

Flow software User Manual

Post-Processing for CINE-PC MRI



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Contents: Introduction to the basic functions of Flow software, and post-processing for CINE-PC MRI.

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1. Software Introduction

1.1.Purpose

“Flow” is a one-stop, multi-platform software based on IDL programming language dedicated to post-processing of CINE phase contrast MRI sequence (CINE-PC).

The first version of Flow software was developed by Dr. Olivier BALEDENT in 2001 and has been used for many years in many hospitals and laboratories, providing technical support for many research projects. To support the post-processing of CINE-PC sequences in the REVERT project and the collaboration between multiple hospitals and laboratories, Dr. Pan LIU has upgraded the Flow software with additional features and optimized the image reading function to better support each manufacturer's protocol.

1.2.Opening the software

Open the software folder and double click on “Flow.exe” or “Flow.app” to open the software, you can also create a desktop shortcut for this software.

Flow_EPI				
	Nom	Modifié le	Type	Taille
	IDL87	01/09/2022 17:06	Dossier de fichier...	
	license	29/08/2022 14:45	Dossier de fichier...	
:				
	config	16/09/2022 17:29	Paramètres de c...	1 Ko
	Flow	19/09/2018 19:34	Application	152 Ko
	Flow	21/05/2019 17:42	Paramètres de c...	1 Ko
	flow	06/09/2022 09:30	IDLbinaryFile	9 246 Ko

1.3.Software Updates

To update to the latest version of the software, just replace the "flow.sav" file in the folder with the latest version.

Flow_EPI				
	Nom	Modifié le	Type	Taille
	IDL87	01/09/2022 17:06	Dossier de fichier...	
	license	29/08/2022 14:45	Dossier de fichier...	
:				
	config	16/09/2022 17:29	Paramètres de c...	1 Ko
	Flow	19/09/2018 19:34	Application	152 Ko
	Flow	21/05/2019 17:42	Paramètres de c...	1 Ko
	flow	06/09/2022 09:30	IDLbinaryFile	9 246 Ko
	Flow.Sav			

1.4.The main steps of post-Processing

The main post-processing process of this software contains:

Readout all series of a patient through the DICOMDIR file and display them in the series list.

Select the target series, load the images of the series into the main interface for visualization, and perform operations such as contrast adjustment and image fusion.

Open the CINE-PC post-processing interface and select the target vessel in the main interface.

Image segmentation algorithms are used to define the ROI of the target vessel or cerebrospinal fluid (CSF), and then the software automatically extracts the parameters within the ROI, such as blood flow, maximum velocity, average velocity, flow volume and other curves.

For signal correction, select a stationary tissue for background field correction. If there is an aliasing effect, a de-aliasing operation is supported.

Finally, the results of the post-processed target vessel are saved to the corresponding directory for later recall.

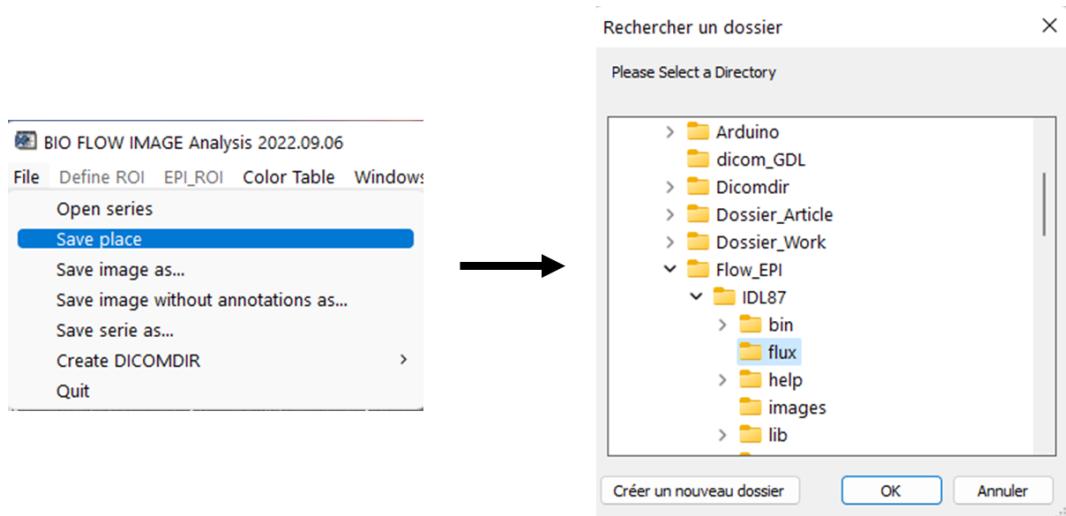
2. Main interface

The main interface is mainly for image loading, image observation, contrast adjustment. It consists of a menu bar, two image viewing windows and four operation sliders.



2.1. Setting the save folder

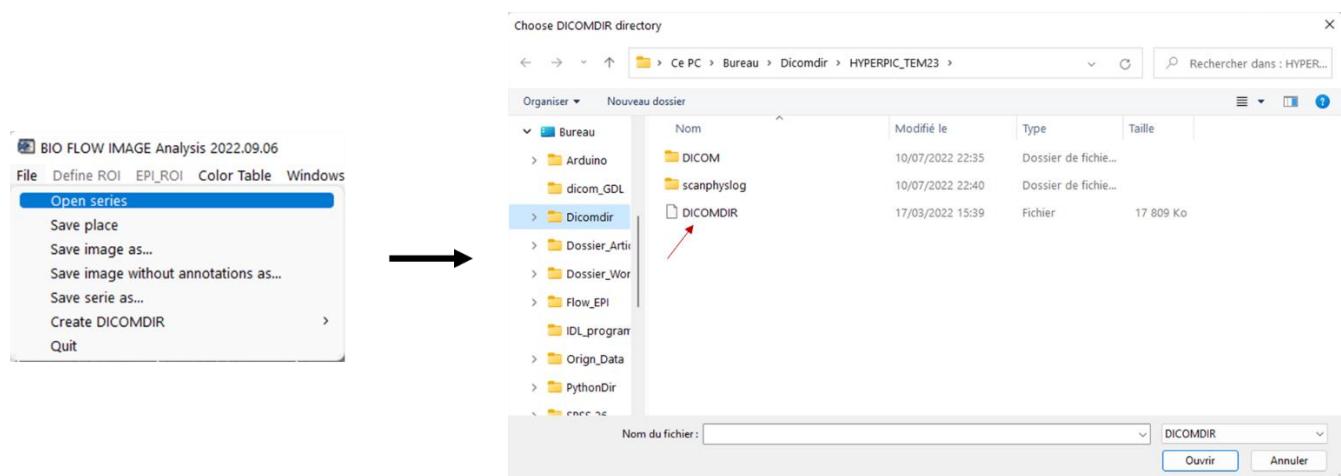
The default save location is the Flow folder -> “IDL87” -> “flux” folder. In this folder, the software will create a subfolder named after the patient’s name, all data obtained from post-processing will be saved in this folder. Users can change the default save path by clicking “File” -> “Save place”.



2.2. Reading DICOMDIR file

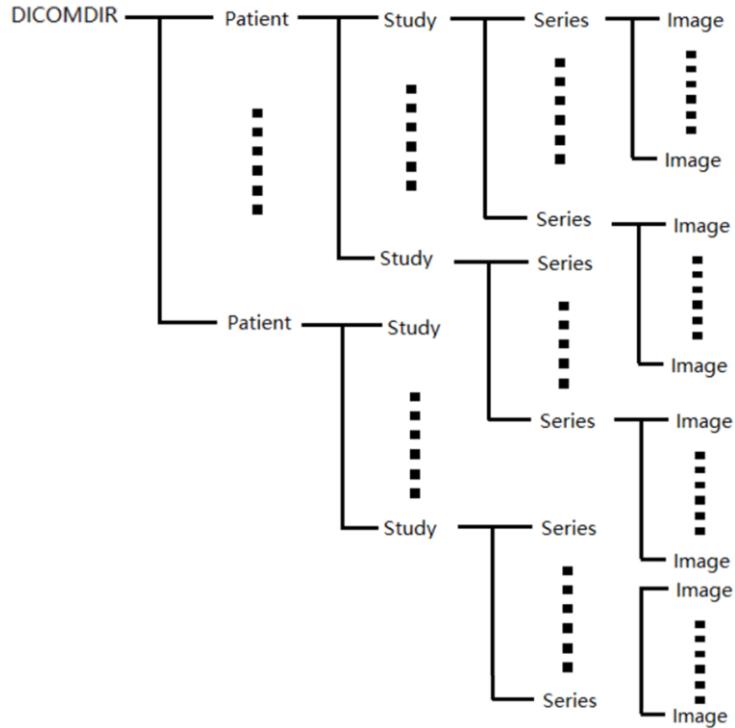
The DICOMDIR file can be considered as a directory file of all DICOM files of one acquisition. By reading the DICOMDIR file, the software can locate all DICOM files and integrate each DICOM file into a series list, which makes it easy for the user to select the target series.

Click “File” -> “Open Series” in the menu bar, select the target DICOMDIR file, and click “OK” to wait for the Series list to pop up (It will take about 3 seconds to read DICOMDIR with 1000 DICOM files linked).



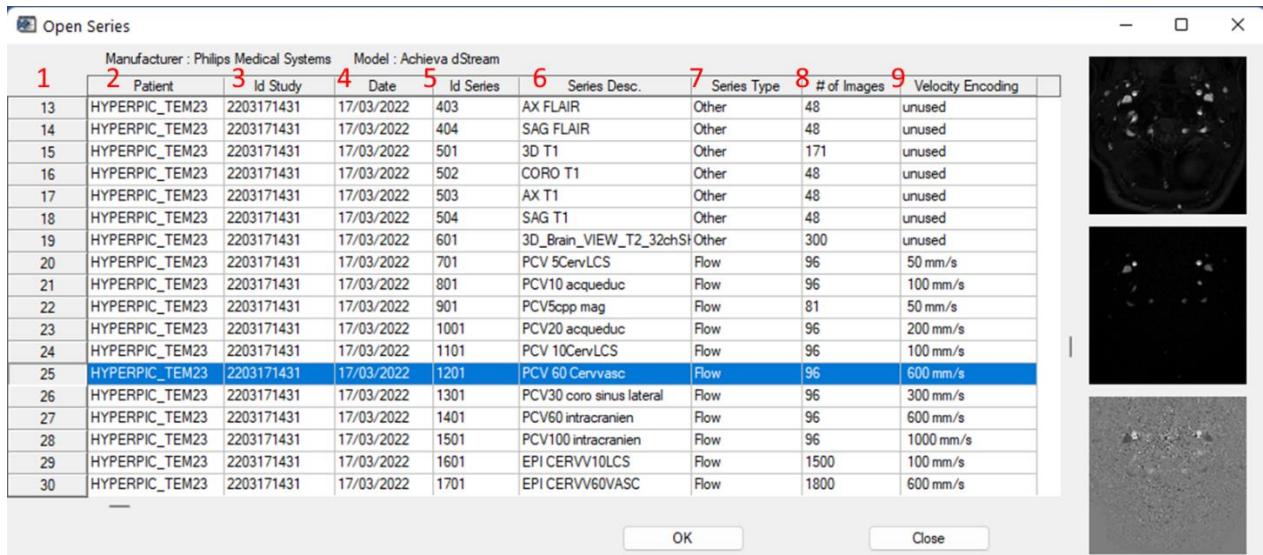
2.3. Series List

As shown in the image blow, a DICOMDIR files are presented as a 4-tier structure where a patient contains one or more studies, each study contains one or more series, and each series contains one or more images.



Usually, DICOMDIR files contain only one patient and one study. The columns in the series list from left to right are:

1. Series number, the first item is 0.
2. Patient name, the patient's name in this example has been de-identified.
3. Study ID.
4. Acquisition time of this Study.
5. Series ID.
6. The description of the series, which can be considered as the name of the series, is used to define the type of the series and some important parameter values.
7. The type of the series, the type of phase contrast sequence is “Flow”.
8. The number of images contained in the Series; it should be noted that CINE-PC contains 3 types of images. Therefore, for the CINE-PC series containing 32 phase contrast images, the number of images is $32 \times 3 = 96$.
9. Velocity encoded value, as known as VENC value. Used for phase contrast series.

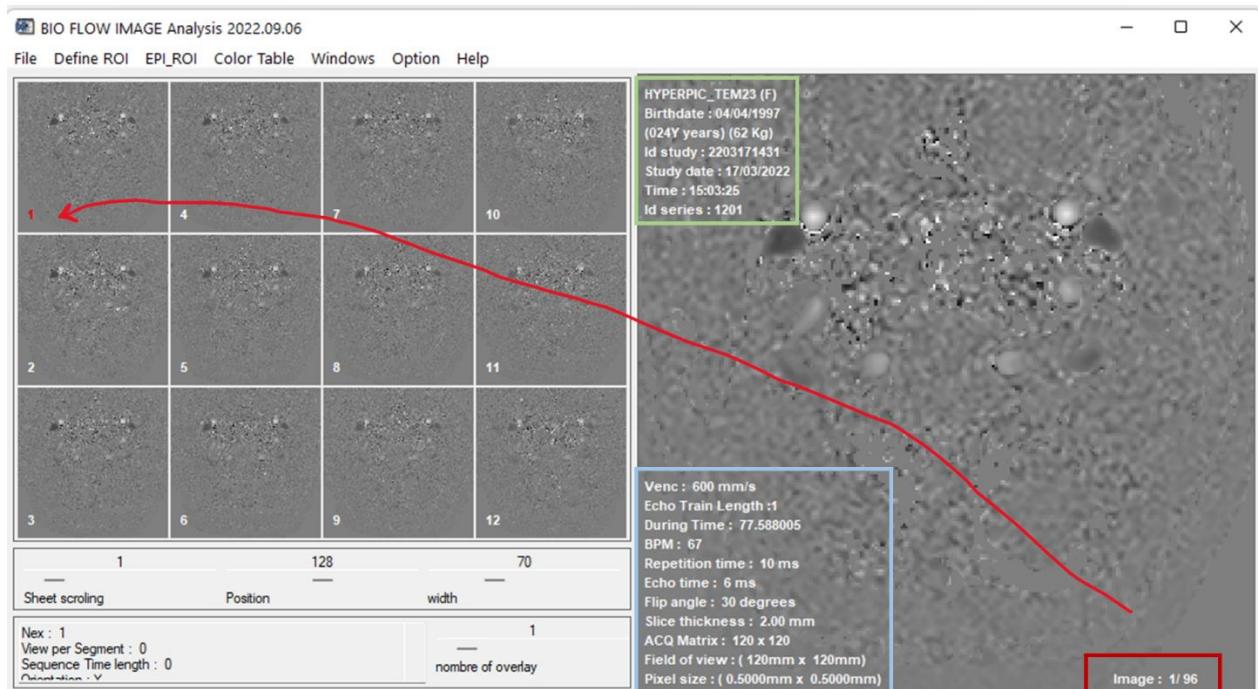


The model's name of the devices and its manufacturer are displayed at the top of the series list. The three windows on the right side of the list can display three preview images of the selected Series. As mentioned above, CINE-PC contains 3 types of images, from top to bottom are: amplitude images, amplitude images of phase images, and phase contrast images.

Select the target sequence and click "OK" to load the images of the target series into the Flow software.

2.4. Image viewing

After the images were loaded into the main interface, it was displayed as follows:

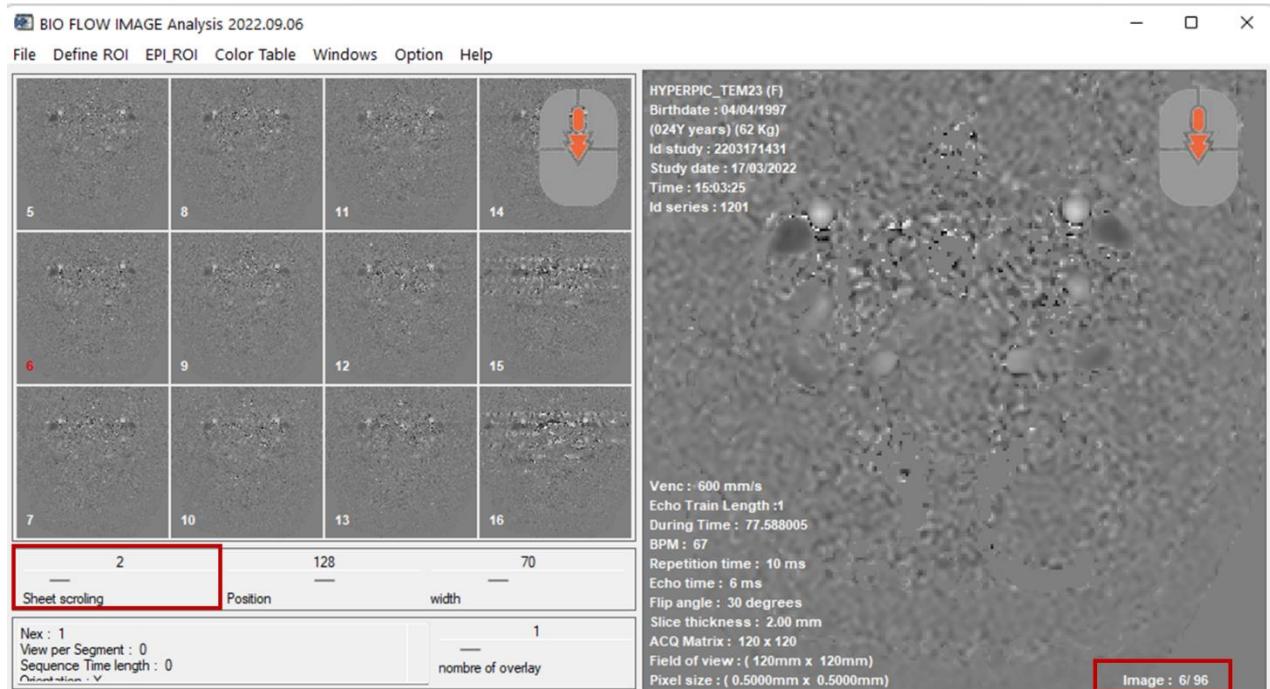


There are two display windows on the main interface. The main window on the right shows the currently selected image. The information in the lower right corner (red box) shows the current image serial number, while the upper right corner (green box) shows information about the patient, study and series, and the lower left corner shows the parameters of the current sequence (blue box).

The secondary window on the left shows a preview of 12 images with the image number in the lower left corner. The image with a red serial number indicates that this image is displayed in the main window.

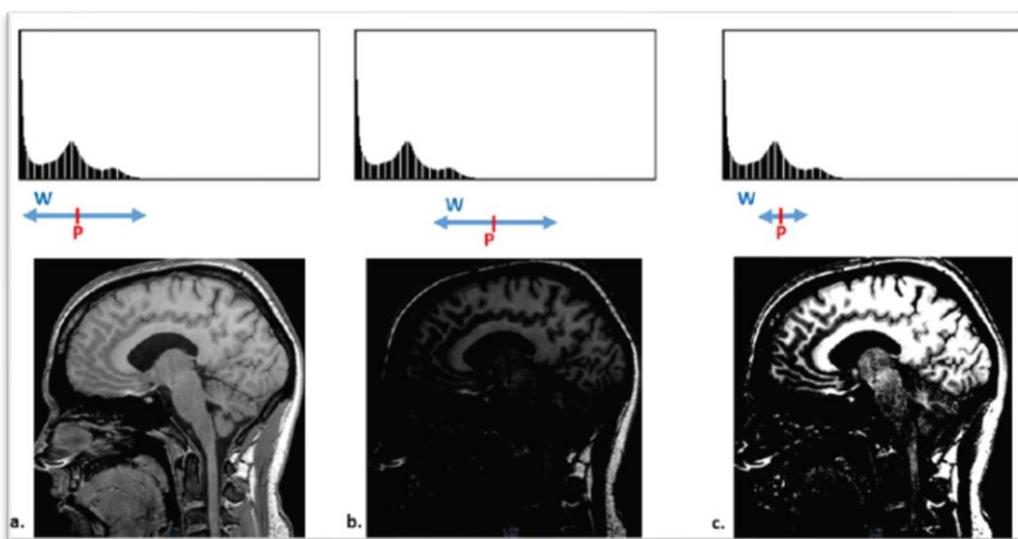
2.4.1. Switching images

Both the main window and the secondary window could switch images with the mouse wheel. The secondary window can also switch images via the “Sheet scrolling” slider (red box).



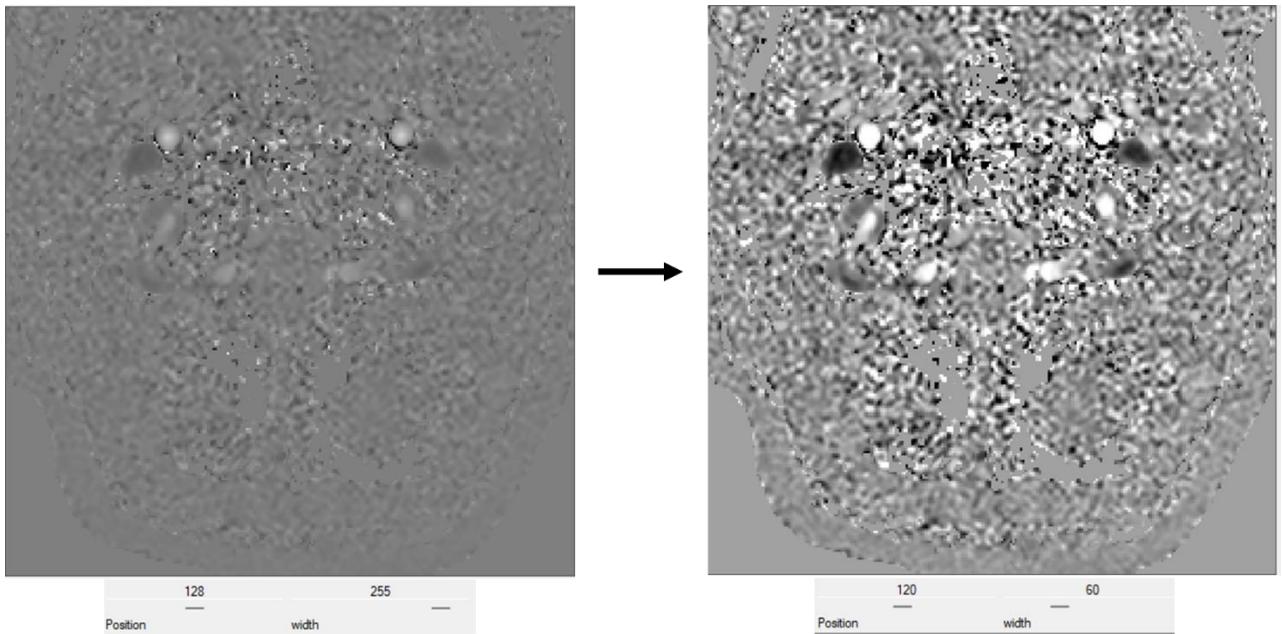
2.4.2. Adjusting Contrast

The image contrast can be adjusted by adjusting the “Position” and “Width” sliders. As shown in the figure below, the value of “Position” represents the center of the grayscale range to be extracted, and “Width” represents the width of the grayscale window to be extracted.



