed from two ellipses placed on the internal and IMT walls.

To place a Transverse ROI

**1** Click Transverse from the tool panel.

> **Note:** Only one type of projection can be placed on an image. Once a Transverse ROI exists on the image, the user will be unable to select or place a Longitudinal ROI.

2 Select the edge detection method to be used: Manual, Automatic.

**3** Select the type of ROI to be traced: IMT, Lumen.

4 Within the image displayed, use the cine loop review buttons to select a reference frame to be used for ROI placement.

5 Manually drawn ROIs are traced by clicking on the first point (see ① below) and clicking again on the last point of the inner diameter line (see ② below). After tracing, the ellipses created can be modified.
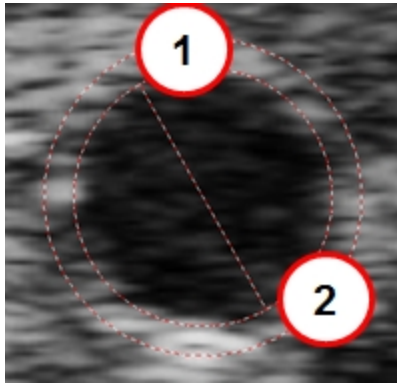
6 ROIs can be moved, resized, rotated or deleted, and the inner ellipse can be moved beyond the outer one, if no intersection between ellipses exists and if the center of outer ellipse is contained in the inner one.

Automatically detected ROIs are created by defining an inclusive area. An orthogonal axis is placed and used as the principal axis. The axis is traced by left clicking on the first point which is on the outside edge of the vessel wall (see ① below) and then left clicking again on the last point orthogonal to border line, again on the outside edge of the vessel wall (see ② below).
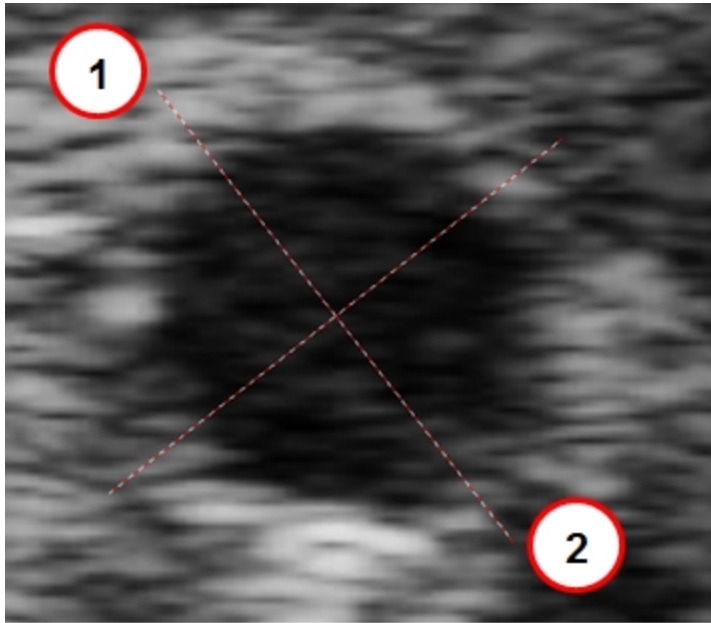
7 After the ROIs axis is defined, a floating window panel appears in order to further define the points on the walls of the ROI, three options are available: Discard (select if you want to delete the newly placed ROI), Accept (select if you want to process the newly placed ROI), Label (type text to label the ROI). See below.
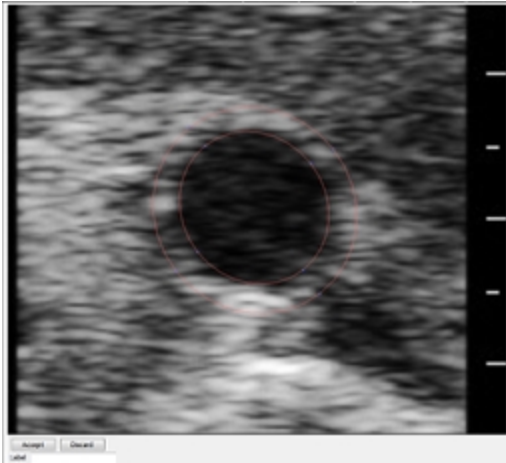
8 (Optional) More than one ROI can be placed on an image. To add another ROI, click **Trace New ROI**.

9 (Optional) An ROI can be further modified, even after processing. Click **Modify Existing ROI** and then click **Process**. To cancel the editing mode without applying changes, click **Esc** on your keyboard.

10 (Optional) Click **Undo Editing** to undo the just completed ROI edit.

Processing Data

In order to obtain analysis data from an ROI, the ROI needs to be processed.

Processing can be done in two ways:

- Clicking **Process** on the tool panel after ROIs have been placed and modified on the image.

  > **Note:** When processing via the Process button, all unprocessed ROIs will be processed.

