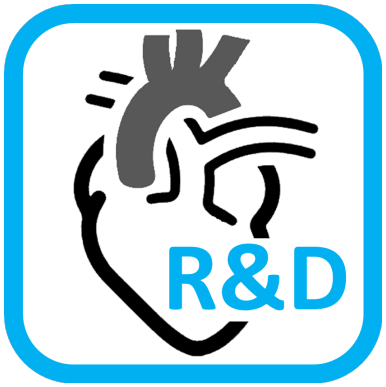
Segment
Instructions For Use - English US version



2026-04-23

Software version 4.3.0.2

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1 Terms and conditions

1.1 Conditions for use

- The software should be used to read medical images in DICOM format from medical scanners. Images can be supplied either by CD's or by using DICOM standard to transfer files directly from the scanner or PACS systems.
- Users are required to investigate the regulatory requirements pertinent to their country or location prior to using Segment. The user is responsible for obeying these statues, rules, and regulations.
- The user is responsible for installing Segment. Medviso provides online assistance in the installation process if needed. To install Segment you need to be Administrator on the computer to install on.
- Users should participate in an online training session held by Medviso prior to use of Segment. This is provided by Medviso as a part of the software trial process.
- The device is for multiple patient, multiple use.
- The expected lifetime of Segment is 3 years from the date of manufacture.

1.2 Intended users

Caution: Federal law restricts this device to sale by or on the order of medically trained professionals.

1.3 Indications for use

Segment is a software that analyzes DICOM-compliant cardiovascular images acquired from magnetic resonance (MR) scanners. Segment specifically analyzes the function of the heart and its major vessels using multi-slice, multi-frame and velocity encoded MR images. It provides clinically relevant and reproducible data for supporting the evaluation of the function of the chambers of the heart such as left and right ventricular volumes, ejection fractions, stroke volumes, peak ejection and filling rates, myocardial mass, regional wall thickness, fractional thickening and wall motion. It also provides quantitative data on blood flow and velocity in the arterial vessels and at the heart valves. Segment is tested on MR images acquired from both 1.5 T and 3.0 T MR scanners. The data produced by Segment is intended to be used to support qualified cardiologist, radiologist or other licensed professional healthcare practitioners for clinical decision making. **It is a support tool that provides relevant clinical data as a resource to the clinician and is not intended to be a source of medical advice or to determine or recommend a course of action or treatment for a patient.**

1.4 Intended patient population

The device can be used on the following patient population

Age	From newborn to adult.
Weight	No limitations in software.
Height	No limitations in software.
Health	No limitations in software.
Patient state	Patient is not user

1.5 Applicable medical indications

The device can be used for the following medical indications:

- Measure the following cardiac structures in cardiac MR images:
  - LV and RV volumes
  - Areas and distances
- Measure the following parameters in cardiac MR images:
  - Flow in phase contrast images

1.5.1 Medical condition

Cardiovascular disease

1.5.2 Contraindications and side-effects

No contraindications are identified for usage of Segment.
No side-effects are identified for usage of Segment.

1.6 Clinical performance

The safety and performance endpoints for Segment are to provide:

- Automatic, reproducible, segmentation and analysis methods for LV, RV, and vessel tracking with a bias that corresponds to less than 10% compared to reference standard,
- A decrease in the analysis time for CMR image analysis compared to when only using manual analysis methods.

1.6.1 Clinical benefit

Quantification of cardiac function from CMR images using Segment are delivered with a higher reproducibility and time gains compared to only manual analysis.

1.7 Safety Instructions

Caution used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in minor or moderate injury or material damage. Caution consists of the following elements:

- Information about the nature of a hazardous situation,
- Consequences of not avoiding a hazardous situation, and
- Methods of avoiding a hazardous situation.

The following cautions are valid for Segment:

CAUTION: The measurement results may not reflect the exact situation because the measurements are inaccurate.
Minor inaccuracy of value(s) in patient record. No harm to patient.

- Correct volumetric measurement and tissue characteristics values greatly depend on the final segmentation,
- Manually check and, if necessary, correct the algorithm segmentation results using your clinical knowledge,
- The automatic segmentation algorithms provides an initial assumption of contour definitions. It is the responsibility of the user to verify and correct the results,
- Review the patient report for errors prior transmitting the final result,
- Quantitative analysis is dependent on the quality and correctness of the image source data,
- The software may only be used by professionals trained in cardiac MR image analysis,
- Segment is a support tool that provides relevant clinical data as a resource to the clinician and is not intended to be a source of medical advice or to determine or recommend a course of action or treatment for a patient.

CAUTION: The user reads a revision of the user manual that differs from their software revision, so the user gets incorrect information on how to use the software.
Extra work for user, since the software cannot be used. No harm to patient.

- Ensure the version number of your Instructions for Use corresponds to your software version number. The correct Instructions for Use for your software can always be found under the Help menu, while the latest can be found on the Medviso webpage.

CAUTION: Antivirus software has not been installed or updated.
Patient stress and/or anxiety.

The computer where Segment is installed should have:

- Firewall,
- Anti-virus software installed and running,
- Back-up on patient data, and
- Personal login to access the software (in the preferences for Segment the user can activate user login to the device and user logging for the usage of the device.)

Each MRI scanner is unique and different phase contrast pulse sequences have to be individually validated for each scanner, as each scanner has individual sources of error that can affect flow quantification.

In the event that the use of Segment causes a serious incident, such that it results in physical OR psychological harm to the user and/or patient, this shall immediately be reported to Medviso AB (support@medviso.com), as well as the competent authority of your Member State (Ministries/Agencies of Health and/or Medicines).

1.8 Accuracy and Precision

The limit of accuracy and precision in Segment is lower than 0.029%.

2 Conventions and Abbreviations

2.1 Typographic conventions

Caution used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in minor or moderate injury or material damage.

Information intended to help the user achieve optimal use of the software. Includes usage considerations, limitations, or recommendations that do not relate to safety.

A reminder to the user of their responsibilities under applicable regulatory requirements.

`A`	Key `A` at the keyboard.
`Ctrl-A`	Control key. Hold down `Ctrl` key and `A` simultaneously.
	Icon in toolbar.
`*.mat`	Filename extension.
`C:/Program`	Folder.
File	Menu, e.g. File menu.
File→Save As	Sub menu, e.g. under the File menu the item Save As is found.
Close	Push/Toggle button in the graphical user interface.

2.2 Abbreviations

CMR	Cardiac Magnetic Resonance
LV	Left Ventricle
PWV	Pulse Wave Velocity
RV	Right Ventricle

3 Getting started

3.1 System requirements

- Operating System:
  - Windows 11
  - Windows Server 2019
- Processor: Any Intel or AMD x86-64 processor with a minimum of four logical cores
- Computer with 8 GB of memory or preferably 16 GB
- Harddisk with at least 5 GB of available space
- Graphics card supporting both DirectX and OpenGL
- To use the full functionality of the report function:
  - Microsoft Word
  - Adobe PDF reader
- To access full version of machine learning algorithms in Segment:
  - CUDA enabled NVIDIA graphics card with 4 GB memory or more
  - GPU architecture: Ampere, Turing, Volta, Pascal
- For users with additional modules not included in the free research version:
  - Internet connection for software license management and software download. We recommend a speed of at least 24 Mbit/s.

Recommendations

- Systems with two screens
- Using SSD disk for reading data

3.2 Installation and upgrading

To install or upgrade Segment, log in to our website (https://medviso.com/download2/) and download the installation file. Run the installation file under administrator privileges on the machine and follow the instructions in the figures below.

For more information on installation and network connectivity, please consult the separate installation manual found on our website (https://medviso.com/user-manuals2/). For assistance, please contact `support@medviso.com`.

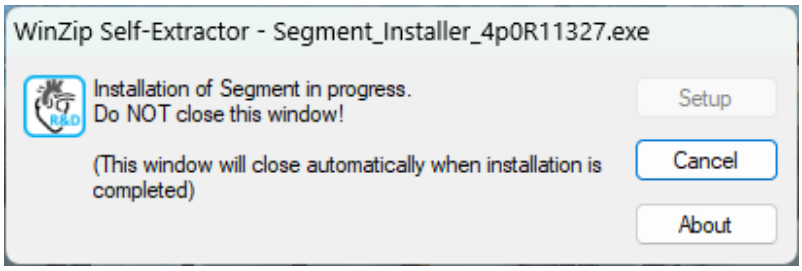


Figure 1: The installation starts automatically. Do not close this window, it will close automatically when the installation is completed.