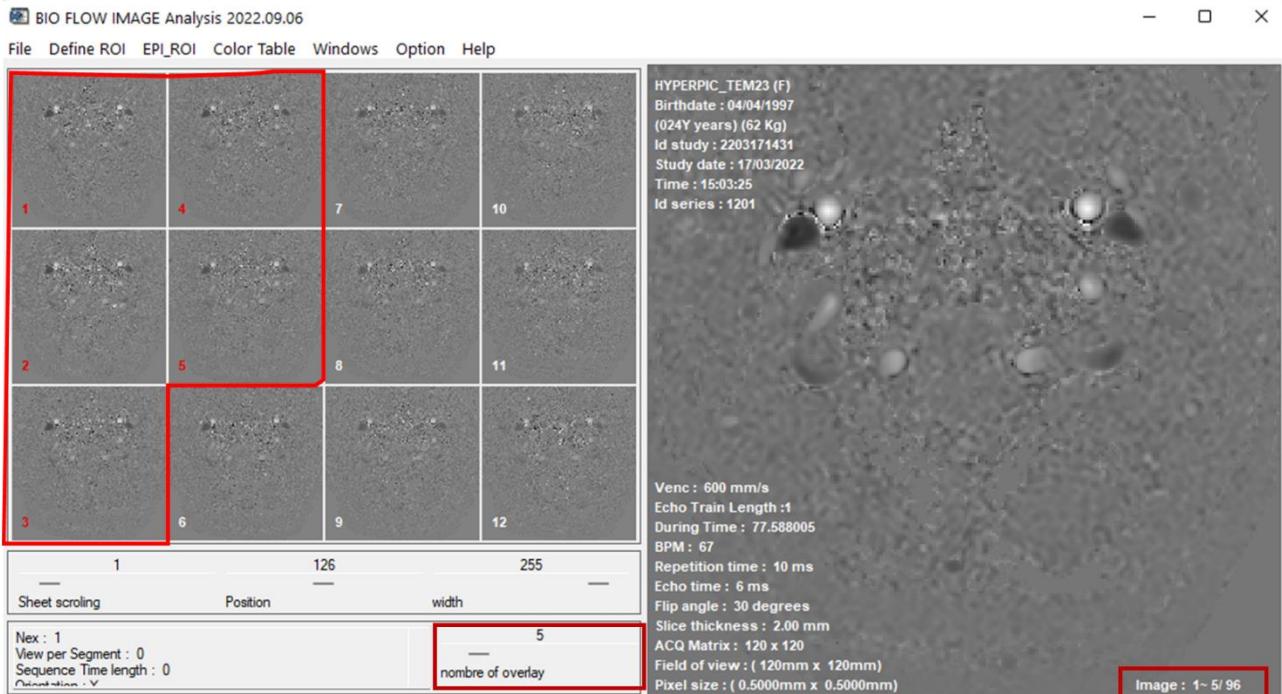
For example, the grayscale histogram range of the original image of this phase contrast image below is 0-255. If “Position” is set to 120 and “Width” is set to 60, it means that the original image is displayed with a histogram

normalized from 60 to 180. Thus, the contrast between arterial vessels (white) and venous vessels (black) is enhanced.



2.5. image fusion

By setting the “number of overlay” slider (red box), multiple images can be fused into one and displayed in the main window. After fusion, the image position in the main window will show the range of images that been used for fusion (red box: 1~5/96) and in the secondary window the images number will changed to red.



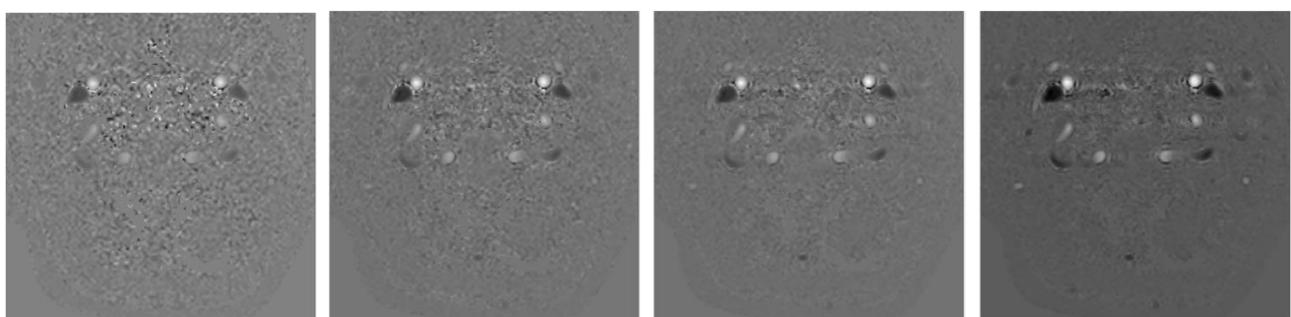
The main purpose of image fusion is used to remove the interference of stationary tissue in phase contrast images. By averaging the intensity of pixels in multiple images, high noise areas such as cavities, bones, etc. can be effectively smoothed to help users locate target vessel or CSF.

Overlay of 1

5

15

32



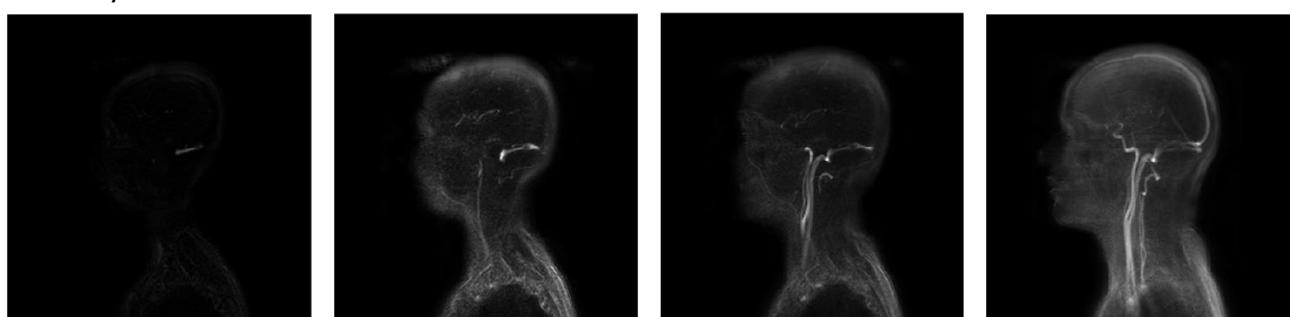
Another purpose is to fuse multiple sections of 3D-PCA, thus making it easier to analyze the vascular path.

Overlay of 1

10

20

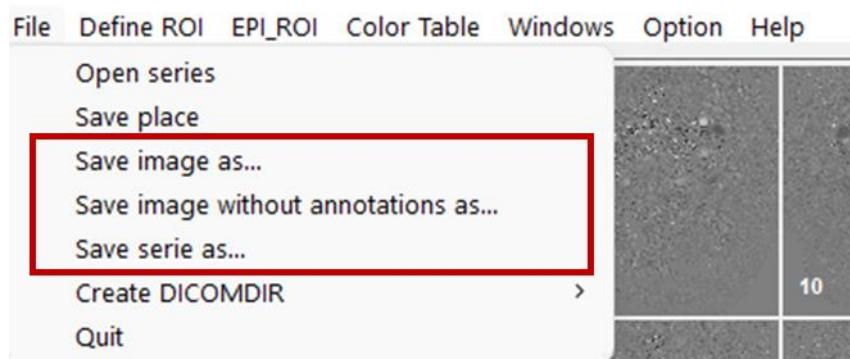
70



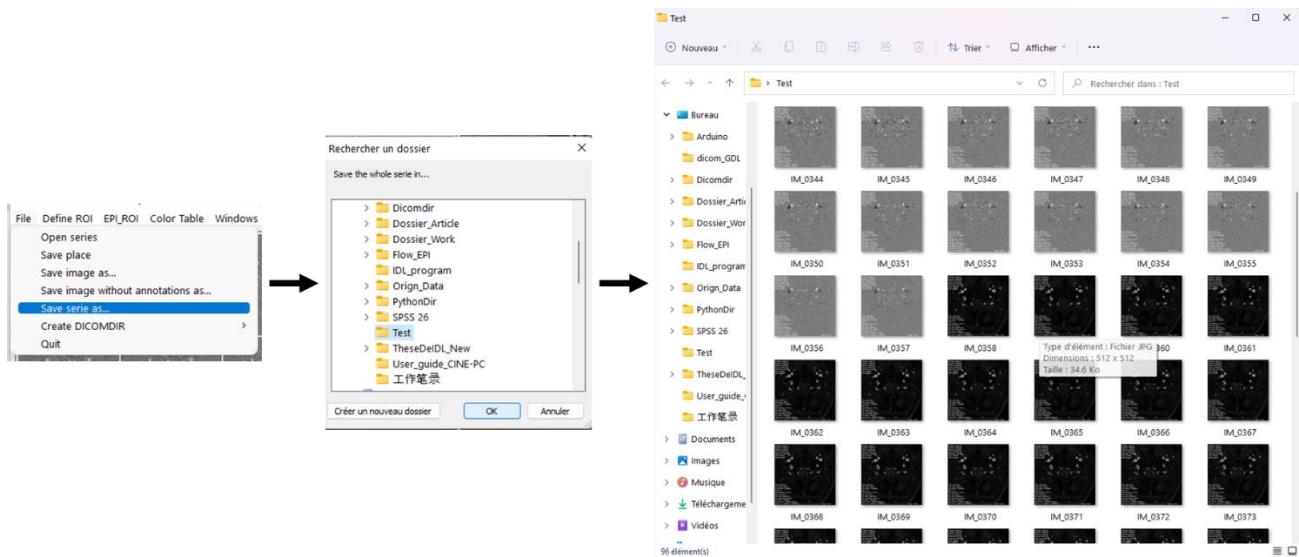
The fused images still allow image switching (mouse wheel control in the main window), for example, when the “number of overlay” is 10, the fused image of 1-10 will be displayed in the main window, and after rolling down the mouse wheel, the fused image of 2-11 will be displayed in the main window.

2.6. Image Saving

There are three options for image saving in “File” drop-down menu. From top to bottom:



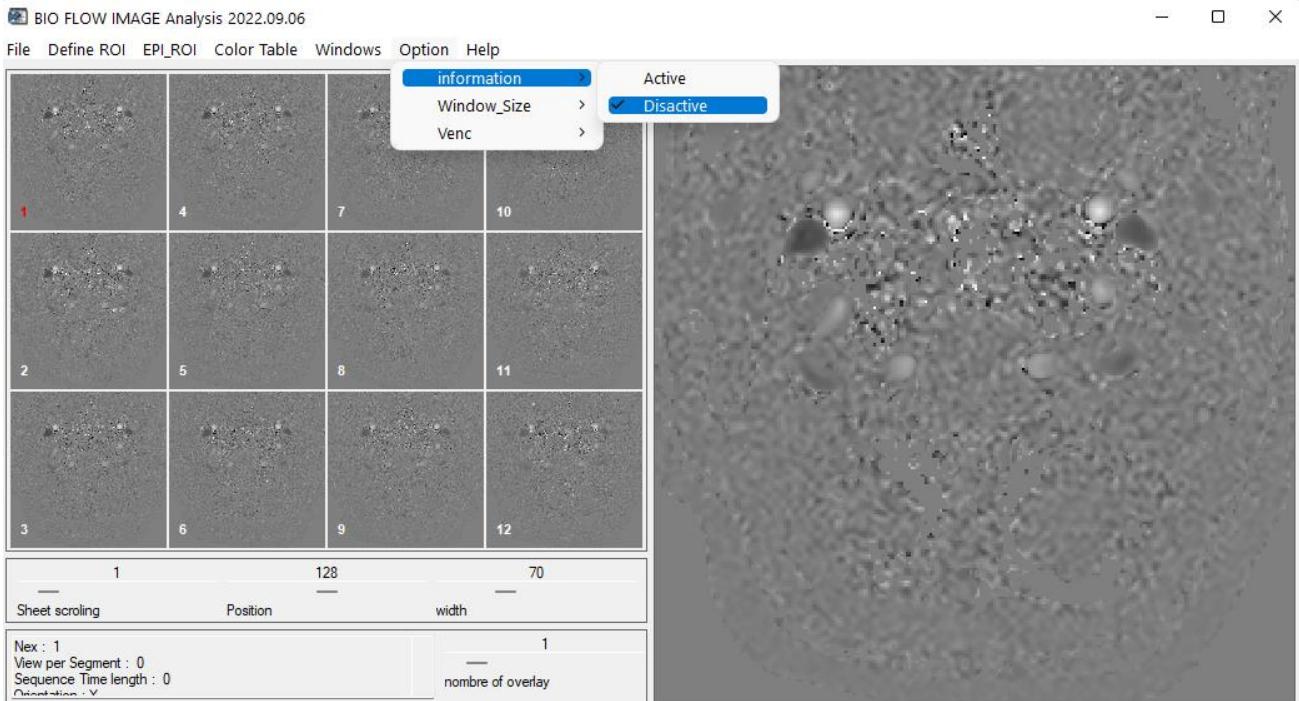
- Direct saving of main window image (with patient information and sequence parameters)
- Save a pure image of the main window (no patient information and sequence parameters)
- Save all images of the current Series. Note: If there are too many sequence images, it is highly recommended to save them to a folder rather than directly to the desktop.



The image above shows an example of saving all sequence images to a folder, you can notice that all images contain patient information and sequence parameters. If you wish to save the images without information, you need to turn off the information display on the main window. See 2.7 错误!未找到引用源。 for details on how to do this.

2.7.Turning off the main window information display

The information on the main window helps us to better visualize the images, patient information and sequence parameters. However, sometimes it can obscure the image or we don't want to expose the patient's privacy, thus we need to hide the information. To do this, click on “Option” -> “information” -> “Disactive” in the menu bar, in this case, the information will not be included when saving the serial images.

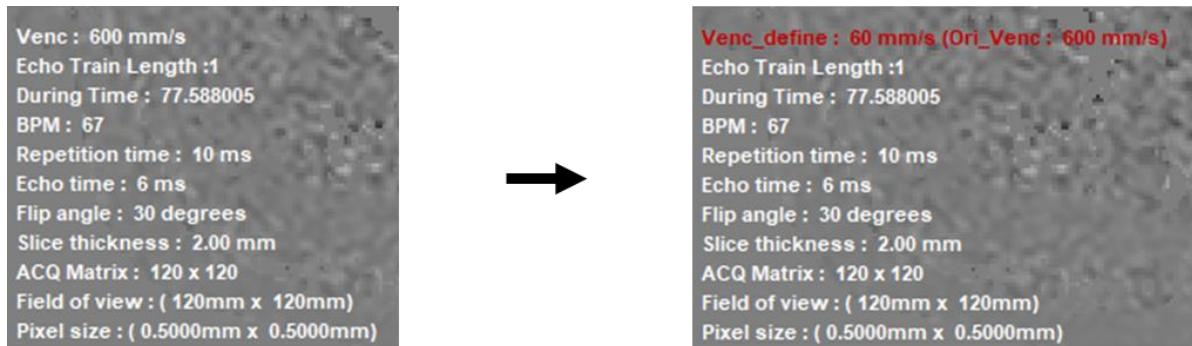


2.8. Set user VENC

Sometimes the DICOM protocols of different manufacturers or individual devices differ slightly, which can lead to errors in VENC reading, the software supports manual correction of the VENC. Click “Option” -> “Venc” -> “Set custom Venc”, enter the correct VENC value in the window. If you want to return to the original VENC, click “Use Original Venc”.

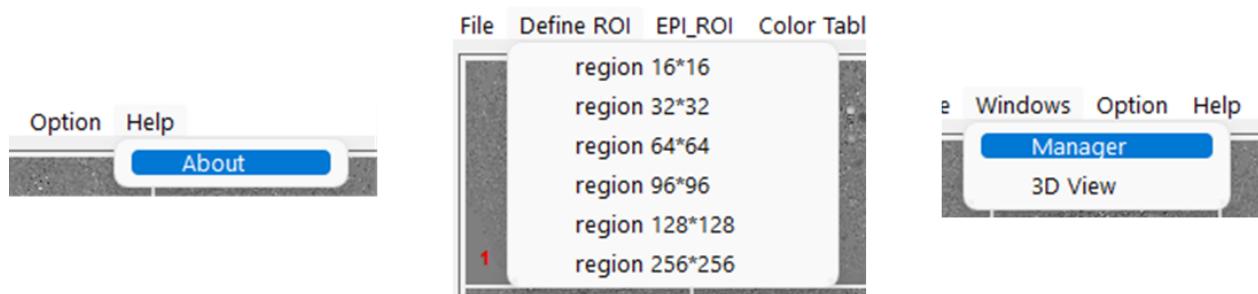


After changing the VENC value, the VENC in the main window sequence information bar will turn red.



2.9. Other options

“Help” -> “About” in the menu bar indicates that displays the software version information. “Define ROI”, which opens the CINE-PC post-processing window for post-processing, is the main content of this user manual and will be described in detail in chapter 3 错误!未找到引用源。. “Windows” -> “Manger” to open the data view manager, will be described in section 8.2.

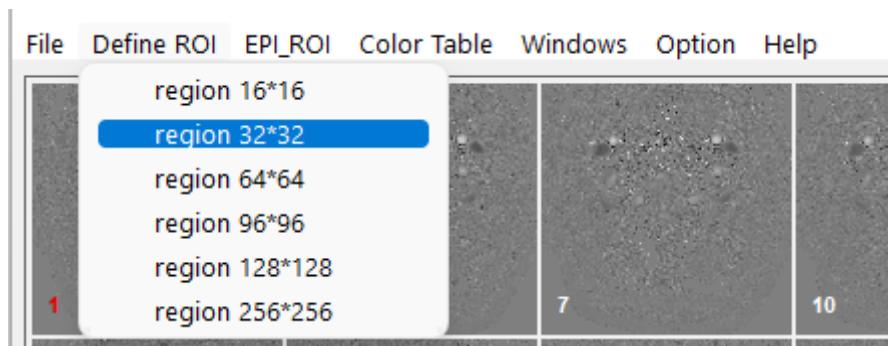


3. CINE-PC post-processing interface

This interface allows segmentation of CINE-PC sequence images, information extraction, signal observation, signal correction, and information saving. It is the main operation interface for CINE-PC sequence post-processing.

3.1. Select the appropriate FOV and open the CINE-PC interface

Click “Define ROI” -> “region n*n” to open the CINE-PC interface.

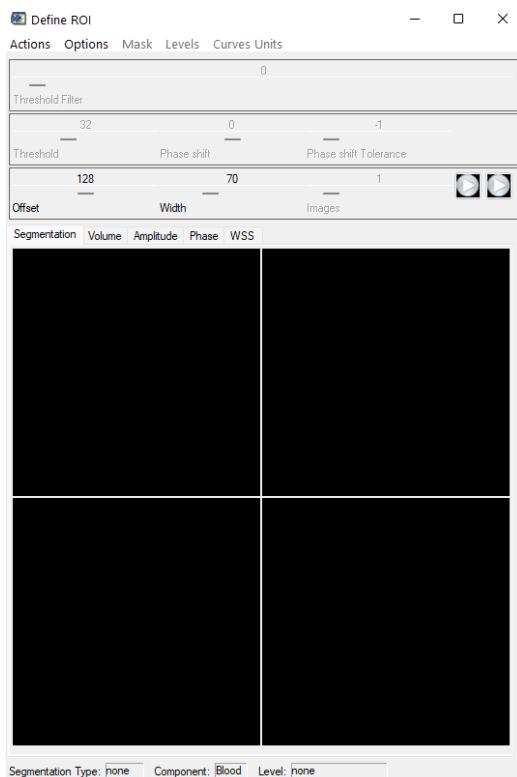


$n*n$ indicates the number of acquisition pixels contained in the rows and columns of the FOV. Under the condition that the target vessel or CSF can be included, it is better to set the FOV as small as possible, which has two main benefits:

- Reduce the computational effort of the segmentation algorithm and increase the post-processing speed.
- Increase the accuracy of image segmentation because the selected FOV will be displayed on a 128*128 size window, smaller FOV will show more details, and improve the accuracy of manual correction of ROI.

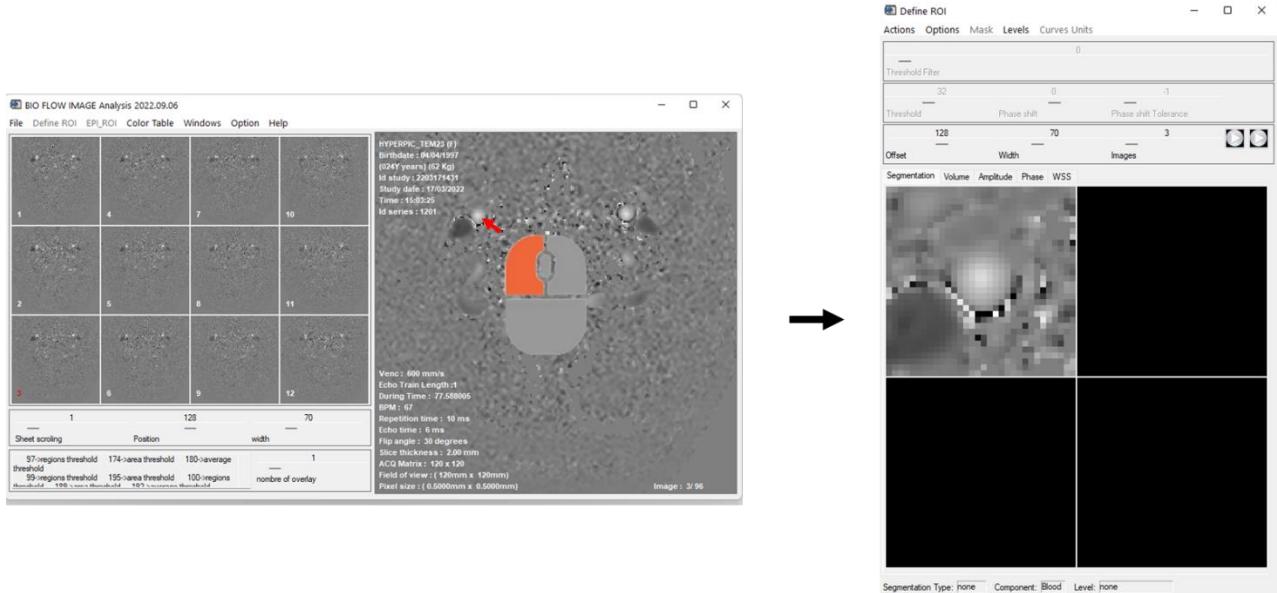
In general, for the post-processing of cerebral vessels, we choose 32*32. For the post-processing of CSF at C2-C3 level, we choose 64*64.

Click on the corresponding FOV size to open the CINE-PC interface.



3.2.Defining the target vessel location in main interface

After opening the CINE-PC interface, it is necessary to define the location of the target vessel. Just click the left mouse button in the main window of the main interface. For example, if we locate the right internal carotid artery, click the left button at the position of the red arrow shown in the figure below, while a FOV of 32*32 reconstructed pixels size will be displayed in the CINE-PC window. The pixel size is enlarged in the CINE-PC interface because we have selected a small FOV.

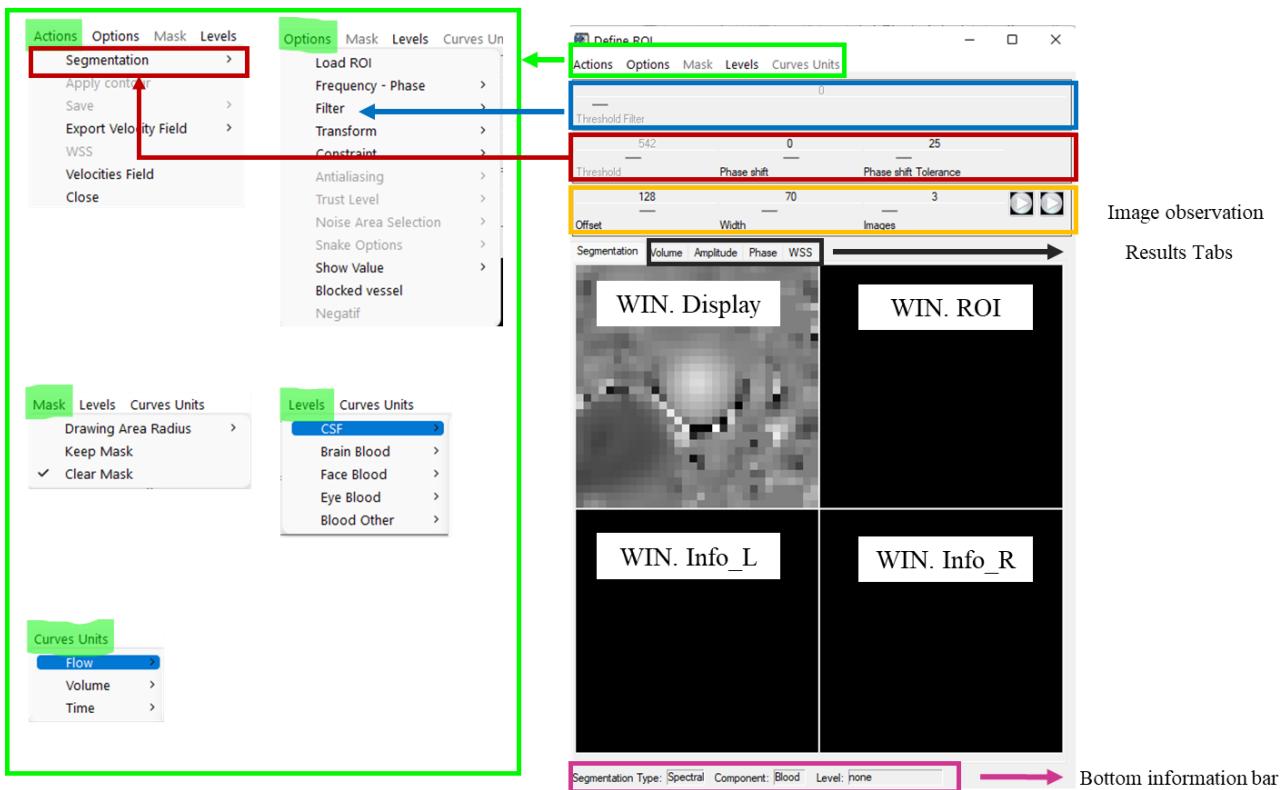


Note that there is no need to close the CINE-PC interface for switch to another target vessel, just redefine the next target vessel in the main interface.

