QFlow 4D 1.1

User Manual

Medis Medical Imaging Systems bv
Schuttersveld 9, 2316 XG Leiden, the Netherlands

http://www.medisimaging.com

Legal Notices

Copyright Notice

Trademark Acknowledgments

DICOM is the registered trademark of the National Electrical Manufacturers Association for its standards publications relating to digital communications of medical information. All other brands, product, and company names mentioned in this document are trademarks or registered trademarks of their respective owners.

QFlow is a registered trademark of Medis Associated bv.

Regulatory Information

Intended Use

QFlow 4D is software intended to be used for the visualization and analysis of MR 4D flow images of the heart and blood vessels. QFlow 4D is intended to support the following visualization functionalities:

- cine loop and 2D review
- double oblique review
- 3D review by means of MIP and volume rendering
- 3D reformatting
- performing caliper measurements

QFlow 4D is also intended to support the following analyses:

- MR velocity-encoded flow quantification

These analyses are based on contours that are either manually drawn by the clinician or trained medical technician who is operating the software, or automatically detected by the software and subsequently presented for review and manual editing. The results obtained are displayed on top of the images and provided in reports.

The analysis results obtained with QFlow 4D are intended for use by cardiologists and radiologists to support clinical decisions concerning the heart and vessels.

Indications for Use

QFlow 4D is indicated for use in clinical settings where validated and reproducible quantified results are needed to support the visualization and analysis of MR images of the heart and blood vessels for use on individual patients with cardiovascular disease.

When the quantified results provided by QFlow 4D are used in a clinical setting on MR images of an individual patient, they can be used to support the clinical decisions making for the diagnosis of the patient or the evaluation of the treatment applied. In this case, the results are explicitly not to be regarded as the sole, irrefutable basis for clinical diagnosis, and they are only intended for use by the responsible clinicians.

Limitations

Currently no limitations have been specified for QFlow 4D 1.1.

WARNINGS

🛑 QFlow 4D must be used by cardiologists, radiologists, or trained technicians who are qualified to perform cardiac analysis. If the analysis results are used to reach a diagnosis, the results must be interpreted by a qualified medical professional. In clinical practice QFlow 4D should not be used for purposes other than those indicated in the section Intended Use.

🛑 You are explicitly recommended to measure flow parameters only in sequences that are validated for flow measurements. Reliable measurement results can only be obtained with validated acquisitions.

🛑 Users must have sufficient proficiency in the selected operating language, read this manual and become familiar with the software and be able to obtain reliable analysis results.

Note on Monitor Aspect Ratio and Resolution

🛈 The shapes of objects and calipers displayed may be slightly distorted when the resolution is set to an aspect ratio different than the monitor's physical aspect ratio. This distortion does **NOT** affect the accuracy of measurements or analyses. To avoid distortion, set the resolution of the monitor to an aspect ratio equal to the physical aspect ratio. LCD monitors typically operate best at their native resolution. Microsoft Windows recommends a resolution when it has sufficient information to do so.

European Regulations

CE 1639	QFlow 4D is qualified as a class IIa medical device. It complies with the requirements of the Dutch Medical Devices Decree (Besluit Medische Hulpmiddelen, Stb. 243/1995) and the European Medical Device Directive 93/42/EEC.

North American Regulations

QFlow 4D has clearance for market in the United States by the FDA (Food and Drug Administration) under the provisions of Section 510(k) of the Food, Drug, and Cosmetic Act.

Caution
Federal law restricts this device to sale by or on the order of a physician.

QFlow 4D complies with the requirements of the Canadian Medical Devices Regulations and has been licensed as a Class II medical device.

Other Regulations

QFlow 4D complies with the requirements of the Japanese Pharmaceutical and Medical Device Law and has been licensed as a Class II medical device.

Conventions Used

The following conventions and acronyms are used throughout this manual to indicate mouse and keyboard actions and to refer to elements in the user interface.

Mouse

Click	Press and release the primary mouse button. If you are left-handed, you may have set the right mouse button as your primary mouse button.
Click and drag	Press and hold the primary mouse button. Drag the mouse to perform a function. Release the primary mouse button. If you are left-handed, you may have set the right mouse button as your primary mouse button.
Right-click	Press and release the secondary mouse button. If you are left-handed, you may have set the left mouse button as your secondary mouse button.
Middle-click	Press and release the wheel button or the middle mouse button. If you have a two-button mouse, press and release the left and the right mouse button simultaneously.
Double-click	Press and release the primary mouse button twice.
Wheel	Rotate the mouse scroll wheel.

Keyboard

SHIFT/CTRL+click	Press and hold down the SHIFT/CTRL key on your keyboard while you click a button or object.
CTRL+K	Press and hold down the CTRL key on your keyboard while you press K, then release both keys.

Typographical Conventions

On the **Annotations** node of the **Results pane…**	Names of buttons, fields, menus, menu options, and tab names are capitalized and in bold.
Procedures > Text Annotation	A sequence of menu options that you select to perform a specific task is indicated by angular brackets.
View > Movie	A sequence of menu options that you select to perform a specific task, is indicated by angular brackets.
Label: `Flow Analysis`	Text that you type or that appears on the screen, such as annotation labels, is displayed in Segou UI.
In the **Display** tab, select the **Hide all drawings** option.	Names of buttons, fields, menus, menu options, and tab names are capitalized and in bold.

Symbols Used

Reference: Points to related documentation, or to related sections in this document, that may be relevant to your situation.

Tip: Provides helpful information or an alternative working method.

Note: Promotes additional information.

Caution: Tells you to be careful when performing a task.

Warning: Warns you of a potentially dangerous situation in the image representation or analysis, which may lead to incorrect results. You are advised to follow the instructions to avoid this.

Table of Contents

Introduction

1   About QFlow 4D

QFlow 4D is the Medis software solution designed to support the 3D visualization and 2D quantification analysis of 4D flow MR studies. It enables cardiologists, radiologists, and technicians to quantify arterial and transvalvular blood flow.

QFlow 4D supports cardiologists, radiologists, or trained technicians, to select the appropriate oblique views of the cardiac anatomy or surrounding vessels for quantitative flow analysis.

QFlow 4D runs as an app in the Medis Suite product. The functionality of Medis Suite, including instructions on how to start QFlow 4D and load image data, is described in the Medis Suite user manual. The Medis Suite documentation is available from the User documents tab, which can be opened as follows;

- Press F1.
- Select the ![help icon] help button.
- Select the Medis Suite main menu button in the upper right corner ![menu icon] > **Help** > **User Documents**

1.1   QFlow 4D Usage

Availability of the product QFlow 4D is dependent on licenses. If you would like to purchase a license for one or more of the QFlow 4D applications, please contact Medis.

2   System Requirements

2.1   Hardware

QFlow 4D:
- Intel or compatible quad-core processor
- 16 GB of RAM
  If you are using larger image sets, particularly with multiple time points, please ensure you have adequate memory.
- 250 GB of available hard disk space, SSD recommended
  (if you want to store series locally, make sure you have enough disk space)
- 3-button mouse, scroll-wheel recommended
- CD-ROM player to install the software from CD-ROM
- A USB port or network connection to transfer the installer to the system
- Video card supporting OpenGL and with 512 MB memory
- Widescreen monitor supporting a minimum resolution of 1920x1080 pixels
- Network interface card of at least 100MBit/s to access, receive, and send series over the network

Sentinel license server:
- Intel or compatible processor with a minimum speed of 550 MHz
- 128 MB of RAM
- 1 GB of available hard disk space
- Network interface card

NOTES:
- All hardware must be compliant with the operating system
- For the license server, a PC with a fixed IP address or a reserved IP address in the DNS server is strongly recommended

2.2   Operating System

QFlow 4D:
- Microsoft Windows 7, SP1, 64 bit version
- Microsoft Windows 8.1, 64 bit version
- Microsoft Windows 10, 64 bit version
- Microsoft Windows Server 2008 R2, SP1, 64 bit version
- Microsoft Windows Server 2012 R2, 64 bit version
- Microsoft Windows Server 2016, 64 bit version

Sentinel license server:
- Microsoft Windows 7, 32 and 64 bit version
- Microsoft Windows 8, 32 and 64 bit version
- Microsoft Windows 8.1, 32 and 64 bit version
- Microsoft Windows 10, 32 and 64 bit version
- Microsoft Windows Server 2008, 32 and 64 bit version
- Microsoft Windows Server 2008 R2, 64 bit version
- Microsoft Windows Server 2012, 64 bit version
- Microsoft Windows Server 2012 R2, 64 bit version
- Microsoft Windows Server 2016, 64 bit version

3   Support

Medis is committed to offering high-quality products and services. If you have questions about the software, or if you would like to make suggestions for improvements in the software or in the documentation, please contact the Medis helpdesk.

If you contact the Medis helpdesk by e-mail, mention the name of the software and the version number in the subject field. To look up the version number of your software, select ⋮ > **Help** > **About….**

North and South America

Medis Medical Imaging Systems, Inc.
E-mail: support@medisimaging.com
Telephone: +1 919 278 7888 (working days 9.00-17.00 EST)

Europe, Africa, Asia and Australia

Medis Medical Imaging Systems bv
E-mail: support@medisimaging.com
Telephone: +31 71 522 32 44 (working days 9.00-17.00 CET)

4   The QFlow 4D Workspace

QFlow 4D is launched from the app toolbar, app context menu, or app pane of Medis Suite, by

selecting the QFlow 4D is app icon ![icon]. Detailed information on how to start an application and how to load series into the application, is described in the Medis Suite user manual.

This chapter covers the following topics:

- Overview
- Menu bar
- Toolbars
- Workspace panes
- Viewing

4.1 Overview

The main workspace consists of a menu bar, toolbars, workspace panes and the central window area which is comprised of Double Oblique, 3D-MIP and Velocity image viewports. There are also results and properties panes.
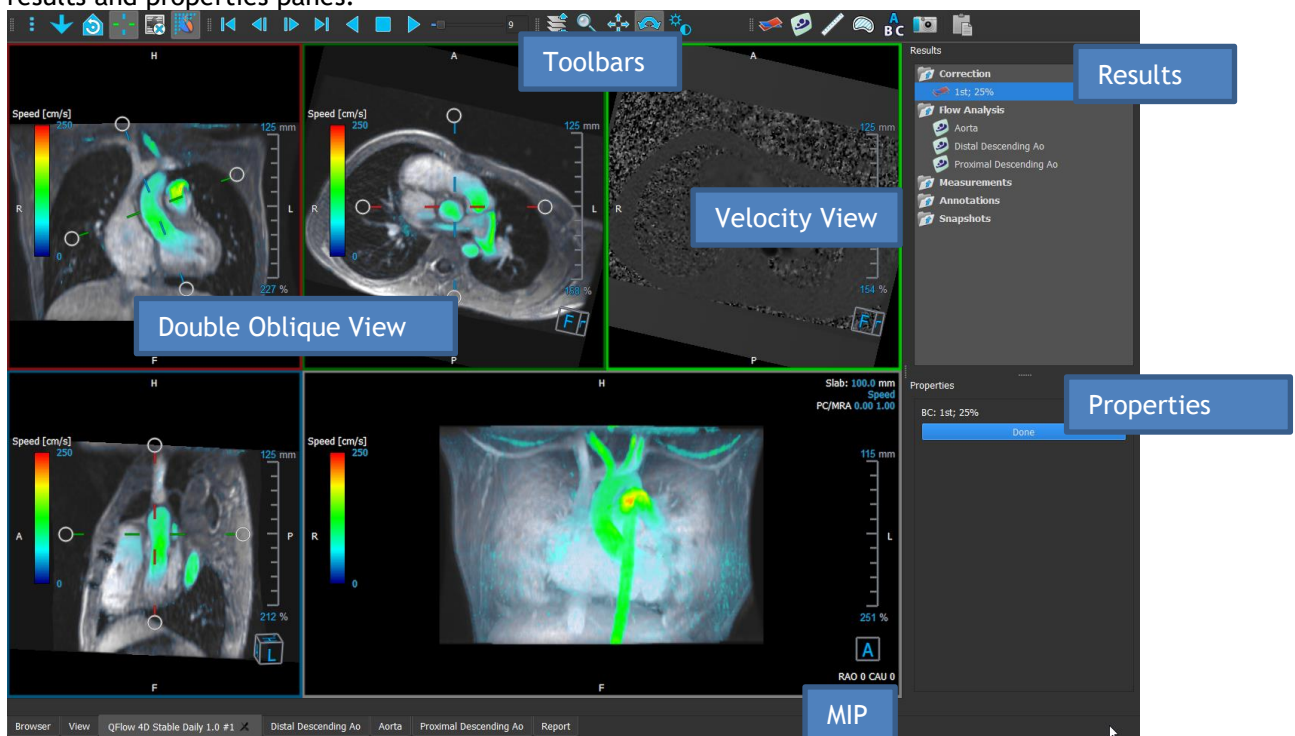

Figure 1 : Workspace Overview

You can customize the workspace by hiding, resizing or moving the workspace panes and toolbars. Any changes that you make to the workspace are saved for each individual Windows user.

