

# QFlow 4D 1.1

## User Manual

March 17, 2025

9.19.400.11.12

v12.0

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## 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 *formation*. 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

1

- Menu bar
- Toolbars
- Workspace panes
- Viewing

### 1.1 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.

### 1.2 Menu

The menu contains commands to activate the application functionality.

To make the menu visible:

• Select on the menu icon **select** 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	Þ	Panes	Show or hide a workspace pane
<u>T</u> oolbars	Þ	Toolbars	Show or hide a toolbar
<u>C</u> ine	Þ	Cine	Control the frame selection
I <u>m</u> age control	Þ	Image Control	Control the image display
P <u>r</u> ocedures	Þ	Procedures	Start a new procedure
<u>R</u> eset layout	F6	Reset layout	Reset the default layout
Initial view state	T	Reset Window/Level	Reset the default window/level
🕂 Show/Hide a <u>x</u> es	Ctrl+K	Initial view state	Reset the view state
Options		Show/Hide axes	Enable/Disable axes visibility
<u>н</u> ер		Options	Application default settings
		Неір	User documentation and About

### 1.3 Toolbars

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

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#### 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 **I** > 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.

lcon	Function			
General Toolbar				
:	Show the menu			
	Go to the initial view state, reset zoom $\ \$ pan $\ \$ window width $\ \$ window level			
	Verify flow direction.			
30	Go to the Flow Analysis 3D Layout.			
20	Go to the 2D View Layout.			

lcon	Function		
-1-	Show and Hide Axes		
	Toggle image text overlay		
*	Remove background noise on speed 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		
e	Set the cine playback speed		
Mouse Controls Toolbar			
¥	Stack		
	Zoom		
¢‡ ₽	Pan		

lcon	Function				
\$ <sup>‡</sup>	Window width and window level				
	Swivel (only if the 3D viewport is selected)				
Procedures To	Procedures Toolbar				
<b>*</b>	Background Correction on data				
$\overline{\bullet}$	Phase Unwrapping on data				
	Start a flow analysis				
	Start a Mitral Valve flow analysis				
<b>A</b>	Create a distance measurement				
	Create an area measurement				
A B C	Create a text annotation				
	Create a snapshot				
	Copy all measurement results to the clipboard				

### 1.4 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.

### 1.4.1 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.
Edit	Edit the procedure
Duplicate	Duplicate the procedure
Export to:	Export the procedure to disk.
Export to Repository:	Export the procedure to a repository.

Remove:

Delete the procedure.

### 1.4.2 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.

Properties			
Label: Distance 01			
9.1 mm			

Label: PV annulus (2)	Veins	►	
75.1 mm	Pulmonary	►	
	Aorta	►	
	Valves	•	PV annulus (1)
	RVOT	►	PV annulus (2)
	Defects	►	TV annulus (1)
	Coronaries	►	TV annulus (2)
	Stents	►	MV annulus (1)
	Pericardial Thickness	►	MV annulus (2)
			AV annulus (1)
			AV annulus (2)

Figure 3 Predefined Labels Menu

## Viewing

### Viewing

### 2.1 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.

① 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,

2

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.

U QFlow 4D only loads MR DICOM series.

### 2.2 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:

10

• 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 Frame: 21/53 and allow you to change image or display properties with your mouse.

### 2.3 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



to enable Verification of Flow Direction Layout.

#### To enable Flow Analysis 3D Layout

ress to er

to enable Flow Analysis 3D View Layout.

#### To enable 2D View Layout



to enable 2D View Layout.

### 2.3.1 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

### 2.3.2 Flow Analysis Layout

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

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

#### 2.3.2.1 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

#### 2.3.2.2 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

 $\bigcirc$  Change the slab thickness and or the window width/level to optimize the view on the heart.

#### 2.3.2.3 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

### 2.3.3 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.

#### 2.3.3.1 Adjusting the layout

To adjust the viewport layout

- Click in the general toolbar. A table of rows and columns will appear.
- Drag the mouse to determine the number of viewport rows and columns.



• The viewport layout will be applied



#### To clear a series from a viewport

- Select the viewport
- Click in the general toolbar

#### To clear all series from all viewports

• Click 🧤 in the general toolbar

#### 2.3.3.2 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.

#### 2.3.3.3 Cross Referencing



The scanline **define** and cross hair **define** tools enable 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 scanlines



Click I in the general toolbar to enable or disable the scanlines



To enable/disable the crosshairs





 $\bigcirc$  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.