Once this step is completed, we can finish the rest of the post-processing process in the CINE-PC interface.

3.3.Introduction of the CINE-PC interface

As shown in the figure below, we briefly introduce the CINE-PC interface in the order from top to bottom.



3.3.1. 5 options in the menu bar

The menu bar contains 5 drop-down menus (green boxes) from left to right:

- Actions: Mainly contains segmentation algorithms, Application ROI functions, etc., more details in section 4.3.
- Options: Includes functions such as loading ROI, defining segmentation type (Frequency-phase), image denoising (Filter), background field correction (Noise Area Selection), de-aliasing (Antialiasing), signal observation (Show Value), etc.
- Mask: It mainly contains the function to adjust the ROI, see section 4.2 for details.
- Levels: It is the save option that assigns names to common arterial vessels, venous vessels, and cerebrospinal fluid, as detailed in section 7.2.
- Curves Units: Changing the units of signals, see details in section 5.5.

3.3.2. The 3 slider zones

- The blue slider area is the image denoising adjustment slider, activated by clicking on the menu bar “Option” -> “Filter”, see details in section 3.4.2.
- The red slider area is used for the tuning of the parameters of the semi-automatic segmentation algorithm, see more details in section 4.3.
- Yellow slider area is the image observation and image contrast adjustment area, from left to right, “offset” and “width” sliders control the image contrast, the same role as the “position” and “width” sliders in the main interface (2.4.2). The “Image” slider switches the image displayed in WIN.Display. The two buttons on the far right can display the amplitude image and the phase contrast image as animations in WIN.Display.

3.3.3. Results Tabs

Tabs for expanded display of data within the image and ROI, such as Volume for blood flow or CSF, pixel intensity of amplitude images, and for background field correction.

3.3.4. The four windows

These 4 windows are the core area of the CINE-PC interface.

- WIN.Display: The main observation window of the image, while displaying the contour lines of the ROI.
- WIN.ROI: The window for image segmentation especially for manual segmentation correction.
- WIN.Info_L & WIN.Info_R: Auxiliary information display windows. For example, to help display some temporary information or intermediate information when performing semi-automatic segmentation. As well as the windows to display flow or velocity curves after the segmentation has been completed.

3.3.5. Bottom information bar

Displays some current status information:

- Segmentation: The currently used segmentation method.
- Component: The type of the currently segmented target, Blood or CSF, is a conditional parameter of the semi-automatic segmentation algorithm.
- Level: The name of the current target. Default value: “None”.

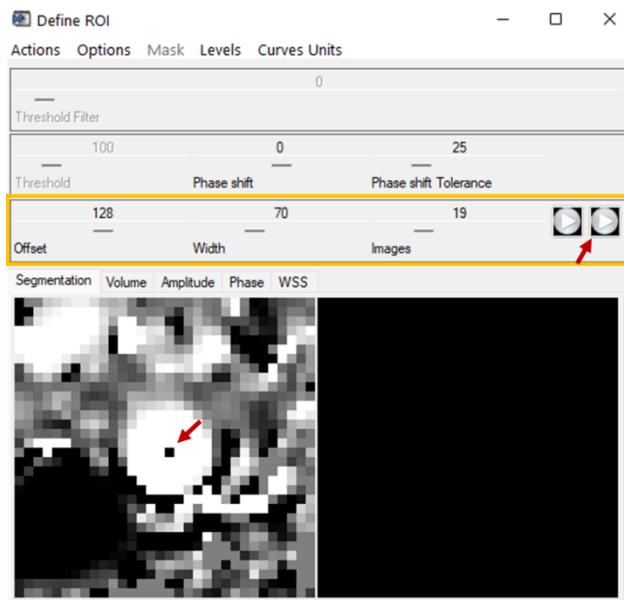
3.4. Before image segmentation

Before performing image segmentation, there are some tasks can help us to better perform the post processing.

3.4.1. Viewing the amplitude image and phase contrast image animation

You can click on the corresponding two “Play” buttons to watch the animation of all amplitude images and phase contrast image frames of the series, through the animation we can observe whether there is a large displacement of the vessels or whether there is an aliasing effect.

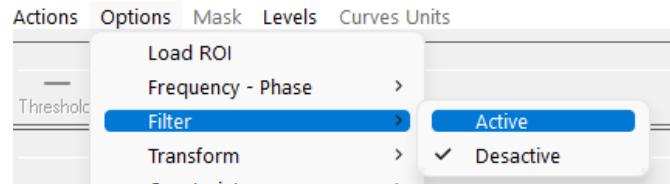
As shown in the figure below, after clicking the “Play” button of the phase contrast image, we observe in the WIN.Display that the ICAR appears aliasing at 19th frame. This requires us to perform the corresponding de-aliasing process afterwards, see section 6.2.



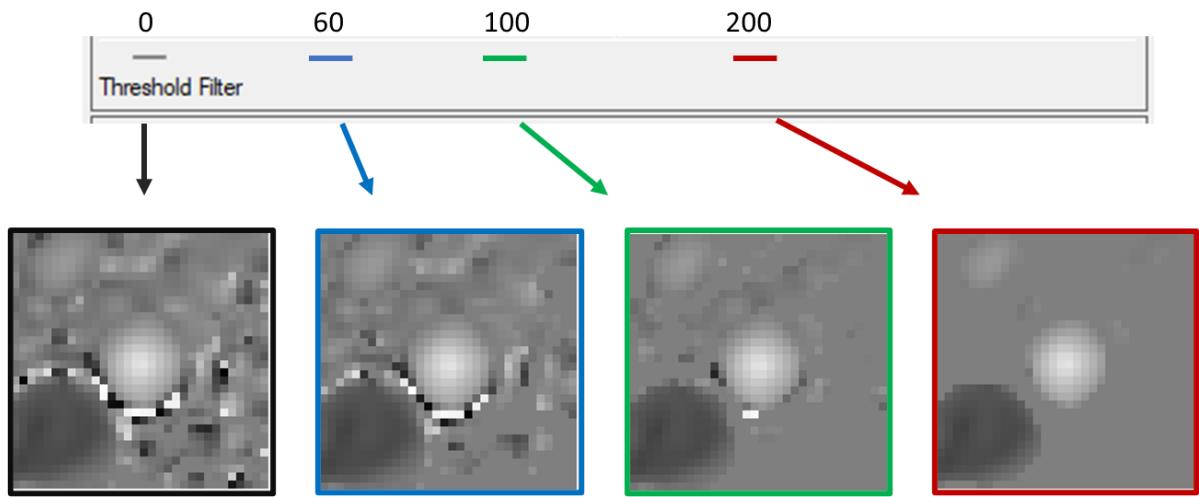
3.4.2. Image denoising

The average value of the pixel velocities of stationary tissue, like muscles, cavities and bone tends to 0 (i.e., the average pixel intensity of all frames is 127), so these locations can be distinguished (pixel intensity is assigned to 127) using an average pixel intensity threshold for the purpose of removing background noise.

Click “Options” -> “Filter” -> “Active” in the menu and then remove the background noise by adjusting the “Threshold Filter” slider.



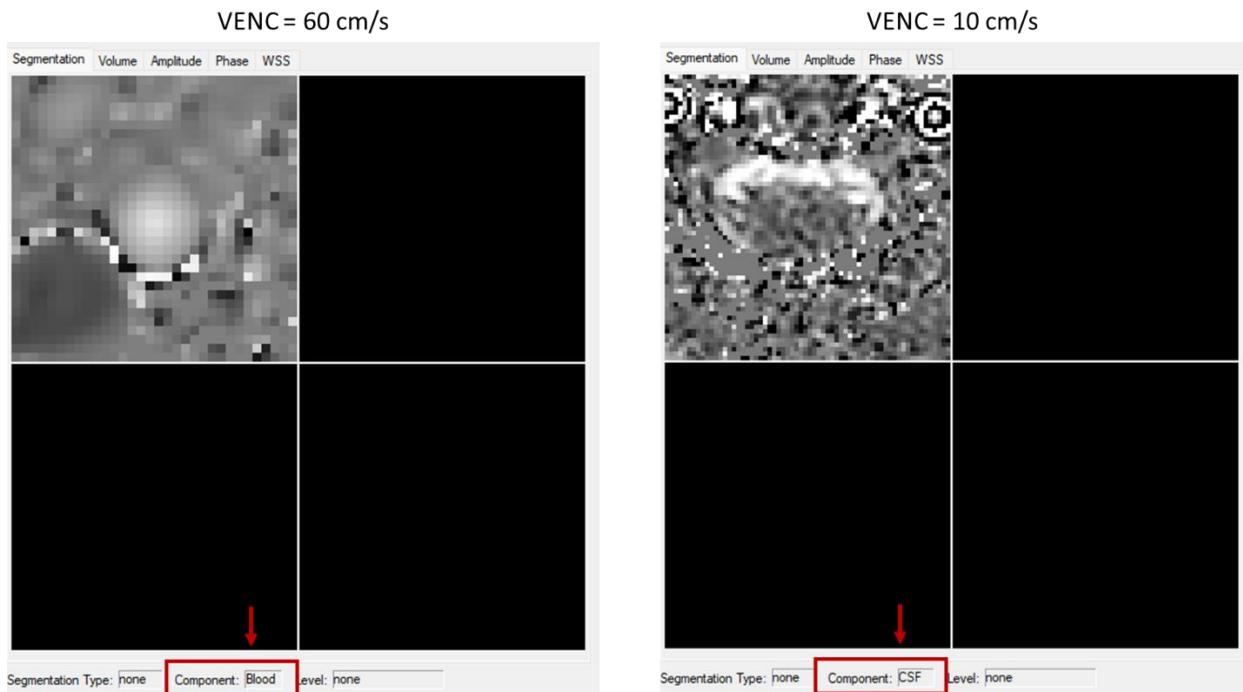
As shown in the figure below, the larger the threshold value is, the more background is removed. Note that too large a threshold may remove the boundary part of the vessel, because the blood flow velocity in the boundary of the vessel is not very large, therefore a too large threshold will cause an underestimation of the segmentation area. The software's semi-automatic segmentation algorithm can segment vessels well even in the presence of background noise.



On the other hand, it is better not to use the image denoising function in the post-processing of the CSF, because the algorithm will treat the CSF as a stationary tissue.

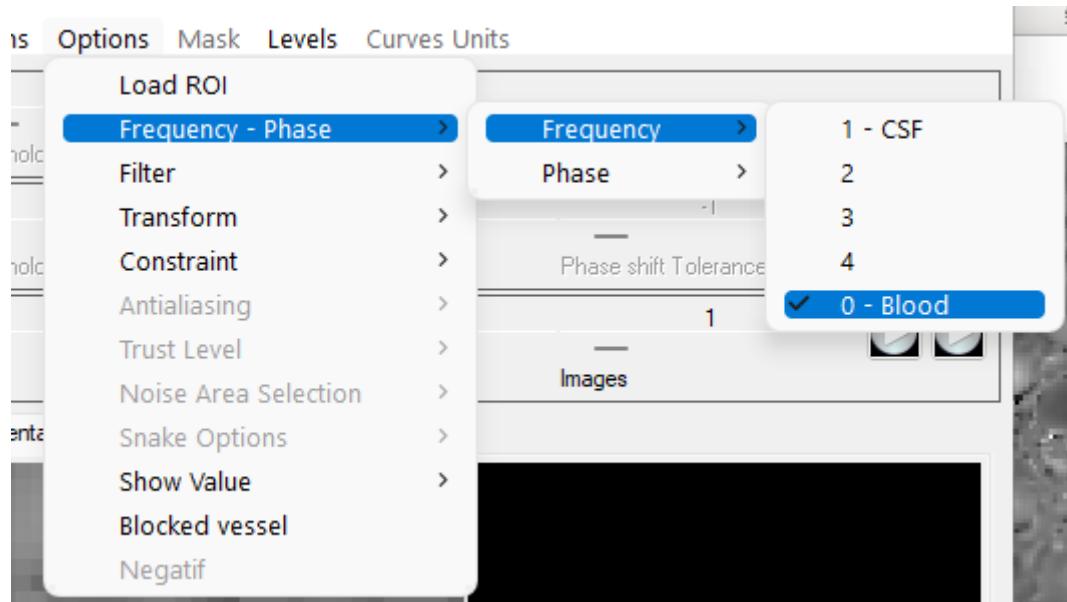
3.4.3. Confirmation of target type

The software automatically sets the target type to “Blood” or “CSF” based on the VENC value, and displays the target type in the “Component” information box at the bottom.



The semi-automatic segmentation algorithm is slightly different for different target types, and only after the correct target type is determined can the subsequent image segmentation be continued. Usually, the software can define the target type correctly. However, there are special cases, such as use a small VENC to observe a low flow velocity vessel, or use a big VENC to see the CSF with a high flow velocity. In these case, the target type needs to be manually corrected as follows:

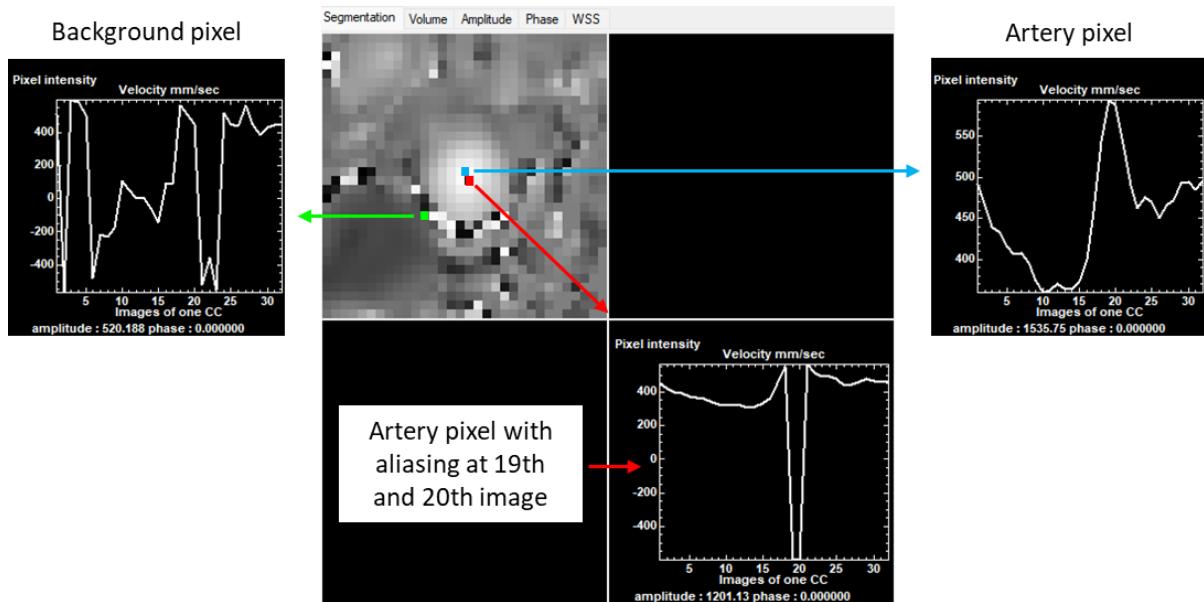
Click “Options” -> “Frequency” – “Phase” -> “0 – Blood” or “1 – CSF”.



Once you have completed your modification, you can confirm it in the “Component” information box.

3.4.4. Other operations

Left-click on a pixel in WIN.Display and the velocity curve of this pixel will be displayed in WIN.Info_R. In this way you can further differentiate between pixels with different characteristics.

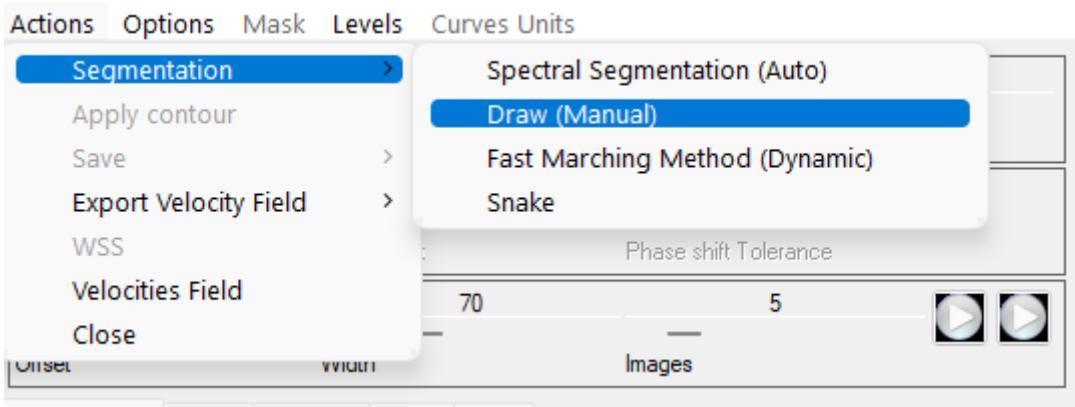


4. Image segmentation

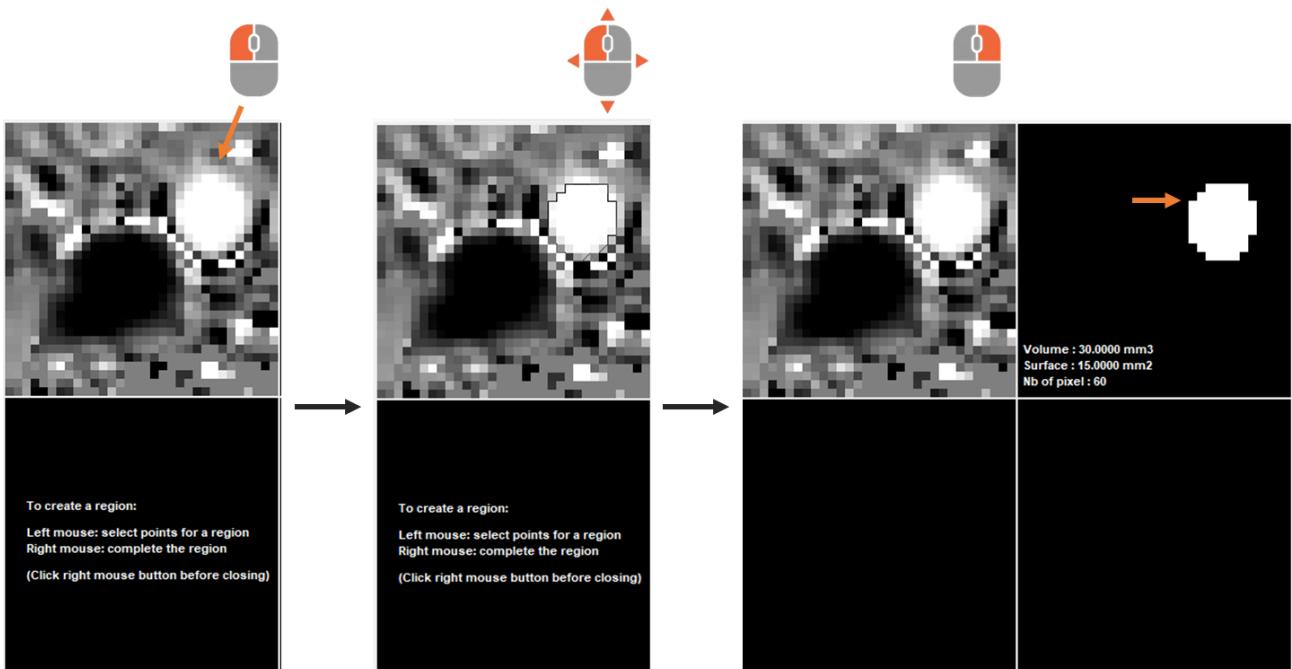
The purpose of image segmentation is to extract the ROI of the target vessel or target CSF to perform signal extraction. In this chapter, we will first introduce manual segmentation and manually correction of the ROI, and then focus on the process of semi-automatic segmentation.

4.1. Manual segmentation-Draw

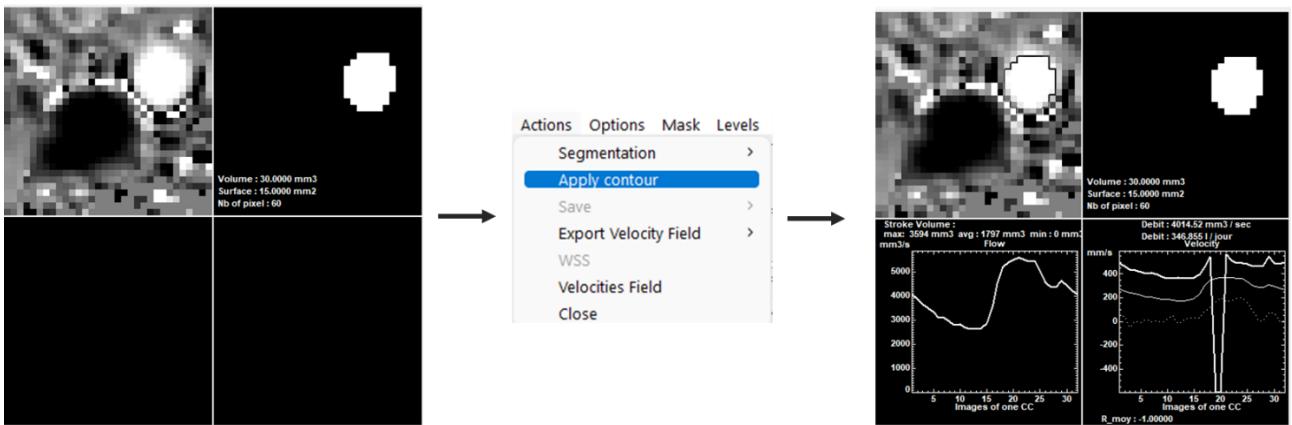
Click “Actions” -> “Segmentation” -> “Draw (Manual)”.



As shown in the figure below, left click on the target vessel in WIN.Display, drag the mouse to complete the contour line of the target vessel, and finally click the right mouse button to finish the manual definition of ROI. A binary image will be displayed in WIN.ROI to represent the ROI of the target vessel.



If this ROI is deemed to meet the requirements and no modification is needed, then click “Actions” -> “Apply contour” in the menu bar to apply this ROI, the software will automatically extract the signals of the flow rate, velocity, etc. within the ROI and display them in WIN.Infos. If the ROI needs to be modified, you can manually modify the ROI in WIN.ROI, see 4.2 for details.