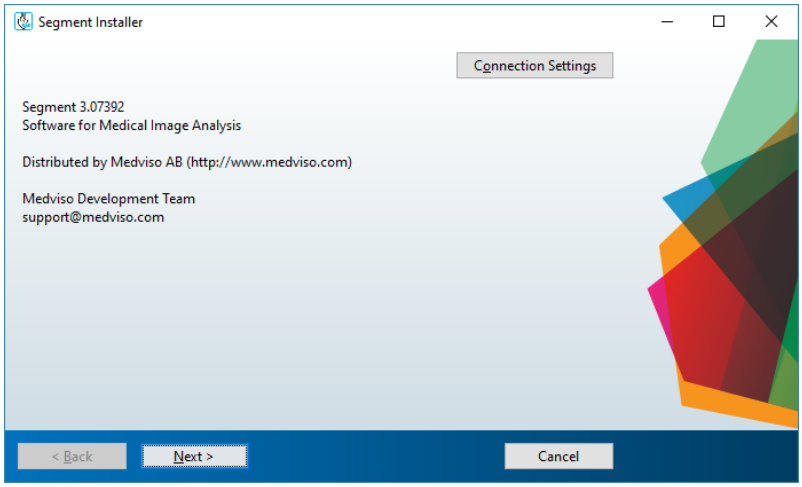


Figure 2: Click on `Next`.

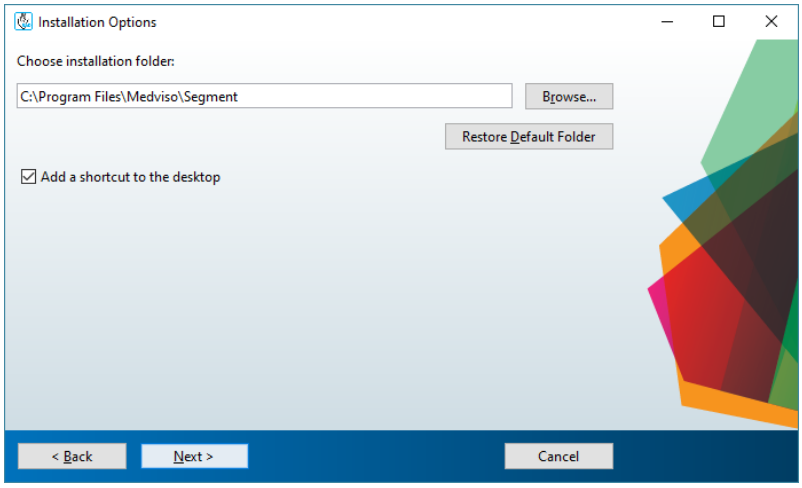


Figure 3: Select `Add a shortcut to the desktop`. Click on `Next`.

For first time installation, `Matlab Compiler Runtime (MCR)` needs to be installed according to Figure 4 - 7. For upgrading, continue according to Figure 8.

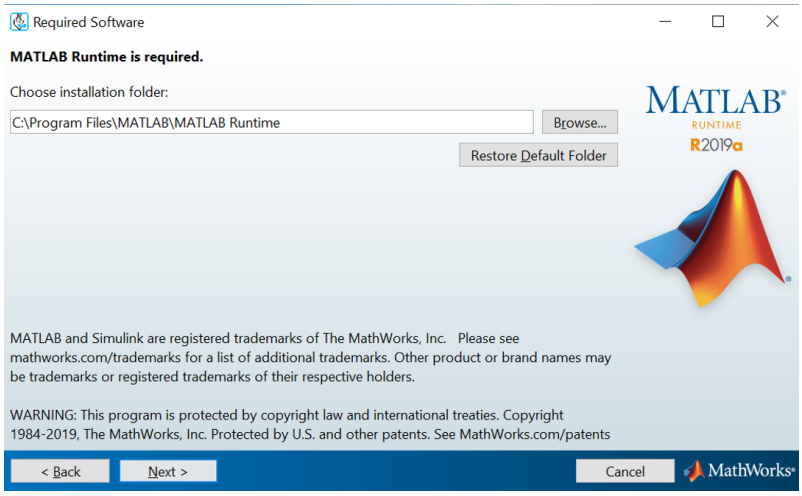


Figure 4: Click on `Next`.

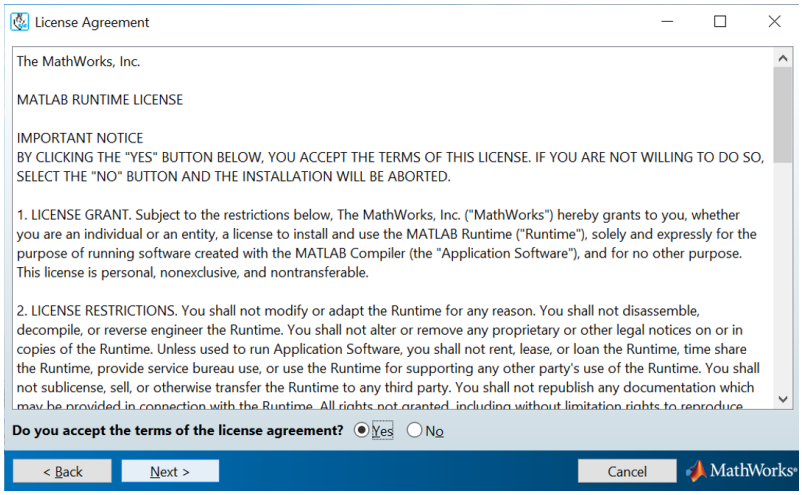


Figure 5: Select `Yes`. Click on `Next`.

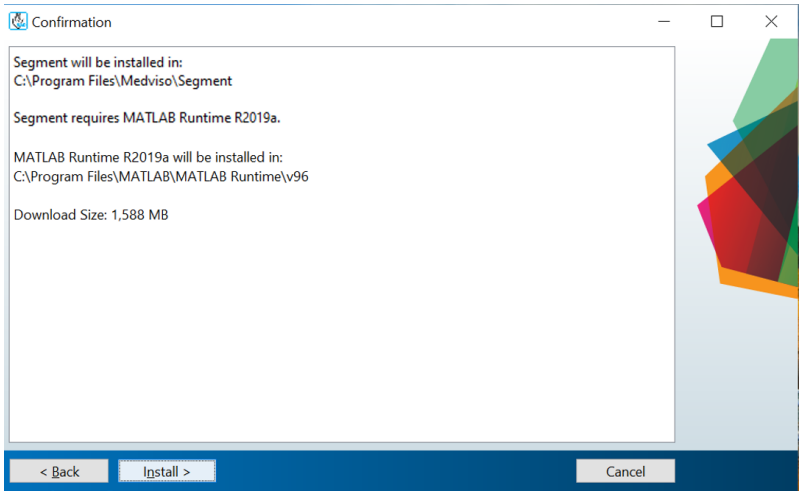


Figure 6: Click on `Install`.

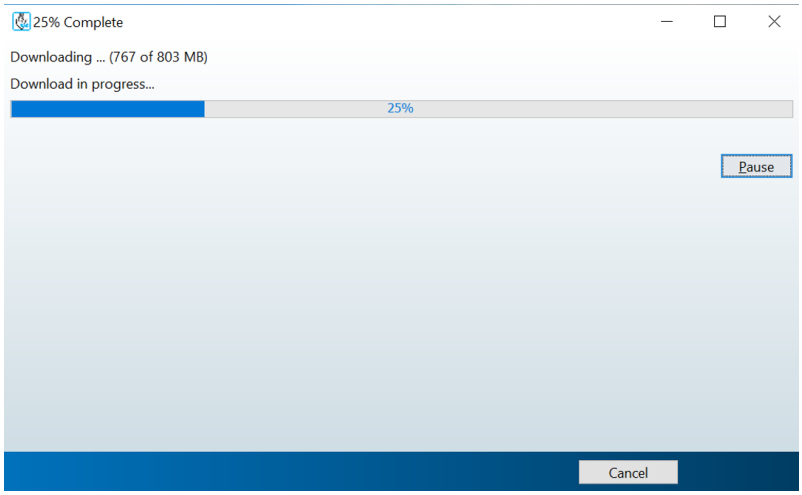


Figure 7: Wait for completed process.

For upgrading, only install Segment according to Figure 8 - 9.

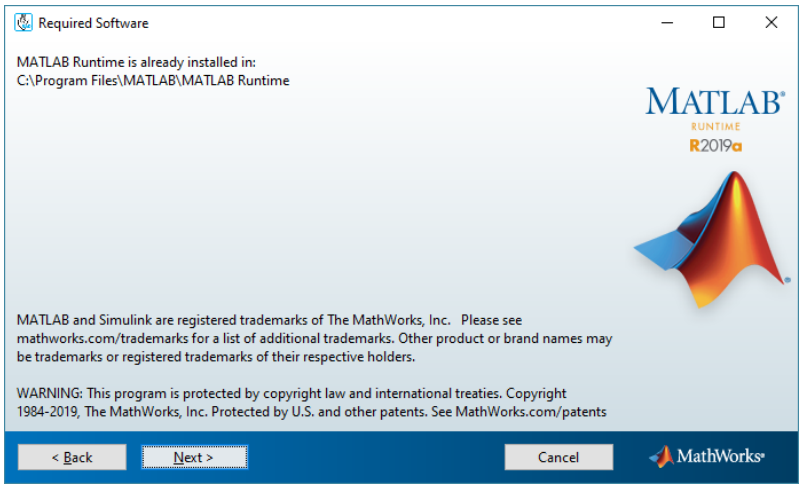


Figure 8: Click on `Next`.