4.2   Menu

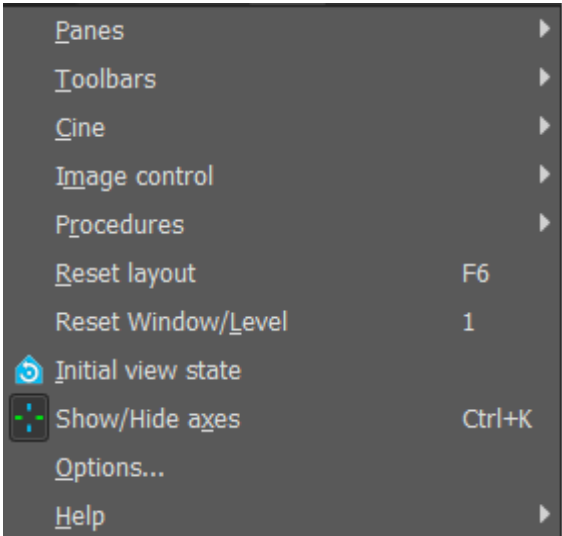The menu contains commands to activate the application functionality.

To make the menu visible:

- Select on the menu icon ⋮ in the **General** toolbar.

The menu commands are organized into the following main menus; **Panes**, **Toolbars**, **Cine**, **Image Control**, **Procedures** and **Help.**

In addition, there are menu items; **Reset layout, Reset Window/Level, Initial View State, Show/Hide axes** and **Options**. For some of these commands, tool buttons are available in the toolbars as shortcuts.

ⓘ Menu commands may be grayed out when you are performing a procedure, such as an area measurement. You can make the menu commands active by canceling or finishing the procedure.

Menu	Command	Description
Panes ▶ Toolbars ▶ Cine ▶ Image control ▶ Procedures ▶ Reset layout F6 Reset Window/Level 1 🔵 Initial view state ⊹ Show/Hide axes Ctrl+K Options... Help ▶	Panes	Show or hide a workspace pane
	Toolbars	Show or hide a toolbar
	Cine	Control the frame selection
	Image Control	Control the image display
	Procedures	Start a new procedure
	Reset layout	Reset the default layout
	Reset Window/Level	Reset the default window/level
	Initial view state	Reset the view state
	Show/Hide axes	Enable/Disable axes visibility
	Options	Application default settings
	Help	User documentation and About

4.3 Toolbars

You can move toolbars to another part of the main window. You can also show or hide toolbars.

To move a toolbar:

- Click on the double-bar grip handle ▊ of the toolbar and drag it.

  You can now move the toolbar to any location on the sides of the main window. Simply click and drag the toolbar to its new position. The position of the toolbar is saved when you close the application.

To show or hide a toolbar:

1. Select [⋮] > **Toolbars**.

2. Select a check box to show the toolbar, clear a check box to hide the toolbar.

Or,

1. Right-click in the toolbar area. This opens a context menu.

2. Select a check box to show the toolbar, clear a check box to hide the toolbar.

The state of the toolbars is saved when you close the application.

Icon	Function
General Toolbar	
⋮	Show the menu
🔄	Verify flow direction.
3D	Go to the Flow Analysis 3D Layout.
2D	Go to the 2D View Layout.
🔄	Go to the initial view state, reset zoom \ pan \ window width \ window level

Icon	Function
	Show and Hide Axes
	Remove background noise on speed overlay
	Toggle image text overlay
Cine Toolbar	
	Go to the first frame
	Go to the previous frame
	Go to the next frame
	Go to the last frame
	Play a cine in backward direction
	Stop the cine
	Play a cine in forward direction
	Set the cine playback speed
Mouse Controls Toolbar	
	Stack
	Zoom
	Pan

Icon	Function
	Window width and window level
	Swivel (only if the 3D viewport is selected)
Procedures Toolbar	
	Background Correction on data
	Phase Unwrapping on data
	Start a flow analysis
	Create a distance measurement
	Create an area measurement
	Create a text annotation
	Create a snapshot
	Copy all measurement results to the clipboard

4.4 Workspace Panes

By default, the workspace displays the following panes to the right of the image viewports:

- **Results**
- **Properties**

You can show or hide panes, dock panes, combine panes into one tabbed panel and remove panes from a panel.

To show or hide a pane:

- Select > **Panes**, and select a hidden pane to show it, or select a visible pane to hide it.

To dock a pane:

1. Click and drag the title bar of the pane.

2. Move the pane to the sides of the viewer window to select one of the dock areas.

    As the pane approaches a dock area, the area is highlighted with a dotted line. The pane can be combined with another pane or inserted separately.

3. When the dock area of your choice appears highlighted, release the mouse button.

    This docks the pane into the selected position.

To combine panes into one tabbed panel:

- Click and drag the title bar of the pane to the title bar of the pane with which you want to combine it.

    This creates a tabbed panel.

To remove panes from a panel:

- Click and drag the title bar of the pane away from the panel.

4.4.1 Results Pane

The **Results** pane shows the following in QFlow 4D.

- It shows standard procedures, i.e. measurements, annotations and snapshots performed on the series that is loaded in the viewport.
- It shows the **Background Correction.**
- It shows the list of **Flow Analyses.**
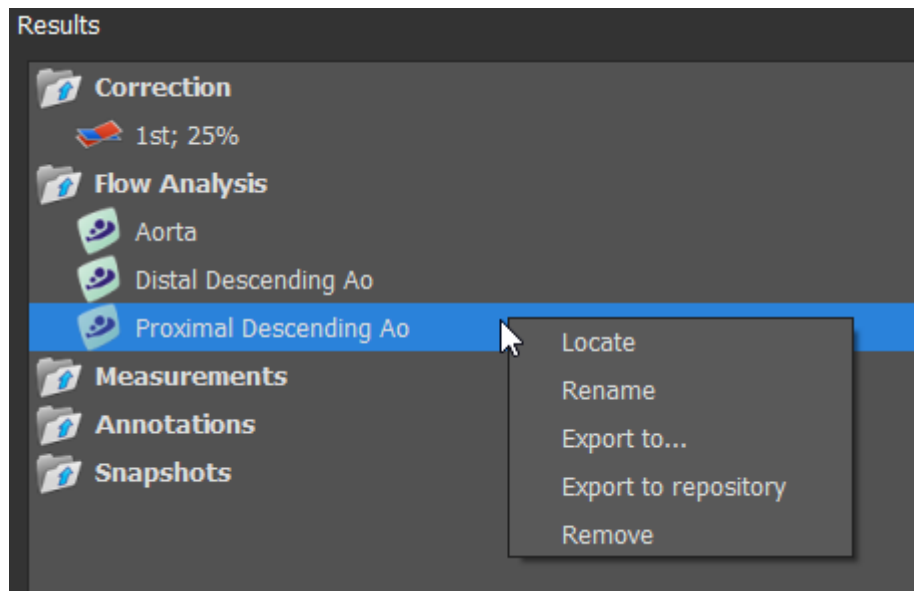
Figure 2 Results Pane

You can collapse and expand an item by selecting on the group header.

You can right-click a procedure to perform actions on the procedure. Depending on the type of procedure, you will get a context menu with several options.

Locate: The image and the image orientation at which the procedure was originally performed will be activated. Locate is automatically enabled for Flow Analysis.

Rename: Rename the procedure.

Export to: Export the procedure to disk.

Export to Repository: Export the procedure to a repository.

Remove: Delete the procedure.

💡 Flow Analysis procedures offer a list of pre-defined labels.

4.4.2 Properties Pane

The **Properties** pane shows the properties of the selected procedure. You can modify QFlow 4D standard procedures, i.e. measurements, annotations or snapshot procedures as well as the Flow Analysis reconstructions.

To modify a label (Measurements, Annotations and Snapshots):

1. On the **Results** pane, select the procedure.

2. On the **Properties** pane, select the ellipsis [...] on the right of the **Label** field and select a predefined label, or type a custom label and press Enter.
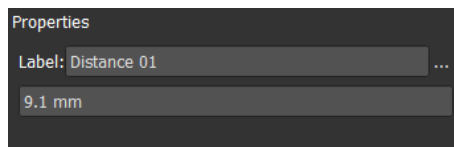
Figure 3 Predefined Labels Menu

5 Viewing

5.1 Loading Series

Series can be loaded into QFlow 4D from the **Series Browser** of Medis Suite. Refer to the Medis Suite user manual for detailed instructions.

A 4D flow MRI dataset consists of time-resolved, three-dimensional series encoded in three velocity directions and a single modulus (or magnitude) series. QFlow 4D, also supports short and long-axis series.
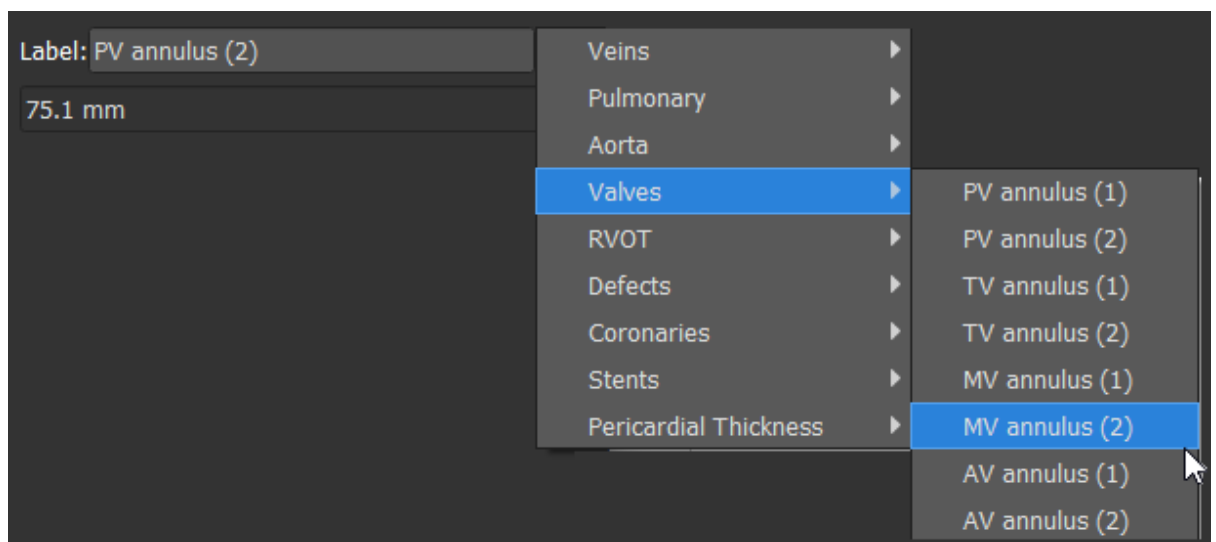
ⓘ QFlow 4D requires at least one set of 4D flow MRI dataset to begin visualization.

To load series from the Series Browser of Medis Suite

1. Select three sets of 4D flow velocity series and one 4D flow modulus series, in the image or text view of the Medis Suite **Series Browser**.