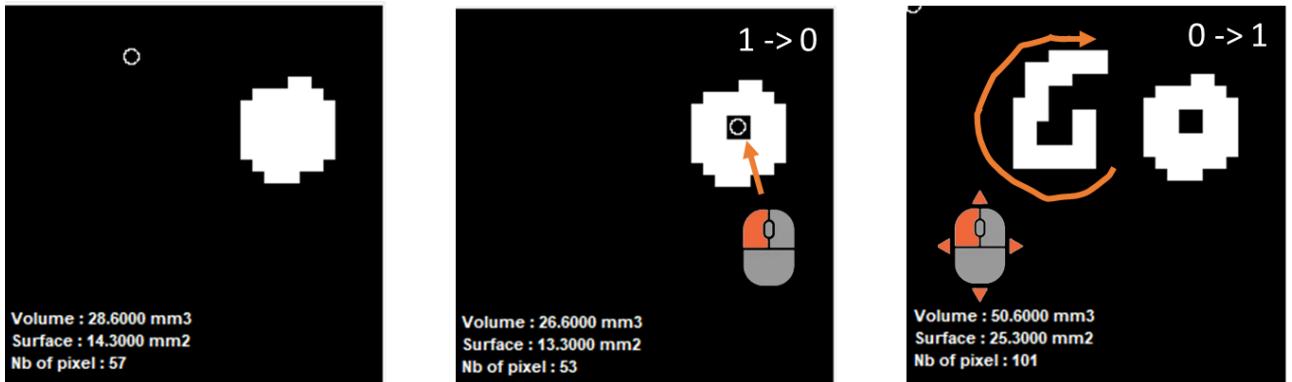


4.2. ROI manual adjustment

The ROI mask can be modified directly in WIN.ROI. The related operations are as follows:

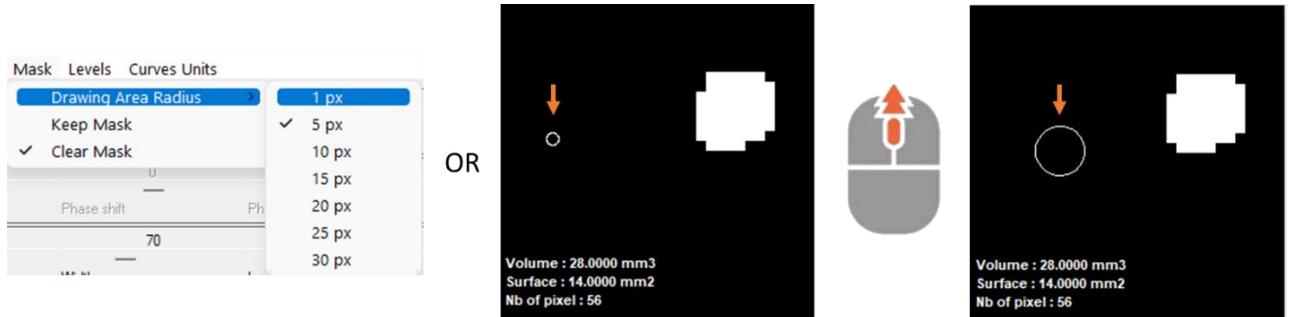
4.2.1. Add/remove ROI pixels

Left mouse click at the target location to change the status/value of the pixel (0=black=unselected, 1=white=selected), depending on the value of the pixel at the clicked location, if it belongs to ROI (value=1, white) then a delete operation is performed, and vice versa, an add operation is performed. You can also hold down the left mouse button and move the mouse to make a wide range of changes.



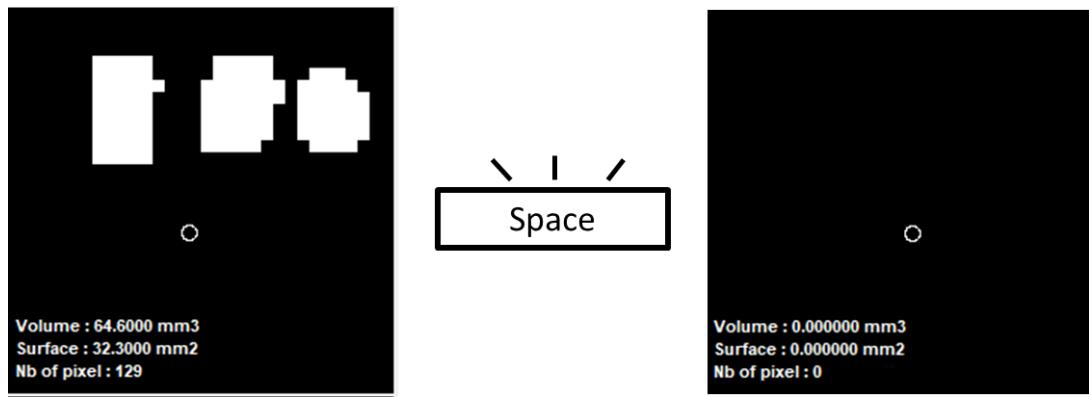
4.2.2. Adjusting the brush radius

Click “Mask” -> “Drawing Area Radius” to adjust the radius of the brush, or just use the mouse wheel to quickly adjust the brush size. Slide up to increase the brush radius.



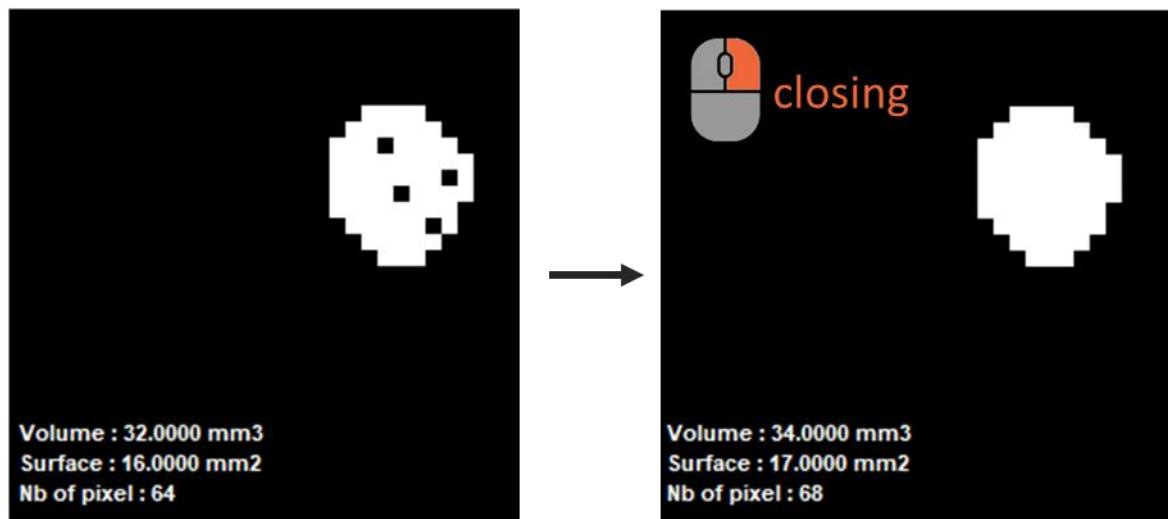
4.2.3. Clearing ROI

Clear the ROI by clicking the “SPACE” button inside the WIN.ROI.

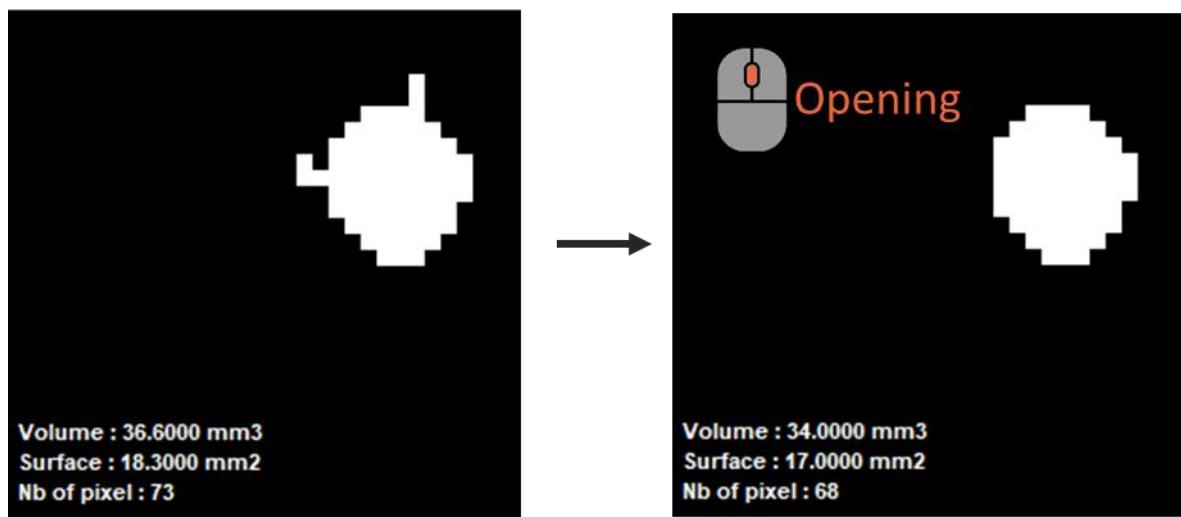


4.2.4. Mathematical morphology

Right-click inside the WIN.ROI to perform a closing operation on the ROI (dilation then erosion) to fill in the holes in the ROI.



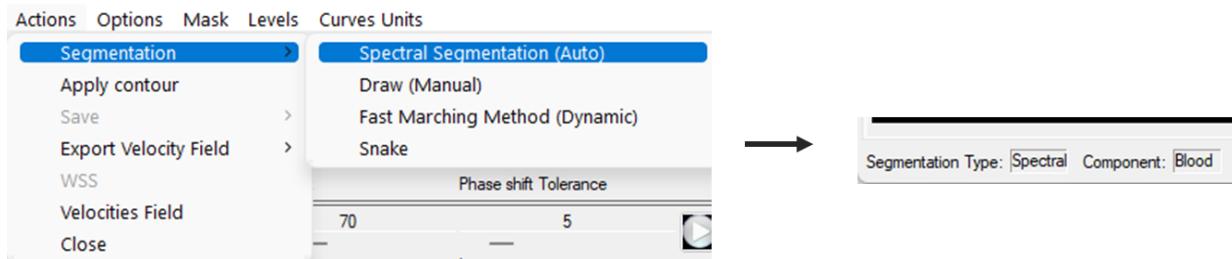
By clicking the middle mouse button to perform an open operation on the ROI (erosion then expansion) to make the contour smoother.



The above is all the operations of ROI manual correction within the WIN.ROI, which can basically meet the requirements for use. While the ROI is modified, the contour line of ROI will be displayed in WIN.Display, which is convenient for users to check.

4.3. Semi-automatic segmentation -Spectral

Semi-automatic segmentation algorithms that distinguish pixel identity based on the frequency domain characteristics of each pixel's velocity signal is more convenient and accurate than manual segmentation. Click “Actions” -> “Segmentation” -> “Spectral Segmentation (Auto)” to call this function, in the same time, the “Segmentation Type” information box in the bottom will be displayed as “Spectral”.

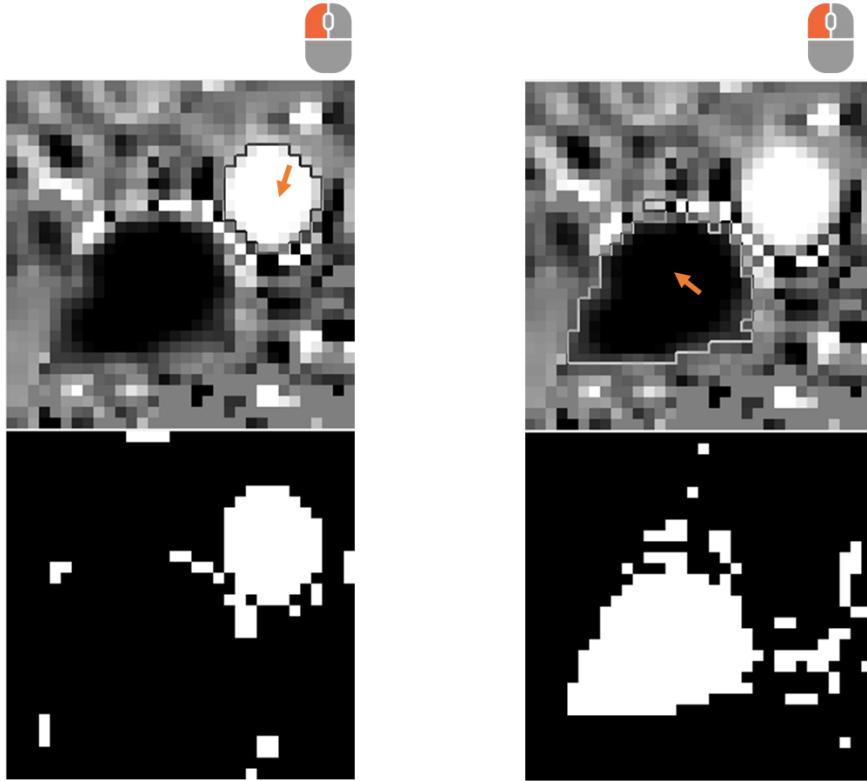


This algorithm is slightly different for the segmentation of blood vessels and CSFs. We will first start with the relatively simple blood vessels segmentation. If the “Component” in the bottom information bar does not match the target type, for example, “Blood” is displayed when segmenting CSF, refer to 3.4.3 for modification.

4.3.1. For vessels segmentation

A Click on the target vessel

We will continue with the example of the right internal carotid artery (ICADR, white) and the jugular vein (black). After calling up the semi-automatic algorithm, we first need to click on our target vessel in the WIN.Display. Due to the different phase values of the f0 component of the velocity signals of arterial and venous pixels, the algorithm can easily distinguish between arteries and veins. After clicking the target vessel, WIN.Info_L will show the preview image of ROI simultaneously.



B Adjustment threshold

In the above figure, we can see that after semi-automatic segmentation, the ROI of artery or vein has been basically segmented out, but there are still some over-segmentation phenomena, so adjust the slider in the segmentation control area (red box) to further improve the accuracy of ROI. For the segmentation of blood vessels, we only need to adjust the first slider (Threshold) in the control area.



WIN.Info_L will show a preview of the ROI in real time during adjusting. Adjust the “Threshold” to the right position according to this preview image. The figure below shows the variation of ICAR's ROI at different Threshold. As a rule of thumb, Threshold at 300 or at 400 is appropriate, and under-segmentation may exist at 500.

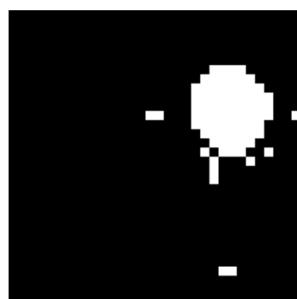
Threshold: 200



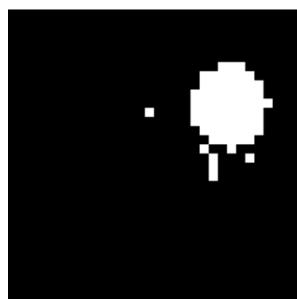
300



400

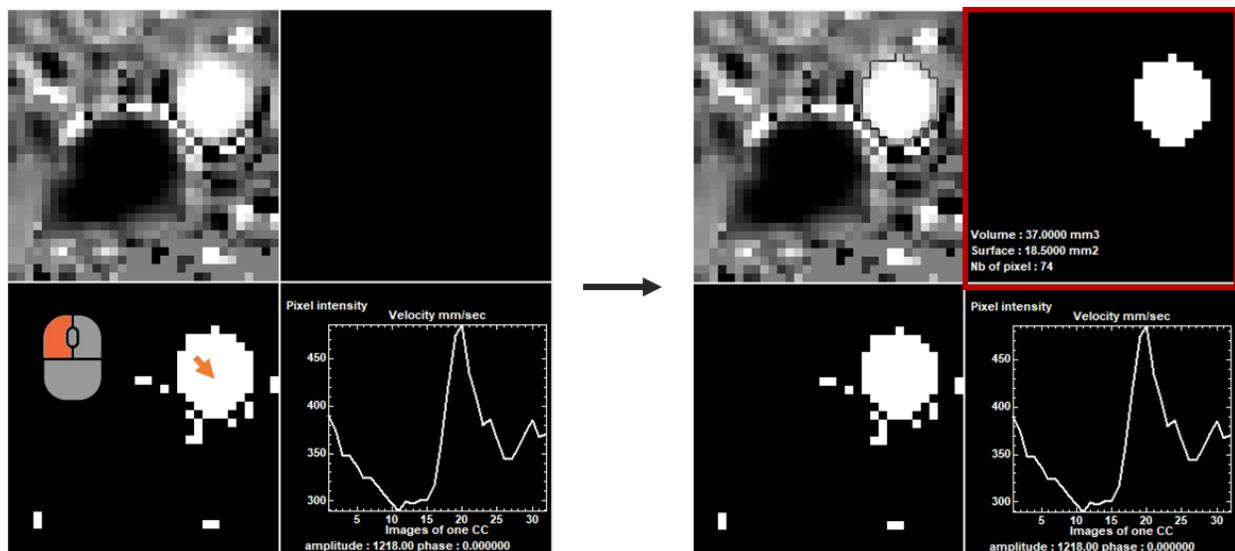


500



C Confirmation ROI

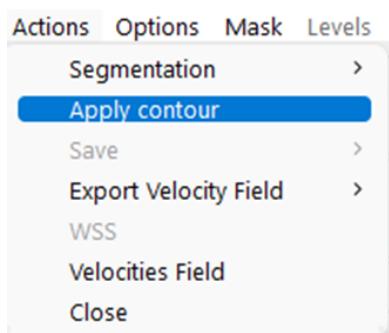
Click the ROI in WIN.Info_L and at the same time, the ROI will be synchronized to WIN.ROI, and you can continue to make manual modifications to the ROI in WIN.ROI. Refer to 4.2 for details.



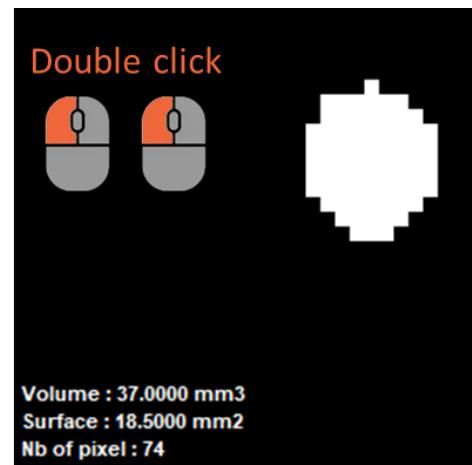
In WIN.ROI, some information of this ROI will be displayed at the same time, Surface: the area size of the ROI, Nb of pixel: the number of reconstructed pixels contained in the ROI, Volume: the product of Surface and the thickness of the slice.

D Apply ROI

After confirming the accuracy of the ROI you can apply the ROI, there are two ways for application, by clicking “Actions” -> “Apply contour” in the menu bar or by double-clicking the left mouse button inside the WIN.ROI.



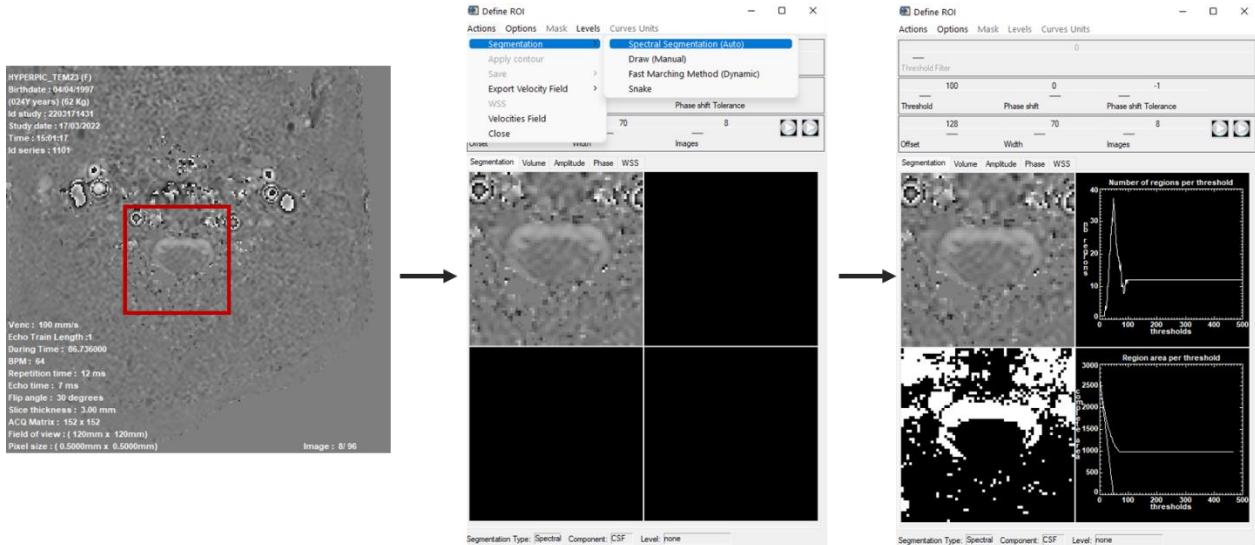
OR



At this point, the semi-automatic segmentation about blood vessels is completed.

4.3.2. For CSF segmentation

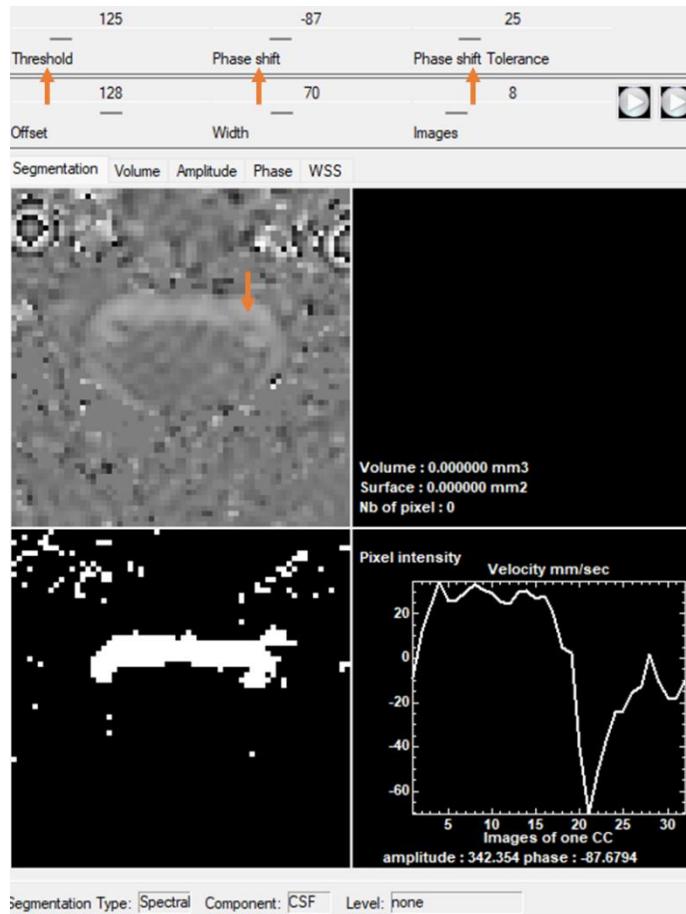
We take the CSF segmentation at the C2-C3 level as an example. The segmentation process is similar to that of vessel segmentation except for the step of adjusting the threshold value. Similarly, first check if the “Component” in the bottom info bar is CSF, if not, we need to correct it (3.4.3).



A Click on the target CSF

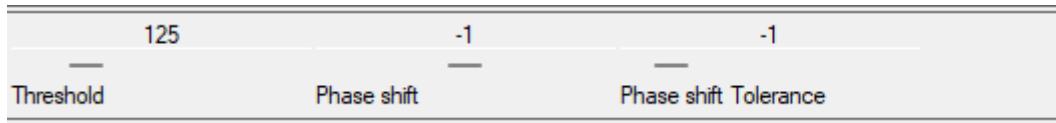
By clicking the left mouse button on the CSF in WIN.Display, the software first extracts the velocity signal of this pixel, then performs a Fast Fourier Transform on this signal to obtain the frequency domain signal, and automatically adjusts the three parameter sliders by analyzing the amplitude and phase of the first frequency component (f_1) of the frequency domain signal.

The difference here compared to the vascular one is that there are 3 parameters that need to be adjusted to segment the CSF.