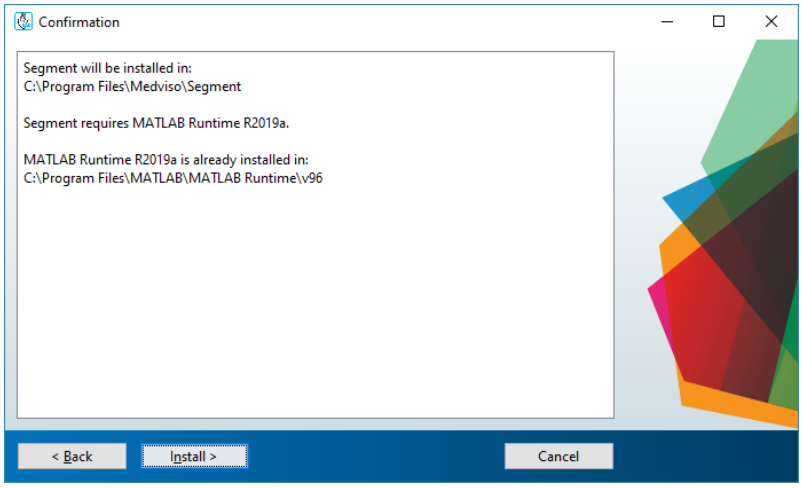


Figure 9: Click on `Install`.

For first time installation or upgrading, continue according to Figures 10 - 11.

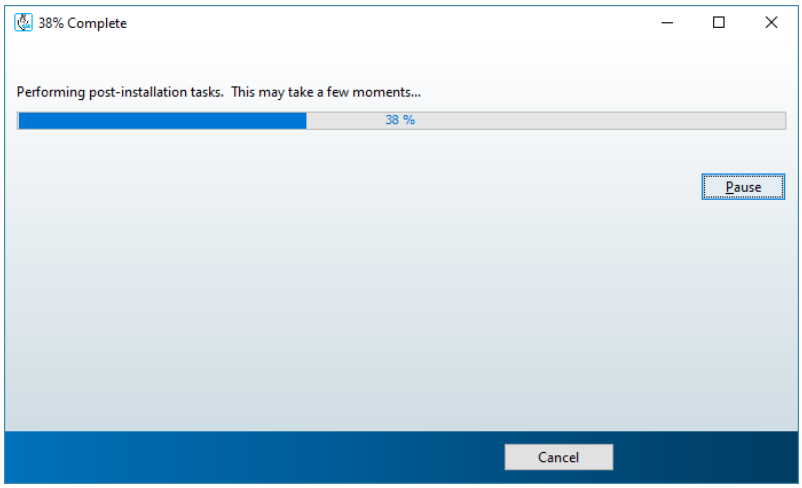


Figure 10: Wait for completed process.

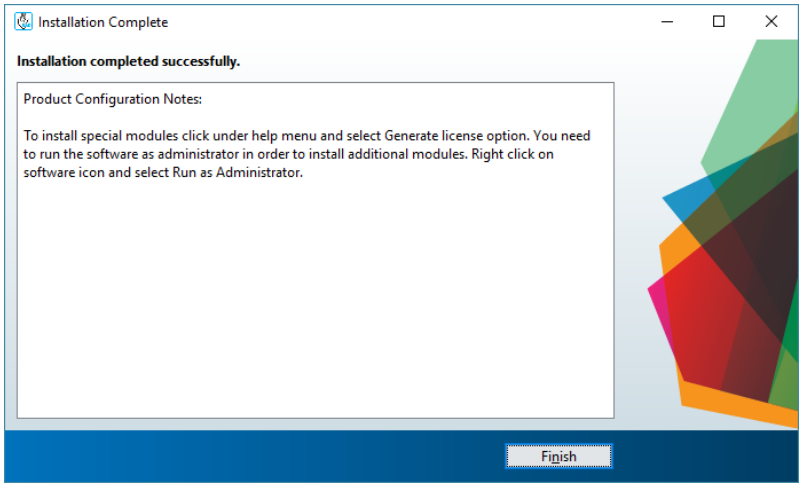


Figure 11: Click on `Finish`.

3.3 First time running Segment

The first time you run the software to configure it you need to run the software as Administrator. Right click on the shortcut to the software and select Run as administrator. Note that it is not sufficient to be logged in as administrator on the computer.

The first time Segment is started, it runs a setup process which can take a while, so be patient. When starting the software, the image in Figure 12 should be displayed. If it is not displayed, then the software is not correctly installed.

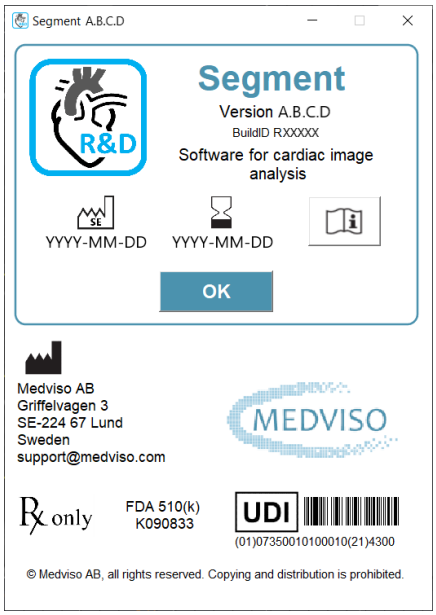


Figure 12: Startup window for Segment.

To complete the setup, set preferences and window positions as described in Sections 3.3.1 and 3.3.2.

3.3.1 Setting preferences

It is recommended to set the preferences of which folders to use to avoid browsing each time you want to load or save a file. It is invoked by using the  icon (p). Set `Data`, `Export` and `CD` folders.

3.3.2 Setting window positions

The position of the main window for Segment can be set by dragging the window to an optional position and size. The size and position will be saved so that next time Segment is launched the same position will be used. In case where one have switched to another monitor, Segment may move outside the screen. In this case you could press `Ctrl-0` to reset GUI positions. This is also available under the File menu (a).

3.4 Add software license code

This section only applies if you have a commercial purchased license for Segment, for the free research version no license is needed. For new installations you need to add your license code for Segment. Add your license code after installation by starting Segment and select `Setup License` under the Settings menu in Segment. Note that you have to run the software as Administrator to be able to add the license code in Segment. If you have lost the license code, please contact `sales@medviso.com`.

3.5 Uninstallation

To uninstall Segment, go to Control Panel and select Uninstall a program (Figure 13). Search for Segment in the programs list, right-click on it and select Uninstall/Change. Do the same steps for uninstalling MATLAB Runtime, but select MATLAB Runtime in the programs list.

User preferences are stored in `AppData`, in the subfolder `Segment` under each user account.

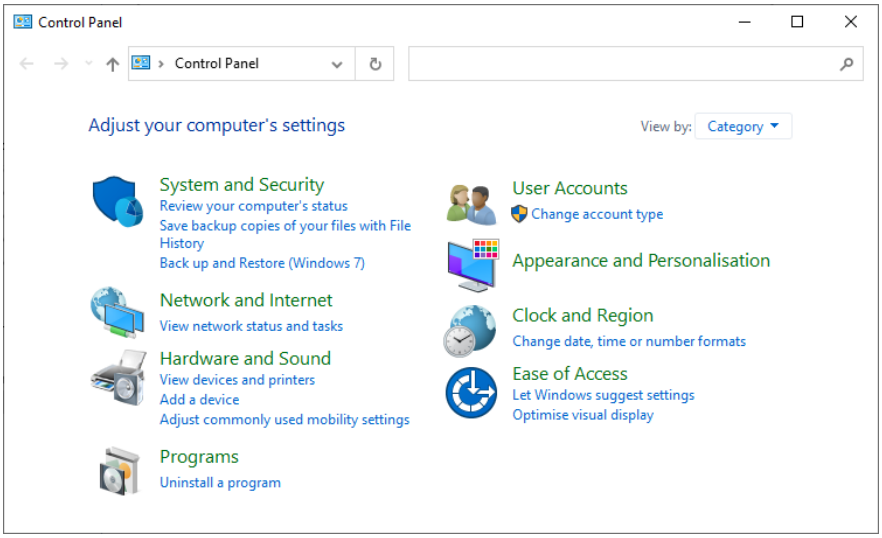


Figure 13: Control Panel

3.6 Software overview

An overview of Segment is given in Figure 19.

To learn more about each tool, hold the mouse over the icon in the software and a help text will be displayed. To exit the software, simply press the x-button in the top right corner.