2. Click and drag the selected items onto any viewport.

Or,

1. Double click an item in the image view or text view of the Medis Suite **Series Browser**.

Or,

1. Select all series in the image or text view of the Medis Suite **Series Browser**.

2. Right-click above the selected series to open a context menu.

   Choose QFlow 4D.

This will load the series into the viewports. By default, a cine will start playing to present all individual image frames.

ⓘ QFlow 4D only loads MR DICOM series.

5.2 Viewports

The viewport text overlay displays detailed information about the patient, the hospital, the image acquisition, and the display settings.

To show or hide the patient and image information:

- Select > **Options**, **Hangings**.

   Select or deselect **Show patient information** or **Show image information**.

Or

- Use 'O' to toggle through the different modes of hiding the overlay displays.

Or

- Select in the toolbar, to toggle through the different modes of hiding the overlay displays.

To maximize an image in the viewport:

- Double-click the image.

   This maximizes the viewport, so that it takes up the entire viewport.

   To return to the original viewport layout, double-click the image again.

 Interactive graphics are displayed in blue color and allow you to change image or display properties with your mouse.

5.3   Viewport Layout

QFlow 4D consists of three independent screen layouts.

- Verification of Flow Direction Layout
- Flow Analysis 3D View Layout
- 2D View Layout

To enable Verification of Flow Direction Layout

Press   to enable Verification of Flow Direction Layout.

To enable Flow Analysis 3D Layout

Press   to enable Flow Analysis 3D View Layout.

To enable 2D View Layout

Press   to enable 2D View Layout.

5.3.1 Verification of Flow Direction Layout

This is the layout used for verification of the flow direction.

Refer to Section: Verify Flow Velocity Directions: Overview
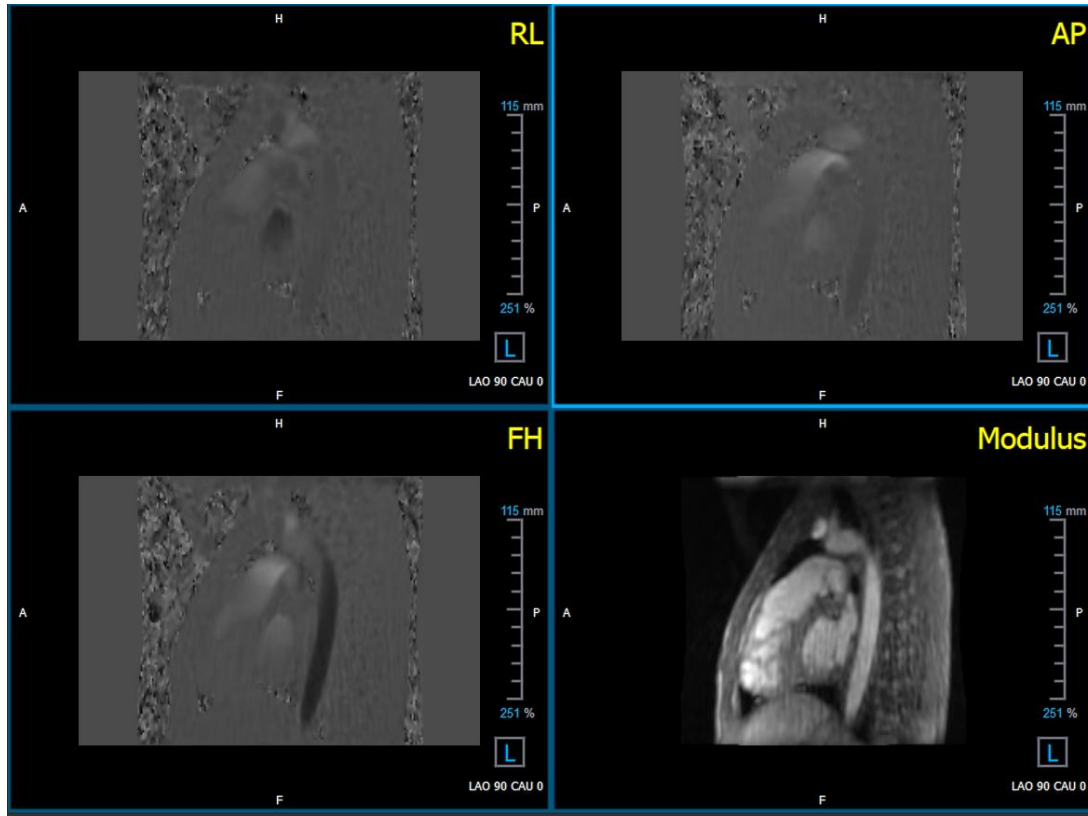
Figure 4 Verification Of Flow Direction Layout

5.3.2 Flow Analysis Layout

The primary layout in QFlow 4D consists of five viewports.

1. Three double oblique views
2. 3D View
3. Velocity view

5.3.2.1 Double Oblique View

The main purpose of the double oblique views is to determine the plane of interest to be used for Flow Analysis in QFlow 4D. The double oblique views show the orthogonal views of the 3D volume.

The double oblique viewports are highlighted in blue in Figure 5 Double Oblique Viewport Layout.
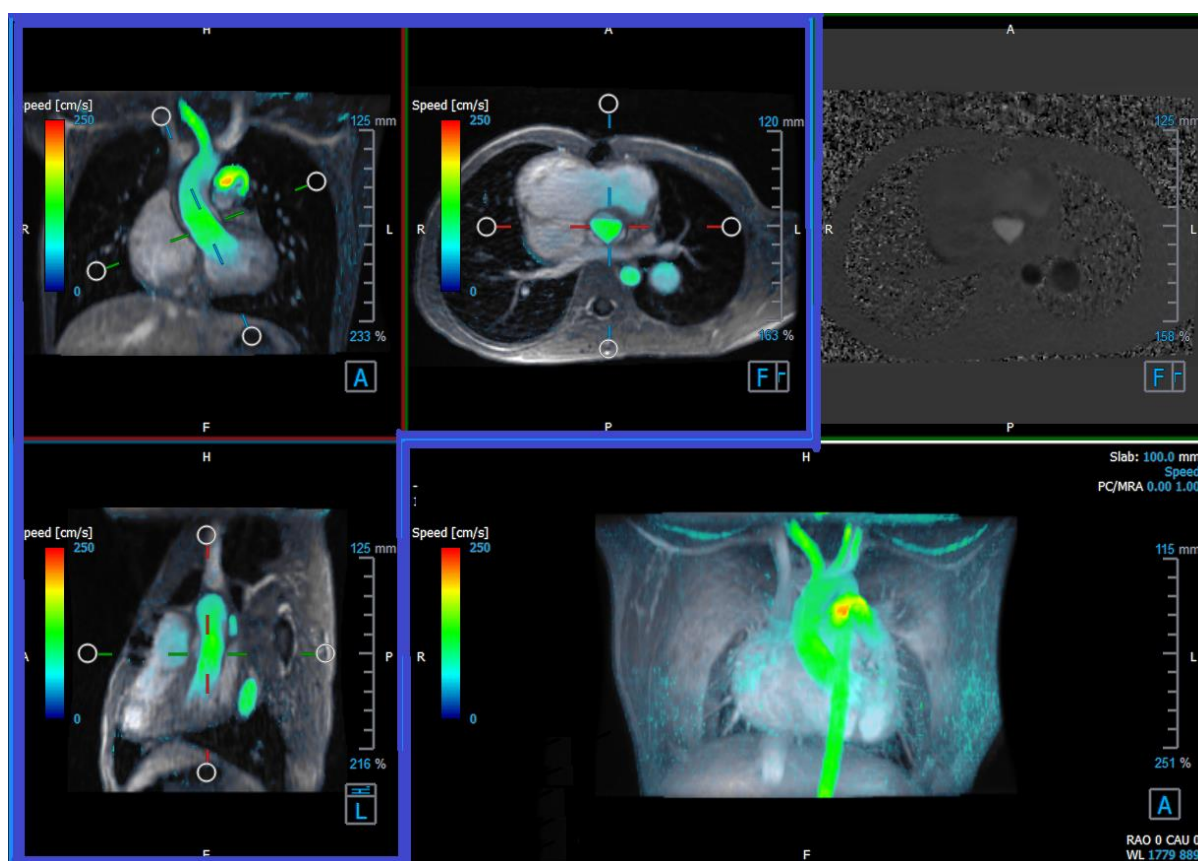
Figure 5 Double Oblique Viewport Layout

5.3.2.2   3D View

The 3D view viewport is highlighted in blue in Figure 6 3D View, viewport.

The 3D view is a viewport that shows the series rendered in 3D.
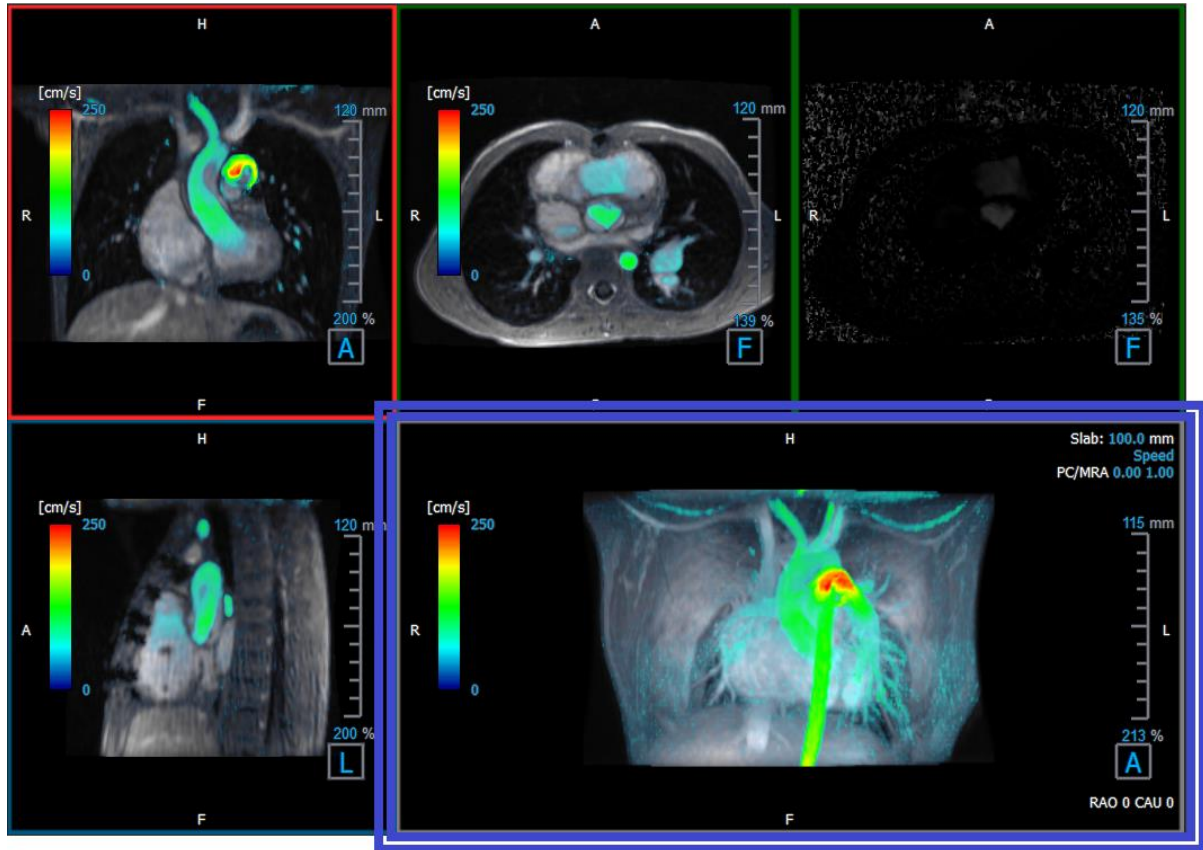
Figure 6 3D View, viewport

5.3.2.3   Flow 2D Representation

The top middle and top right viewports show the series at the reconstruction plane defined by the user for Flow Analysis procedure. The top middle viewport shows the reconstructed modulus image and the top right viewport shows the perpendicular velocities of that plane.