- Within the floating ROI definition window, clicking **Accept**.

To view the processing state of an ROI

There are visible indications of the processing state of an ROI on the image and the ROI thumbnail.

1 View the ROI trace on the image.

- If an ROI on the image has a solid line of color, it has been processed (see below).

- If an ROI on the image has a dashed line, it has not been processed (see below).
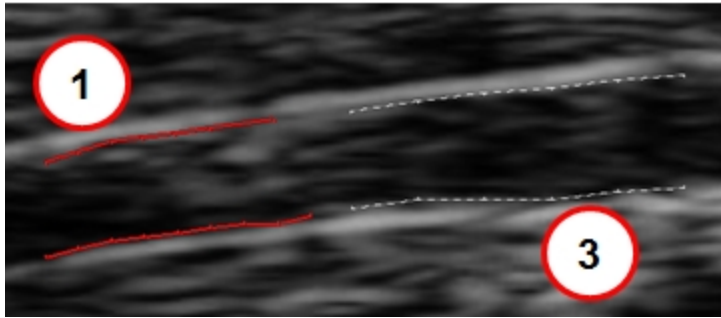
2 View the trace of the ROI within the thumbnail.

- If the trace within the thumbnail is purple with a solid number digit, the ROI has been processed (see ② below).

- If the trace within the thumbnail has a dashed line, the ROI has not been processed (see ④ below).
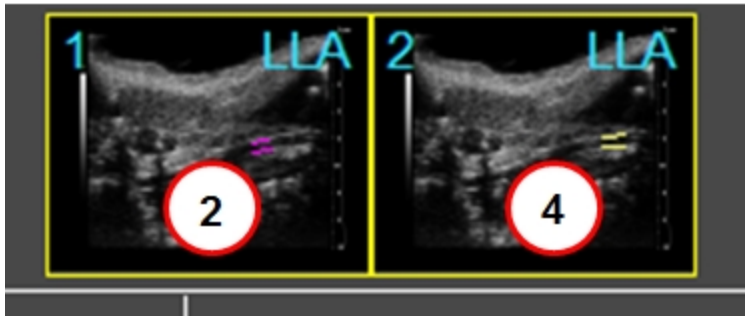

To display analysis results

After processing, select how your would like your analysis to be displayed.

1 Click either the Velocity, Displacement, Strain and Vessel Analysis radio button found on the top-left of main window.

By selecting the available ROI thumbnail(s), the user can select to display specific ROI results within the graphs and image.

2 Velocity vectors or time trajectories can be displayed on the ROI within the image by clicking the **Toggle Border/Velocity Vectors/Trajectory** button in the tool panel.
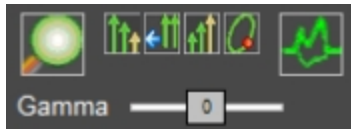
The availability and size of the Velocity vectors displayed can be adjusted using the following controls:

	Decrease Vector Size
	Reset Vector Size
	Increase Vector Size
	Toggle Border/Velocity Vectors/Trajectory

3 Systolic and diastolic pressure must be manually modified to match the subject's data by clicking the **Blood Pressure Modification** button (see below) from the tool panel and entering the actual values for each.
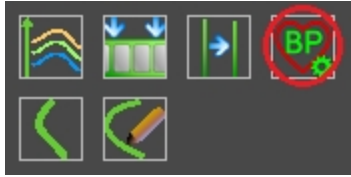
4 The results table in the lower left of the main window displays analysis results for each ROI.

> **Note:** Enable the Toggle ID number on ROIs command from the image context menu or refer to the thumbnails to know which data belongs to which ROI.

In the Results Table, user can choose between the data to be displayed:

- Pulse Propagation Velocity. Analysis results for ROIs on which PPV measurements have been performed.

- Intima Media Thickness. Analysis results for IMT measurements obtained on ROIs (both in Automatic and Manual Edge Detection).

- Diameter/Area. Analysis results after tracking in all the processed frames:

    - Max, min, mean value and percentage spread of diameter.

    - Max, min, mean value and percentage spread of area.

- Distensibility/Elasticity: Analysis results after tracking in all the processed frames:

    - Mean thicknesses of sectors (Transverse ROI) or walls (Longitudinal ROI).

- ○ Distensibility (see appendix A).

- ○ Elasticity of sectors (Transverse ROI) or walls (Longitudinal ROI).

- Wall. Vessel thickness analysis results are displayed and are only for Wall ROIs.

> **Note:** In Transverse mode, only Distensibility/Elasticity and Diameter/Area analysis results are available.

Within the results table, the corresponding measurement units are shown in brackets next to each parameter listed (see below). See Appendix B for details of the parameters available.