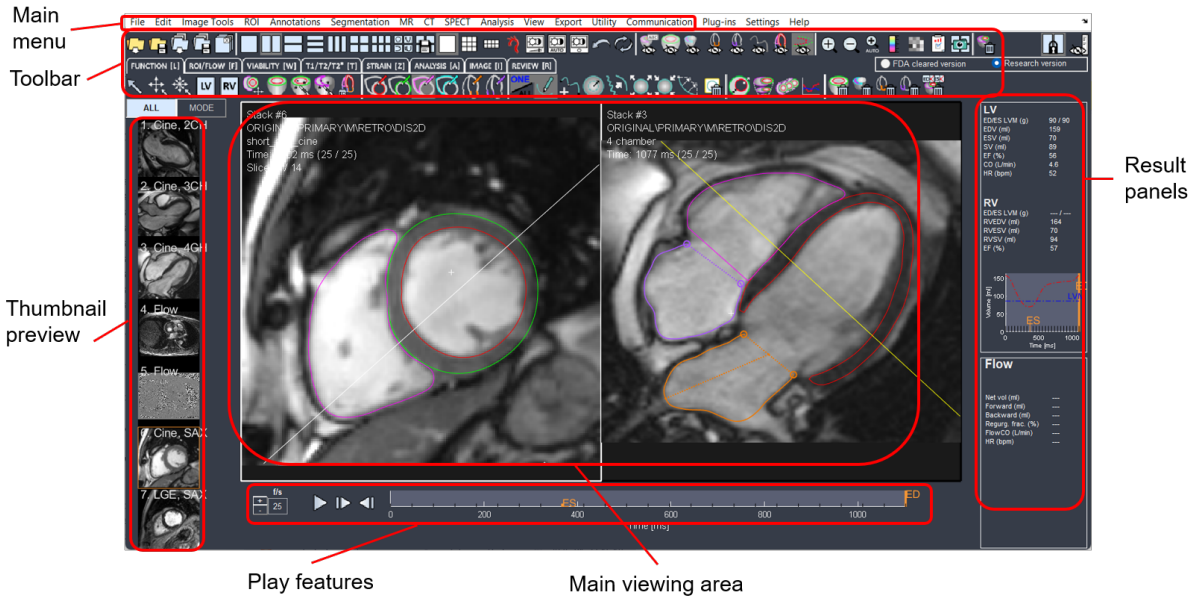


Figure 14: Main graphical user interface.

4 Loading and storing Data

4.1 Loading data

To load patient data from the database, follow Section 4.1.1. To load patient data from PACS, follow Section 4.1.2. To load patient data from network disc, follow Section 4.1.3.

4.1.1 Loading data from database

1. Click on the tool  (b), Figure 15 is shown.

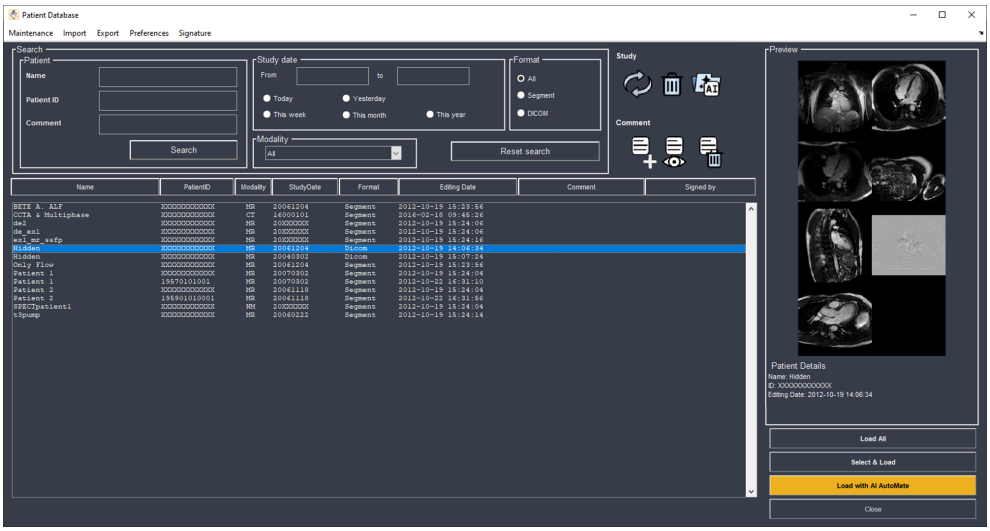


Figure 15: Graphical patient selector.

2. Select patient.
3. Patients can be stored in two formats; DICOM, or Segment format. For images in DICOM format, click Select & Load, Figure 16 is shown. For images in Segment format click Load All.
4. Select image series to load in Figure 16.
5. Click on Load selected.

4.1.2 Loading data from PACS

1. Select Import from PACS in the File menu, Figure 17 is shown.
2. Enter patient or study details and perform search.
3. Select study and series to load.
4. Load the study into Segment by select Retrieve.

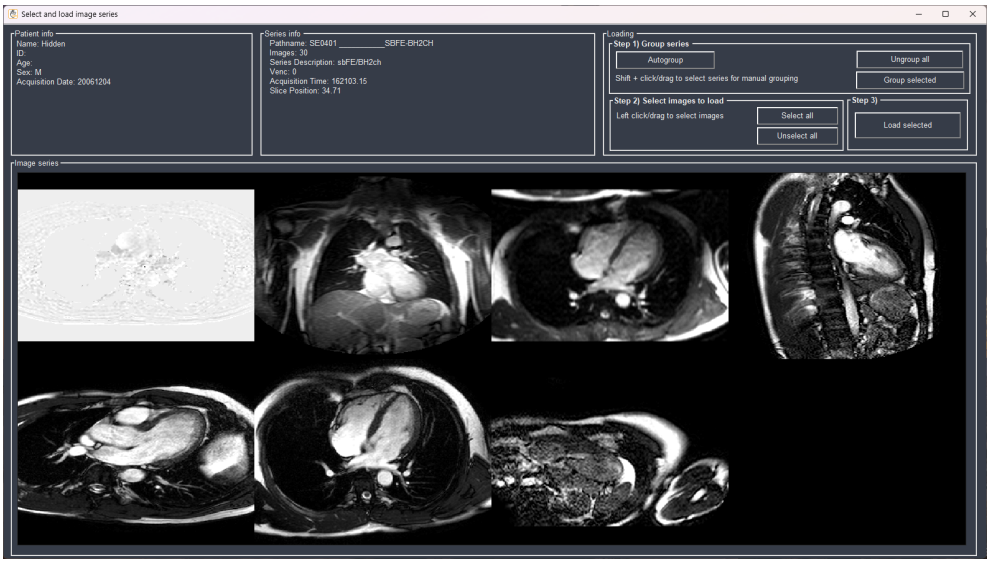


Figure 16: Graphical image series selector.

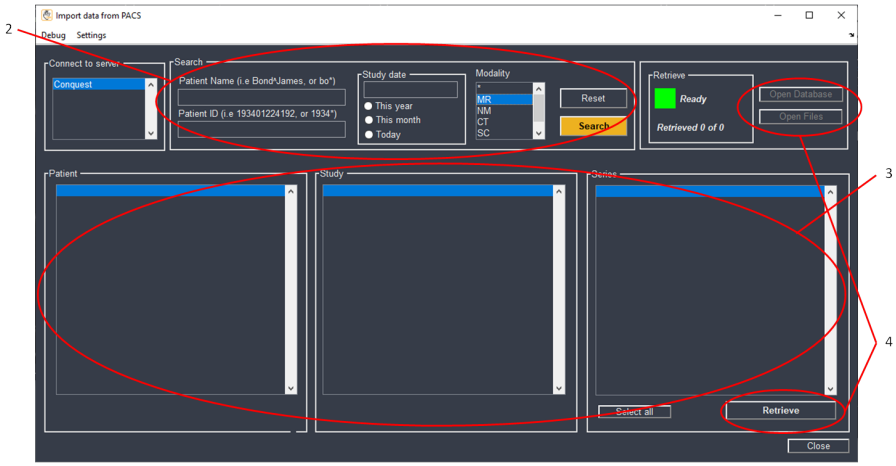


Figure 17: Interface to import image stacks from PACS.

4.1.3 Loading data from network disc

1. Select Open from Disc in the File menu, Figure 18 is shown.

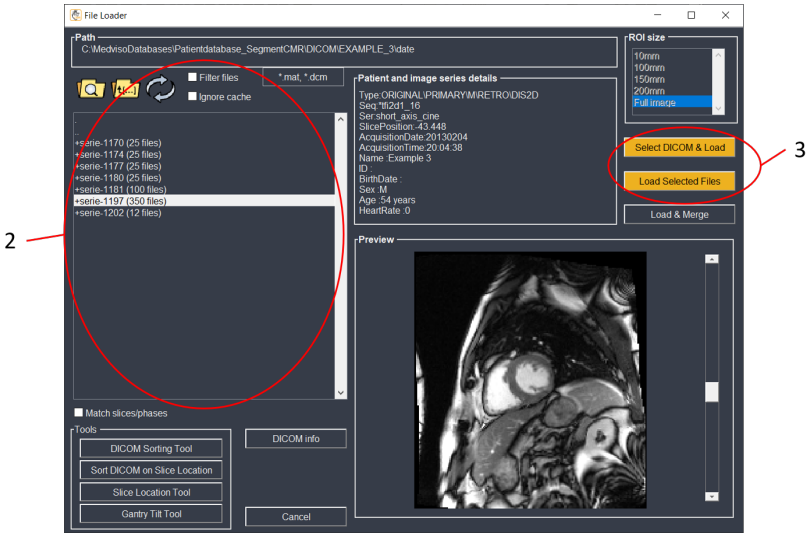


Figure 18: Image stack loading selector.