These two planes, marked in red in Figure 6 The Modulus and Phase series, shows the data that is used for the Flow Analysis.
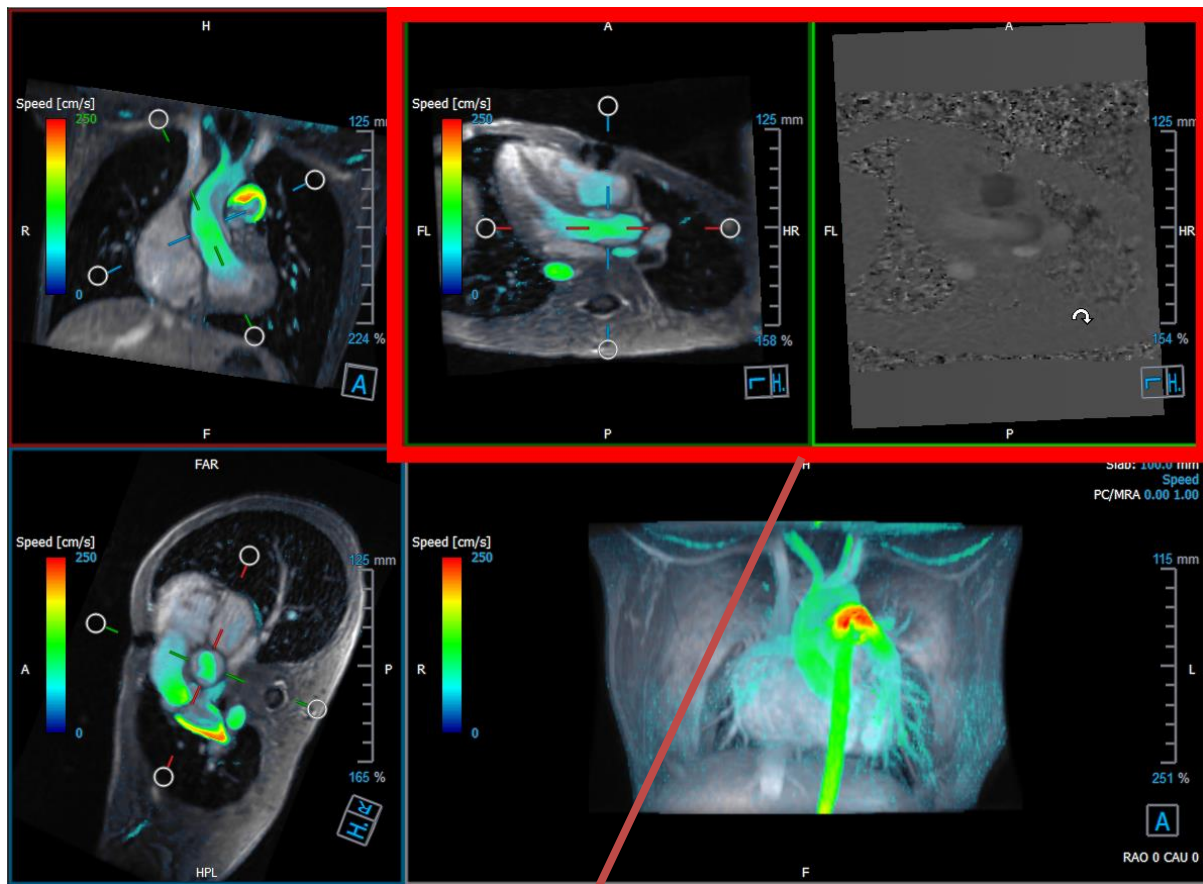
Figure 7 The Modulus and Phase images
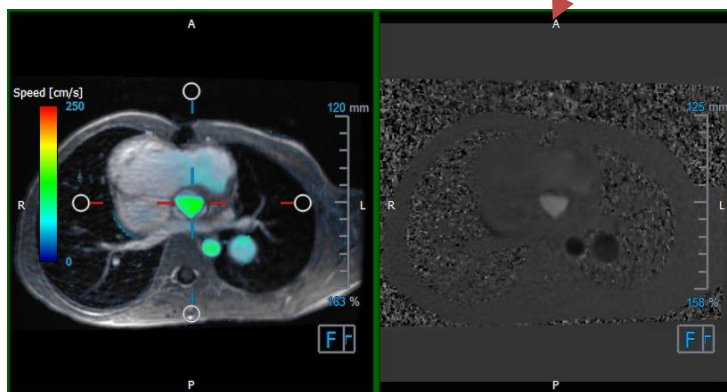
Figure 8 Flow Analysis Plane of Modulus and Phase images

5.3.3 2D View Layout

All viewports show 2D orientation images. Optionally, Speed, Vectors and Streamlines can be displayed.
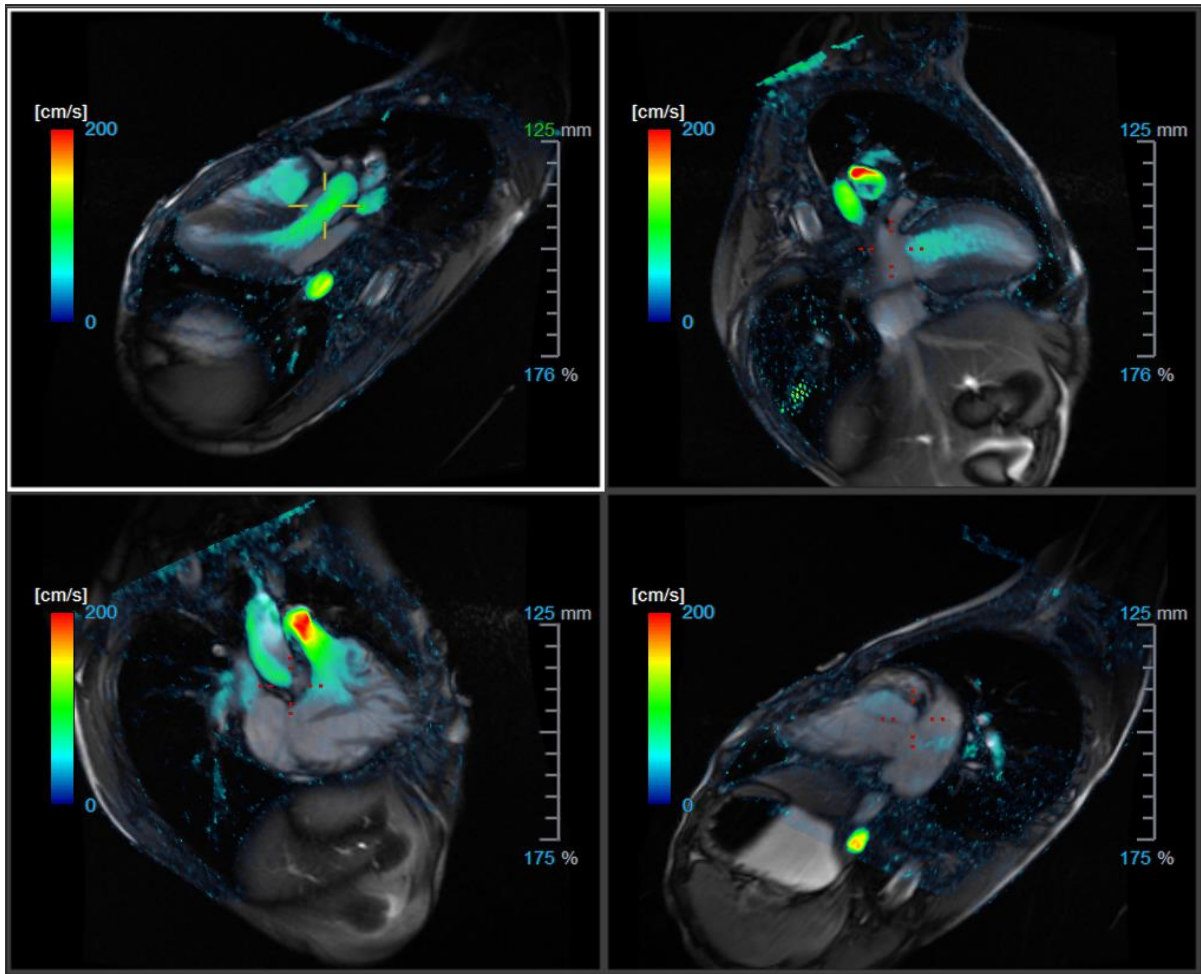
Figure 9 2D View Layout with 4 high-resolution series. A speed overlay is shown on these images.

5.3.3.1   Loading new series into 2D View layout

Series can be loaded in the viewport from the **Series Browser**.

To load series in the viewport

1. Click an item in the image view or text view of the Series Browser to select it.

2. Click and drag the selected series from the **Series Browser** to the viewport.

   This will load the series into the viewport. When multiple slices are contained in the series, the middle slice is displayed by default. When multiple time points are contained in the series, the first time point is displayed by default.

To review all series in the active study

1. Press **Page Down** on your keyboard to load the next series into the viewport.

2. Press **Page Up** on your keyboard to load the previous series into the viewport.

5.3.3.2   Cross Referencing

The cross hair tool enables the user to visually relate the active image and image position with that of the different series loaded in other viewports. Cross referencing is visible when multiple related series are loaded.

To enable/disable the crosshairs

- Click in the general toolbar to enable or disable cross hair.

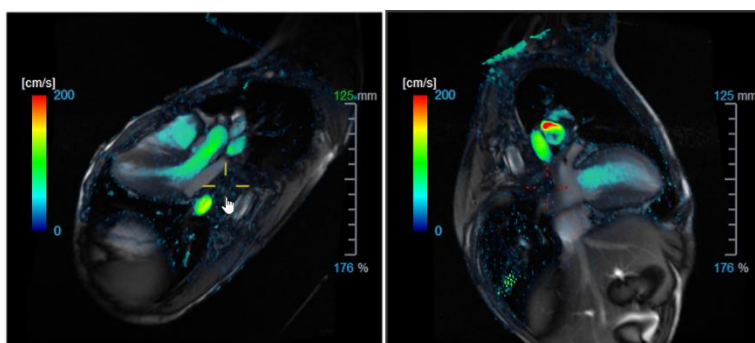💡 A cross hair reference of the same color implies there is an exact or nearby position cross reference. A different color cross hair indicates the position is out of range of the cross hair in the active image.

5.4 Noise Removal

QFlow 4D Noise Removal is a utility for visualization only. It is available when viewing images in the **Flow Analysis 3D View Layout** and **2D View Layout**. It filters out the air and the surrounding static tissue, essentially highlighting motion velocity of the blood-pool. When Noise Removal is enabled, it will be automatically applied to the three double-oblique views, the 3D and **2D View layout** viewports. The velocity viewport on the top right of the **Flow Analysis 3D Layout**, is unaffected.

There are two parameters governing the behavior of the Noise Removal, the standard deviation threshold and the modulus threshold.

- The standard deviation threshold can take values from 0-1%. It defines the static tissue to be removed based on the velocity of the tissue.
- The modulus threshold can take values from 0-100% and the area to be removed based on the intensity of the modulus image. The area removed is based on the intensity of modulus image and corresponds mainly to the surrounding air and the lungs.

🛈 QFlow 4D Noise Removal has no effect on quantification or numerical results, and it is not applied to any data.

🛑 Please ensure that QFlow 4D Noise Removal only removes noise from the images.

5.4.1   Noise Removal Options

To modify Noise Removal settings:

1. Select ⋮ > **Options**, **Noise Removal**.
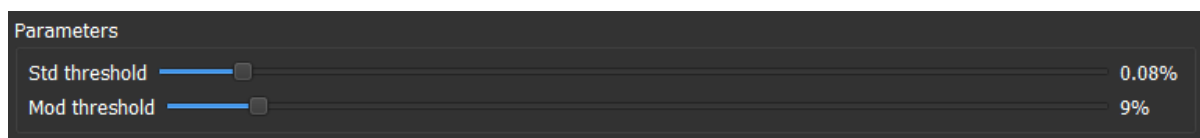
Higher values, in both cases, will cause more of the speed overlay to be removed from the image.