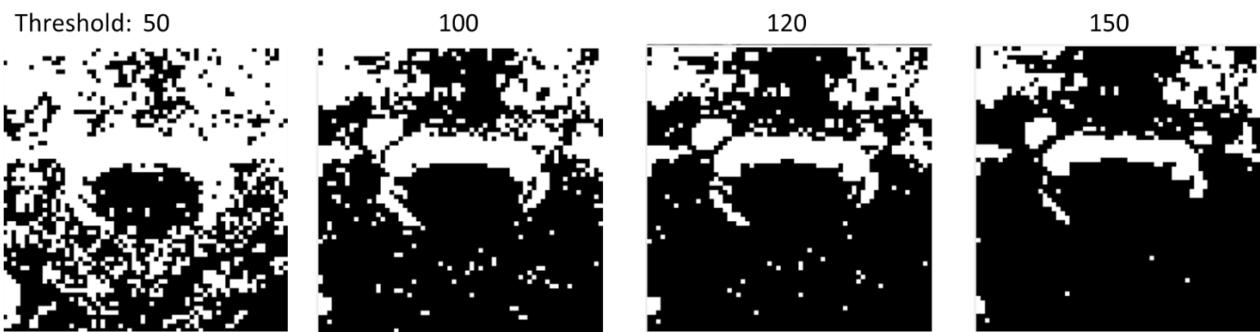
B Adjustment threshold

To allow users to make better adjustments, here is a brief explanation of the meaning of the three sliders:



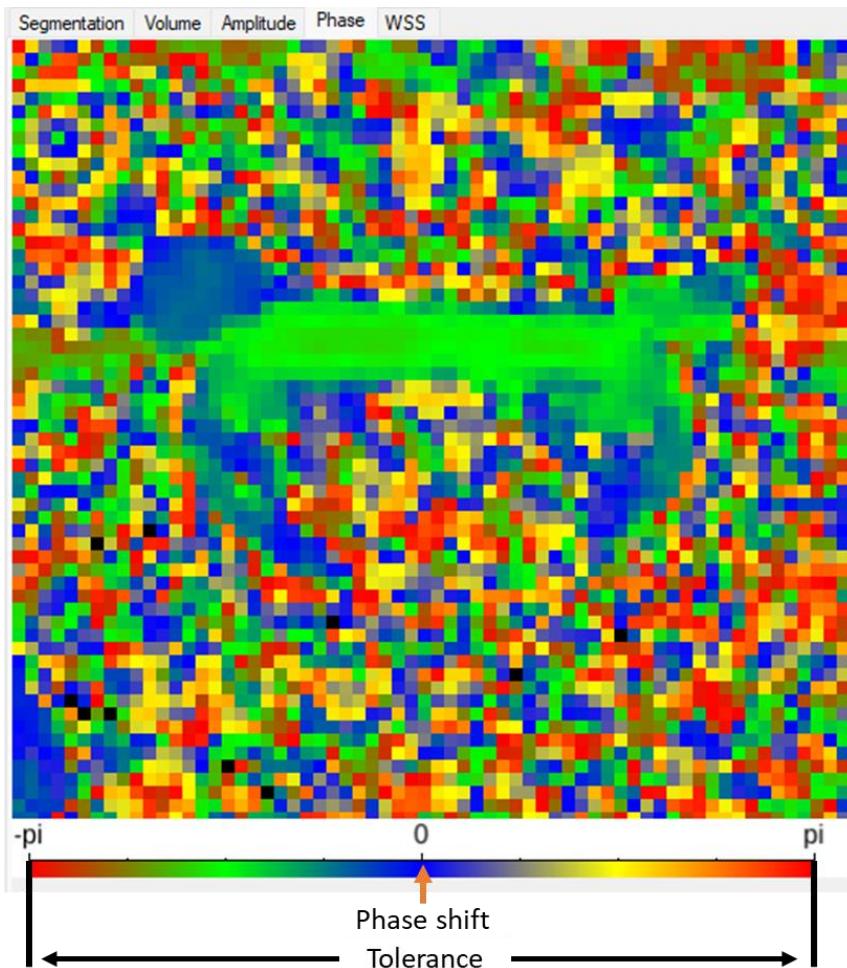
The software identifies each pixel based on the first component (f_1) characteristic of the spectral signal of their velocity signal. f_1 can be thought of as the heartbeat frequency component (since the period of the signal is the same as the heartbeat period). f_1 is a complex number containing both amplitude and phase values, hereafter noted as f_1 -amplitude and f_1 -phase.

“Threshold” denotes the threshold value of the f_1 -amplitude. By adjusting this “Threshold”, it is possible to remove some tissues with small heartbeat frequency components. As shown in the figure below, without considering the phase threshold (Tolerance = -1), the CSF can be roughly segmented by just adjusting the “Threshold”. The general shape of the CSF is basically visible when the “Threshold” is set to 100, but there is still some noise interference around it.

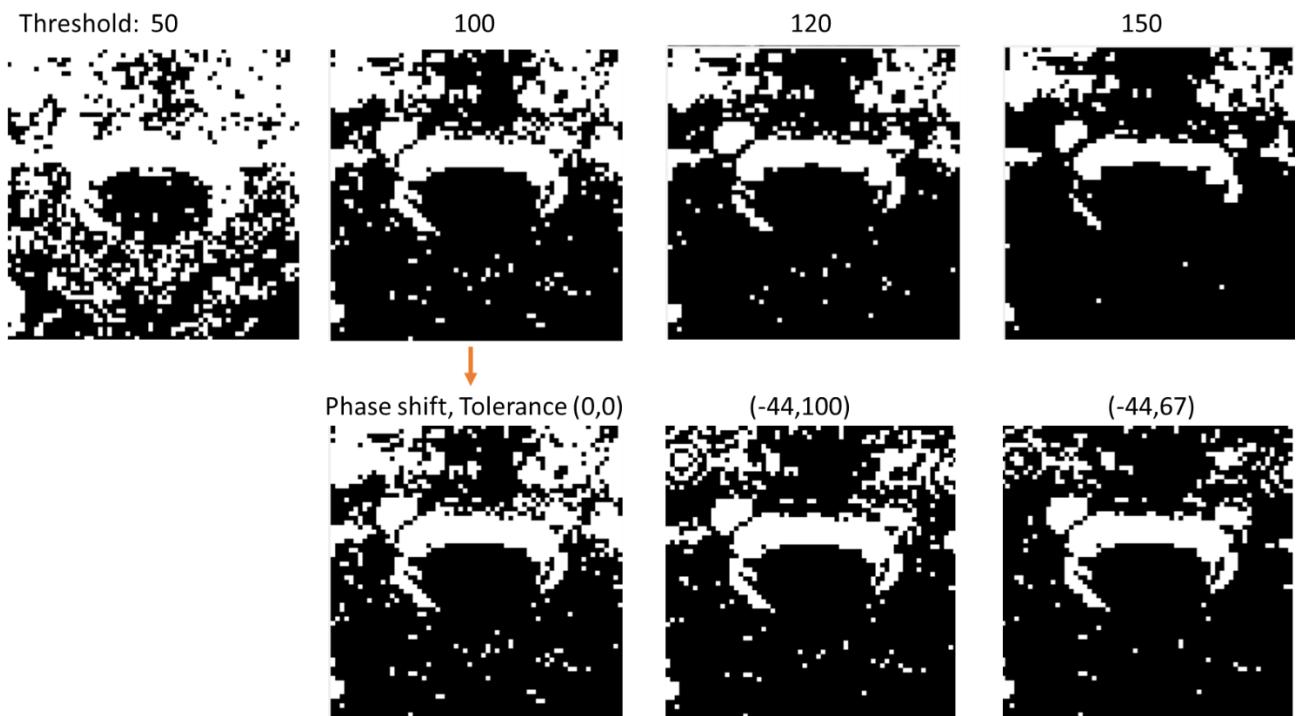


The “Phase shift” and “Phase Shift Tolerance” (later called Tolerance) sliders set thresholds for the f1 phase, more specifically, the two sliders are more like a phase band-pass interval filter.

To make it easier to understand, we use the image in the “Phase” tab for explanation. The color of each pixel in this image represents its f1-phase value, the “Phase shift” represents the center of the phase bandpass interval, and the “Tolerance” is the width of the phase bandpass interval. By adjusting the two sliders we can remove the pixels with different f1-phase values from the CSF.

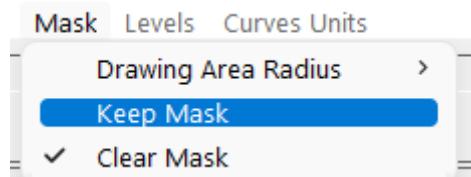


As shown in the figure below, we further optimize the segmentation results by setting the f1 phase interval threshold with Threshold=100. It can be seen that adding the f1 phase interval threshold can effectively remove the influence of other tissues on the segmentation results, while ensuring the accuracy of the ROI of CSF.



C Confirmation ROI

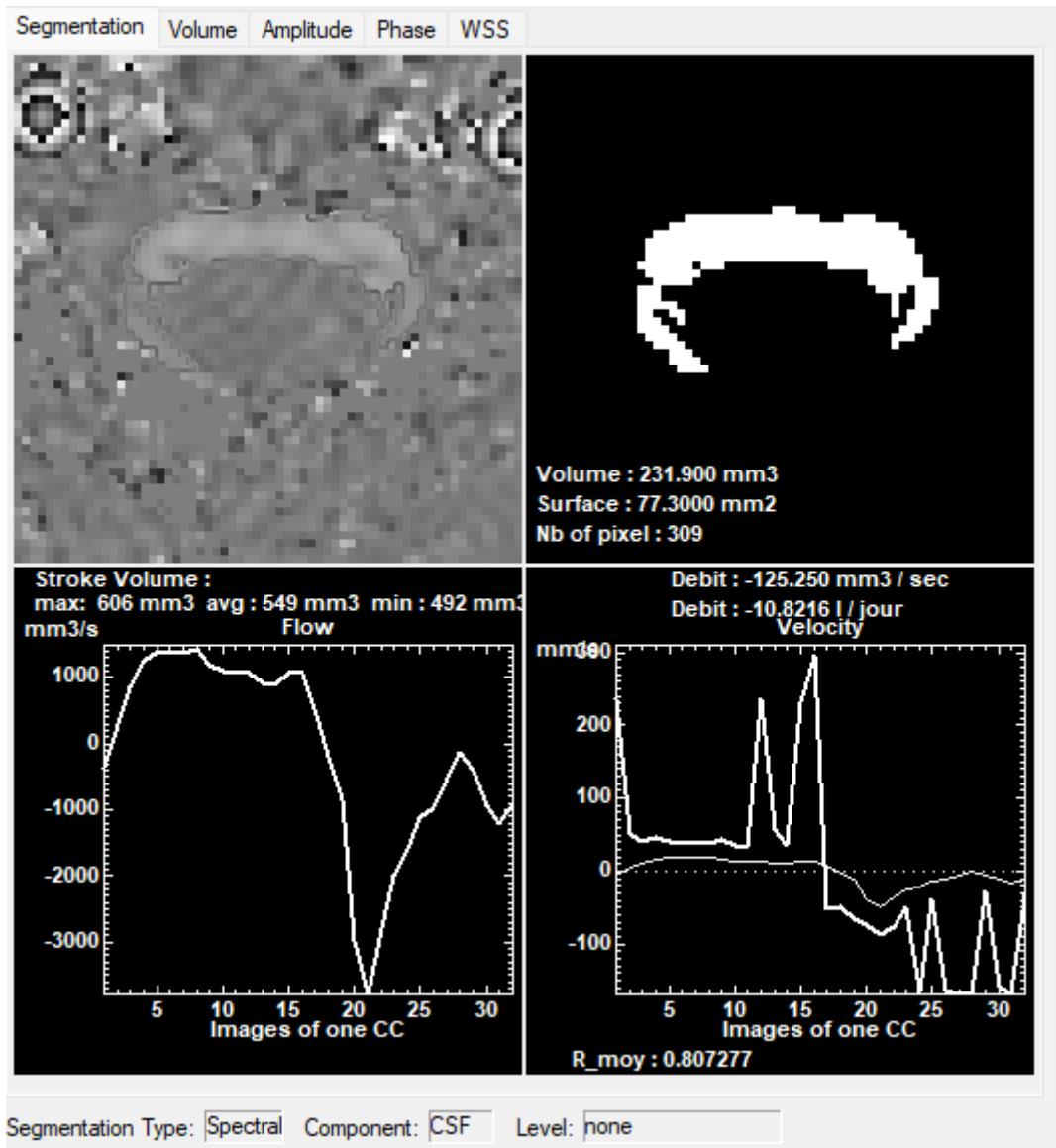
The same as vessel segmentation, click on the ROI of the CSF in the WIN.Info_L to copy it in the WIN.ROI. It should be noted here that sometimes the CSF ROI is disconnected, and we only need to make multiple clicks on the separated ROI in WIN.Info_L to sum the ROI in WIN.ROI. If the selected ROI in WIN.ROI disappears after clicking ROI in WIN.Info_L, it means the mask clearing mode is selected, you can re-enable the multi-select ROI function through the menu bar “Mask” -> “Keep Mask”.



ROI can also be adjusted manually for CSF's ROI in WIN.ROI, more details in 4.2.

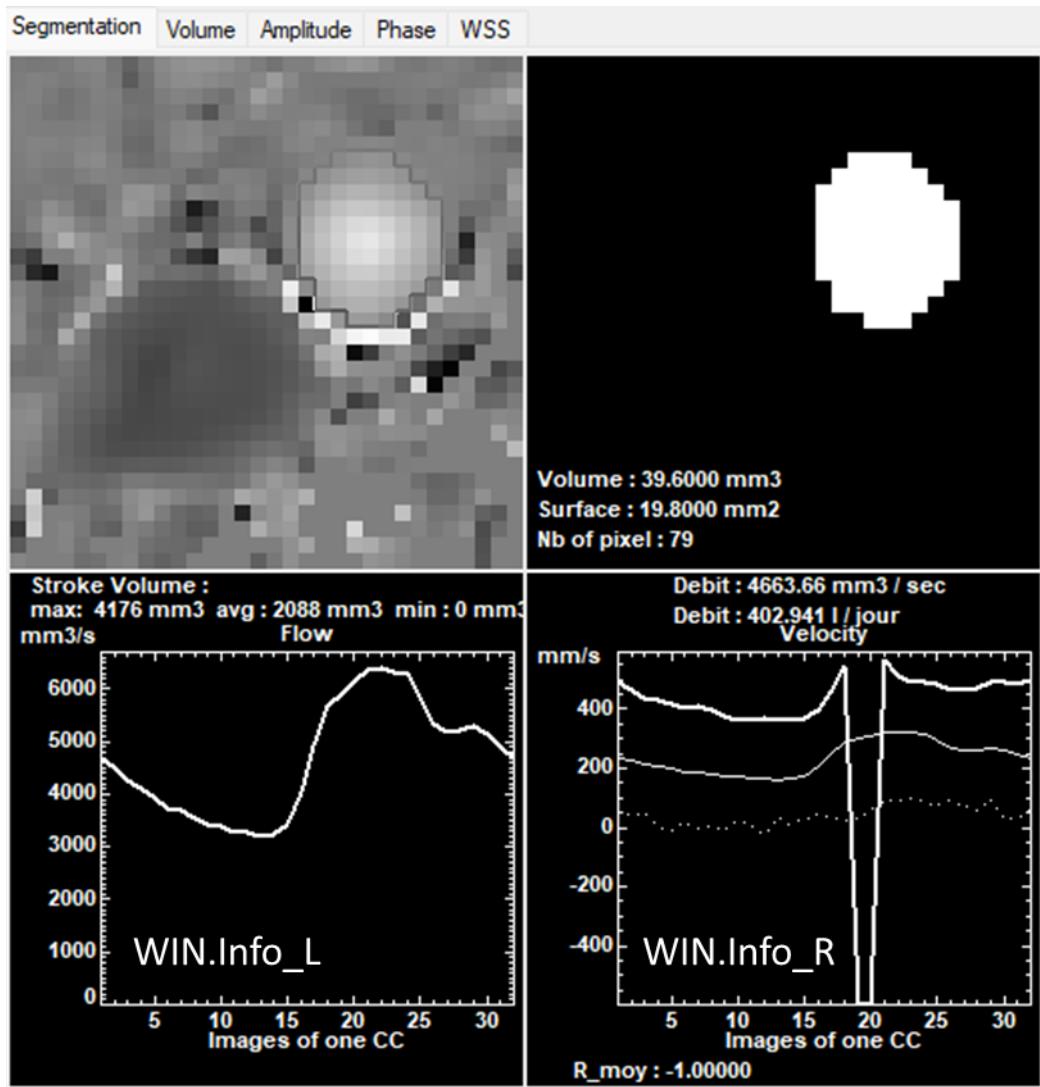
D Apply ROI

Apply the ROI by clicking on “Actions” -> “Apply contour” in the menu bar or by double-clicking the left mouse button in WIN.ROI. Afterwards, the flow rate curve and the velocity (maximum, minimum and average velocity) curves of the ROI will be displayed in WIN.Info_L and WIN.Info_R.



5. Signal observation

Still taking ICAR as an example, after completing the segmentation and applying ROI, the software automatically generates various signals of ICAR and displays them in different windows. In this chapter, the windows for the various parameter signals are described. Note that the velocity and flow rate signals need to be calibrated in order to be used, and we will describe how to perform signal calibration in Chapter 6.



5.1. Flow rate curve window WIN.Info_L

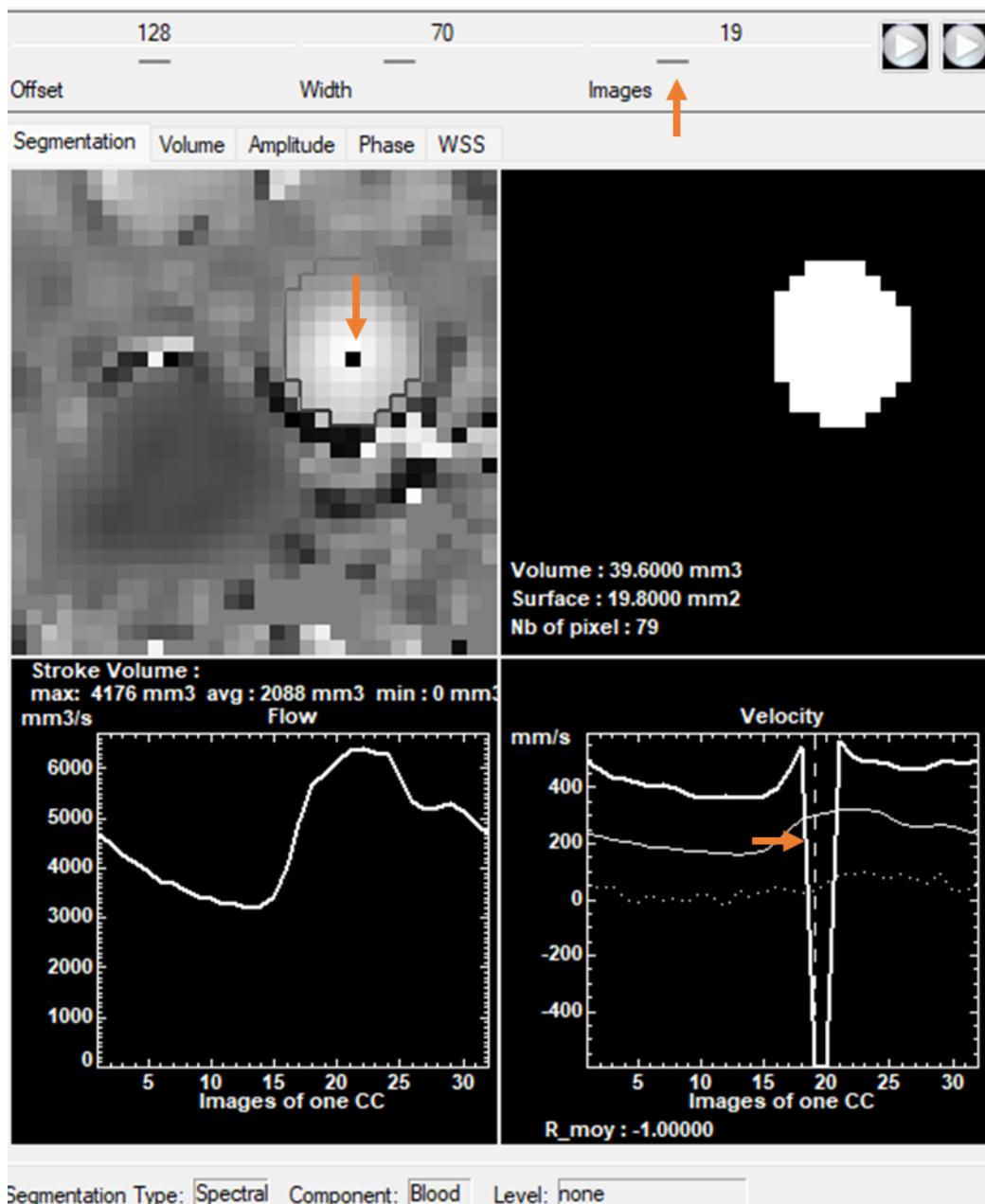
The flow curve of the ROI is displayed in WIN.Info_L. Each flow data point is obtained by multiplying the ROI area and the average velocity of the pixels within the ROI. At the top of the curve is also displayed the stroke volume parameter, which is the integral of the flow rate over positive and negative values. “max” indicates the maximum Stroke volume value (here the Stroke volume of the artery is positive, so “max” indicates the stroke volume of the artery), “avg” indicates the average of Stroke volume positive and Stroke volume negative, which is a parameter for CSF analysis.

5.2. Velocity curves window WIN.Info_R

Three velocity curves are shown in WIN.Info_R: the bolded line indicating the maximum absolute velocity within the ROI, the line indicating the average velocity within the ROI, and the dotted line indicating the minimum absolute velocity within the ROI.

In the velocity map we can observe if there is noise or if there is aliasing within the ROI. In this example, we can see that the maximum value of ROI in the 19th and 20th images is negative, which is against common sense. There are two possible reasons for this. The image segmentation process did not segment the ROI accurately, causing the ROI to pick up the noise around the vessel. The second possible reason is that there is aliasing in

this artery. We can confirm by dragging the images slider to the 19th phase contrast image, As shown in the figure, the artery does have a aliasing phenomenon and requires a de-aliasing operation, see 6.2 for de-aliasing.



While dragging the images slider, a vertical dotted line will be displayed in WIN.Info_R.

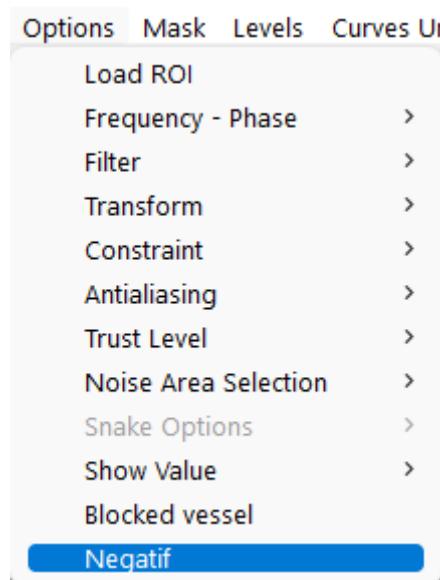
5.3. Volume and Amplitude Tabs

Click the “Volume” tab to see the Volume curve. Click on “Amplitude” tab to see the pixel intensity of amplitude image curve within ROI.



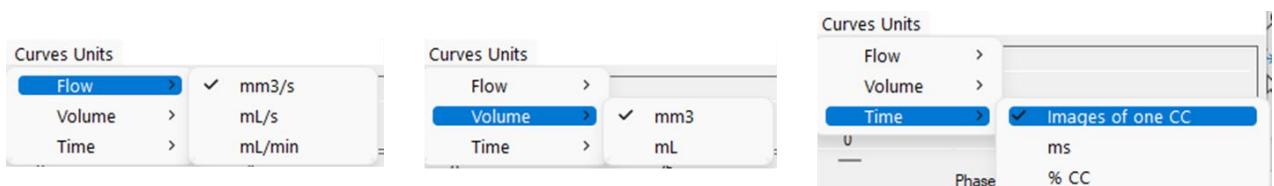
5.4. Positive and negative switching

For processing veins, we want to get positive values for both velocity and flow rate in order to facilitate later analysis. In this case it is possible by clicking on “Options” -> “Negatif” in the menu bar.



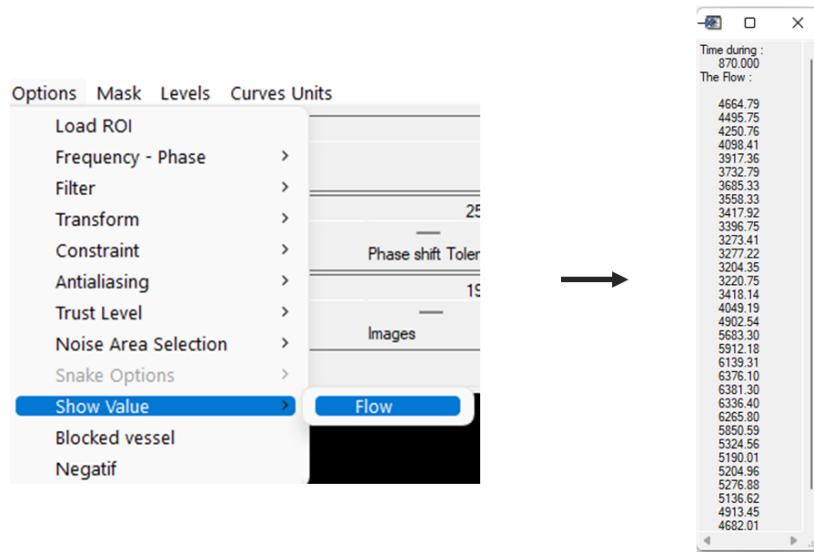
5.5. Changing units

You can change the units of Y and X values for Flow rate and Volume curves by clicking “Curves Units” -> in the menu bar. The default unit of X-axis is the serial number of the image, the default units of flow rate is mm³/s and for volume is mm³.