2. Select image stack to load.

3. For images in DICOM format, click Select DICOM & Load, Figure 16 is shown. Select image series to load in Figure 16. For images in Segment format, select image stack to load and click on Load Selected Files.

4.2 Storing data

1. To store images including delineation to Patient Database, click on the tool  (b).

2. To store images including delineation to Disc, select Save to Disc in the File menu (a).

3. To store images including delineation to PACS, select Save to PACS in the File menu (a).

5 Image viewing tools

An overview of Segment is given in Figure 19.

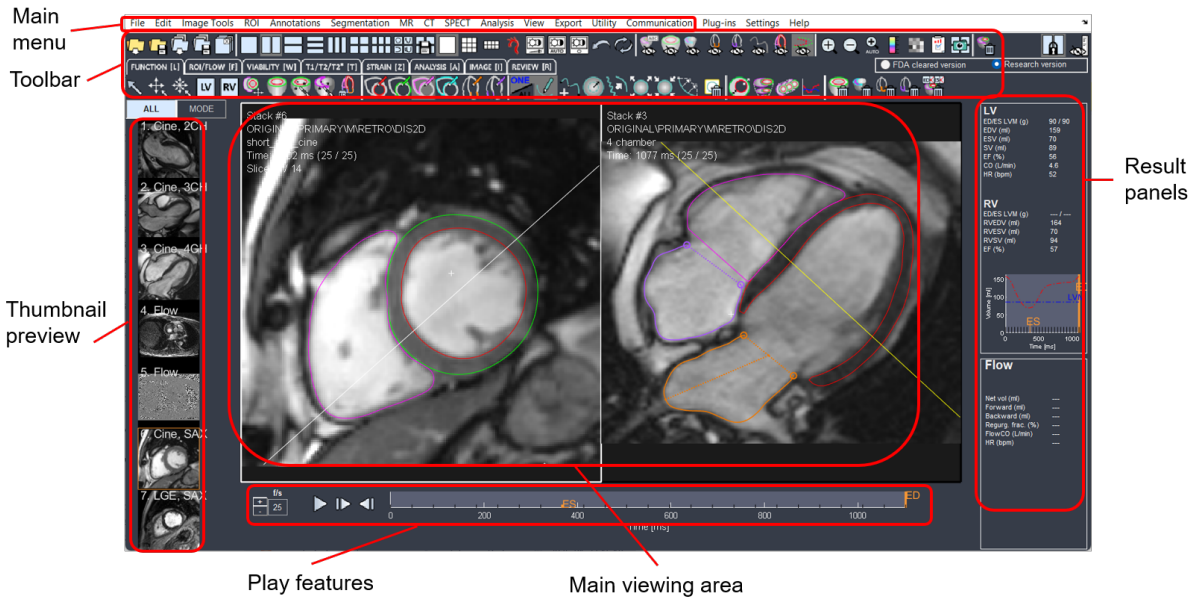


Figure 19: Main graphical user interface.

5.1 Viewing options

- Choose panel viewing option by using , , , , , , , , (c)
- To play a movie of the image stacks, use the tools , , . Set the frame rate by entering a value in the edit box, or using the plus/minus buttons. (d)
- Select ALL to show all thumbnails or MODE to display thumbnails relevant for the selected feature tab. (e)
- To synchronize all image stacks, use the tool
- To change between single frame mode or all frames mode, use the tools
- To hide the result panel, use the tool

5.2 Crop image stack

1. Click on IMAGE [I] (h).
2. Select the tool (i).

3. Crop an image stack by mark the region in the image stack.

5.3 Zoom

1. Select image stack.
2. Use the tools  and  (f) to zoom in and zoom out in the image stack.

5.4 Adjust contrast

5.4.1 Manual adjustment

1. Select image stack.
2. Select the tool  (i) under  (h).
3. Adjust the contrast and brightness by right click and drag the mouse in the image stack (right-left for contrast and up-down for brightness).

5.4.2 Automatic adjustment

- To automatically adjust contrast and brightness in the selected image stack, select  (i) under  (h).
- To automatically adjust contrast and brightness in all loaded image stacks, select  (i) under  (h).

5.5 Measure distance

1. Click on  (h).
2. Select the tool  (i).
3. Measure a distance by dragging the mouse from start to end point in the image stack.
4. To make a curved line, with pressed `Shift` set points at desired positions on the image.

5.6 Hide/Show overlay

1. Select image stack with any type of overlay.
2. Use the tool  to show or hide all overlays like segmentation, text, points, measurements.

5.7 Resample image stack

Select image stack you want resample and choose the following resampling type:

- Select Upsample/Downsample Image (In Plane) under menu Resample image stack under menu Image tools to increase/decrease image resolution (in plane).
- Select Upsample/Downsample Slices under menu Resample image stack under menu Image tools to increase/decrease number of image slices.
- Select Upsample/Downsample Temporal under menu Resample image stack under menu Image tools to increase/decrease number of time frames.

6 Image settings

6.1 Manually set image description

1. Right click on the thumbnail for the image stack.
2. Select Select Image Description in the context menu.

6.2 Image description upon loading

The image description is automatically set in the loading process by comparing information from the DICOM tags with the information in the text file `imagedescription.txt`.

1. The text file is found in the folder where Segment is installed.
2. Manually update the text file according to the structure as defined in the first row in the text file.

6.3 Patient details

Edit patient details by selecting  under 

.

7 LV segmentation

7.1 LV analysis

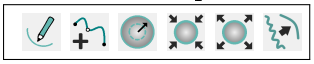
7.1.1 Automatic LV segmentation

Segmentation in all time frames

a. To run the fully automatic LV segmentation in all time frames, a CUDA enabled NVIDIA graphics card is required.

b. Start the fully automatic LV segmentation by select FUNCTION [L] (h) and select  (i).

c. The segmentation result is presented in the main window where volumes curve can be reviewed (k) and the measured LV volumes are presented, according to Figure 20 (j).

d. If needed, correction of the LV segmentation can be performed by selecting  or  , and combining with one of the tools:  (i).

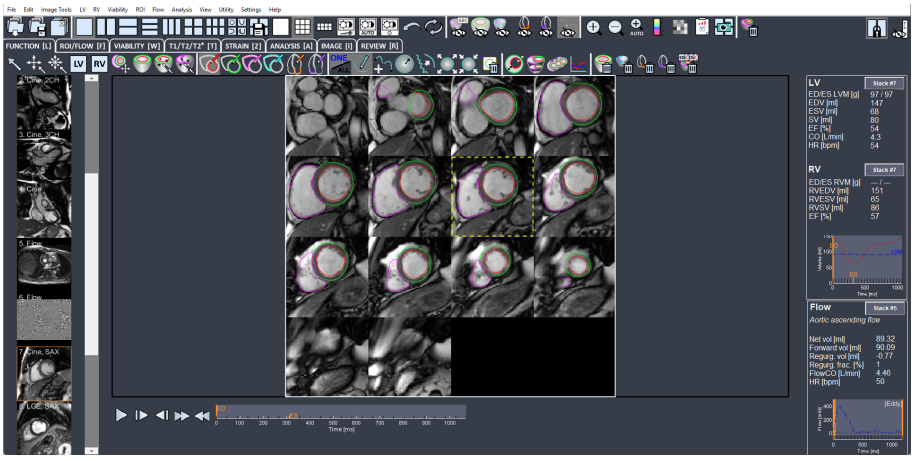


Figure 20: LV analysis result.

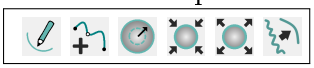
Segmentation in ED and ES time frames

a. For those not having a CUDA enabled NVIDIA graphic card, the fully automatic LV segmentation is provided for segmentation in ED and ES.

b. Start by manually define end-diastole and end-systole.

c. Start the fully automatic LV segmentation by select FUNCTION [L] (h) and select  (i).

d. The segmentation result is presented in the main window where volumes curve can be reviewed (k) and the measured LV volumes are presented, according to Figure 20 (j).

e. If needed, correction of the LV segmentation can be performed by selecting  or  , and combining with one of the tools:  (i).