5.4.2   Enable/Disable Noise Removal

To enable/disable noise removal:

1. Select ![icon] in the toolbar to enable Noise Removal.
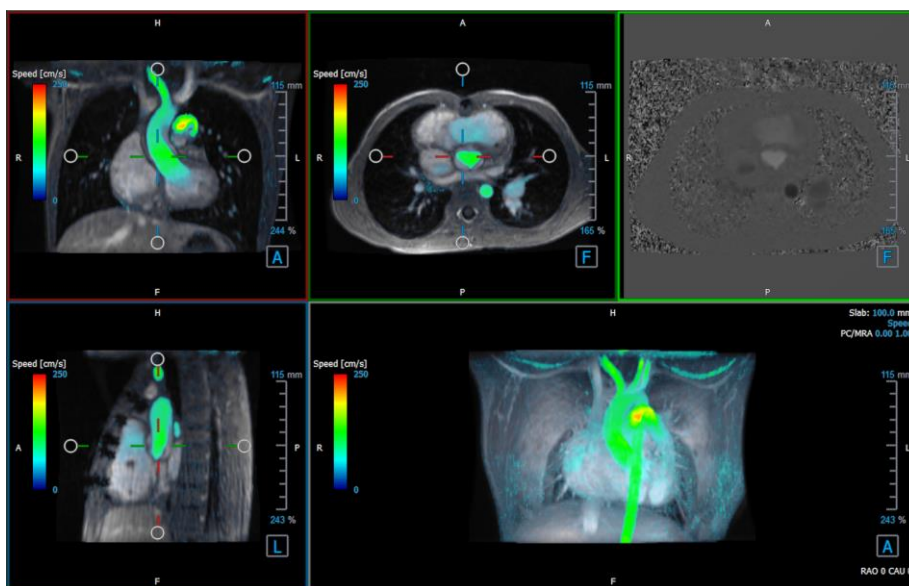
Figure 10 *Noise Removal Enabled*

2. Select ![icon] in the toolbar to disable Noise Removal.
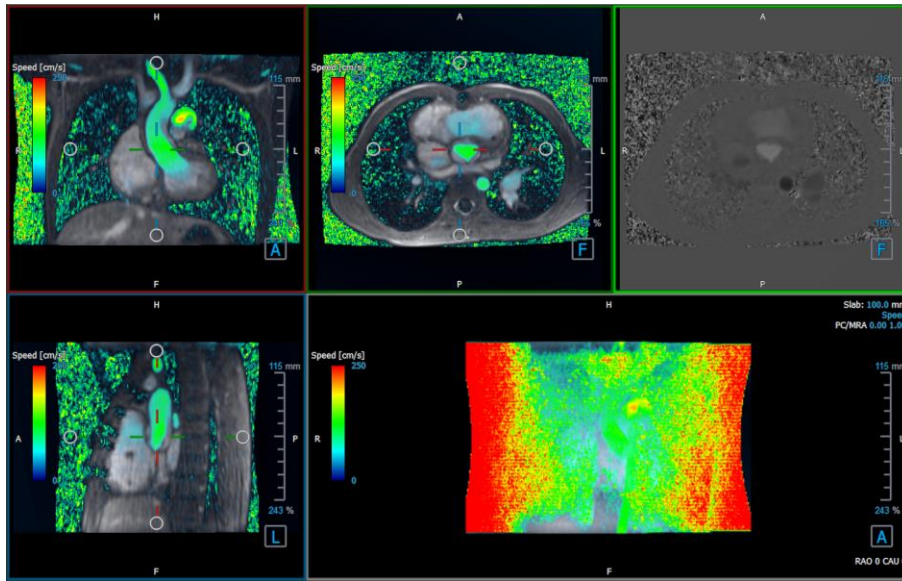
Figure 11 Noise Removal Disabled

5.5 Viewport Overlay Visualization

QFlow 4D provides multiple overlays types, each defining different visual aspects of the data.

- PCMRA
- Speed
- Streamlines
- Vectors

5.5.1 Toggle Overlay Representation

Overlays showing speed, steamlines or vectors may be enabled or disabled. In the Flow Analysis 3D layout, they are visible in the three double oblique viewports and the 3D MIP viewport. In the 2D View Layout, the overlays are visible in all viewports with a loaded series.

To modify the overlay representation in the Flow Analysis Layout:

1. Select the top right-hand corner text in the 3D MIP viewport. It will toggle from
   - **No Overlay**
   - **Speed**
   - **Streamlines**
   - **Vectors**
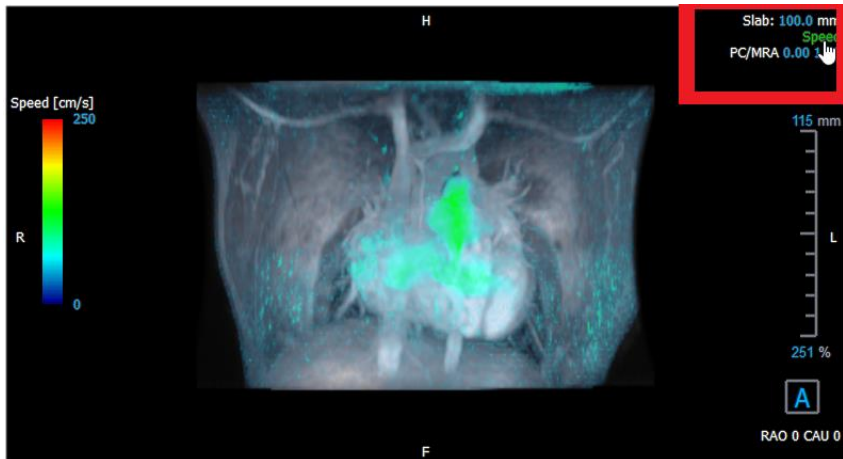
Figure 12 *Select Overlay Type Annotation in the Flow Analysis 3D Layout*

Or,

1. Right-click the top right-hand corner text in the 3D MIP viewport. This opens a context menu.

2. Select **No overlay**, **Speed, Streamlines or Vectors.**

To modify the overlay representation in the 2D View Layout:

1. Right-click the top right-hand corner text in any viewport. This opens a context menu.

2. Select **No overlay, Speed, Streamlines or Vectors**.
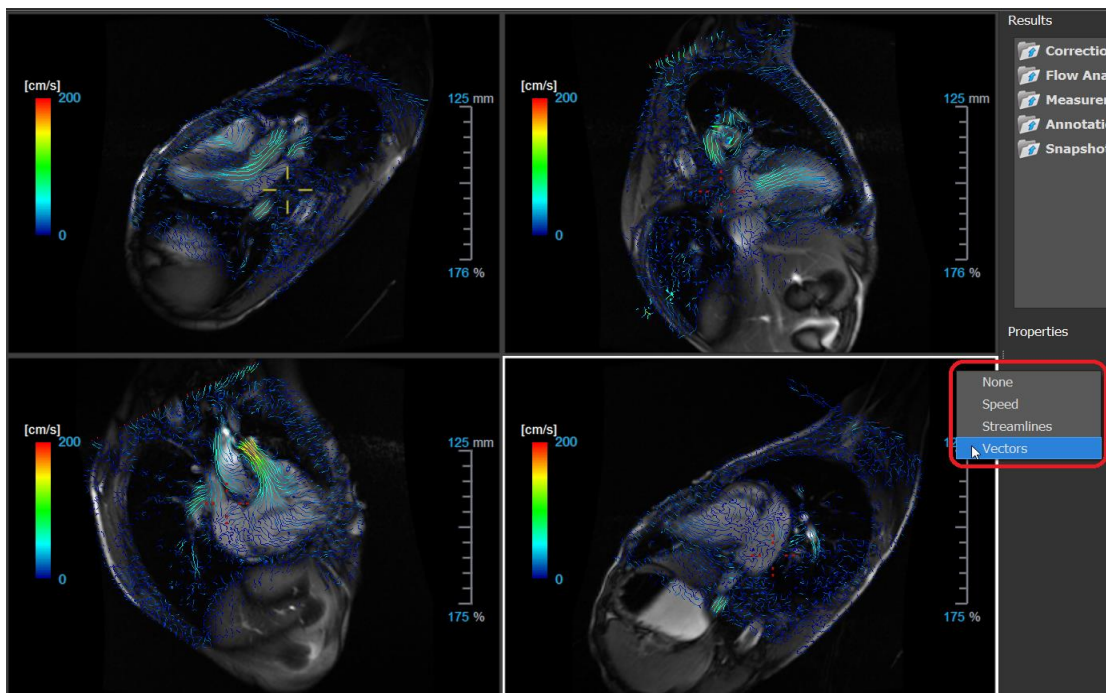
Figure 13 Select Overlay Type Context Menu in the 2D View Layout

5.5.2 Streamlines Plane of Origin overlay

When Streamlines are shown in the 3D MIP viewport the plane of origin of the streamlines is also visible. The plane of origin represents the axial view, that is the top middle double oblique viewport (DOV) marked in green. The plane also represents the reconstructed modulus image position and orientation.
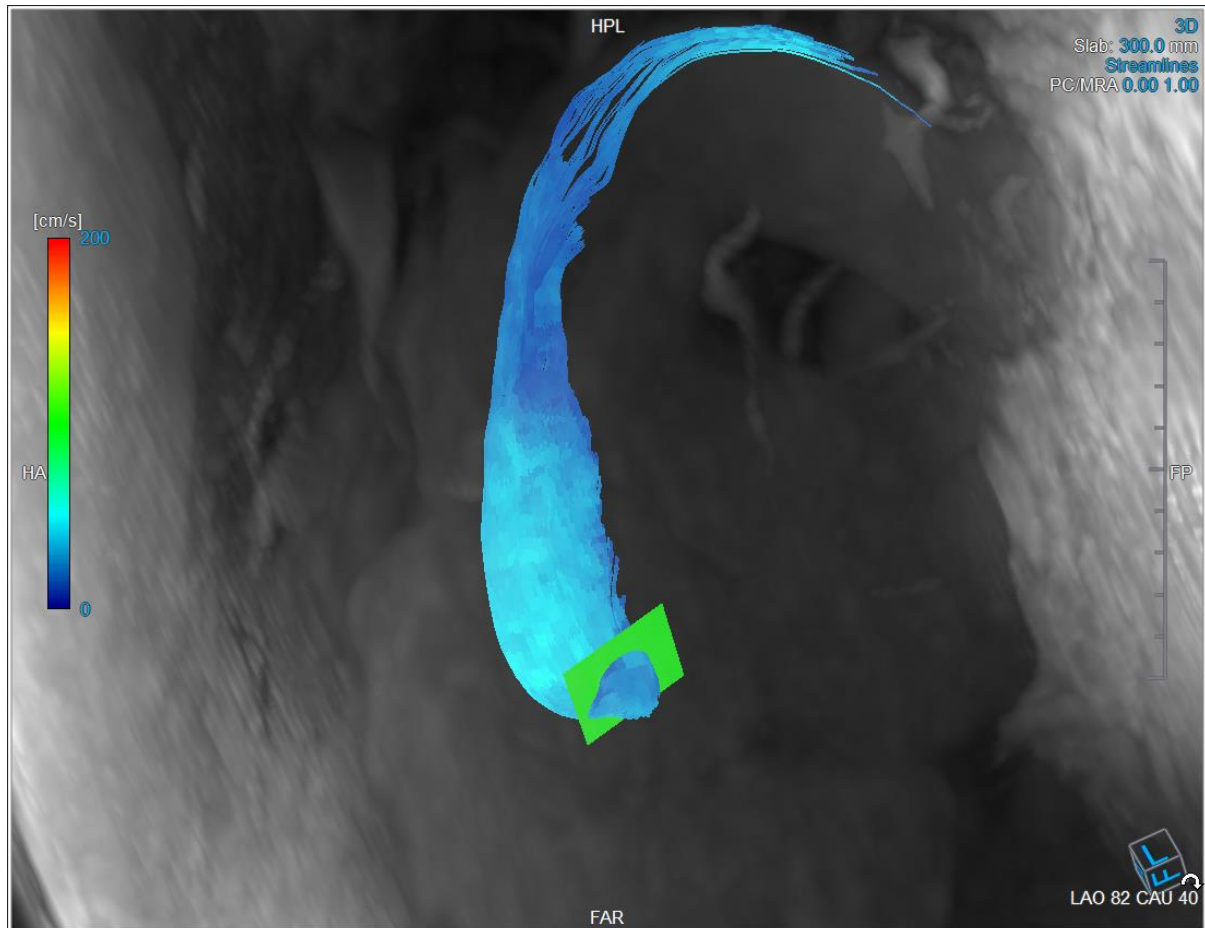
Figure 14 The 3D MIP viewport showing Streamlines and the Plane of Origin in the Flow Analysis 3D Layout

To modify the Plane of Origin in the Flow Analysis Layout:

1. Select either the sagittal viewport which has a blue border, or the coronal viewport with a red border.

2. Modify the position of the axes.

To Modify the position of the axes.