### 2.4 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.

**U** 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.

#### 2.4.1 Noise Removal Options

To modify Noise Removal settings:

1. Select > Options, Noise Removal.

Parameters	
Std threshold	0.08%
Mod threshold	9%
✓ Enable auto Noise Removal	

0 Higher values, in both cases, will cause more of the speed overlay to be removed from the image.

① If Enable auto Noise Removal is selected, Noise Removal will be applied after loading the data.

#### 2.4.2 Enable/Disable Noise Removal

To enable/disable noise removal:

1. Select in the toolbar to enable Noise Removal.



Figure 10 Noise Removal Enabled

2. Select in the toolbar to disable Noise Removal.



Figure 11 Noise Removal Disabled

### 2.5 Viewport Overlay Visualization

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

- PCMRA
- Speed
- Streamlines
- Vectors

### 2.5.1 Toggle Overlay Representation

Overlays showing speed, streamlines 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

#### To modify the Vector overlay size and quantity in the Flow Analysis Layout:

- 1. Select the top right-hand corner text in the 3D MIP viewport.
- 2. Toggle or select Vectors
- 3. Hoover over either the Size or Number values.
- 4. Right-click the value to modify it.

#### Or,

5. Scroll the mouse wheel up and down to modify the value.

Or,

6. Reset to the value to its default setting, by clicking the middle mouse button.



Figure 14 Select Vector Overlay & Modify the Size and Quantity in the Flow Analysis 3D Layout

### 2.5.2 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 15 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  $\widehat{\sim}$ .
- 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.

### 2.6 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 low 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.

 $\stackrel{\bigcirc}{=}$  The cine speed can be modified with the slider  $\stackrel{\frown}{=}$  in the Viewing toolbar.

### 2.7 Mouse Controls

### 2.7.1 Stacking

You can move through the frames using **Stacking** when you see the stack cursor  $^{ightarrow} ar{\mathbb{D}}$  .

#### 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.

### 2.7.2 Zooming

You can zoom in and out of the viewport using Zooming when you see the magnify cursor  $^{ imes}$  .

#### 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.

### 2.7.3 Panning

You can move the image within the viewport left, right, up and down using **Panning** when you see the hand cursor  $\langle \uparrow \rangle$ .

#### 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.

#### 2.7.4 Window Width and Level

You can adjust the window width and level (WWL) when you see the WWL cursor  $\stackrel{\text{\tiny WL}}{\longrightarrow}$  .

#### 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.

#### 2.7.5 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.

### 2.8 Standard Measurements

QFlow 4D supports the following standard measurements:

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

#### 2.8.1 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 16 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.

#### 2.8.2 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 17 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.

### 2.8.3 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 18 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.

#### 2.8.4 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

### 3

## 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

### 3.1 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 19 Modulus Image

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

① The orientation cube located at the bottom right corner can be modified to change the viewing orientation. Refer to Figure 19 Modulus Image.



#### 3.1.1 Verify All Flow Velocity Directions

To verify all velocity directions:

1. Press in the toolbar.



2. Make the MODULUS viewport orientation LEFT

① "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





Figure 21 Verify Flow Velocity Direction Layout

#### 3.1.2 Verify HF / FH Velocity Direction

To verify the HF / FH velocity direction:

1. Press in the toolbar.

2. Make the MODULUS viewport orientation LEFT

① "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.

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

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



### 3.1.3 Verify AP / PA Velocity Direction

To verify the AP / PA velocity direction:



- 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.

① If the aortic arch is white, in the viewport containing PA / AP view, then velocity encoding direction should be AP.

① If the aortic arch is black, in the viewport containing PA / AP view, then velocity encoding direction should be PA.



Figure 22 AP Positively encoded viewport, with a white aortic arch and a darker descending aorta.

### 3.1.4 Verify RL / LR Velocity Direction

To verify the AP / PA velocity direction:

1. Press in the toolbar.

2. Make the MODULUS viewport orientation ANTERIOR

① "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.

① 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.

0 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 23 RL Positively encoded viewport, with proximal and distal ascending aorta

#### 3.1.5 Close the Velocity Direction Verification View



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

### 3.1.6 Custom System Options

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

### 3.2 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, 1<sup>st</sup> 2<sup>nd</sup> and 3<sup>rd</sup>, 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.

A Noise Removal has no effect on background correction.