7.1.2 Semi-automatic LV segmentation

(cine)

1. Start the LV analysis by select FUNCTION [L] (h) and select  (i). A new interface is open, as shown in Figure 21.

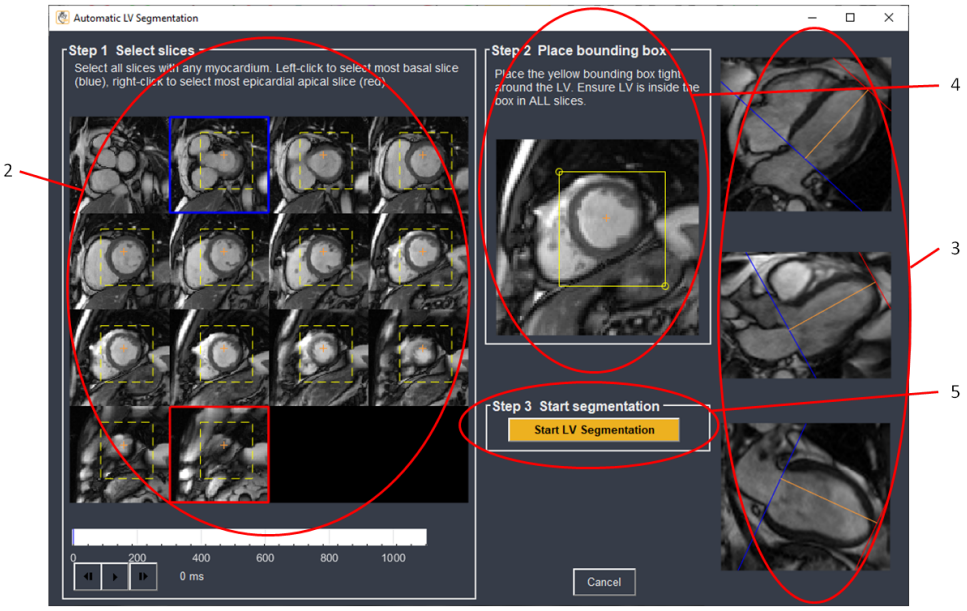


Figure 21: LV analysis GUI.

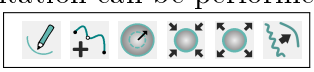
2. Select the slices covering the left ventricle by left-click to select most basal slice and right-click to select most epicardial apical slice.

3. Review the slice selection in the long-axis views.

4. Ensure that the bounding box comprises the LV in ALL slices, otherwise drag in the corners of the bounding box.

5. Start the automatic LV segmentation.

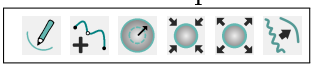
6. The segmentation result is presented in the main window where volumes curve can be reviewed (k) and the measured LV volumes are presented, according to Figure 20 (j).

7. If needed, correction of the LV segmentation can be performed by selecting  or  , and combining with one of the tools:  (i).

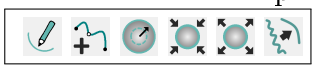
7.1.3 Automatic LV segmentation (general stack)

a. To run the fully automatic LV segmentation in all time frames, a CUDA enabled NVIDIA graphics card is required.

b. Start the fully automatic LV segmentation by select ANALYSIS [A] (h) and select  (i).

c. If needed, correction of the LV segmentation can be performed by selecting  or  , and combining with one of the tools:  (i).

7.1.4 Manual LV segmentation

Manual delineation of the LV can be performed by selecting  or  , and combining with one of the tools:  (i).

7.1.5 Clear LV segmentation

To clear the LV segmentation, select  (i) under FUNCTION [L] (h).

7.1.6 Copying LV segmentation

To copy the LV segmentation to another image stack, select Import Segmentation From Another Image Stack under menu LV (a).

7.1.7 Segmentation of papillary volume

1. To include papillary muscles in the LV myocardial segmentation, select menu item LV - Automatic Estimation of Papillary Volume.

2. Adjust the segmentation of the papillary volumes by select menu item LV - Adjust Papillay Threshold (Slider).

3. To clear the papillary segmentation, select LV - Reset Papillary Volume.

7.1.8 Validation of LV segmentation (cine)

Table 1 presents the mean bias between reference volumes by expert readers and the volumes by the automatic segmentation algorithm in 65 patients [1]. No uncertainty/error information is shown in the software together with the measurements.

Table 1:

LVM	-2.1 ± 8.9 g
EDV	-2.0 ± 10.2 ml
ESV	-1.9 ± 7.0 ml
EF	0.2 ± 4.6 %

1. Medviso White Paper, LV validation, 2025. Available upon request by contact support@medviso.com.

7.1.9 Imaging recommendations

Recommended imaging protocol for LV analysis in Segment CMR follows the SCMR guidelines [1]. In short 1,5 or 3T, SSFP slice thickness 6-8 mm with 2-4 mm interslice gaps equal to 10 mm, temporal resolution less than 45ms.

1. C. M. Kramer, J. Barkhausen, S. D. Flamm, R. J. Kim, E. Nagel, and P. Society for Cardiovascular Magnetic Resonance Board of Trustees Task Force on Standardized, Standardized cardiovascular magnetic resonance (CMR) protocols 2013 update, J Cardiovasc Magn Reson 15 p 91, 2013.

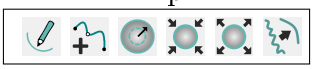
8 RV segmentation

8.1 Fully automatic RV segmentation

a. To run the fully automatic RV segmentation, a CUDA enabled NVIDIA graphics card is required.

b. Start the fully automatic RV segmentation by select FUNCTION [L] (h) and select  (i).

c. The segmentation result is presented in the main window where the measured RV volumes are presented, according to Figure 22 (j).

d. If needed, correction of the RV segmentation can be performed by selecting:  or  , and combining with one of the tools:  (i).

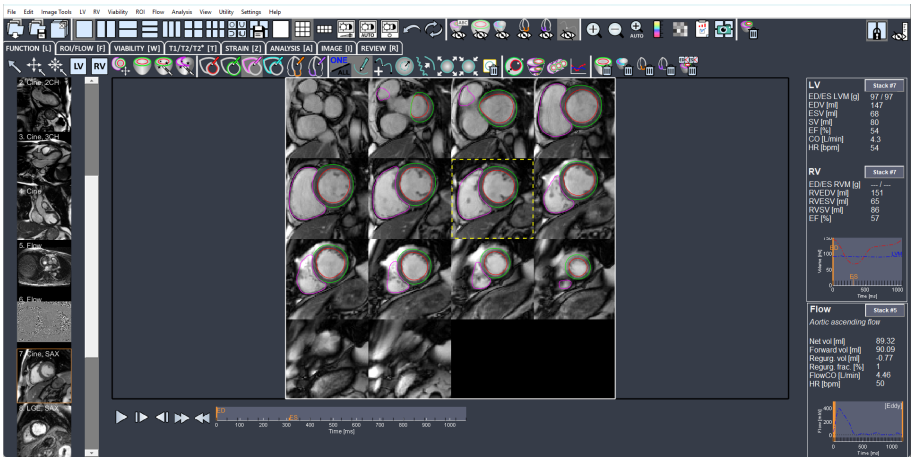


Figure 22: RV analysis result.

8.2 Semi-automatic RV segmentation

1. For those not having a CUDA enabled NVIDIA graphic card, the semi-automatic RV segmentation is provided instead of the fully automatic RV segmentation.

2. Start the semi-automatic RV segmentation by select FUNCTION [L] (h) and select  (i). A new interface is open, as shown in Figure 23.

3. Set RV center and select the slices covering the right ventricle by left-click to select most basal slice and most apical slice.

4. Review the slice selection and center line in the long-axis views.

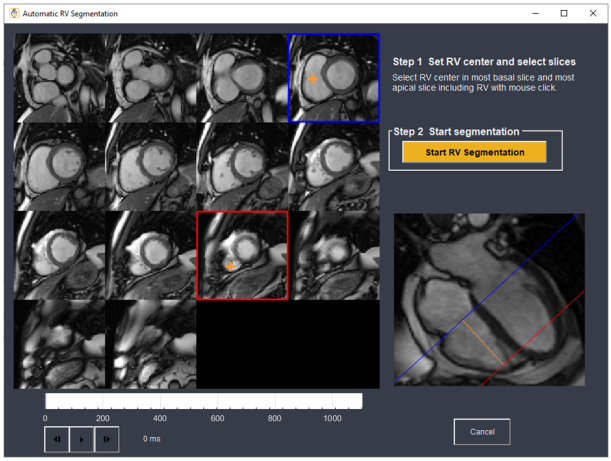


Figure 23: RV analysis GUI.

5. Start the RV segmentation process.

6. The segmentation result is presented in the main window where the measured RV volumes are presented, according to Figure 22 (j).

7. If needed, correction of the RV segmentation can be performed by selecting: or , and combining with one of the tools: (i).

8.3 Manual RV segmentation

Manual delineation of the RV can be performed by selecting: or , and combining with one of the tools: (i).

8.4 Clear RV segmentation

To clear the RV segmentation, select (i) under FUNCTION [L] (h).