1. Move the mouse to a circular grip at the end of one axis. The mouse cursor changes to the Rotate cursor ⟳.

2. Click and drag the axes to the desired angle.

Or,

3. To drag the axes vertically, press the Ctrl key after pressing the mouse key, then drag.

4. To drag the axes horizontally, press the SHIFT key after pressing the mouse key, then drag.

5.6   Frame Selection

You can move forward or backward through the frames in the image in several ways.

Moving through frames can be done by using buttons:

- Press ◀| or |▶ on the Viewing toolbar to move to the previous or next frame.

Or,

- Press ◀ or ▶ on the Viewing toolbar to play a cine through the frames in backward or forward direction. Click ■ to stop the cine.

Or,

- Press |◀ or ▶| on the Viewing toolbar to move to the first or last frame.

Moving through frames can be done by using keys:

- Press the left or right arrow key to move to the previous or next frame.

Or,

- Press CTRL + left arrow, CTRL + right arrow to play a cine through the frames in backward or forward direction. Press Esc to stop the cine.

Or,

- Press HOME or END to move to the first or last frame.
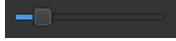
Moving through frames can be done by using interactive graphics:

- Select the interactive graphics for frame selection ('Frame') on the viewports to move to the next frame.

Or,

- Right-click the interactive graphics for frame selection ('Frame') and enter the desired frame number.

The cine speed can be modified with the slider ▭ in the Viewing toolbar.

5.7   Mouse Controls

5.7.1 Stacking

You can move through the frames using **Stacking** when you see the stack cursor ⌖.

To activate the stacking mouse control:

- Press ⬚ in the mouse controls toolbar.

Or,

- Select **Stacking** from the viewport context menu.

To stack forward or backward through frames:

- Click and drag the mouse left and right or down and up to scroll through the frames. It will loop to the first or last frame.

Or,

- Independent of the stacking mouse control status, you can scroll the mouse wheel to stack through the frames. It will stop at the first or last frame.

5.7.2 Zooming

You can zoom in and out of the viewport using **Zooming** when you see the magnify cursor ⌕ .

To activate the zooming mouse control:

- Press ⌕ in the mouse controls toolbar.

Or,

- Select **Zooming** from the viewport context menu.

To zoom in and out:

- Click and drag the mouse forward and backward to zoom in and out.

Or,

- Independent of the zooming mouse control status, you can click and drag on the interactive zoom scale graphics, or hold Ctrl and scroll the mouse wheel up and down, to zoom in and out.

💡 The current zoom factor is displayed on the scale graphics in the viewport.
The value above the scale is the physical size of the scale.
The number below the scale indicates the relative zoom:
100% means one display pixel equals one acquisition pixel.

5.7.3   Panning

You can move the image within the viewport left, right, up and down using **Panning** when you see the hand cursor 🖑 .

To activate the panning mouse control:

- Press ⟲ in the mouse controls toolbar.

Or,

- Select **Panning** from the viewport context menu.

To pan the image:

- Click and drag the mouse in any direction.

Or,

- Independent of the panning mouse control status, you can middle-click and drag the mouse in any direction to pan the image.

5.7.4   Window Width and Level

You can adjust the window width and level (WWL) when you see the WWL cursor ✳ .

To activate the window/level mouse control:

- Press 🔆 in the mouse controls toolbar.

Or,

- Select **Window/Level** from the viewport context menu.

To adjust the window width and level:

- Click and drag in the viewport

  - Right or left to increase or decrease the width.

  - Down or up to increase or decrease the level.

Or,

- Independent of the window/level mouse control status, right-click and drag

  - Right or left to increase or decrease the width.

  - Down or up to increase or decrease the level.

Or,

- Independent of the window/level mouse control status, click on the window width or level interactive graphics and drag up or down to increase or decrease the window width or level.

Or,

- Independent of the window/level mouse control status, right-click on the window width or level interactive graphics and enter the desires values.

💡 The current window width and level values are displayed in the lower-right overlay graphics in the viewport.

5.7.5 Initial View State

To reset the zooming, panning and window width and level settings to the initial view state:

- Press ⟲ to reset the zooming, panning and window width and level.

5.8   Standard Measurements

QFlow 4D supports the following standard measurements:

- Annotations,
- Distance measurements,
- Area measurements,
- Snapshots.

5.8.1   Annotations

You can add annotations to a viewport to mark it for analysis or to draw attention to specific details. Annotations are displayed in the viewport. All annotations of the active study are listed on the **Results** pane.

Figure 15 Example Annotation

💡 When you select another series or navigate to another time point in the active series, your annotation is no longer displayed in the viewport. This is because the point to which the annotation refers does not lie on the currently visible image. To see your annotation again, right-click on the annotation on the **Results** pane and select **Locate**; or double-click on the annotation on the **Results** pane.

For details on creating, editing and deleting annotations, see the Medis Suite User Manual.

5.8.2   Distance Measurements

A procedure to measure the distance from one point to another. When you have measured a distance, you can modify the annotation and the end points of the measurement. All distance measurements of the active study are listed on the **Results** pane. All distance measurements of the active session are listed on the **Results** pane of Medis Suite.

Figure 16 Example Distance Measurement

💡 When you select another series or navigate to another time point in the active series, your distance measurement may not be displayed on the viewport. This is because the points between which you measured do not lie 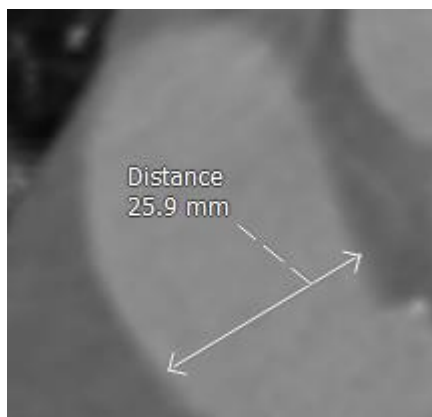on the currently visible image. To see your measurement again, right-click on the measurement on the **Results pane** and select **Locate**; or double-click on the measurement on the **Results pane**.

For details on creating, editing, and deleting distance measurements and copying the results to clipboard, see the Medis Suite User Manual.

5.8.3   Area Measurements

You use the area measurement tool to draw and measure 2D areas. When you have measured an area, you can modify the area contour or annotation. All area measurements of the active study are listed on the **Results pane**. All area measurements of the active session are listed on the **Results** pane of Medis Suite.

Figure 17 Example Area Measurement

💡 When you select another series or navigate to another time point in the active series, your area measurement may not be displayed on the viewport. This is because the image on which you measured the area is not the same as the currently visible image. To see your measurement again, right-click on the measurement on the **Results pane** and select **Locate**; or double-click on the measurement on the **Results pane**.

For details on creating, editing, and deleting area measurements and copying the results to clipboard, see the Medis Suite User Manual.

5.8.4   Snapshots

You can save snapshots as evidence of an analysis or diagnosis. Snapshots are displayed on the **Properties** pane and are listed on the **Results pane**. When a snapshot is created, you can modify the name at any time.

💡 When you select another series or navigate to another time point in the active series, the annotations and measurements shown in the snapshot may not be displayed on the viewport. This is because the points at which the annotations and measurements were created do not lie on the currently visible image. To return to the same series and time point where a snapshot was created, right-click on the snapshot on the **Results pane** and select **Locate**; or double-click on the snapshot on the **Results pane**.

For details on creating, editing and deleting snapshots, see the Medis Suite User Manual.

QFlow 4D Analysis

6   Performing a QFlow 4D Analysis

The Flow Analysis procedure reformats a series of time-resolved 3D volumes, into a 2D CINE series, which can then be quantified in QFlow.

To perform a QFlow 4D flow analysis, you may use the following guidelines.

- Load series
- Visually inspect the data
  Apply Noise Removal: Refer to, Noise Removal Noise Removal [5.4].
- Optional: Verify All Flow Velocity Directions
- Optional: Create a Phase Unwrapping
- Optional: Create a Background Correction
- Start a Flow Analysis
- Review Reporting
- Save the Session

6.1   Verify Flow Velocity Directions: Overview

A 4D flow MRI dataset consists of time-resolved, three-dimensional series encoded in three velocity directions and a single modulus (or magnitude) series. In QFlow4D, the three velocity orientations are as follows

- LR/RL (Left-Right/Right-Left)
- HF/FH (Head-Feet/Feet-Head) and
- AP/PA (Anterior-Posterior/Posterior- Anterior)

If velocity encoding is positive, the pixels are white and if it is negative, the pixels are black. In a series where the data is encoded in RL direction, the areas showing the flow from right to left would be positive and visually seen as white pixels, while areas showing the flow left to right would be negative and seen as black.

Given that there is no standardization in the velocity encoding directions in the 4D Flow MRI field, the directions in the data should be verified.

🛑 The user must check all orientations.

🛑 Not all Siemens and Philips scanners have 4D Flow MR acquisition protocol available for their series. As such, the correct velocity directions cannot be warranted and therefore should be verified.

🛑 Post processing packages may change the velocity encoding directions.

💡 If QFlow 4D did not correctly determine the velocity encoding, contact Installation & Support for assistance in correctly configuring your system. Refer to the Support section.

Figure 18 Modulus Image

ⓘH, P, A and F are indicators that assist in determining the flow direction and image orientation.

ⓘ The orientation cube located at the bottom right corner can be modified to change the viewing orientation. Refer to Figure 18 Modulus Image.
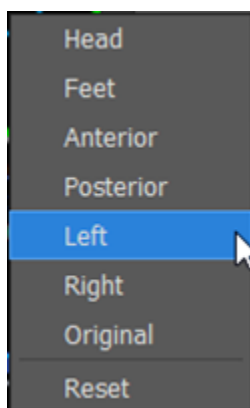
6.1.1 Verify All Flow Velocity Directions

To verify all velocity directions:
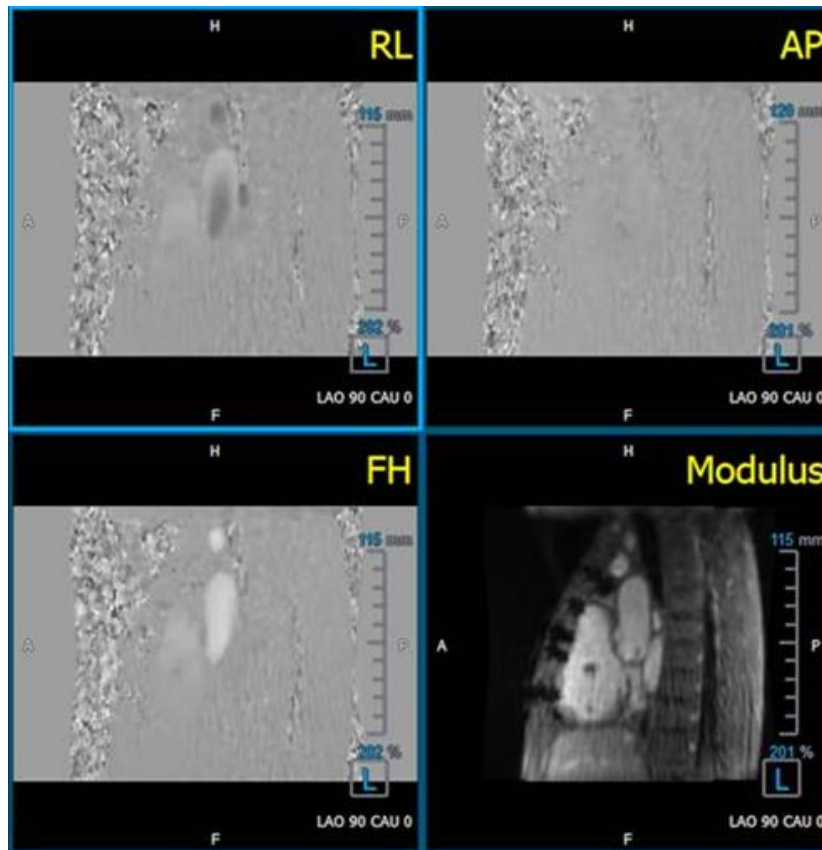
1. Press ![icon] in the toolbar.