### 3.2.1 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



2. Select • > Options, Background Correction and check the "Enable auto Background Correction" option.

Parameters	
Std threshold	25%
Fitting order 🔍 1st 💿 2nd 🔵 3rd	
✓ Enable auto Background Correction	

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

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

#### 3.2.2 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.

Premoving a Background Correction updates all reconstructions in the current session.

#### 3.2.3 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.
  - The Enable auto Background Correction, can be selected.

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

U If Enable auto Background Correction is selected, Background Correction will be applied after loading the data.

### 3.3 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.

A Noise Removal and Background Correction have no effect on Phase Unwrapping.

#### 3.3.1 Enable Phase Unwrapping

#### To enable Phase Unwrapping. in the toolbar. 1. Press The Properties pane of the Phase Unwrapping Phase Unwrapping: displays the following; 3% Cancel Phase Unwrapping progress **Cancel** button, to cancel the unwrapping or E > Options, Phase Unwrapping and check the "Enable auto Phase Unwrapping" 2. Select option. Parameters Upper threshold 1.00 Venc Lower threshold -1.00 Venc Enable auto Phase 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.

### 3.3.2 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.

 $\blacksquare$  Removing a Phase Unwrapping updates all reconstructions in the current session.

#### 3.3.3 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
The Enable auto Phase Wrapping can be selected.

Any changes to the Phase Unwrapping parameters Upper Threshold and Lower Threshold are applied to **all** Background Corrections **and** Reconstructions.

U If Enable auto Phase Unwrapping is selected, Phase Unwrapping will be applied after loading the data.

### 3.4 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.

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

U 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.

### 3.4.1 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,

- 1. Right-click in the viewport area. This opens a context menu.
- 2. Select Flow Analysis

### 3.4.2 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 24 QFlow2D hosting the Flow analysis

### 3.4.3 Multiple Flow Analysis's

QFlow 4D supports multiple Flow analyses. Each new Flow analysis creates a new tab.



Figure 25 Results Pane with multiple flow analysis



Figure 26 List of multiple tabs, each with a flow analysis

### 3.5Mitral Valve analysis

The Mitral Valve procedure enables the quantification of valvular blood flow. The QFlow4D data is a time-based 3D series, which is automatically reformatted into a 2D series before it is quantified by QFlow 2D.

These are the steps to complete a Mitral Valve analysis.

- 1. Load a QFlow 4D dataset, in addition to a 2 chamber, and 4 chamber cine series.
- 2. Start a Mitral Valve analysis.
- 3. Change the plane of interest, for each phase, if it is required.
- 4. Complete a QFlow 2D analysis.
- 5. Rename the analysis label, from "Mitral Valve" to an appropriate label.

UThe procedure requires both 2 and 4 chamber cine series to determine the Mitral valve location.QFlow 4D

① All Mitral Valve Analyses results are stored in the QFlow 4D results, reports and session.

① Multiple Mitral Valve analyses may be started.

The flow analysis in QFlow 4D is performed in a separate tab outside QFlow 4D using the existing QFlow 2D application.

#### 3.5.1 Start Mitral Valve analysis

QFlow 4D supports locating, renaming, editing, duplicating and removing of the Mitral Valve analyses. The analysis is labelled by default "Mitral Valve".

#### To start a Mitral Valve analysis

• Select from the toolbar.

Or,

- 1. Right-click in the viewport area. This opens a context menu.
- 2. Select Mitral Valve.

#### 3.5.2 Change the plane of interest

The Mitral Valve procedure allows you to move the plane of interest for each phase by individually positioning the axes. The default plane of interest is based on the automated Mitral Valve location.

You can adjust this plane by applying a positive or negative **"offset"**, which effectively moves the plane parallel to the default Mitral Valve plane.

- A positive offset moves the plane toward the cardiac apex.
- A negative offset moves the plane toward the atrium.

This offset is measured in millimetres and can be copied to all phases.

#### To adjust the plane of interest

• Select "Edit" in context menu.

Results	
📷 Correction	
📷 Flow Analysis	
👩 Valves	
Mitral Valve	
<ul> <li>Measurements</li> <li>Annotations</li> <li>Snapshots</li> </ul>	Locate
	Rename
	Duplicate
	Export to
	Send to Medis Suite
	Remove
	Remove

- Navigate to the phase that needs correction.
- Adjust the plane of interest, by adjusting the axes in either top left or bottom right viewport.



• Navigate to another phase that needs correction

Or,

• Apply an offset to each plane for all phases in the properties pane



Or,

•

Click Copy to All to copy the current plane location and orientation to all phases.