Diameter/Area ▼				
◀▶	ROI #1	ROI #2	ROI #3	ROI #4
Mean Diameter (mm)	0.41	0.50	0.48	0.47
Mean Area (mm^2)	0.13	0.19	0.18	0.18
Max Diameter (mm)	0.41	0.50	0.48	0.48
Max Area (mm^2)	0.13	0.19	0.18	0.18
Min Diameter (mm)	0.41	0.50	0.48	0.47
Min Area (mm^2)	0.13	0.19	0.18	0.18
Dia Perc Spread (%/100)	0.00	0.00	0.00	0.01
Area Perc Spread (%/100)	0.01	0.00	0.01	0.01

Longitudinal ROIs

In each analysis graph, a ruler can be activated for additional measurements. Right-click on a measurement wall, then click **Activate Ruler** in the context menu (see ① below as an example on a Radial Velocity graph).
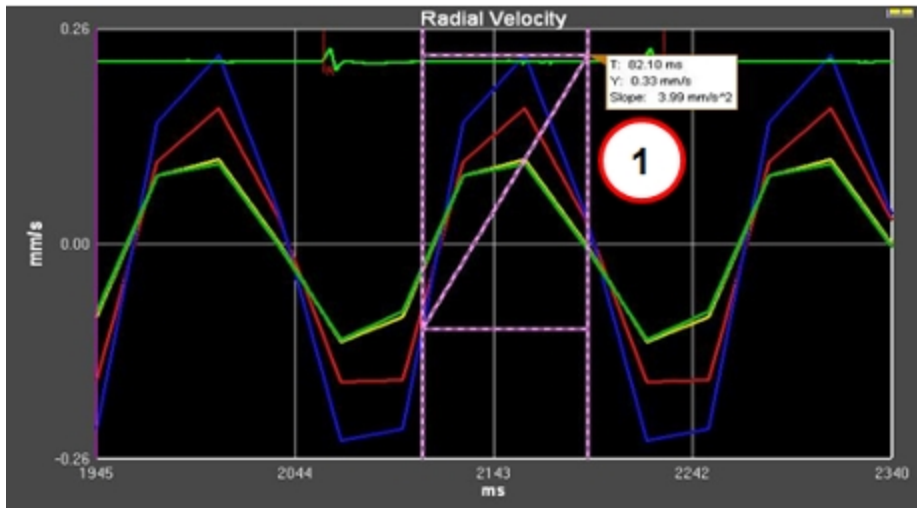
Velocity data

Each wall of an ROI can be separately activated or deactivated by pressing left mouse button on the wall itself.

Analysis graphs are displayed for each velocity – Radial and Tangential - and the graph colors correspond to the wall colors (see below).

Velocities are intended as radial positive if moving toward the lumen and tangential positive if moving rightward.

If the Draw Differences box is checked, then for each pair of walls selected, the velocity difference is shown on the Analysis graphs.

The positive addend border is painted with a continuous colored line, while the negative addend is drawn with a dotted line of the same color. Each colored pair corresponds to the color on the Analysis graphs. Walls can be selected from different ROIs.

Displacement data

Each wall of a Longitudinal ROI can be separately activated or deactivated by pressing left mouse button on the wall itself. Once activated, its corresponding color will be displayed in the Analysis graphs.

Displacements are intended as radial positive if moving toward the lumen and tangential positive if moving rightward. In each graph, by acting on its context menu, a ruler can be activated to perform further measurements.

If the Draw Differences box is checked, then for each pair of walls selected, the velocity difference is shown on the Analysis graphs

The positive addend border is painted with a continuous colored line, while the negative addend is drawn with a dotted line of the same color. Each colored pair corresponds to the color on the Analysis graphs. Walls can be selected from different ROIs.

Strain analysis

Each wall of a Longitudinal ROI can be separately activated or deactivated by pressing left mouse button on the wall itself. Once activated, its corresponding color will be displayed in the Analysis graphs.

Analysis graphs are displayed for each velocity – Radial and Tangential - and the graph colors correspond to the wall colors (see below).

Strain is a measure of the extent of deformation (lengthening or shortening) that tissue undergoes. Here, it is measured against the cardiac cycle through data obtained from physiological monitoring of the subject animal.

To calculate strain a particular point, the distance/length between that point and a secondary point next to (Tangential) or across from (Radial) it is measured at one time-point in the cardiac cycle. This is then compared to the

same measure at another instant in the cardiac cycle. The differences between these samples, represented as a percentage, is the strain.

If the Draw Differences box is checked, then for each pair of walls selected, the velocity difference is shown on the Analysis graphs.

The positive addend border is painted with a continuous colored line, while the negative addend is drawn with a dotted line of the same color. Each colored pair corresponds to the color on the Analysis graphs. Walls can be selected from different ROIs.

Vessel analysis

Area (see ① below) and Distensibility (see ② below) is displayed in the Analysis graphs. For Wall and IMT ROIs, the inner walls must be selected. See Appendix A for further Distensibility details.

External ROI walls will be displayed on a Shear graph (see ③ below).