5.6. Showing the flow signal directly

Sometimes we want to copy the 32 values of the flow signal directly, by clicking the “Options” -> “Show Values” -> “Flow” button in the menu bar, the software can display the flow curve directly into the text window for us to copy directly.



6. Signal calibration

After applying ROI, the signal needs to be corrected for background field and for the presence of aliasing, a dealiasing operation is required. This chapter will introduce these two operations in detail.

6.1. Background field correction

The fundamental method of velocity quantification is to use the pixel intensity and VENC value in the phase-contrast image to calculate the flow velocity, and for a 255-grayscale image a pixel intensity of 127 indicates a velocity of 0. This means that the pixel intensity (of phase contrast image) of a stationary tissue should be 127, but in real situations, due to the eddy current effect or uneven magnetic fields, etc., the phase-contrast image always has a certain phase shift, which means that the pixel intensity cannot accurately derive the true velocity. This phenomenon cannot be avoided. Therefore, after completing image segmentation, background field correction must be performed. Especially for the quantization of CSF with small VENC, the smaller the VENC the more it is affected by the phase shift.

The correction method is based on our determination that the stationary tissue pixel intensity should have a theoretical value of 127, so we can simply use the difference between the stationary tissue pixel intensity and 127 as the phase shift value for the correction. For example, if we measure the average pixel intensity of the stationary tissue around the target vessel is 130, then it is known that the phase shift intensity is +3. We can obtain the correct flow data by adjusting the pixel intensity within the target vessel by -3.

In this software we only need to manually define the stationary tissue around the target and the software can automatically perform the background field correction. Due to the influence of magnetic field inhomogeneity, we should select the stationary tissue as close as possible to the target vessel. This is done by clicking on “Options” -> “Noise Area Selection” -> in the menu bar, and there are 5 options in this drop-down menu:

Active: Enable background field correction

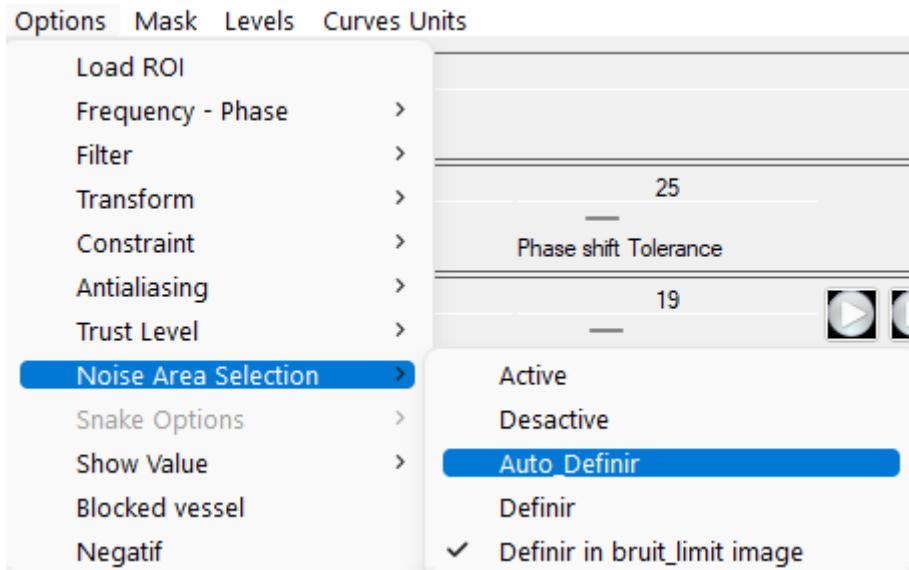
Desactive: Disable background field correction

Auto_Definir: Automatic selection of stationary tissue around the target vessel

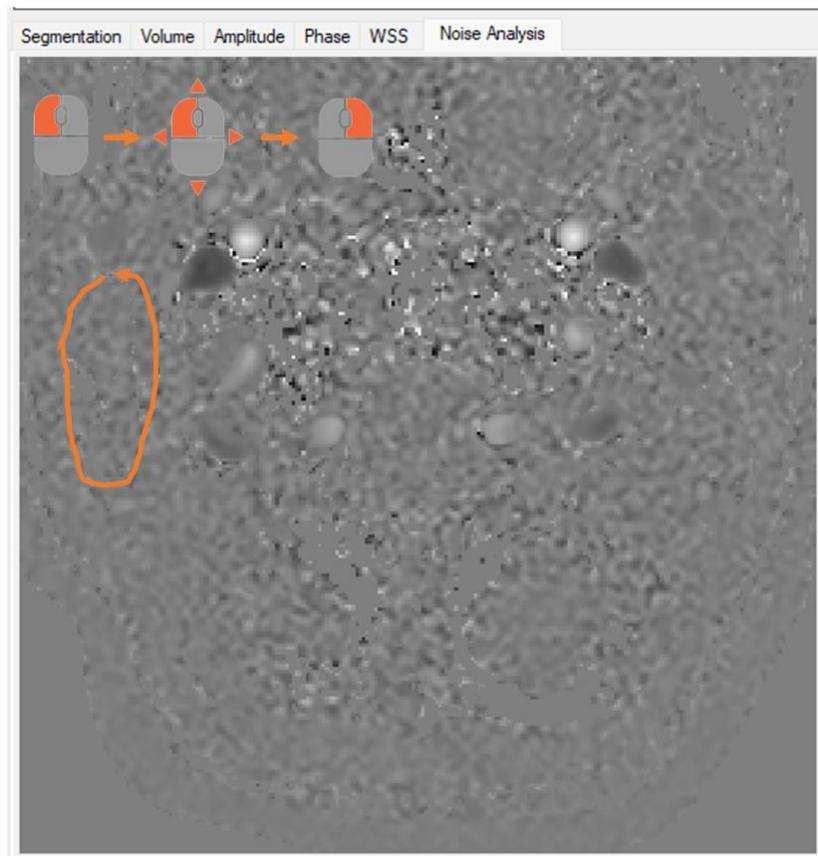
Definir: Selected stationary tissue on the phase contrast image

Definir in bruit_limit image: Selecting stationary tissue on a post-processed image

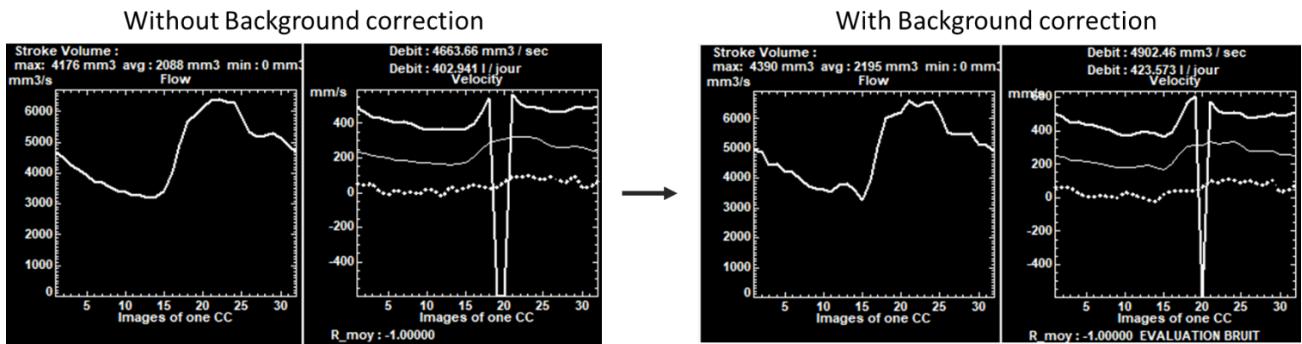
The robustness of the “Auto_Definir” and “Definir in bruit_limit image” algorithms is not very strong and needs further improvement, so we will not introduce them too much here.



Click Definir to enter the Noise Analysis tab for stationary tissue selection. Hold down the left mouse button and drag the mouse to draw the region of stationary tissue, then click the right mouse button to complete the selection of stationary tissue. After that, the software automatically performs background field correction according to the selected area frame by frame.



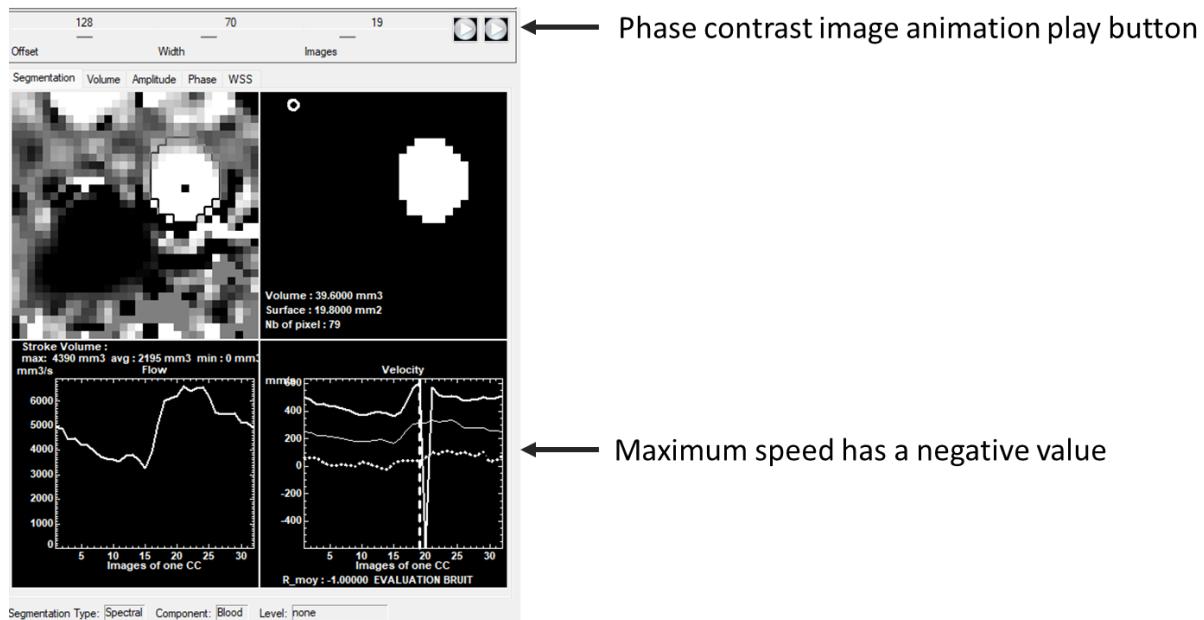
After the background field correction, we can see the changes of flow rate and velocity curve in WIN.Infos.



6.2. Aliasing correction

When the absolute flow velocity of the target vessel or the target CSF exceeds to the VENC, an aliasing effect occurs, which is shown by the phenomenon that the colors of the pixels appear to be inverted.

There are two ways to check for the existence of aliasing in the target vessel, the easiest and most accurate way is to watch the animation of the phase contrast image (3.4.1). Another way is to observe the maximum velocity curve, for example, for arteries, if the maximum velocity curve shows negative values on certain images, then there is a high probability for the presence of aliasing.



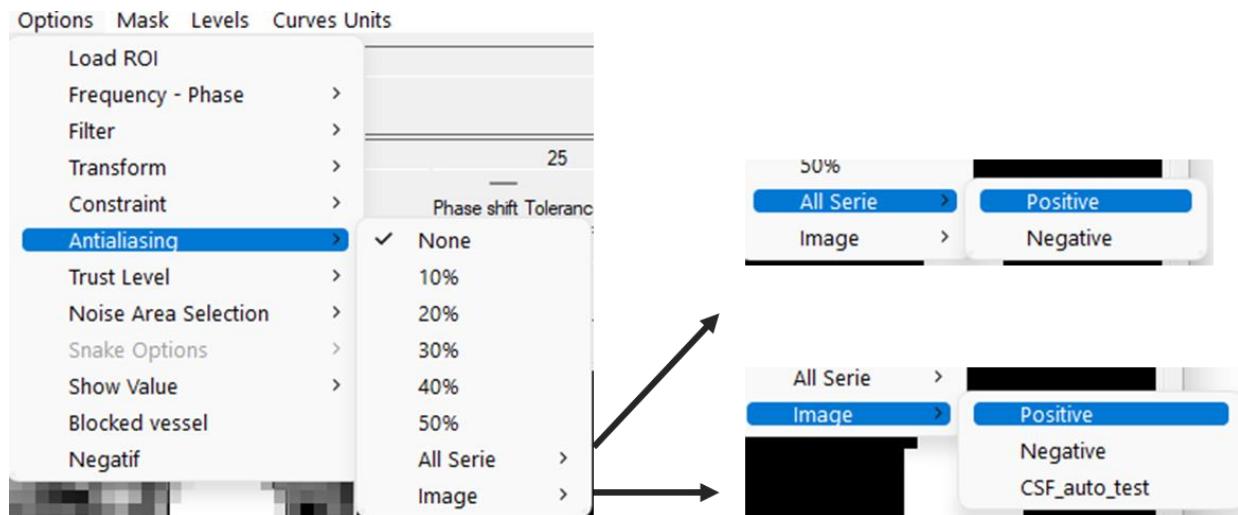
After determining the presence of aliasing in the target vessel, perform de-aliasing by clicking “Options” -> “Antialiasing” -> in the menu bar.

None: Disable de-aliasing correction

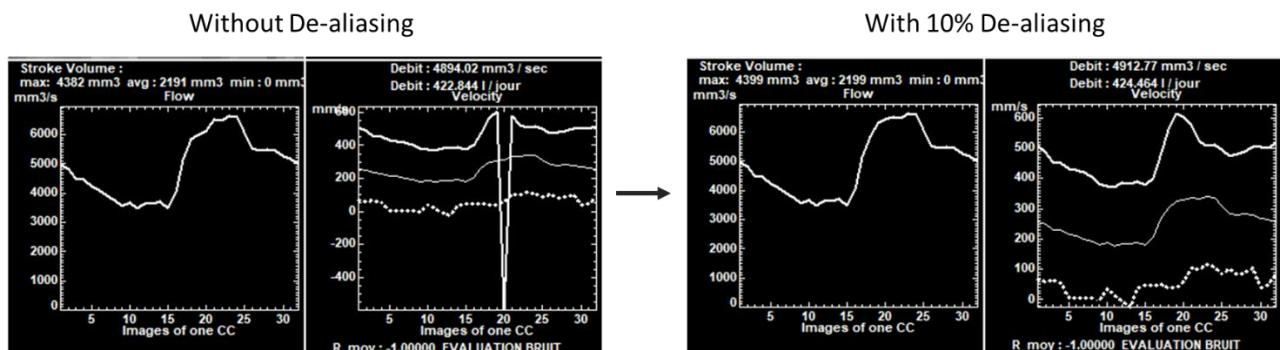
10%-50%: De-aliasing correction is applied to the pixels whose velocity exceeds the corresponding percentage of VENC. For example, if VENC = 60 cm/s, the real velocity of the pixel is 65 cm/s, which exceeds the VENC, so the measured velocity is -(60-(65-VENC)) = -55 cm/s. In this case, selecting the “10%” option will correct the aliasing.

All Serie: Setting all pixel velocities in the series to positive or negative. This is used primarily for arterial or venous de-aliasing corrections. It is important to note that using this correction method must ensure that there is no noise within the ROI, otherwise it will result in a large flow rate overestimation.

Image: Only correct the velocity of the current phase contrast image to “Positive” or “Negative”, mainly used for CSF de-aliasing correction. “CSF_auto_test” is a beta function that set the velocity to positive or negative based on the average velocity within the ROI of each image.



In this example we can choose “10%” for “All Seire” -> “positive” to do the de-aliasing for this ICAR.



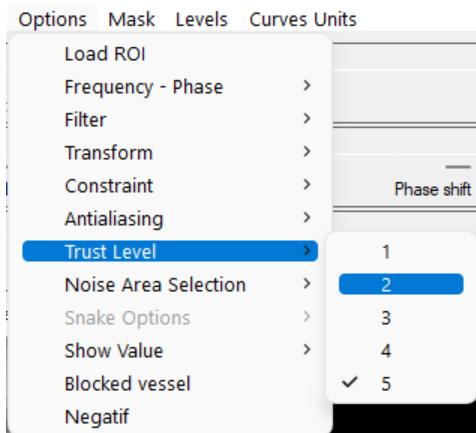
It can be seen that the corrected maximum absolute velocity changes from a negative value to a positive value.

7. Data storage

The data generated during the post-processing process is saved in a folder named after the patient. This chapter describes in detail how data saving is performed and how to view these data.

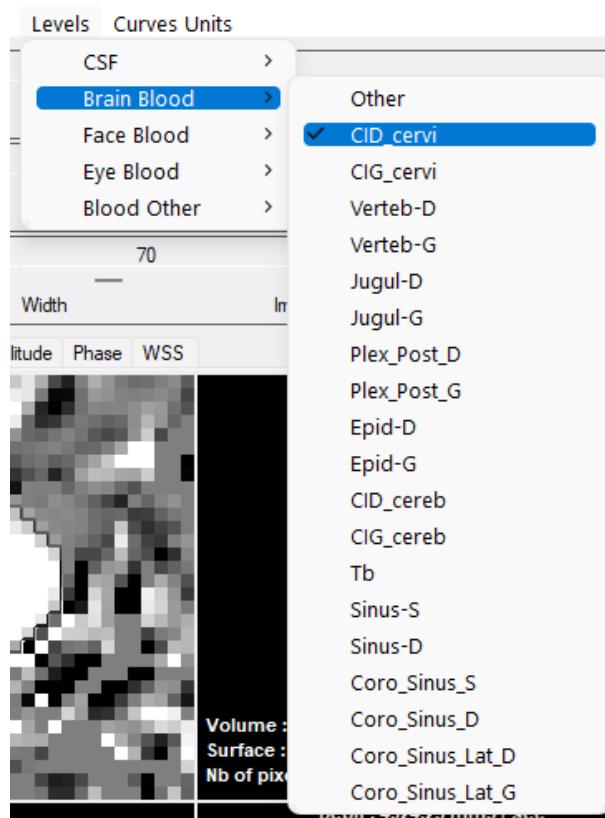
7.1. Setting the trust level

Optional operation, sometimes we are not satisfied with the post-processing result due to image quality or too small blood vessels, etc. In this case, we can modify the trust level of the data (default level is 5). To do this, select “Options” -> “Trust Level” -> select a corresponding trust level.

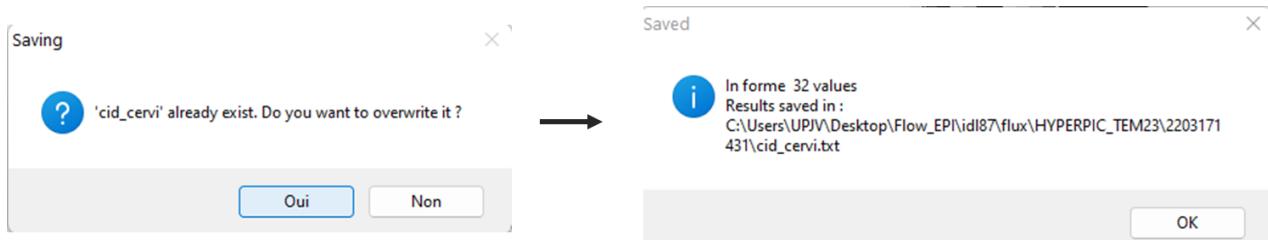


7.2. Naming and saving data

Find the name of the corresponding target vessel or CSF in the “Levels” of the menu bar, for example, the right internal carotid artery in the cervicale section we can choose CID-Cervi (carotide interne droite du Cervical). As there are some French naming conventions in the software, usually Droit corresponds to Right and Gauche corresponds to Left.

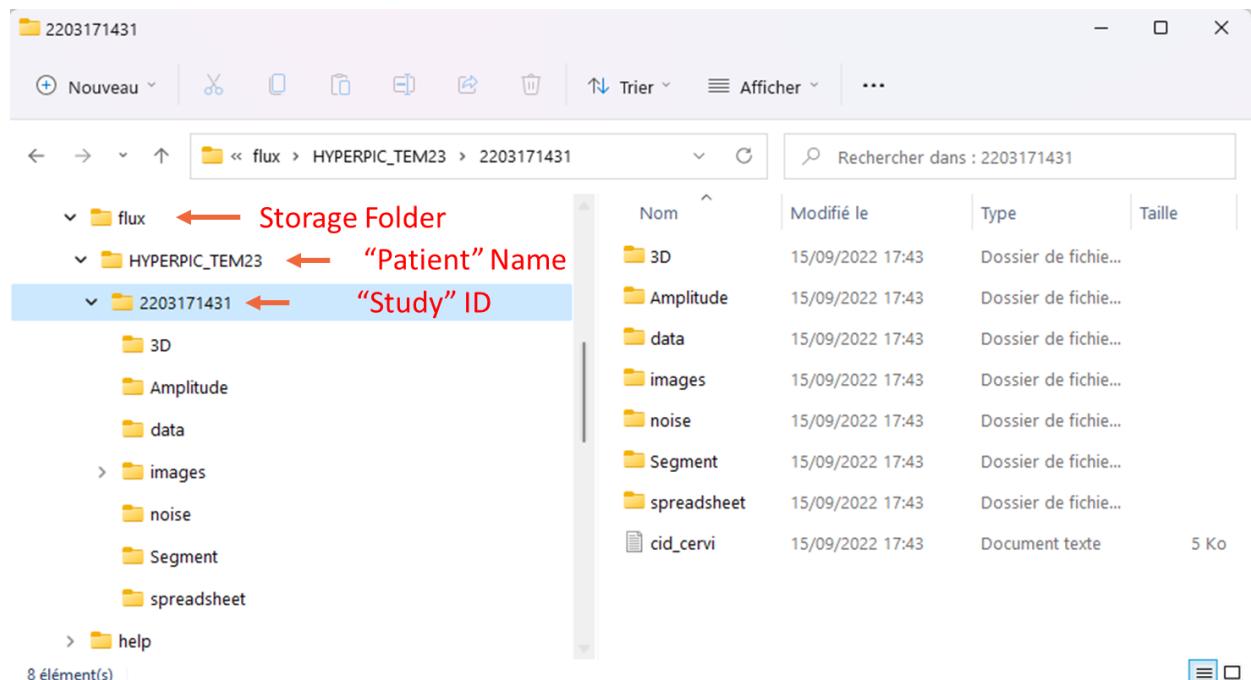


You can click Other to name it by yourself. After naming, the software automatically saves the result to the corresponding directory and pops up a message box. If the named result already exists, it will ask whether to replace the original result.