8.5 Validation of RV segmentation

Table 2 presents the mean bias between reference volumes by expert readers and the volumes by the automatic segmentation algorithm in 50 patients [1]. No uncertainty/error information is shown in the software together with the measurements.

Table 2:

RVEDV	-6.0 ± 10.0 ml
RVESV	-1.0 ± 5.8 ml

1. J. Akesson, E. Ostenfeld, M. Carlsson, H. Arheden, and E. Heiberg, Deep learning can yield clinically useful right ventricular segmentations faster than fully manual analysis, Sci. Rep., vol. 13:1216, pp. 1–10, 2023.

8.5.1 Imaging recommendations

Recommended imaging protocol for RV analysis in Segment CMR follows the SCMR guidelines [1]. In short 1,5 or 3T, SSFP slice thickness 6-8 mm with 2-4 mm interslice gaps equal to 10 mm, temporal resolution less than 45ms.

1. C. M. Kramer, J. Barkhausen, S. D. Flamm, R. J. Kim, E. Nagel, and P. Society for Cardiovascular Magnetic Resonance Board of Trustees Task Force on Standardized, Standardized cardiovascular magnetic resonance (CMR) protocols 2013 update, J Cardiovasc Magn Reson 15 p 91, 2013.

9 ROI analysis

9.1 Manual ROI analysis

1. Click on ROI/FLOW [F] (h).
2. To place a ROI, use one of the tools , or (i).
3. Select ROIs with Shift-click with the tool (i).
4. Set the label of selected ROIs with the tool (i).
5. Set the color of selected ROIs with the tool (i).
6. Select ROI Analysis (i) under ROI to perform ROI analysis according to Figure 24 (h).

Figure 24: ROI analysis GUI.

9.2 Clear ROI segmentation

Clear selected ROIs by selecting , and all ROIs by selecting in the ROI/FLOW [F] mode (h).

9.3 Validation of ROI analysis

Table 3 presents the agreement between reference values by computer phantoms and values by the ROI analysis in 9 phantoms [1]. No uncertainty/error information is shown in the software together with the measurements.

Table 3:

Flow	$y = 1.009x - 2.2m, R^2 = 1.00$

1. E. Heiberg, J. Sjogren, M. Ugander, M. Carlsson, H. Engblom, and H. Arheden, Design and validation of Segment–freely available software for cardiovascular image analysis, BMC Med Imaging 10 p 1, 2010.

10 Flow analysis

10.1 2D flow analysis

1. Display the magnitude image of the phase contrast image pair, as shown in Figure 25.

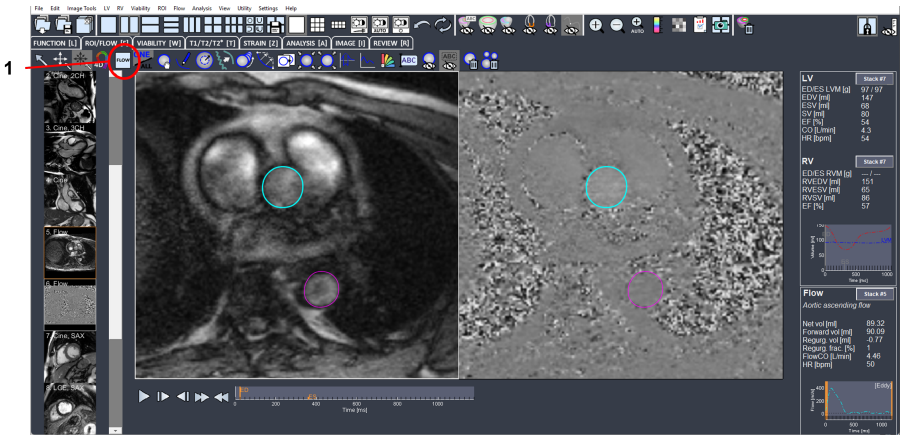


Figure 25: Flow image stack.

2. Click on ROI/FLOW [F] (h).
3. To place a ROI, use one of the tools , or (i).
4. Set the label of the ROI with the tool (i).
5. Set the color of the ROI with the tool (i).
6. To track and segment the vessel, click on (i).
7. Review the segmentation. If necessary, use the correction tool (i).
8. Click on (i), to show flow curve, as shown in Figure 26. The flow integration is performed between the two green bars. These bar can interactively be moved with the mouse to control the range of the integration.
9. Flow values are also presented in main gui, according to set stack, as shown in Figure 25 (l).

10.1.1 Qp/Qs analysis

1. Start with vessel segmentation of both the pulmonary and aorta as described in the previous section. Check the labels so they are correct (`Pulmonary artery` and `Aortic ascending flow`). Otherwise, set the label of the ROIs with the tool (i).

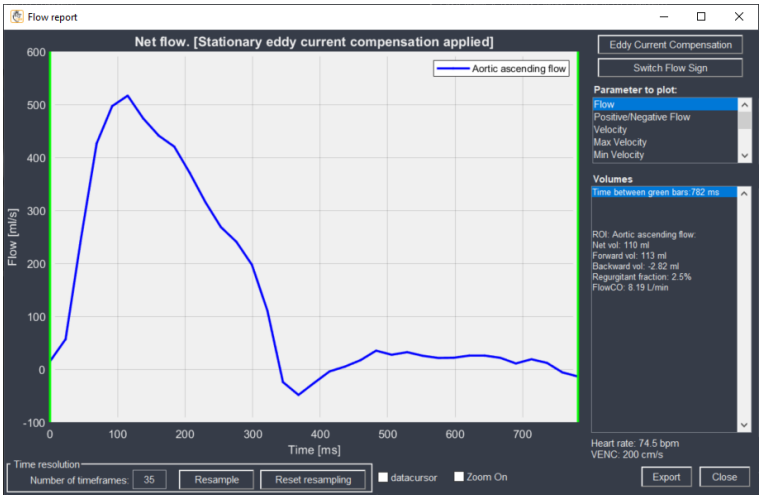


Figure 26: Flow report GUI.

2. Select Qp/Qs Analysis under menu Flow (a).

3. The Qp/Qs ratio is presented in a new message box.

10.1.2 Shunt and valve analysis

1. Start with vessel segmentation of the pulmonary and/or aorta as described in the Section 10.1. Check the labels so they are correct (`Pulmonary artery` and `Aortic ascending flow`). Otherwise, set the label of the ROIs with the tool ABC (i).

2. Select Shunt and Valve Analysis under menu Flow (a).

3. The regurgitant fractions are presented in a new message box.

10.1.3 Clear flow segmentation

Clear current ROI by selecting , and all ROIs by selecting in the ROI/FLOW [F] mode (h).

10.1.4 Eddy current compensation

The eddy current compensation algorithm is a method to reduce background phase errors in MR phase contrast images. Note that it is important that when compensating for eddy current effets the image stack should not be cropped, since the algorithm need phase information from the whole image stack.

1. Select Eddy Current Compensation under menu Flow (a), to open the interface for compensating for eddy current effects, as shown in Figure 27.

2. If necessary, adjust threshold parameters to only include static tissue regions.

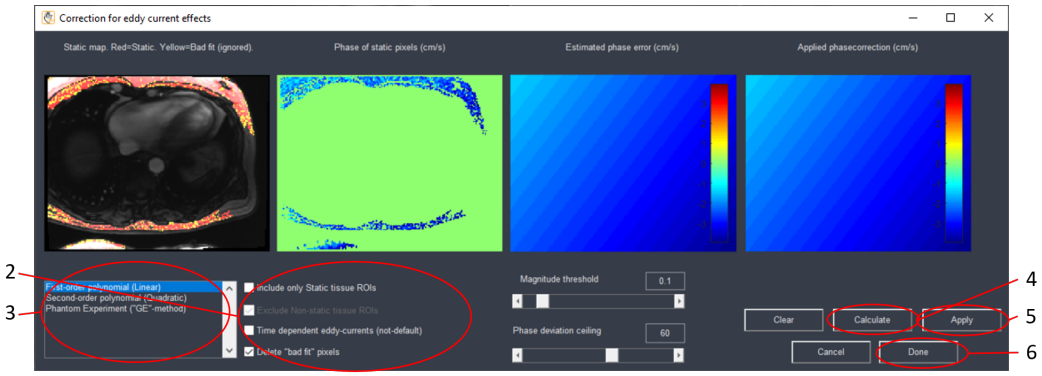


Figure 27: Eddy current compensation GUI.

3. Select compensation method.
4. Click on Calculate.
5. Click on Apply to apply the compensation on the image stack.
6. Click on Done to close the interface.

The function automatically finds stationary parts in the image by selecting a percentage of the pixels whose standard deviation of the phase over time is smallest. The image is divided into four quadrants and the algorithm to find stationary pixels is applied to each quadrant separately. This is done to ensure that there are about the same number of pixels from each quadrant. Pixels taken as stationary tissue are shown as red dots in the Static map. The Magnitude slider controls what magnitude the pixels need to have before being labeled as stationary. By selecting the mode of operation as `Include only Static tissue ROIs`, then ROI's that are labeled Static tissue are taken as stationary areas. This is particularly useful when doing phantom experiments, since the automated identification of static areas fails in cases with stationary flow. The mode of operation `Phantom Experiment (GE-method)`, automatically finds a flow image stacks that have the same scanning parameters. This useful when a static tissue have been scanned in the same position as the patient, as recommended by GE for eddy current compensation. For usage, see paper by Alex Chernobelsky *et al.* [?].