Shear is positive when the outer border shifts rightward with respect to the corresponding inner border.
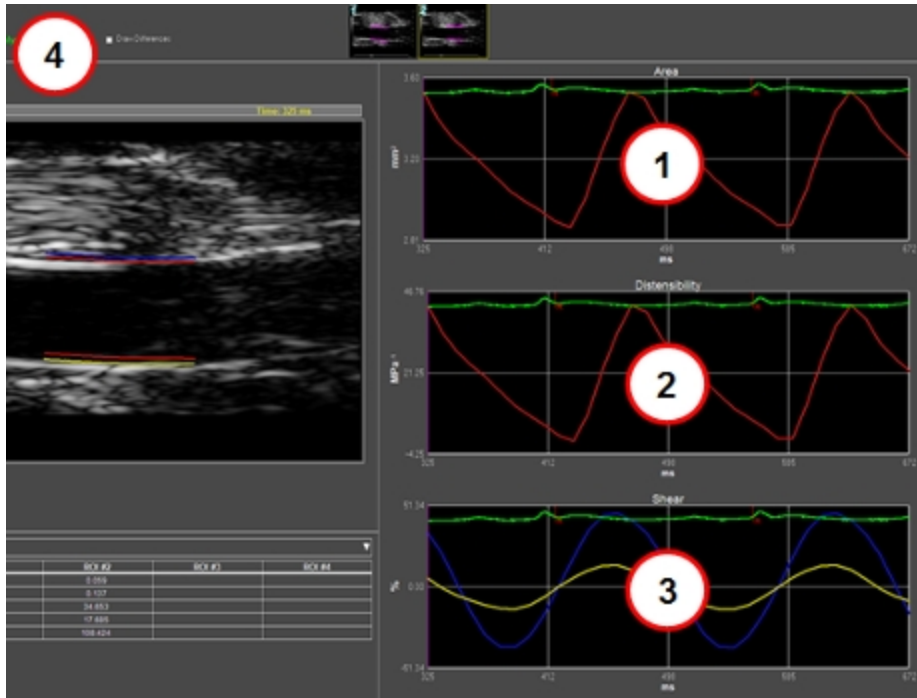
If the Draw Differences box is checked (see ④ above), then for each pair of inner walls selected, the Area and Distensibility difference are shown in the Analysis graphs.

Again, the positive addend ROI borders are painted with a continuous colored line, while the negative addend ROI borders are drawn with a dotted line of the same color. Each pair is associated to the corresponding Analysis graph color.

In the top right corner of the graphs, the percentage of difference versus maximum area or shear is displayed in the corresponding color.

Toggle the Area graph to Diameter graph to display the y axis in mm via right-click on the measurement wall and click **Toggle to Diameter View** in the context menu.

Transverse ROIs

In each analysis graph, a ruler can be activated for additional measurements. Right-click on a measurement wall, then click **Activate Ruler** in the context menu (see ① below as an example on a Radial Velocity graph).
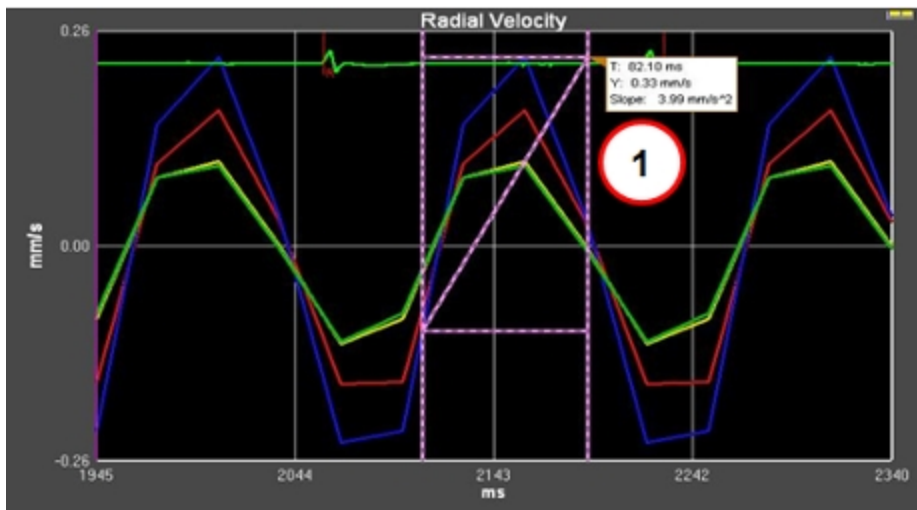
Velocity data

For each ROI, data for each sector can be separately activated or deactivated by a left mouse click on the sector itself.

Analysis graphs are displayed for – Radial Velocity (mm/s) and Rotational Rate (deg/s) - and the graph trace colors (see ① below) correspond to the ROI wall colors (see ② below).

Velocities are intended as radial positive if moving toward the lumen and tangential positive if anti-clockwise.

> **Note:** Borders can be selected from different ROIs.