Figure 19 Verify Flow Velocity Direction Layout

2. Make the MODULUS viewport orientation LEFT

   ⓘ "L" in the square at the right bottom corner of the viewport.

3. In the MODULUS viewport, scroll through the images to find a slice including the descending aorta and the heart chambers.

4. Determine the systolic time frame where the images have the highest velocity intensity signal.

5. Verify HF / FH Velocity Direction

6. Verify AP / PA Velocity Direction

7. Verify RL / LR Velocity Direction

6.1.2 Verify HF / FH Velocity Direction

To verify the HF / FH velocity direction:

1. Press ![icon] in the toolbar.

2. Make the MODULUS viewport orientation LEFT

    🛈 "L" in the square at the right bottom corner of the viewport.

3. In the MODULUS viewport scroll through the images to find a slice including the descending aorta and the heart chambers.

4. Determine the systolic time frame where the images show a definitive velocity signal.

5. Please verify at least one of the following situations described below is correct. If not, contact Medis Support, see section: Support.

    🛈 If the descending aorta is white, in the viewport containing HF / FH view, then the velocity encoding direction should be HF.

    🛈 If the descending aorta is black, in the viewport containing HF / FH view, then the velocity encoding direction should be FH.
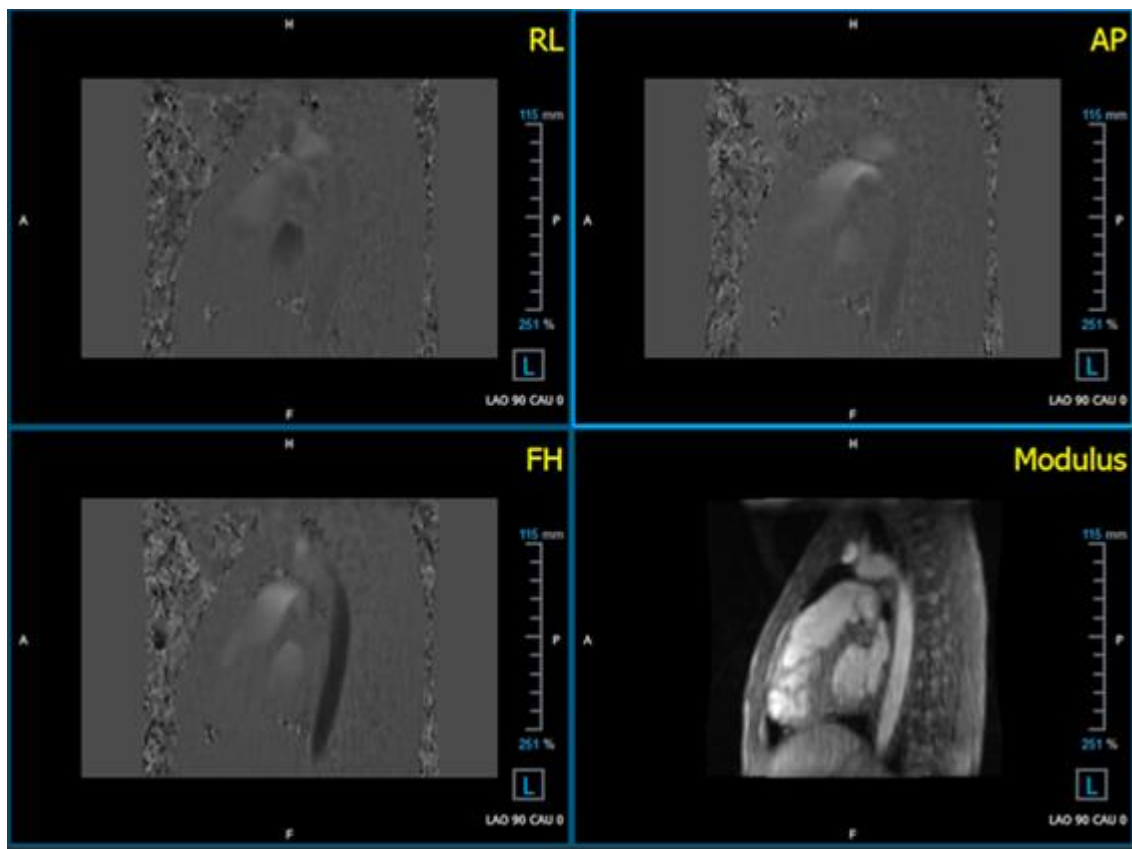

Figure 20 *Verify Flow Velocity Direction Layout*

6.1.3 Verify AP / PA Velocity Direction

To verify the AP / PA velocity direction:

1. Press ![icon] in the toolbar.

2. Make the MODULUS viewport orientation LEFT ("L" in the square at the right bottom corner of the viewport.

3. In the MODULUS viewport find the aortic arch.

4. Determine the systolic time frame where the images show a definitive velocity signal.

5. Please verify at least one of the following situations described below is correct. If not, contact Medis Support, see section: Support.

    ⓘ If the aortic arch is white, in the viewport containing PA / AP view, then velocity encoding direction should be AP.

    ⓘ If the aortic arch is black, in the viewport containing PA / AP view, then velocity encoding direction should be PA.
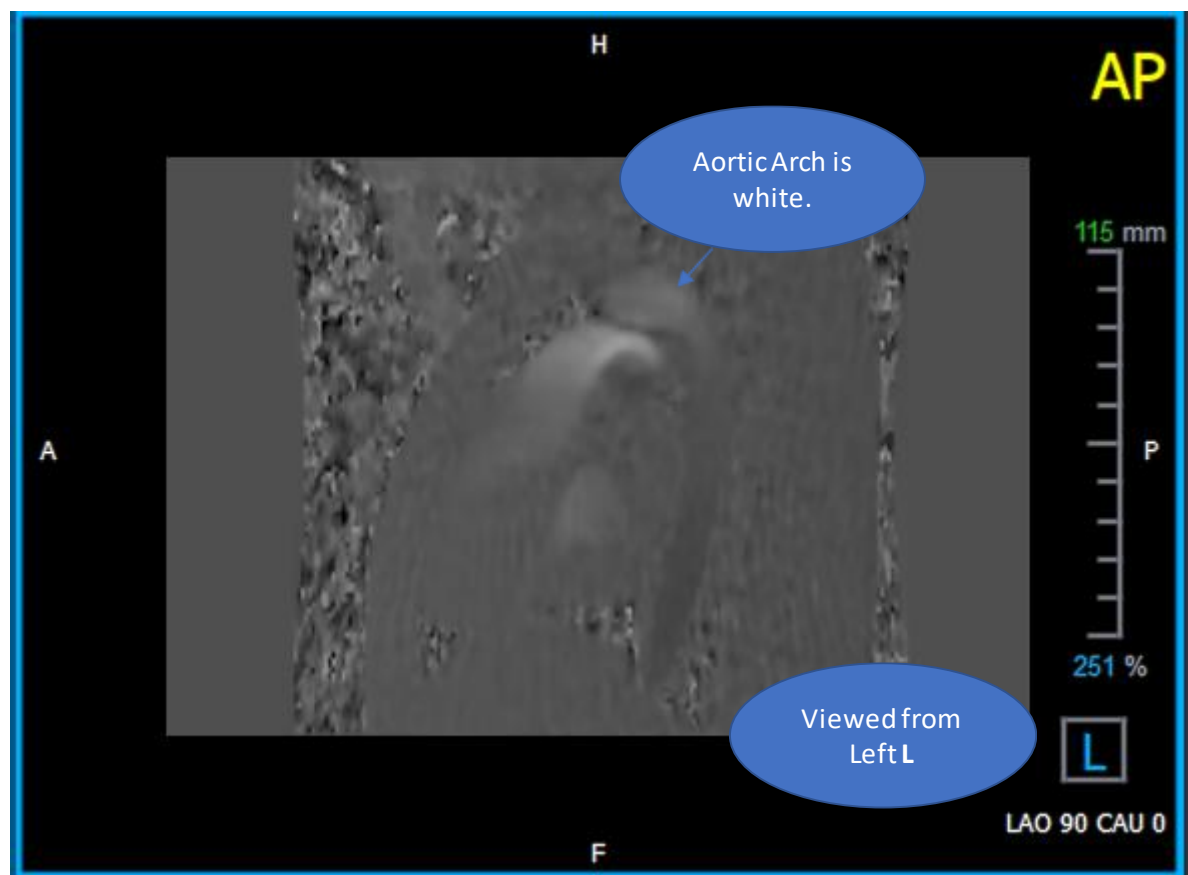

Figure 21 AP Positively encoded viewport, with a white aortic arch and a darker descending aorta.

6.1.4 Verify RL / LR Velocity Direction

To verify the AP / PA velocity direction:

1. Press ![icon] in the toolbar.

2. Make the MODULUS viewport orientation ANTERIOR

   🛈 "A" in the square at the right bottom corner of the viewport.

3. In the MODULUS viewport find the slice including the ascending aorta.

4. Determine the systolic time frame where the images show a definitive velocity signal.

5. Please verify at least one of the following situations described below is correct. If not, contact Medis Support, see section: Support.

   🛈 In the viewport containing RL / LR view, the orientation is LR if the proximal ascending aorta is white and the distal ascending aorta is black.

   🛈 In the viewport containing RL / LR view, the orientation is RL, if the proximal ascending aorta is black and the distal ascending aorta is white.
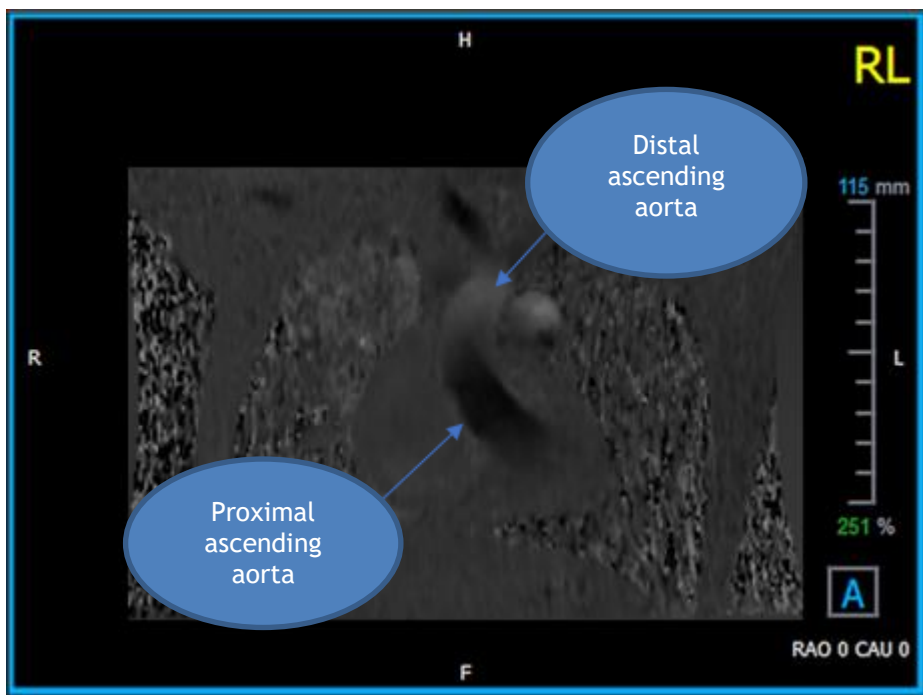

Figure 22 RL Positively encoded viewport, with proximal and distal ascending aorta

6.1.5   Close the Velocity Direction Verification View

1.   Press in the toolbar. The layout will return the QFlow 4D analysis layout.

6.1.6   Custom System Options

If the velocity direction are incorrect for a particular dataset, please contact Medis Installation & Support.