Or,

• Click Finish to accept all changes.

The existing Flow analysis results for the Mitral Valve procedure are deleted when finalizing editing.

### 3.5.3 Flow Analysis App

Flow analysis will be started with the QFlow 4D reformatted dataset. For more information see section 3.4.2 Flow Analysis App.

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### Reporting

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

	Report created by: Report date/time: Session name:	, ,	<b>№</b> Medis
Deblach Chudu Infe	Patient Study Info		
Patient Study Into	Name:		Study date: 11/11/2010
Tachnique	ID:		Description: MRI Heart Morph + Func w/ + w/o Con
Viewer	Birthdate:		Accession number:
V OFlow 4D Stable Daily 1.0 #1	Age/Gender.		Referring physician's name.
V Background Correction	Modality:		Institution name:
Fitting Order: 1	Manufacturer:		Performing physician's name:
Std Threshold: 25%	Manufacturer model:		Operator's name:
> Reconstruction 01 Information			Acquisuon number: 1
V Reconstruction 01 Results ROI 1:[ROI 1] slice 1	Reason for Referral		Edit
Net flow volume 34.17 ml/beat 3.04 l/min			
Forward flow volume (S.I) 34.45 ml/beat 3.06 l/min	OFlow 4D Stable Dai	v 1.0 #1	
Backward flow volume (S.I) 0.27 ml/beat 0.02 l/min	Background Correcti	n	
Regurgitant fraction (S.I) 0.80 %	Fitting Orders 1	>	
Average flow velocity 18.90 cm/s	Filling Order: 1 Ctd Threshold: 250(	13	
Peak flow velocity 145.10 cm/s	Std Threshold, 25%		
Peak pressure gradient 8.42 mmHg	Reconstruction 01 Re	esults ROI 1:[ROI 1] slice 1	
Min vessel area 257.63 mm²	ROI 1:[ROI 1] slice 1	per HB per Minute	
Max vessel area 293.36 mm²	Net flow volume	34.17 ml/beat 3.04 l/min	
V Reconstruction 01 Results ROI 2:[ROI 2] slice 1	Forward flow volume (S	5.I) 34.45 ml/beat 3.06 l/min	
Net now volume -14.14 mi/beat -1.20 i/min	Backward flow volume	(S.I) 0.27 ml/beat 0.02 l/min	
Porward flow volume (S.I) 18.95 mi/beat 1.06 i/min	Regurgitant fraction (S.	I) 0.80 %	
Requirgitant fraction (ST) 25.39 %	Reconstruction 01 Re	sults ROI 2:[ROI 2] slice 1	
Average flow velocity -16.07 cm/s	POT 2:[POT 2] slice 1	per HP per Minute	
Peak flow velocity 102.20 cm/s	Net flow volume	-14 14 ml/beat -1 26 l/min	
Peak pressure gradient 4.18 mmHg	Forward flow volume (	5.1) 18.95 ml/beat 1.68 l/min	
Min vessel area 107.46 mm <sup>2</sup>	Backward flow volume	(S.I) 4.81 ml/beat 0.43 l/min	
Max vessel area 128.93 mm²	Regurgitant fraction (S.	I) 25.39 %	
Impressions	Conclusions	-,	Edit
Extra-cardiac Findings	Coliciusions		Euic
Miscellaneous			
Comments			
Conclusions			

Figure 27 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 Push
- Select the Medis Suite main menu button in the upper right corner -> Help > User Documents

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### 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 **I**help button.

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

## Accuracy of Measurements

QFlow 4D measurements are not intended for a specific clinical purpose and therefore there is no clinical validation, with exception to the length and area measurement calculations, which are validated based on the pixel sizes.

In QFlow 4D all measurements are derived from calculations performed on the loaded DICOM images.

The accuracy of the measurements and calculations exceeds that of the displayed results, by at least one decimal point.

In practice, the image is the limiting factor of the accuracy of measurements. Limiting factors, such as, image resolution both spatial and time-based, image noise, inhomogeneity in the magnetic field and patient determines the accuracy of any given measurement.

Result	Unit	Precision	Accuracy source
Distance measurement	mm	0.1	Not intended for specific clinical measurement.
Area measurement - area	mm²	0.01	Not intended for specific clinical measurement.
Area measurement - circumference	mm	0.1	Not intended for specific clinical measurement.
Area measurement min and max diameter	mm	0.1	Not intended for specific clinical measurement.

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

Reference

Press	То	
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	

## Reference

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.