If the Draw Difference box is checked (see ① below), then for each pair of sectors selected (see ② below), the velocity difference is shown on the Analysis graphs (see ③ below).
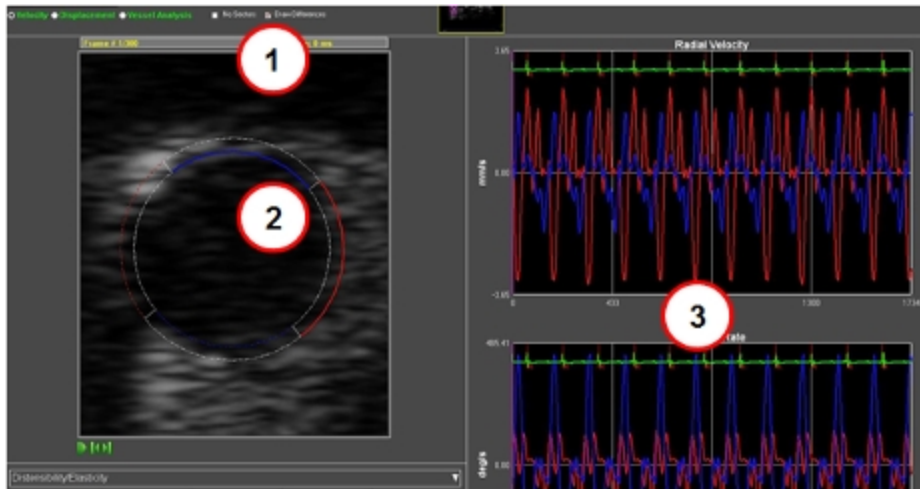
The positive addend border is displayed with a continuous colored line, while the negative addend is displayed with a dotted line of the same color. Each colored pair corresponds to a single colored line of data on the Analysis graphs. Sectors can be selected from different ROIs.

If the No Sectors box is checked (see ① below), each ROI sector will be displayed as a whole contour (see ② below).
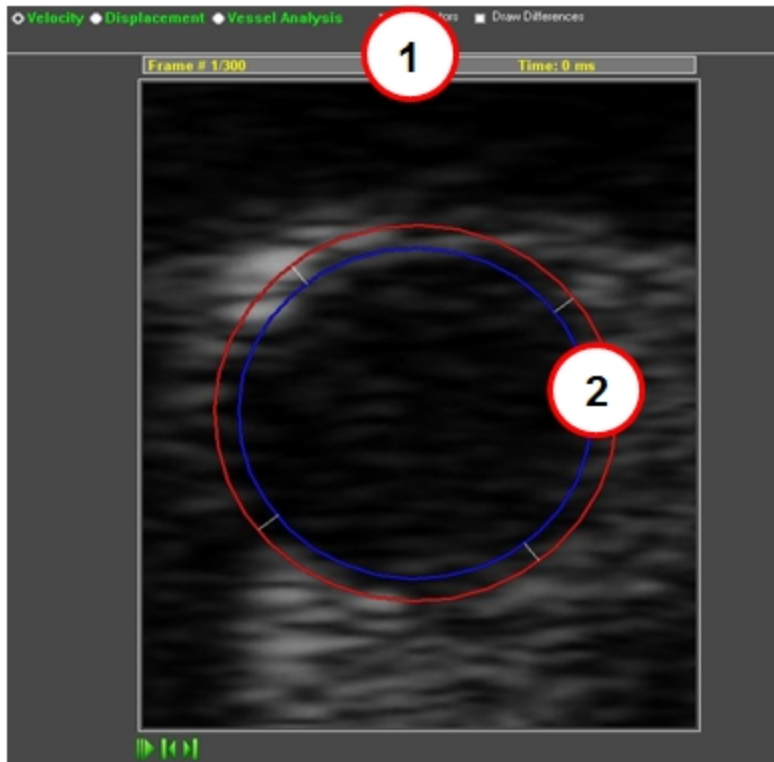
Displacement data

Each sector of an ROI can be separately activated or deactivated by clicking on the line itself.

Analysis graphs for Radial Displacement (micron) and Rotation (deg/s) are displayed and the analysis trace colors correspond to the displayed sector colors.

Displacements will be radial positive if moving toward the lumen and tangential positive if moving rightward.

If the Draw Differences box is checked, then for each pair of sectors selected, the velocity difference is shown on the Analysis graphs.

The positive addend border is painted with a continuous colored line, while the negative addend is drawn with a dotted line of the same color. Each colored pair corresponds to the color on the Analysis graphs. Sectors can be selected from different ROIs.

If the No Sectors box is checked, each ROI sector will be displayed only as a whole contour.

Vessel analysis

Area (mm2) and Distensibility (MPa-1) for each frame can be shown in the Analysis graphs, although for IMT ROIs only the inner diameter can be selected. See Appendix A for further information.

If the Draw Differences box is checked, then for each pair of diameters selected, the Area and Distensibility difference are shown in the Analysis graphs.