6.2   Background Correction

The quality of the phase velocity data may be compromised as a result of background phase distortions. These distortions can be corrected by applying a stationary flow fit algorithm to the data. The Background correction utility is a quantitative tool which removes phase offset errors from the data, thereby correcting phase offset errors.

The background correction which is also known as stationary flow fit algorithm, has two configurable settings, the **Standard Deviation Threshold** to define the static tissue mask and the **Fitting order** which defines the level of complexity of the fitting.

Standard Deviation Threshold.

A low standard deviation threshold value might cause inclusion of insuffient static tissue volume to obtain an accurate background correction
A high standard deviation threshold value might cause inclusion of flow area as static tissue which would result in an inaccurate background correction.
25% standard deviation threshold is the default.

Fitting order

The fitting order of the stationary flow fit algorithm defines the complexity of the fitting planes used to correct the phase offset error. There are three fitting orders, 1st 2nd and 3rd, which in theory, respectively produce more sophisticated background corrections, although they require longer computational time.

The Background Correction settings are used for all Reconstructions and they are published as part of each reconstruction output in the **Results** pane, the **Report** tab in Medis Suite.

⚠ The background correction affects the reconstruction procedure(s). When a background correction is modified or completed, all existing reconstructions in the current session, will be updated to use the new background corrected data.

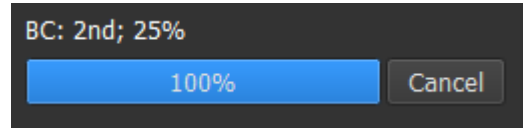⚠ Noise Removal has no effect on background correction.

6.2.1   Enable Background Correction

To enable background correction.

1. Press in the toolbar.

The **Properties** pane of the Background
Correction displays the following;

- Background Correction progress
- The selected threshold
- The selected fitting order
- **Cancel** button, to cancel the correction

The Background Correction can be selected in the Corrections list on the Results pane, which will show the corresponding Properties pane.

From the **Properties** pane each background correction can be located, deleted and renamed. The **Properties** pane shows Background Correction options and progress.

⚠ Any changes to Background Corrections threshold or fitting order are applied to **all** reconstructions in the current session.

6.2.2   Deleting Background Correction

You can delete any Background Correction that was created.

To delete a Background Correction:

1. Select the Background Correction in the **Corrections** list on the **Results pane**.

2. Press Delete on your keyboard or right-click and select **Remove.**

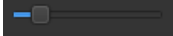   This deletes the Background Correction.

⚠ Removing a Background Correction updates **all** reconstructions in the current session.

6.2.3   Background Correction Options

You can change and apply the Background Correction settings using the options menu.

To modify Background Correction settings:

1. Select > **Options**, **Background Correction.**

- The Std Threshold can be modified with the slider .
- The Stationary Flow Fit, Fitting Order can be selected.

2. 🛑 Any changes to Background Corrections threshold or fitting order are applied to **all** reconstructions in the current session.

6.3   Phase Unwrapping

The quality of the phase velocity data may be compromised as a result of an incorrectly chosen Venc. Velocities higher than Venc cannot be encoded in the phase velocity data, and show up "wrapped", i.e. with a lower value, a phenomenon known as aliasing. The Phase Unwrapping algorithm detects aliasing in the data and undoes it by applying a corresponding shift to the phase velocity data.

The phase unwrapping algorithm has two parameters, and upper and a lower threshold, the values of which can be changed in the options. The initial computation of the phase unwrapping algorithm yields an amount of aliasing that can be any value. However, it is assumed that the aliasing always is 2 Venc. To constrain the algorithm output accordingly, there is an **Upper Threshold** above which values are rounded to 2 Venc, and a **Lower Threshold** below which values are rounded to -2 Venc.

Upper Threshold

The upper threshold can take values between 0 and 2 Venc. Higher values of this threshold cause the algorithm to be more conservative in identifying aliasing in the positive velocity direction, while lower values cause the algorithm to identify aliasing more readily. An upper threshold below 0.5 Venc is not advised.

Lower Threshold

The lower threshold can take values between -2 Venc and 0. Lower values of this threshold cause the algorithm to be more conservative in identifying aliasing in the negative velocity direction, while higher values cause the algorithm to identify aliasing more readily. A lower threshold above -0.5 Venc is not advised.

The Phase Unwrapping is used for all reconstructions, and whether one is present is published as part of each reconstruction output in the **Results** pane, the **Report** tab in Medis Suite.

⚠️ The Phase Unwrapping affects the reconstruction and Background Correction procedure(s). When a Phase Unwrapping is completed, an existing Background Correction, and afterwards all reconstructions in the current session, will be updated to use the new unwrapped data.

⚠️ For performance, apply Phase Unwrapping before Background Correction, and prevent the recompute of the Background Correction after the Phase Unwrapping finishes.

⚠️ Noise Removal and Background Correction have no effect on Phase Unwrapping.
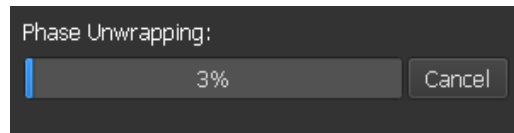
6.3.1 Enable Phase Unwrapping

To enable Phase Unwrapping.

1. Press ⦿ in the toolbar.

The **Properties** pane of the Phase Unwrapping displays the following;

Phase Unwrapping:

3%   Cancel

- Phase Unwrapping progress
- **Cancel** button, to cancel the unwrapping

The Phase Unwrapping can be selected in the Corrections list on the Results pane, which will show the corresponding Properties pane.

From the **Results** pane Phase Unwrapping can be located, deleted and renamed. The **Properties** pane shows the Phase Unwrapping progress.

6.3.2   Deleting Phase Unwrapping

You can delete any Phase Unwrapping that was created.

To delete a Phase Unwrapping:

1. Select the Phase Unwrapping in the **Corrections** list on the **Results pane**.

2. Press Delete on your keyboard or right-click and select **Remove**.

   This deletes the Phase Unwrapping.

⛔ Removing a Phase Unwrapping updates **all** reconstructions in the current session.

6.3.3   Phase Unwrapping Options

You can change and apply the Phase Unwrapping settings using the options menu.

To modify Phase Unwrapping settings:

1. Select ⋮ > **Options**, **Phase Unwrapping**.

   - The Upper Threshold can be modified with the top slider .
   - The Lower Threshold can be modified with the bottom slider .

2. ⛔ Any changes to the Phase Unwrapping parameters are applied to **all** Background Corrections **and** Reconstructions.
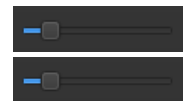
6.4   Flow Analysis

The QFlow 4D Flow analysis is referred to as a **Reconstruction**. The Flow Analysis procedure enables reformatting the time-based 3D volume, into a 2D series, which is then quantified in another app, QFlow 2D.

These are the steps to complete a Flow analysis.

1. Locate the plane of interest. Refer to Double Oblique View.
2. Start a Flow analysis
   - Optionally: Rename the reconstruction
3. Complete a Flow analysis
4. Rename the Flow analysis label, from "Reconstruction" to an appropriate label.

ⓘ All Flow Analyses results are stored in the QFlow 4D results, reports and session.

ⓘ Multiple Flow analyses may be started.

⚠ The flow analysis in QFlow 4D is performed in a separate tab outside QFlow 4D using the existing QFlow application.

6.4.1 Start Flow Analysis

QFlow 4D supports locating, renaming, exporting and removing of the flow analyses. Flow Analysis is labelled by default "Reconstruction".

To start a flow analysis

- Select from the toolbar.

Or,

3. Right-click in the viewport area. This opens a context menu.

4. Select **Flow Analysis**

6.4.2 Flow Analysis App

Flow analysis will be started with the QFlow 4D reformatted dataset.

- Press F1.

- Pushing the help button.

- Select the Medis Suite main menu button in the upper right corner > **Help** > **User Documents**. For detailed instructions on using Flow 2D, refer to the QFlow 2D User manual.

Figure 23 QFlow2D hosting the Flow analysis

6.4.3 Multiple Flow Analysis's
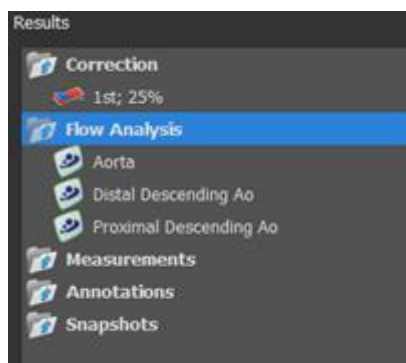
QFlow 4D supports multiple Flow analyses. Each new Flow analysis creates a new tab.

Figure 24 Results Pane with multiple flow analysis
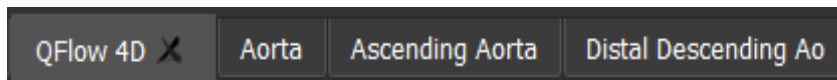
Figure 25 List of multipe tabs, each with a flow analysis

Reporting

QFlow 4D results are made available in the Medis Suite Results pane and in the Medis Suite report.

Figure 26 Medis Suite Report with QFlow 4D Results

The Reporting functionality of Medis Suite is described in the Medis Suite user manual. The Medis Suite documentation is available from the User documents tab, which can be opened as follows;

- Press F1.

- Pushing the [?] help button.

- Select the Medis Suite main menu button in the upper right corner [⋮] > **Help** > **User Documents**

7   Sessions

The QFlow 4D state can be saved in a Medis Suite session. The session can be reloaded to continue or review the analyses.

The session functionality in Medis Suite is described in the Medis Suite user manual. The Medis Suite documentation is available from the User documents tab, which can be opened as follows;

- Press F1.

- Pushing the [?] help button.

- Select the Medis Suite main menu button in the upper right corner [⋮] > **Help** > **User Documents**

<p style="text-align: right;">Reference</p>

8   Shortcut Keys

When you are working with QFlow 4D, you can use several combinations of keys on your keyboard and mouse actions to quickly perform the following tasks.

Press	To
Layout	
F11	Show or hide the workspace window panes
Image control	
Middle-click and hold	Hide all graphics
Middle-click and drag, or Ctrl and drag	Pan
Ctrl+Shift and drag	Zoom
Alt+Shift and drag	Stack
Procedures	
A	Create an area measurement
D	Create a distance measurement
S, or CTRL+SPACE	Create a snapshot
Esc	Stop editing the procedure
Delete	Delete the currently selected procedure

Press	To
SHIFT+Delete	Delete all procedures
Navigation Controls	
HOME	Display the first time point
END	Display the last time point
Arrow up	Display the previous slice
Arrow down	Display the next slice
Arrow left	Display the previous time point
Arrow right	Display the next time point
CTRL+arrow left	Play cine backward
CTRL+arrow right	Play cine forward
Esc	Stop playing cine
Page Up	Display the previous series
Page Down	Display the next series

9   General References

Anterior (or **ventral**) Describes the front or direction toward the front of the body. The toes are anterior to the foot.

Posterior (or dorsal) Describes the back or direction toward the back of the body. The popliteus is posterior to the patella.

Streamlines Describes the blood flow along a anatomical structure, such as a blood vessel. They represent a group of connected lines, where the color of each line indicates the velocity at a given location.

Vectors Describe a microscopic blood particle traversing through the structure of interest. It portrays the direction with an arrowhead and the velocity with color.