10.1.5 Phase unwrapping

The unwrap algorithm is a method to correct wrapped phase values in MR phase contrast images.

1. Select  under ROI/FLOW [F] (h).
2. Enter the original VENC for the dataset.
3. The interface for phase unwrapping is shown, as in Figure 28.

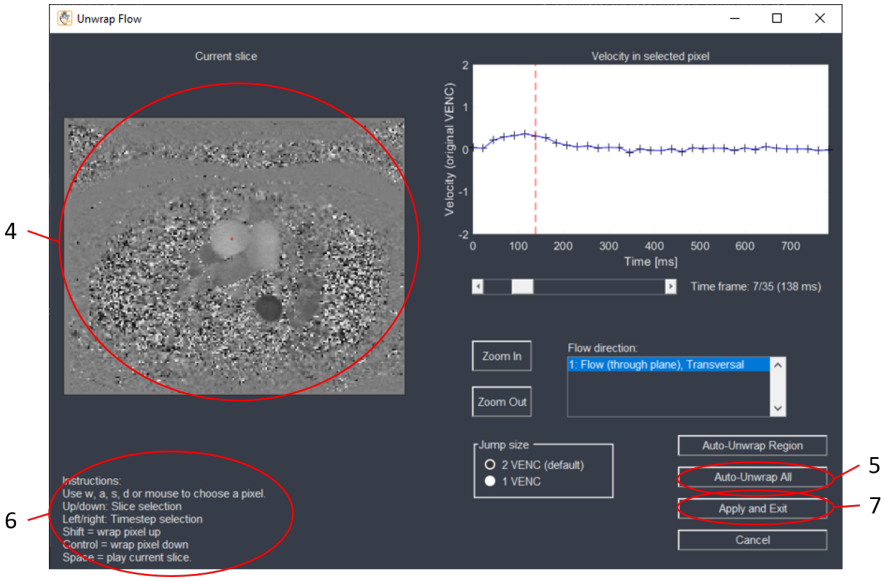


Figure 28: Phase unwrap GUI.

4. Choose a pixel (represented by a red dot in the image).
5. Click on Auto-Unwrap All, to apply the automatic phase unwrapping algorithm to the whole image stack.
6. If needed, use the manual tools to unwrap single pixels.
7. Click on Apply and Exit, to store the unwrapping in the dataset and to return to the main GUI.

10.1.6 Creating angio and velocity magnitude images

It is possible to create a so called angio image that is the magnitude image times the velocity magnitude. This is available under the Flow menu and Create Angio Image. If you have more than one velocity encoding direction it is possible to create a velocity magnitude image that is the square root of the sum of squares of all velocity directions (velocity magnitude). Velocity magnitude image can be created by select Create Velocity Magnitude Image under Flow menu.

10.1.7 Coupling magnitude and flow images

If magnitude and flow image stacks have been loaded into Segmentwithout being coupled to each other, it is possible to couple them using the Couple Magnitude/Phase Flow Image Stacks from the Flow menu. Available magnitude and phase image stacks are then identified and coupled using heuristics.

10.1.8 Pulse wave velocity (PWV) analysis

1. Start with a measurement labelled `Aortic Length` and two ROIs labelled `Aortic ascending flow` and `Abdominal aorta`. This is done by using the measurement tools as described in section 5.5 and flow ROI tools as described in Chapter 10.

2. Select Pulse Wave Velocity Analysis under menu Flow (a), to start pulse wave velocity analysis.

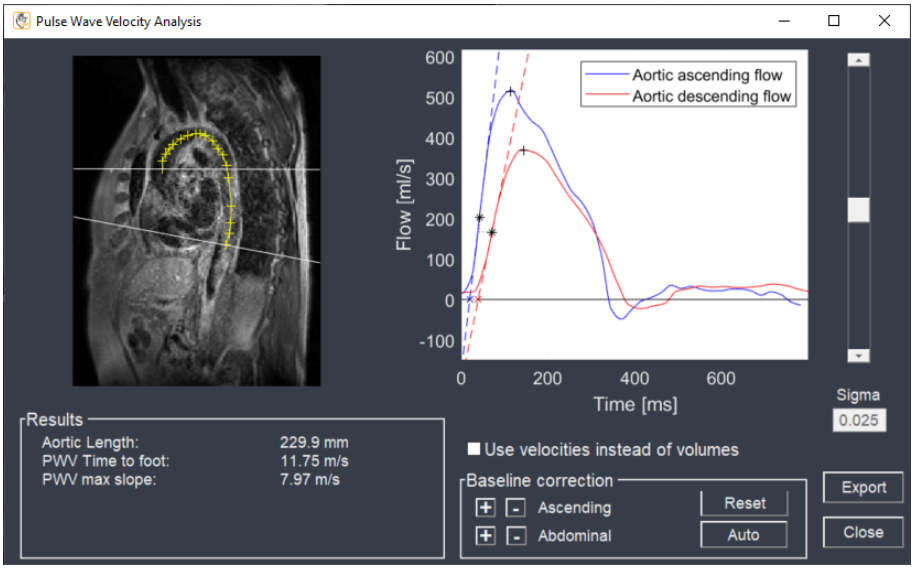


Figure 29: GUI for Pulse wave velocity analysis.

3. To the left the measurement is displayed in yellow and the intersections with images containing flow are displayed as white lines. On the right is a plot of flow curves along with their respective calculated tangents. The sigma parameter in the calculation can be adjusted using the slider.

10.1.9 Validation of Flow analysis

Table 4 presents the mean bias between reference volumes by expert readers and the volumes by the automatic algorithm in patients [1]. Table 5 presents the mean bias between reference values by computer phantoms and the values by the PWV analysis in 10 phantoms [2]. No uncertainty/error information is shown in the software together with the measurements.

Table 4:

Ascending aorta (n=151)	0.0 ± 1.9 ml
Pulmonary artery (n=40)	-1.7 ± 2.9 ml

Table 5:

PWV	0.27 ± 0.32 m/s

1. Bidhult S, Hedström E, Carlsson M, Töger J, Steding-Ehrenborg K, Arheden H, Aletras AH, Heiberg E. A new vessel segmentation algorithm for robust blood flow quantification from two-dimensional phase-contrast magnetic resonance images. Clin Physiol Funct Imaging. 2019 Sep;39(5):327-338.

2. K. Dorniak, E. Heiberg, M. Hellmann, D. Rawicz-Zegrzda, M. Wesierska, R. Galaska, A. Sabisz, E. Szurowska, M. Didziak and E. Hedstrom, Required temporal resolution for accurate thoracic aortic pulse wave velocity measurement by phase-contrast magnetic resonance imaging and comparison with clinical standards applanation tonometry. BMC Cardiovasc Disord, 16(1):110, 2016.

10.1.10 Imaging recommendations

Recommended imaging protocol for flow follows the SCMR guidelines [1]. Slice thickness 5-8 mm, in-plane resolution at least 1/10th of the vessel diameter. VENC adopted to the expected velocities after each scan, phase images should be checked for aliasing. Acquired timeframes more than 20-30. Echo time (TE) should be set to minimal.
Recommended imaging protocol for PWV analysis is through-plane phase-contrast CMR according to Flow Module in [1] with a temporal resolution according to validation paper [4]. According to [4], an acquired temporal resolution of at least 30 ms should be used.

1. C. M. Kramer, J. Barkhausen, S. D. Flamm, R. J. Kim, E. Nagel, and P. Society for Cardiovascular Magnetic Resonance Board of Trustees Task Force on Standardized, Standardized cardiovascular magnetic resonance (CMR) protocols 2013 update, J Cardiovasc Magn Reson 15 p 91, 2013.

11 Bullseye analysis

1. Start with manual or automated segmentation of the LV as described in Chapter 7.
2. Select the image stack to perform bullseye analysis of.
3. Click on the tool  (i) in mode ANALYSIS [A] (h) to open Bullseye analysis interface, as shown in Figure 30.

Figure 30: Bullseye analysis GUI.

4. Set the slice rotation by dragging the slider so the yellow line is in the middle of septum. Click on Update.
5. Select the parameter to plot.
6. Set the viewing parameters.
7. Click on Copy to Clipboard, to export data to spreadsheet.

For the `16 AHA model`, the slices are divided into equal thirds, for basal, mid, and apical parts. For the `17 AHA model`, the apex part is calculated from the most apical slice, and the rest of the slices are divided into equal thirds, for basal, mid, and apical parts. For image stacks with 3 slices only, the `17 AHA model` works as the `16 AHA model`.