Again, the positive addend ROI diameter is painted with a continuous colored line, while the negative addend is drawn with a dotted line of the same color. Each pair is associated to the corresponding graph color.

In the top right corner of the graphs, the percentage of difference versus maximum area or distensibility is displayed in the corresponding color.

If the No Sectors check box is set on ROI Analysis Workspace, each ROI border is displayed only as a whole contour.

Toggle the Area graph to Diameter graph to display the y axis in mm via right-click on the measurement wall and click **Toggle to Diameter View** in the context menu.

Sequence AM-Mode Selection

When loading an image not previously processed in Vevo Vasc, or by clicking **Sequence/AM-Mode Selection**, the data is displayed within the "Sequence AM-Mode Selection" above.

Initially R-waves will automatically be placed on the displayed ECG trace (see below), within the physiological data area.

R-waves can be added by right clicking within the physiological data area. R-waves can be deleted by right clicking on the existing R-wave.

> **Note:** There must be a minimum of two R-wave indicators within the physiological data area.

By drawing a line onto the image (see below), it is possible to create an AM-Mode image to be used as a background reference (see below). The User can toggle the display of this data in the analysis graphs by clicking **Toggle AM-Mode Image** in the tool panel.

The AM-Mode overlay on the image can be modified after placing by selecting and dragging the beginning or end points. It can also be deleted by clicking the image **Erase AM-Mode Line** context menu option.
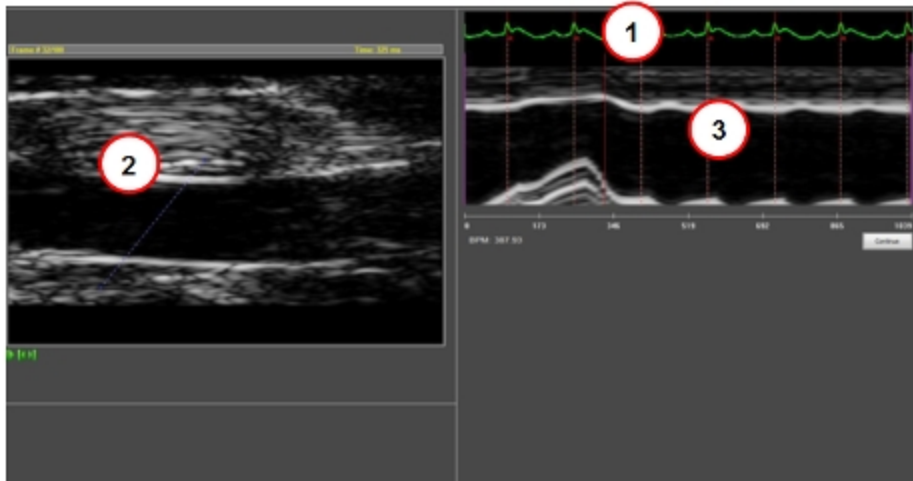
Start and stop time intervals can be defined by moving the purple sliders on the time scale (see ① and ② below). The shaded areas displayed (see ③ below) are excluded from ROI analysis, and the non-shaded areas are included in ROI analysis.
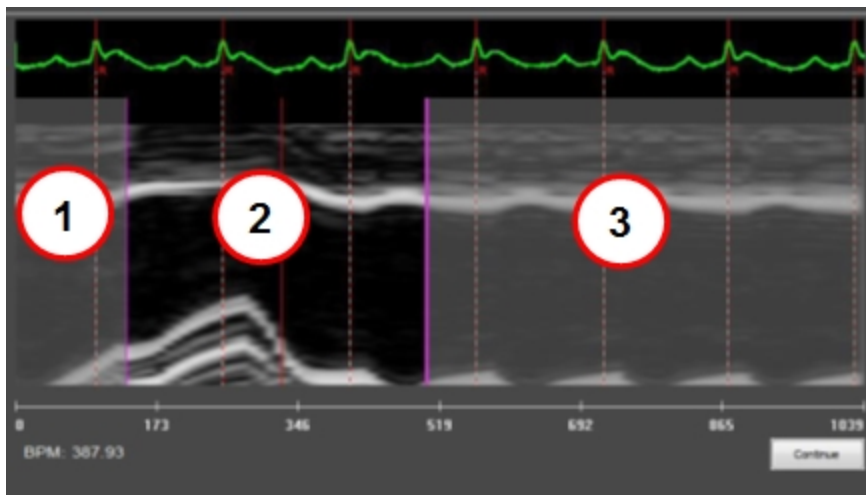
A minimum one cardiac cycle is required to make analysis possible. If less than one cardiac cycle is selected, a yellow warning message is placed near one of the time cursors, and the user will not be able to proceed with the analysis (see below).
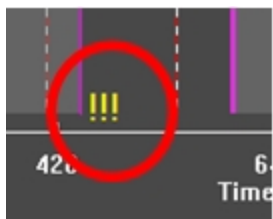
Pulse Propagation Velocity Measurement

Pulse Propagation Velocity (PPV) for longitudinal ROIs can be measured by clicking **Pulse Propagation Velocity** on the tool panel.