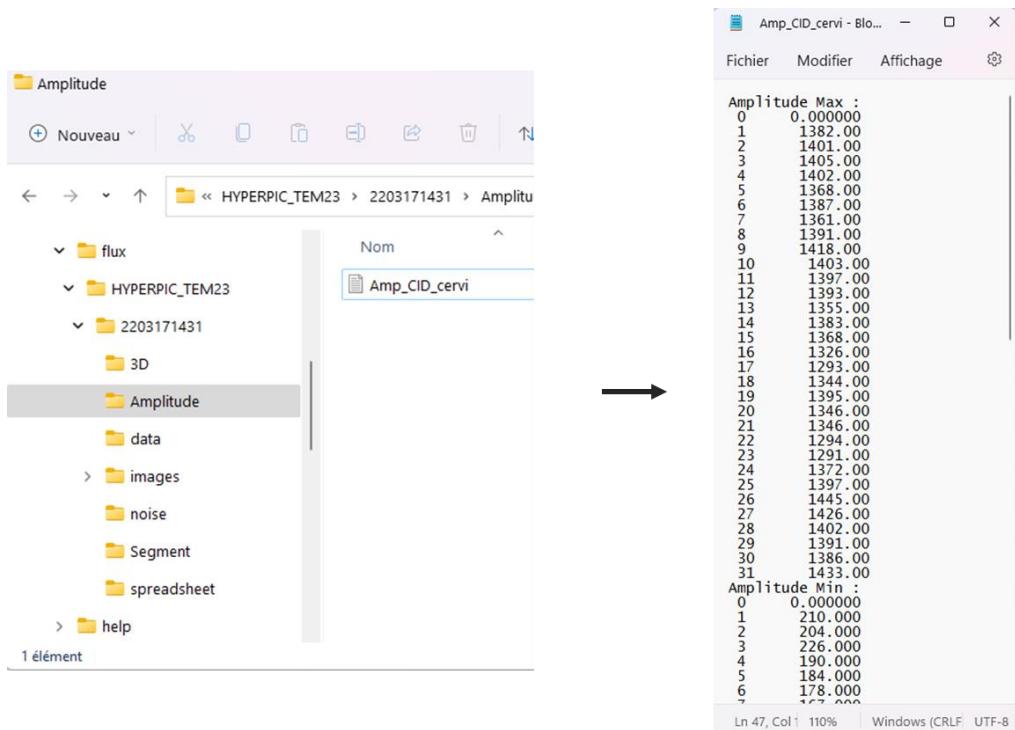


7.3. Introduction of the saving data

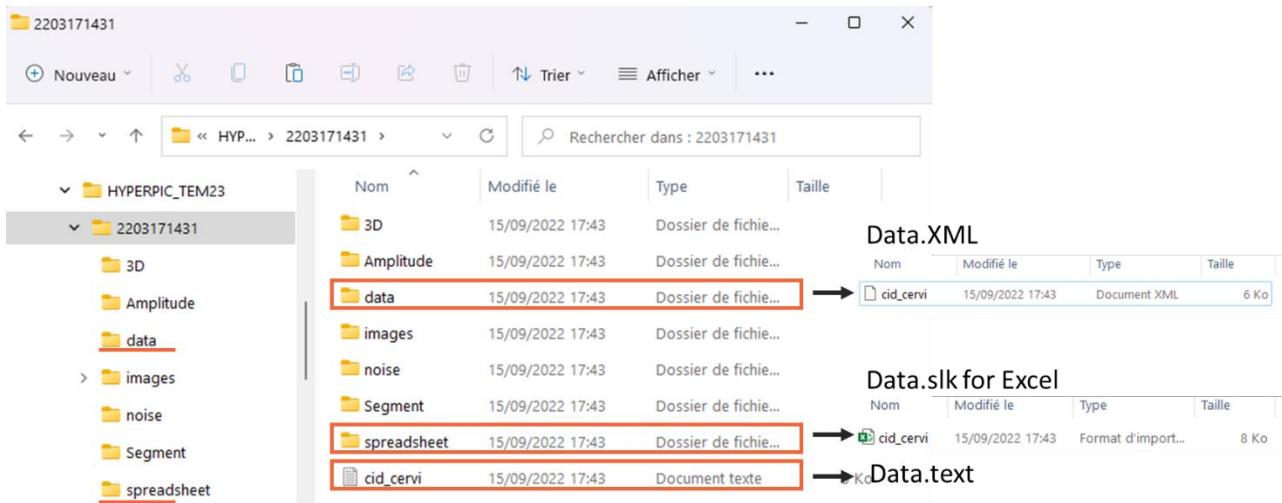
The software will create a corresponding “Patient’s name” folder in the save directory, then create a folder named after Study’s ID value in the Patient folder, and then save all the result data in that folder.



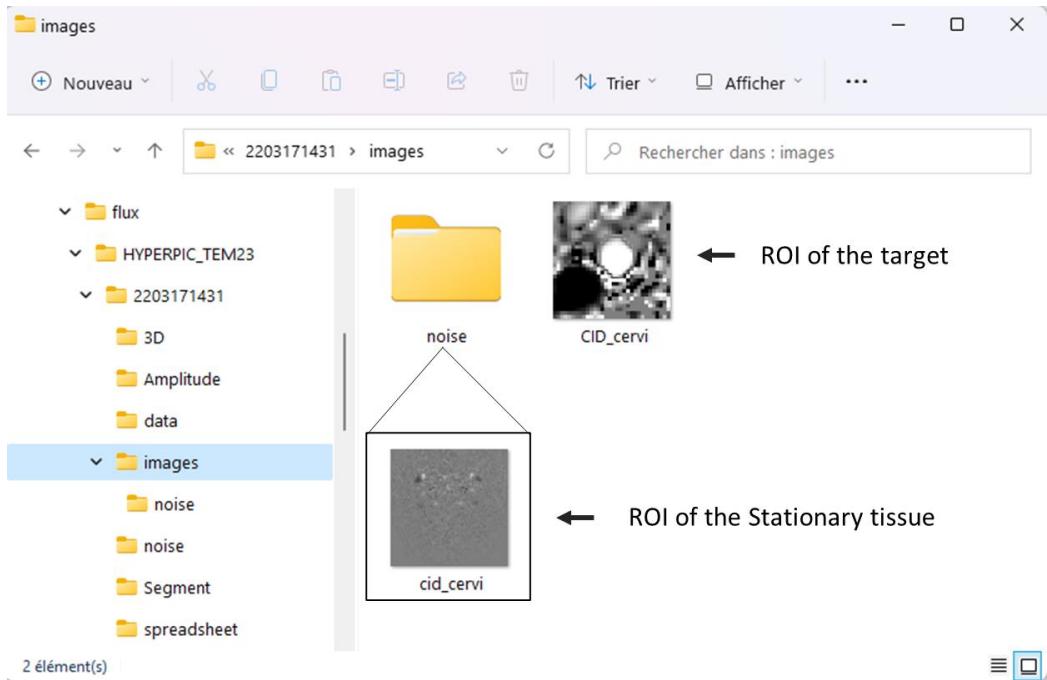
- The Amplitude folder contains pixel intensity (maximum, average, minimum) curves of amplitude image for the target vessel (32 values).



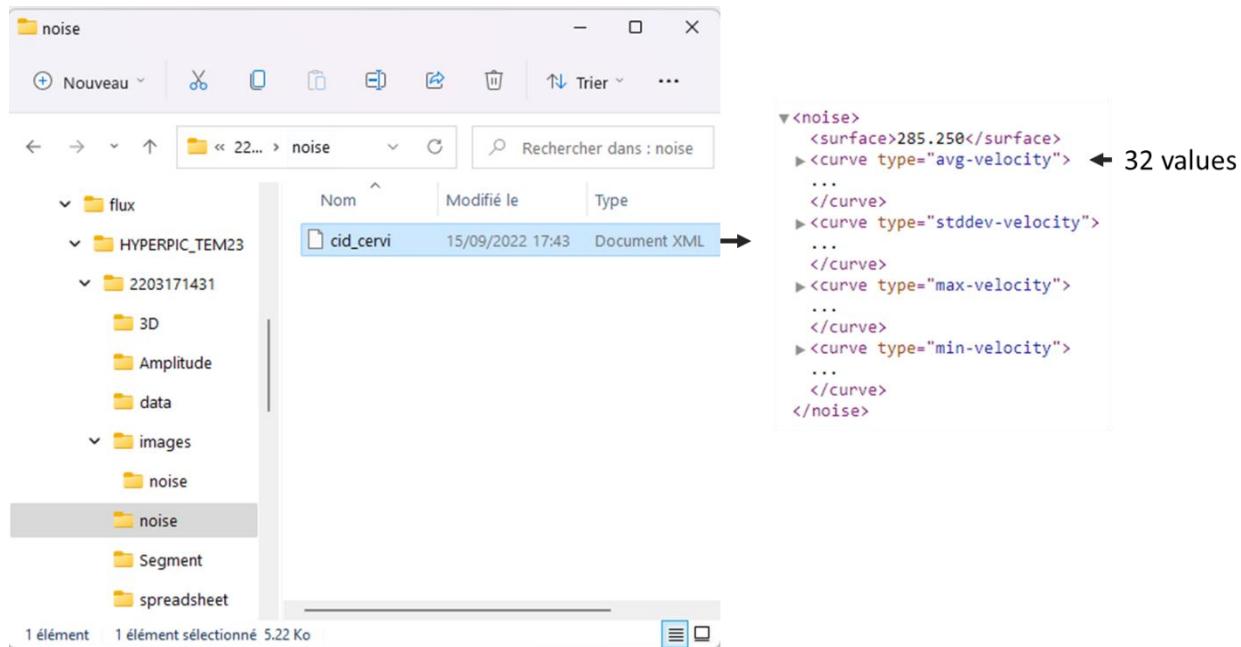
- The most important data, such as flow curves, surface area, velocity and other information are saved together and the software creates 3 different types of save files for these results. These are XML files saved in the “data” folder, SLK files saved in the “spreadsheet” folder, and text files. We will describe these results in detail in the next section 7.3, using the .text file as an example.



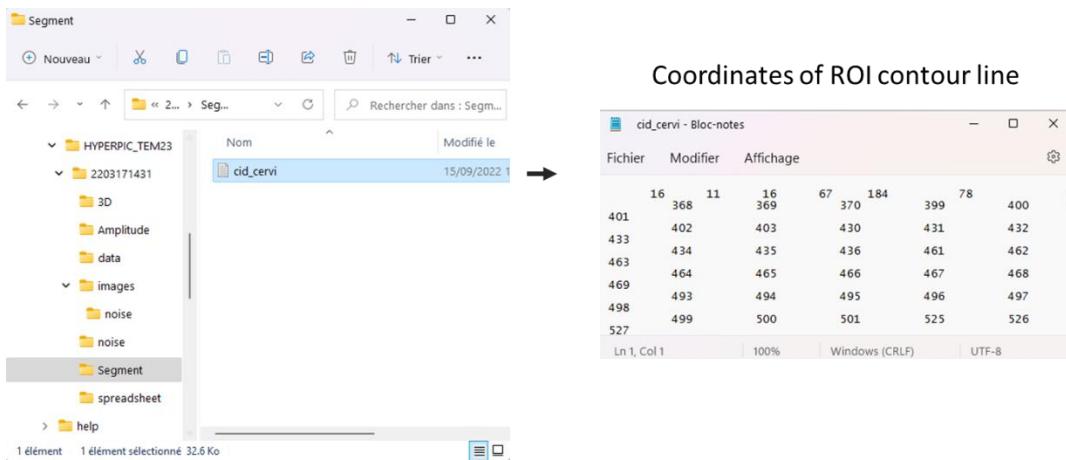
- Images folder contains the ROI images of the target vessel or CSF, and the noise subfolder, which contains the stationary tissue ROI images of the corresponding target vessel or CSF.



- Noise folder contains an XML file that includes the velocity information of the stationary tissue ROI. Includes the average pixel velocity – “avg-velocity”, maximum velocity – “max-velocity”, minimum velocity – “min-velocity” and the velocity standard deviation – “stddev-velocity” within the stationary tissue ROI. The number of data points are the same as the number of phase-contrast images.



- Segment folder contains the ROI data of each target vessel or CSF. This document is mainly used for software readout of ROIs and is not used for data analysis. The details of usage will be described in 8.1.



7.4. Introduction to data files

The main post-processing data for each target vessel or CSF is stored as the same structure in three files, i.e., “Text”, “Slk” and “XML”. We take the .text file as an example, the parameters of the data are detailed in the figure below. In the updated version (2022 dec), *stroke-volume max* and *stroke-volume min* have been replaced with *stroke-volume pos* and *stroke-volume neg*, denoting the positive stroke volume and negative stroke volume respectively.

The screenshot shows a text editor window with the title 'cid_cervi - Bloc-not...'. The file contains the following data:

EXAMEN	2203171431	Study ID
SERIE	1201	Series ID
NIVEAU	CID_cervi	Target vessels Name
I-confiance	5	Trust Level (5 is maximum)
stroke-volume max	4409.54	Maximum absolute Stroke volume (in this case is Stroke volume positive)
stroke-volume moy	2204.77	Mean Stroke volume (Stroke volume Positive, Stroke volume Negative)
stroke-volume min	0.000000	Minimum absolute Stroke volume
BPM	67	Heart rate: beats per minutes
duree positif	0.000000	
VMAX	0.000000	
TMAX%	0.000000	
TMAXms	0.000000	
VMIN	0.000000	
TMIN%	0.000000	
TMINms	0.000000	
D_MAX	6538.02	Maximum Flow rate. D = Débit; Débit (fr) = flow rate (eg)
TD_MAX%	62.3100	Time position % of the Maximum Flow rate = TD_Maxms / cardiac period (%)
TD_MAXms	558.000	Time position (ms) of the Maximum Flow rate
D_MIN	3428.20	
TD_MIN%	43.4650	
TD_MINms	389.239	
INTER1_Vmoy	0.000000	
INTER2_Vmoy	0.000000	
INTER3_Vmoy	0.000000	
INTER4_Vmoy	0.000000	
T_SYSY_Vmoy	0.000000	
indi_acceleration	18.4273	
INDI_RESISTANCE	1.52539	
INDI_PULSATIL	0.630068	Pulsatility index: calculated by (Max flow rate – Min flow rate) / mean flow rate
INDIC_ELASTIC	0.000000	
TYPE_SEUIL	PHASE	
SEUIL	217	
SEUIL_art	0	
SEUIL_vei	0	
DEBIT_Moy_1/j	425.455	Flow rate Moyenne (L/day)
DEBIT_mm3/sec	Flow rate curves (32 values) unite: mm ³ /s	
-----	4976.34	
-----	4795.85	
-----	4611.98	

Then there are the flow rate curve, ROI surface curve, Volume curve and the time axis (ms).

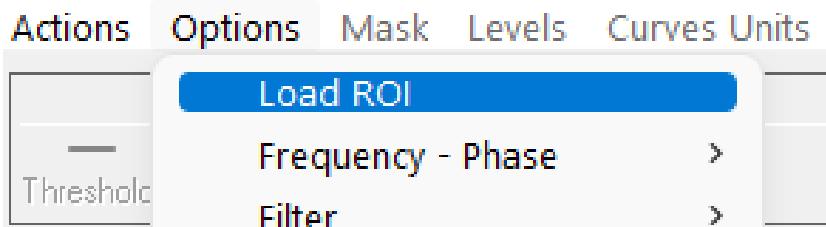
DEBIT_Moy_1/j	425
DEBIT_mm3/sec	
4976.34	
4795.85	
4611.98	
4591.88	
4311.56	
4115.55	
3998.72	
3809.27	
3618.33	
3548.34	
3512.83	
3827.38	
3585.67	
3644.94	
3434.58	
4114.64	
5074.37	
5943.36	
6370.44	
6443.76	
6537.20	
6383.26	
6429.94	
6498.03	
6049.10	
5641.03	
5509.78	
5477.43	
5378.68	
5409.26	
5029.02	
4903.55	
SURFACE_mm2	19.5000
VOLUME_DPL_mm3	0.000000
	133.393
	261.555
	387.249
	509.686
	624.891
	736.016
	843.572
	945.891
	1044.12
	1140.19
	1238.07
	1341.17
	1439.52
	1537.66
	1633.32
	1747.24
	1886.51
	2048.21
	2221.39
	2397.23
	2575.10
	2749.91
	2924.85
	3101.94
	3269.93
	3426.05
	3576.88
	3726.60
	3873.95
	4021.57
	4162.80
Axe des Temps	0.000000
	28.0000
	56.0000
	84.0000
	112.000
	140.000
	168.000
	197.000
	225.000
	253.000
	281.000
	309.000
	337.000
	365.000
	393.000
	421.000
	449.000
	477.000
	505.000
	533.000
	561.000
	590.000
	618.000
	646.000
	674.000
	702.000
	730.000
	758.000
	786.000
	814.000
	842.000
	870.000

8. Data readout

After each post-processing, the software saves the segmentation results in the Segment folder to support later recall. Additionally, the software includes a result manager to facilitate data access. This chapter will introduce these two functions.

8.1. Load ROI

If the target vessel or CSF segmentation data has been saved before and you wish to reload the ROI, you can follow the procedure. In the CINE-PC interface, click “Options” -> “Load ROI” in the menu bar.

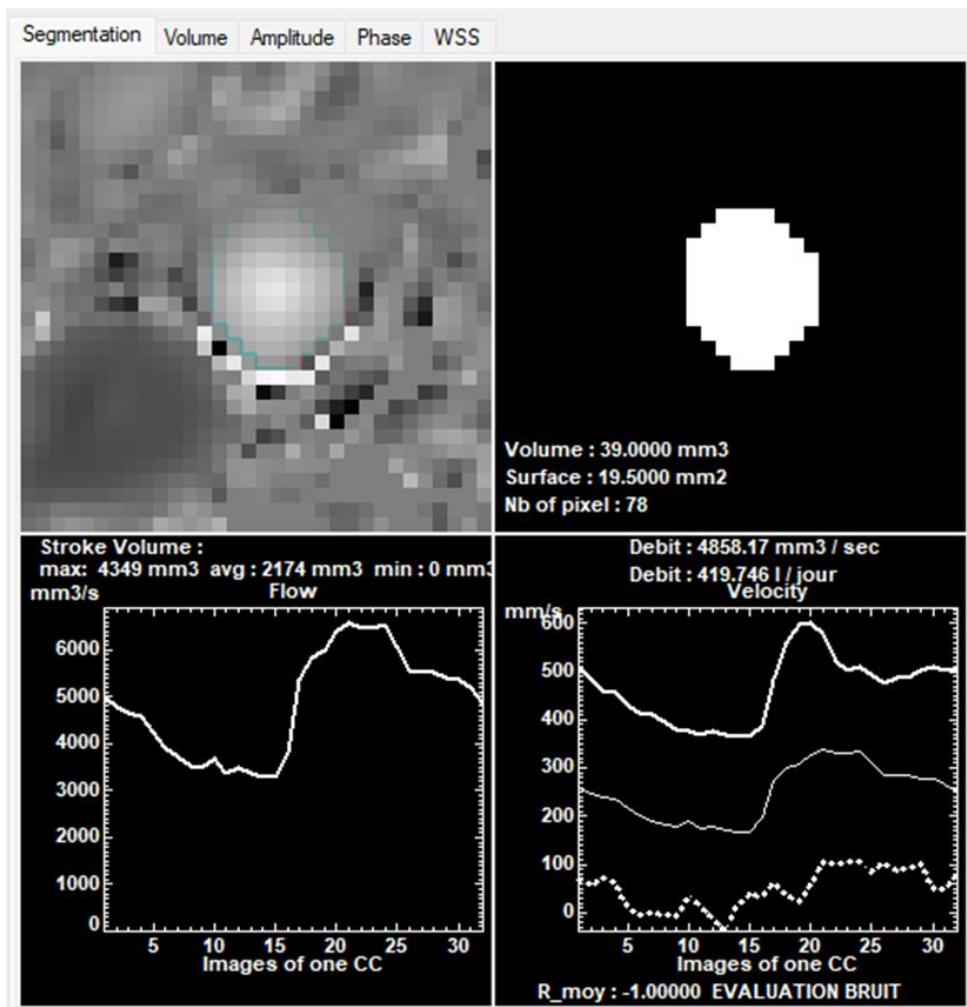


The software will define to the corresponding patient folder, we open the Segment folder, select the corresponding ROI data and click OK to complete the loading ROI process.

Nom	Modifié le	Type	Taille
3D	15/09/2022 17:43	Dossier de fiche...	
Amplitude	15/09/2022 17:43	Dossier de fiche...	
data	15/09/2022 17:43	Dossier de fiche...	
images	15/09/2022 17:43	Dossier de fiche...	
noise	15/09/2022 17:43	Dossier de fiche...	
Segment	15/09/2022 17:43	Dossier de fiche...	
spreadsheet	16/09/2022 10:37	Dossier de fiche...	
cid_cervi	15/09/2022 17:43	Document texte	5 Ko

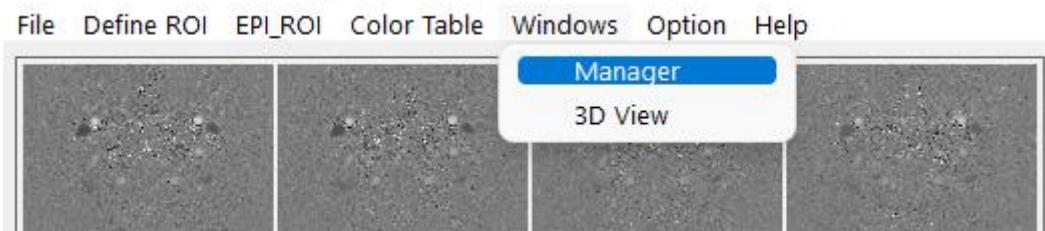
Note that in the current version, this feature is not yet perfect and requires a new signal calibration (background correction and/or de-aliasing) to display the information correctly.

Background field correction and de-aliasing needs to be done again



8.2. Results Document Manager

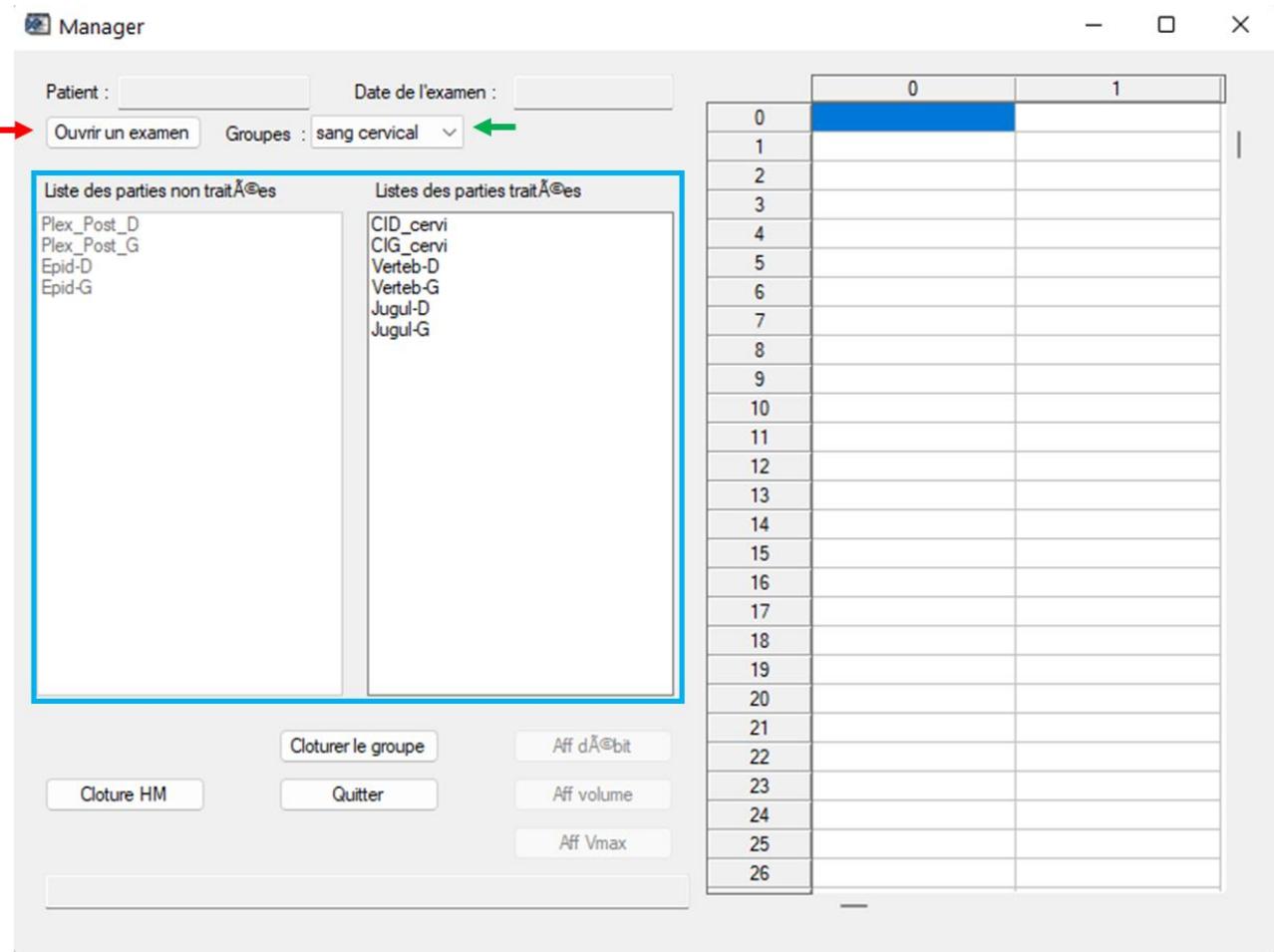
Each patient contains multiple target vessels or CSF data, often requiring multiple files to be opened when entering into other software. To simplify this process, the software provides a simple results file manager. Click “Windows” -> “Manager” in the menu bar of the main interface to bring up the manager interface.