A floating window panel appears. Draw a longitudinal rectangle that covers the traced ROI. Then click **Accept** or **Discard**.

The PPV Definition Workspace opens. On the image, the red longitudinal rectangle is displayed (see ① below).
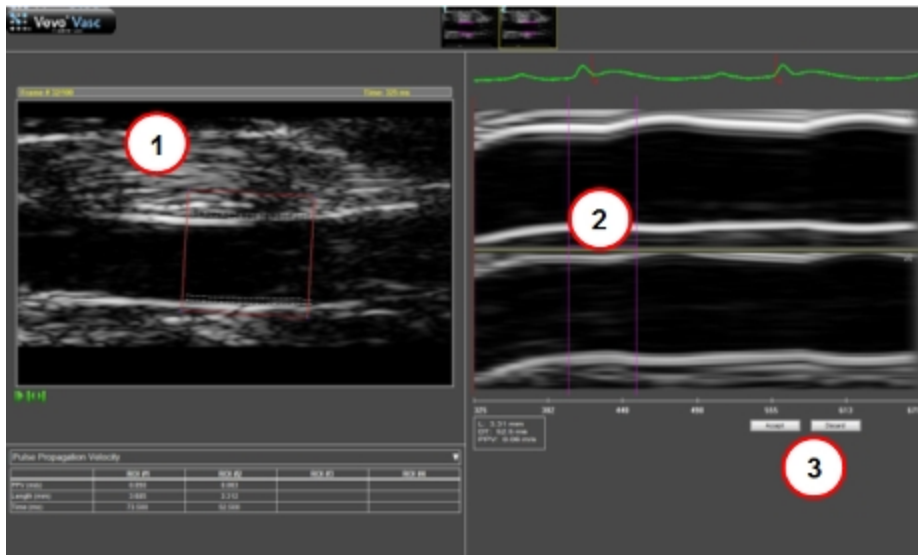
> **Note:** Only one ROI can be shown at a time and it can be selected by toggling on the thumbnails.

Once the ROI is selected, all lines of the rectangle can be adjusted by selecting a line then dragging to a new position. The user can also rotate the rectangle to align the ROI box with the vessel being analyzed, and to get the most appropriate AM-Mode image. Vertical lines of data from the rectangle

will be displayed and identified as the **L**eft (top image) and **R**ight (bottom image) on the ROI (see ② above).

As you adjust the lines of the rectangle, the vertical lines of data that are displayed on the AM-Mode image are adjusted automatically by detecting the edge of the ROI.

After setting the PPV times within the displayed AM-Mode images, click to **Accept** or **Discard** the results (see ③ above).

Once completed, for each traced ROI, the Pulse Propagation Velocity parameters are displayed within the Results Table.

For each ROI, the user can read:

- Pulse Propagation Velocity evaluated in m/s.

- ROI length used for PPV evaluation in mm.

- Time duration used for PPV evaluation in ms.

Deleting a Vevo Vasc Analysis

A specific image's Vevo Vasc analysis can be deleted from the Study Browser.

In the Study Browser, select an image which has already been processed with Vevo Vasc—the image will be identified by '(Vevo Vasc)' within the Mode column.

Right click the **Delete Vevo Vasc Analysis** option in the context menu.

The Vevo Vasc analysis associated with the selected image has been deleted.

Exporting Data

Images and data can be exported by selecting one of the Export options available within the Tool Panel (see below).
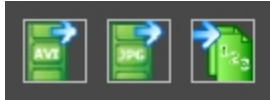
	Export Video
	Export Images
	Export Data

By clicking **Export Video**, you are able to export either the B-Mode/EKV Only, or the Whole Screen in one of the following formats: Uncompressed AVI, MS Video 1 AVI, MS Video 9 AVI, Animated GIF, or WMV Format.

By clicking **Export Images**, you are able to export either the Current screen or All graphs, and is given the option to save the data in one of the following formats: JPG format, BMP format, or TIFF format.

By clicking **Export Data**, you are able to export the following: Excel and CSV.

- Excel exports all data into one excel file (*.xml).

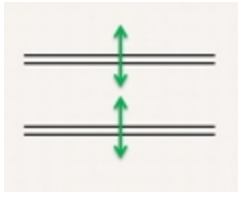- CSV can export the following options:
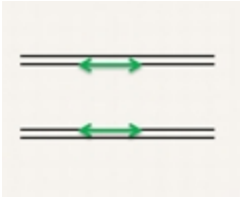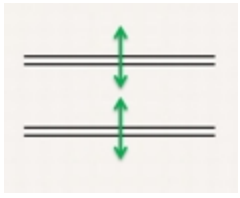
- Velocity, Displacement, Strain, Vessel Analysis. Selecting any of these options will export all the numeric values of currently visualized plots in a tab separated CSV file.

- Results Table. Exports the Results Table in a tab separated CSV file.
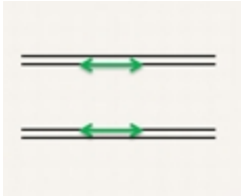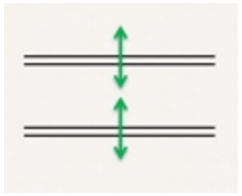
Appendix 1

Parameters

Velocity

Longitudinal	 Tangential Velocity	 Radial Velocity
Transverse (Cross-sectional)	 Radial Velocity	 Rotational Rate

Displacement

Longitudinal	Tangential Displacement	Radial Displacement
Transverse (Cross-sectional)	Radial Displacement	Rotation

Strain

Longitudinal Strain is the lengthening or shortening (if negative) of the vessel wall along its length.
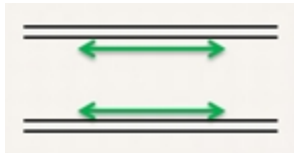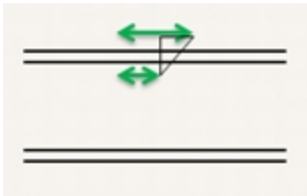

In formulas,

Strain = $(L(t) - LO)/LO$

where:

LO is the length at the R-wave

This corresponds to circumferential strain in cardiac (LV) strain analysis (REF: 2011 Kim et al.)

Shear

Shear graph is evaluated as the time plot of the arctan of shear strain normalized to ROI thickness. So a 100% shear is intended as "a thickness equivalent" relative movement of the borders.

Is the angular deformation between external and internal borders. The difference between the two displacements (starting from zero at the R) divided by the thickness.
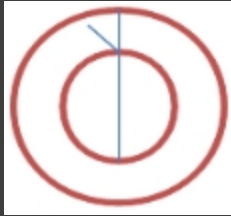
$$Sh = \frac{1}{h(t)} \int_R^t \triangle V dt$$

where:

h is the thickness

$\triangle V$ is the difference in tangential (longitudinal) velocity between external and internal borders.

(REF: 2006 Cinthio et al.)

> **Note:** For Transverse (Cross-sectional View), Shear is the same as above, where tangential displacements are rotations.

Elasticity

Elasticity is calculated according to the following formula:

$$E = 0.1333 \cdot (P_{sys} - P_{dia}) \cdot \frac{T_{dia}}{T_{dia} - T_{sys}}$$

where:

T is the thickness at systole or diastole

Frames corresponding to systole and diastole are calculated automatically

P_{sys} and P_{dia} are systolic and diastolic pressure which can be manually entered into Vevo Vasc.

Distensibility

Distensibility graph is evaluated as a time plot of:

$$D(t) = 7.5 \times \left[\frac{\left(\frac{Area(t) - Area(dia)}{Area(dia)} \right)}{Pressure(sys) - Pressure(dia)} \right]$$

Distensibility parameter is evaluated as:

$$d = 7.5 \times \left[\frac{\left(\frac{Area(sys) - Area(dia)}{Area(dia)} \right)}{Pressure(sys) - Pressure(dia)} \right]$$

Note: The actual blood pressure must be entered via the "Blood Pressure Modification" button on the Tool Panel for a correct evaluation of the distensibility parameter in the results table.

Appendix 2

Results table

Longitudinal ROIs

Parameter	Measurement	Units
Pulse Propagation Velocity	PPV	m/s
	Length	mm
	Time	ms
Intima Media Thickness	IMT Meas Near	um
	Std Dev Meas Near	um
	IMT Meas Far	um
	Std Dev Meas Far	um
Diameter/Area	Mean Diameter	mm
	Mean Area	mm^2
	Max Area	mm^2
	Min Diameter	mm
	Min Area	mm^2
	Dia Perc Spread	%/100
	Area Perc Spread	%/100

Longitudinal ROIs

Parameter	Measurement	Units
Distensibility/Elasticity	Thickness Near	um
	Thickness Far	um
	Distensibility	1/MPa
	Elast Near	kPa
	Elast Far	kPa
Wall	Thickness Near	um
	Std Dev Meas Near	um
	Thickness Far	um
	Std Dev Meas Far	um

Transverse ROIs

Parameter	Measurement	Units
Diameter/Area	Mean Diameter	mm
	Mean Area	mm^2
	Max Diameter	mm
	Max Area	mm^2
	Min Diameter	mm

Transverse ROIs

Parameter	Measurement	Units
	Min Area	mm^2
	Dia Perc Spread	%/100
	Area Perc Spread	%/100
Distensibility/Elasticity	Thickness S1	mm
	Thickness S2	mm
	Thickness S3	mm
	Thickness S4	mm
	Distensibility	1/MPa
	Elasticity	kPa
	Elast S1	kPa
	Elast S2	kPa
	Elast S3	kPa
	Elast S4	kPa

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