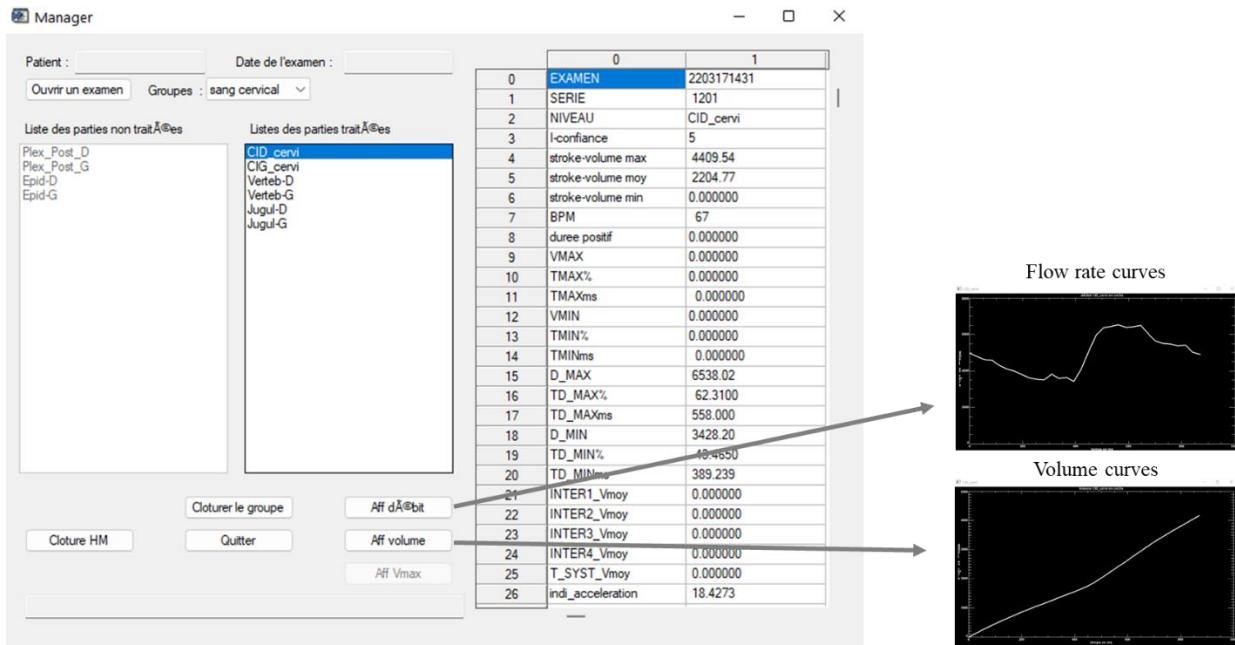
As shown below, “Ouvrir un examen” (red arrow) indicates that to open a patient's results folder, it should be noted that the “Study ID” folder needs to be selected here, because a patient maybe contains multiple “Study ID” folder. For example, here we open the “Study ID” folder “2203171431” under the “patient” folder “HYPERPIC_TEM23”.

The green arrow points to the drop-down menu for selecting a section. Here we select Sang Cervical.

The blue window shows the target vessels or CSF data under the current section, if post-processing has been done (data available) it will be shown in the list on the right side, otherwise, it will be shown in the list on the left, for example here we have post-processed 4 arteries (CIDs, Vertebs) and 2 veins (Juguls) of the Cervical section.



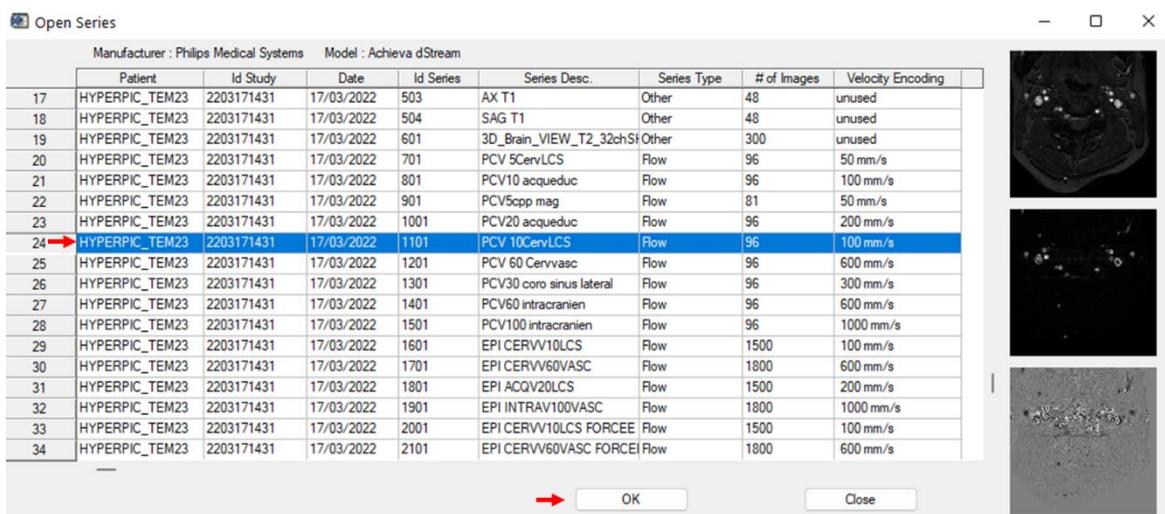
Select the target vessel or CSF and its result data will be displayed in the matrix on the right. We can copy it directly to other post-processing software. The buttons on bottom used to show the flow curve or volume curve of the target vessel or CSF.



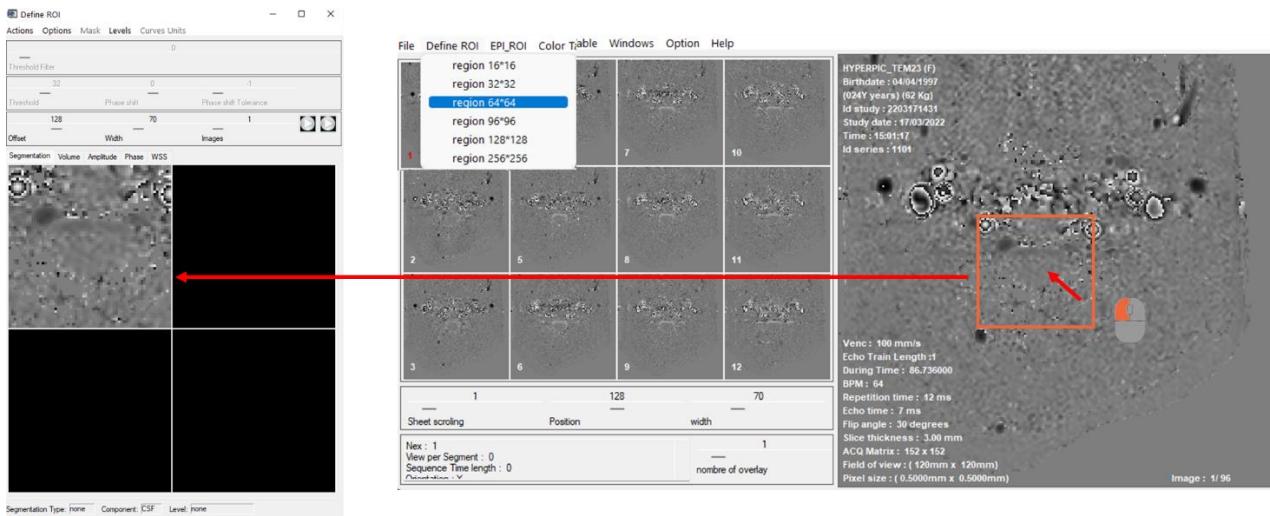
9. Simple example for CSF

We take the CSF at the C2-C3 level as an example to quickly and simply demonstrate the following post-processing process.

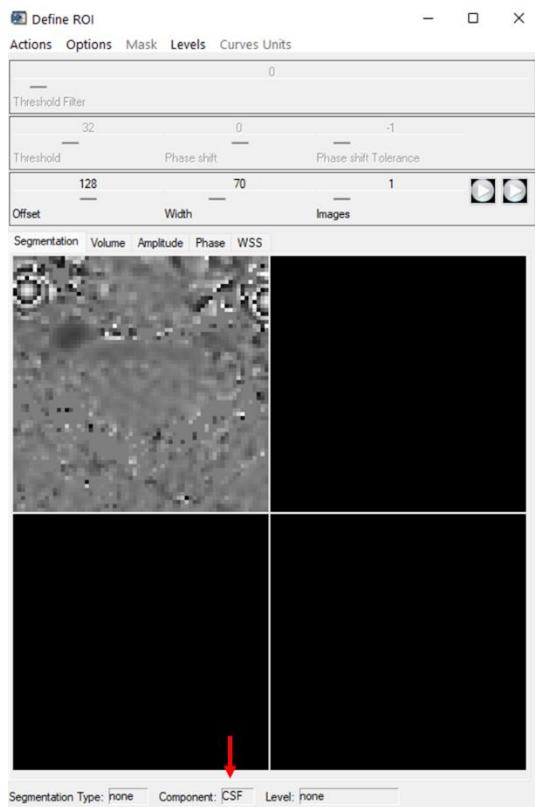
1. Click “File” -> “Open Series” in the main interface and select DICOMDIR file. Wait for the series list to pop up (2.2).
2. Select the CSF Series with VENC = 100 mm/s (2.2).



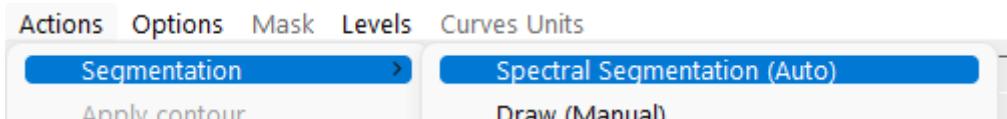
3. Click “Define ROI” -> “64*64” in the main interface to open the CINE-PC post-processing interface, and click the target CSF location in the main observation window of the main interface. Load the CSF post-processing FOV into the CINE-PC interface (3.1).



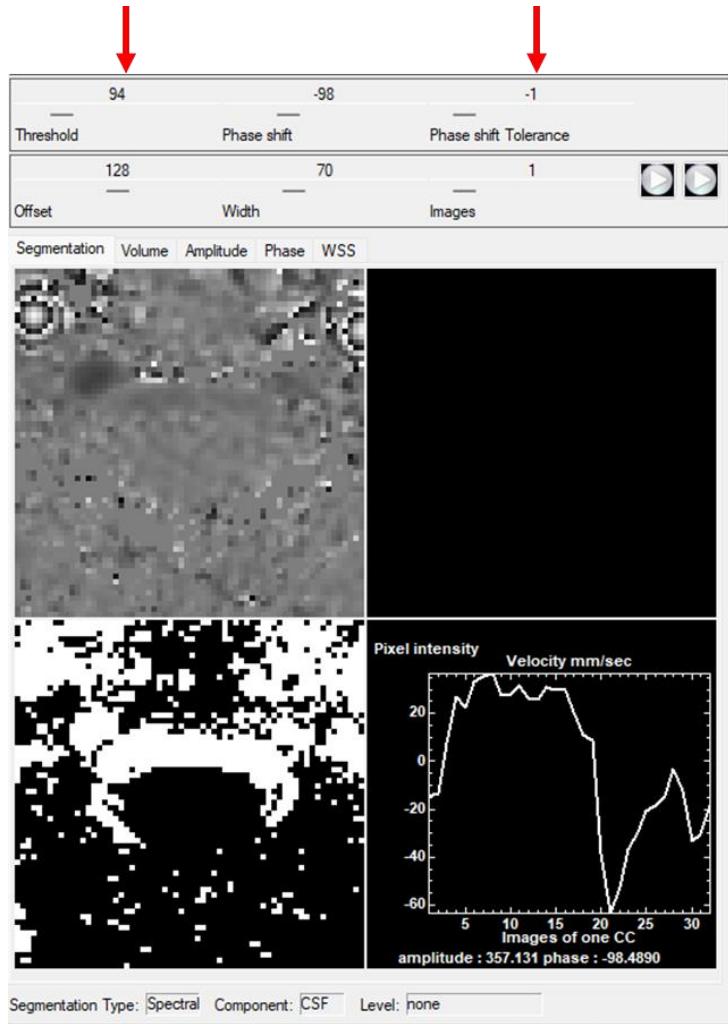
4. Check if the target type is “CSF”, otherwise it needs to be corrected (3.4.3).



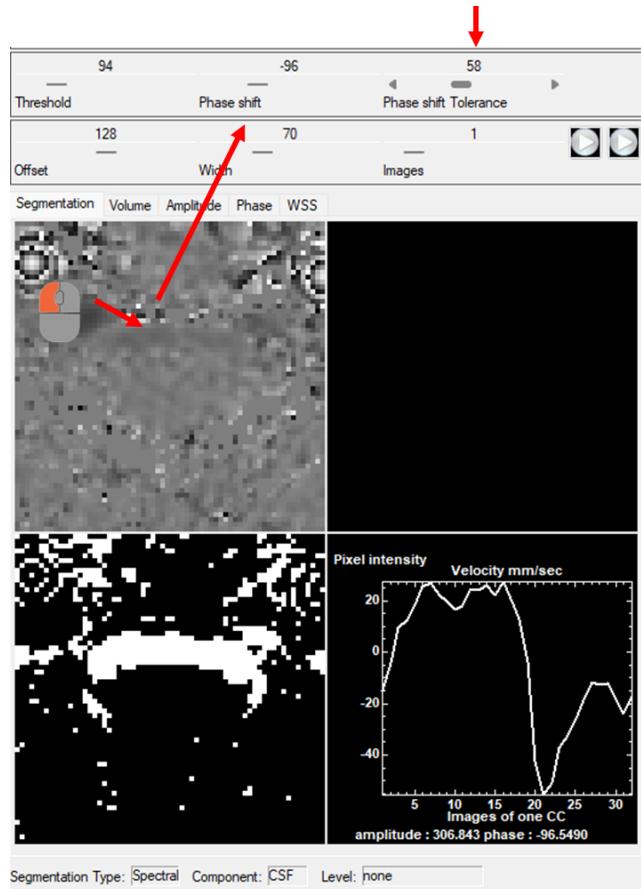
5. Click “Actions” -> “Segmentation” -> “Spectral Segmentation (Auto)” in the menu bar to start semi-automatic segmentation (4.3.2).



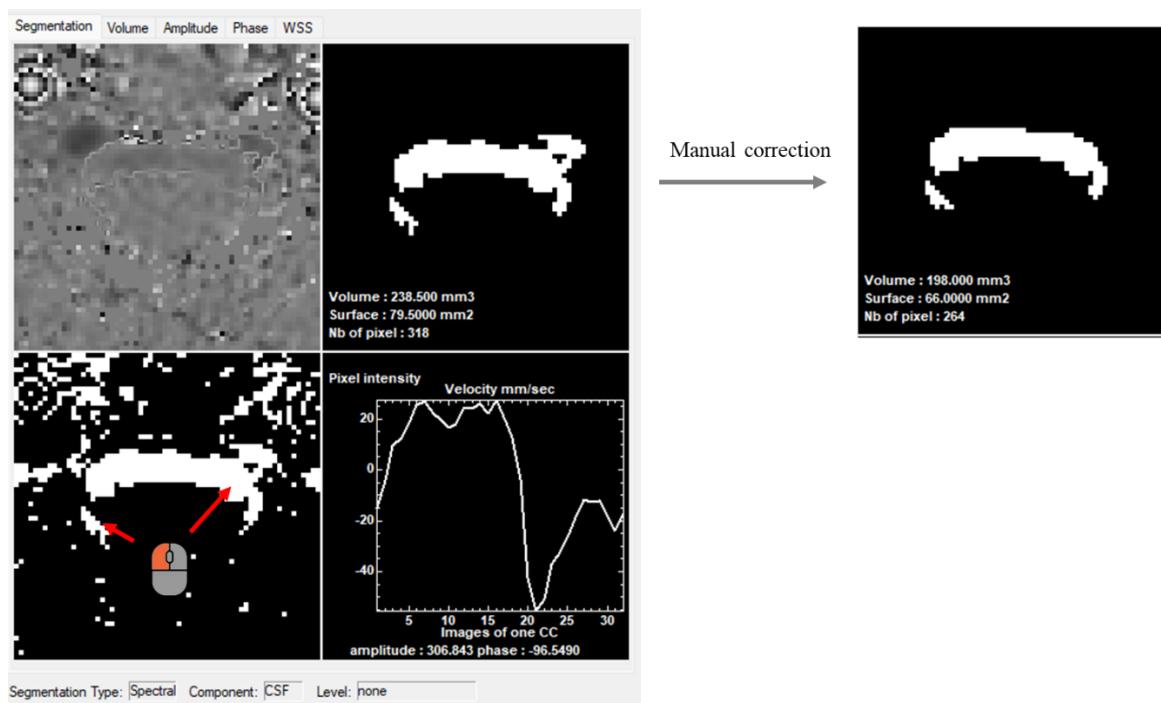
6. You can first set “Phase shift Tolerance” to -1 to turn off the Phase Interval threshold. Adjust the “Threshold” to the appropriate value. the ROI preview image can be viewed in the lower left window WIN.Info_L (4.3.2.B).



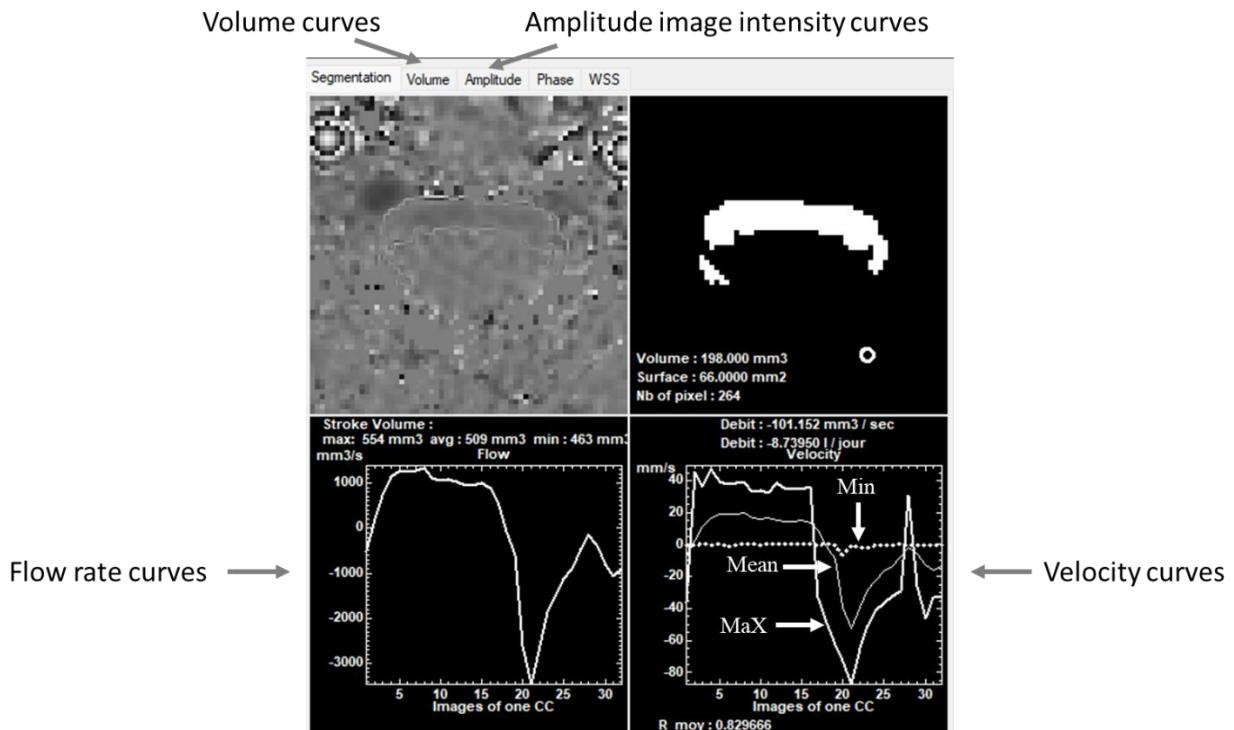
7. Continue to adjust the phase interval threshold, click on the CSF in the upper left window (WIN. Display), the software can automatically assign a value to the “Phase Shift” slider, we just need to adjust the “Tolerance” slider to the appropriate position (4.3.2.B).



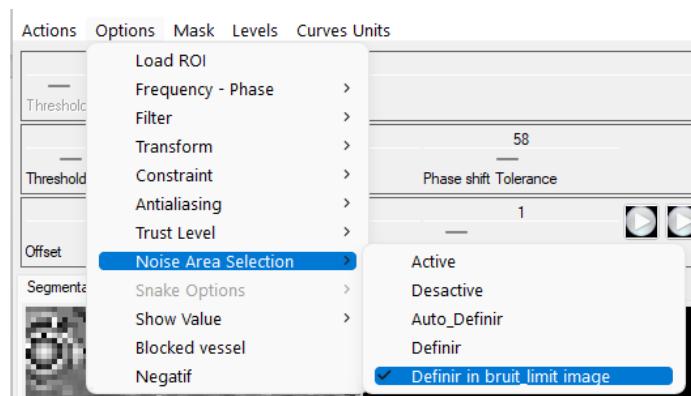
- Click on the ROI of CSF in WIN.INFO_L to confirm the selection, you can click multiple times to add more than one ROI. the ROI will be copied to the upper right window (WIN.ROI) simultaneously, you can further adjust the ROI in WIN.ROI (4.2).



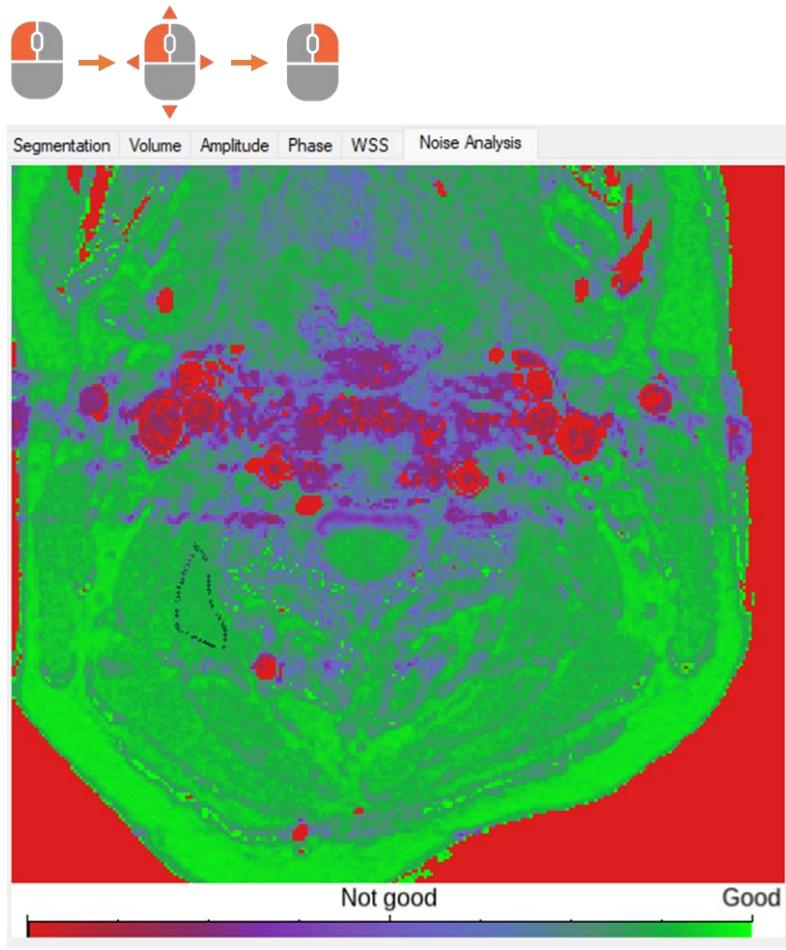
- Click “Actions” -> “Apply contour” in the menu bar or double click in WIN.ROI to apply the ROI. The software will display the flow and velocity curves within the ROI in WIN.Infos (5).



10. Click “Options” -> “Noise Area Selection” -> “Definir” or “Definir in bruit_limit_image” on the menu bar to define a stationary tissue ROI around the CSF. The software will use this ROI for background field correction. You can continue with de-aliasing if there has an aliasing effect (6.2).



For example, if you select “Definir inbruit_limit_image”, press and hold the left mouse button in the window to select a green area and click the right mouse button to confirm the ROI of stationary tissue.



11. You can directly click the “Options” -> “Show value” -> “flow” to view or copy the flow signal. You can also select a corresponding name in the “Levels” drop-down menu to save the results dat. The saved data can be viewed via “Windows” -> “manger manager” in the main interface (8.2). At this point, the post-processing is complete.