

KCL STANDARD OPERATING PROTOCOL FOR ATRIAL CMR PROCESSING WITH CEMRGAPP

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This document supplies, in detail, the process of analyzing atrial LGE and MRA images for the purpose of quantifying atrial fibrosis and generating a 3D model of signal intensity. The thresholds used for image acquisition and the specific MR sequences are not explained here.

It is assumed that you have downloaded the latest version of CEMRG and that your image acquisition software can output to the DICOM format.

PREPARE IMAGES

IF USING OSIRIX

1. Expand the list of scans using the grey arrow to the left of the patient name in Osirix
2. Select the CE MRA and LGE CART 20 MIN scans; right click on Export > DICOM.

Regardless of where you export the scans from, there cannot be any spaces in the path (folder names) to the folder where your DICOMS are stored, therefore replace the spaces with “_” or remove them.

OPEN AND PROCESS IN CEMRG

1. Set up the perspective –Top Menubar - Window > Open Perspective > Cemrg Scar Perspective (often already in by default upon second time opening)
2. Click '**Load DICOM**'. Click 'Scan directory' and select the directory created above.
3. Double click CE MRA; the view changes to the display window – click the tab bar at the top of the window back to the MITK DICOM browser, then load in the LGE CART to data manager

4. Drag the LGE sequence so that it is at the top of the Data Manager (LGE at the top, CE MRA at the bottom).
5. Click **'Process Images'**
 - a. Select (highlight in blue) the MRA and LGE in the Data Manager by holding the shift key.
 - b. Click 'Convert to NIFTI' and choose a project directory. Again, this project directory must not have any spaces in the file names of the path. This project directory will output all of the files associated with the analysis including the final scar VTK file. It is recommended to create a separate folder for each scan analysis.
6. Click **'Segment Images'**
 - a. click 'no' to 'Do you have a segmentation to load?'
 - b. on the right-hand panel, click the box with a yellow tag to name the segmentation – 'LA' is recommended– ensure patient image drop down in the segmentation tab reads CEMRA (the order of import should ensure this is correct each time).
 - c. Right clicking on the "LA" in the data manager on the left allows you to change the colour and transparency of the segmentation. It can be easier move the transparency down to about half but adjust as needed so that the border of the atrial blood pool can be accurately defined.
 - d. Adjust the size of the windows to optimize your view of the LA in the axial plane
 - e. use the region growing tool to segment the atrium, segmenting only in the axial plane (if the tools are greyed out – try clicking on the "3d tools" tab and then clicking back on the "2d tools").
 - f. Start segmenting
 - i. We recommend the first slice to be the mid body of the atrium – as judged on the sagittal section.
 - ii. Then go from bottom to top, ensuring the basal slice does not include the coronary sinus.
 - iii. Ensure that a slice represents the ostia of each pulmonary veins but do not extend coverage into a distal branch, remain within the main vein.
 - iv. It is recommended to delineate the appendage accurately to ensure that it is separate from the Left upper vein.
 - v. Optional: this step can help if the left sided structures are merging into one uniform body (dependent on patient anatomy and image quality)
 1. Add a sagittal slice from the centre of the atrial body which avoids the appendage and veins – aiming for maximal size.
 2. Add a second sagittal slice which encircles the left sided veins and appendage.
 - vi. Control Z will undo a region growing area if it is incorrect

- g. On the right hand-side, Switch Interpolation drop down from “none” to “3D”.
- h. At this stage it is important to see that the green outline follows the contours that you are expecting for the atrial wall. Avoiding holes and inaccurate continuities and in the axial plane ensure that the left upper vein and appendage are separate.
- i. Before you click confirm you can alter the segmentation by disabling the interpolation and subtracting/adding segmentation to the atrium as previously.
- j. Once happy that, Clicking confirm brings up ‘Save Segmentation’ before proceeding – name this ‘LA.nii’

7. Click Registration

- a. select (highlight in blue) the LGE and the MRA.
- b. Hit ‘register’ (red screen of code will appear)
- c. Select (highlight in blue) the LA segmentation in the data manager
- d. Hit ‘**transform**’ – Brings up Save Registration as “LA-reg.nii” and a further box of red command text
- e. Now, assess the LA-reg and the LGE in the display and make sure that the segmentation is ‘good’ – i.e. has the correct shape and alignment with the LGE

8. Click PV clipper

- a. Select “LA – reg” in Blue – click PV clipper –
- b. Hit ‘OK’ for the default parameters (this creates a *surface* which the PV clipper works off, rather than a *segmentation*)
- c. Position the mouse over the veins, one by one and then appendage and press the space bar to drop seeds.
 - i. Note that the centerlines for clipping the veins will start from the seeds. If you position the seed off to the side of the vein (or if there is a proboscis which is off centre) then the centre line will be squint and the normal will be off axis.
 - ii. If there are common ostia; use a single seed. It is safer to cut off more rather than less i.e. cut more proximally to ensure that vein wall is removed but not into atrial body.
 - iii. Do not aim to put seed as distal as possible but try to place on a point that represents the centre of the structure.
- d. For the appendage select “appendage (cut)”
- e. Press ‘find centrelines’, and wait for the centrelines to compute
 - i. Once finished click “display clippers” – it is often easier to see the orientation of the clippers by pressing “o” on the keyboard to change the opacity.
- f. Choice of clipping mode:
 - i. Automatic – ideally use automatic and just use the slider to reposition the disks more proximal or distal, only do this *if absolutely needed*.
 - ii. Other choices
 - 1. Manual I – get to this option by pressing the right arrow key. The disks turn green and you will have a manual clipper which is in the

shape of a circle with customisable normals and diameter. (Keep the arrow keys pressed for a few seconds if the disk doesn't move in your direction and it is jumpy). Use the arrow keys to change the orientation and the slider at the bottom of the panel to move proximal or distal. The number can be changed to change the relative size of the clipper.

2. Manual II – you also have another option where you continuously place seeds on the mesh by pressing the space bar and creating a contour around surface you wish to cut. This option is automatically activated by pressing the space bar when hovering the mouse over the appropriate point on the mesh. If the point projects incorrectly it can be deleted by using the delete button to remove the last seed placed on the mesh. (If you press space and do not see a dot appear then it is probably on the reverse surface)

Click “Clip Segment image” when happy.

9. Create Surface

- a. Select in blue ‘PVeinsCropped image’
- b. click ‘Create Surface’ and select the default parameters by clicking ok – This brings up a further text box with command line operations and creates “PVeins croppedimage Mesh” in data manager
- c. REVIEW the created surface for accuracy – this will be applied to the LGE image for scar interrogation. All parts of the surface in contact with the white clipper remnants will not be included in the analysis (they will be coloured green on scar map)

10. MV Clipper

- a. Deselect all items in the data manger apart from the LGE image.
- b. Select coupled crosshair rotation with the small crossed box at the top right corner of the viewer window.
- c. Manipulate this to create as closely as possible a 4 and 2 chamber view. Ensure that your crosshairs as closely as possible meet in the middle of the mitral valve orifice, so that one axis points to the apex and the other just touches the basal ventricular myocardium.
- d. The 3rd view should show a kidney shaped mitral valve orifice “en face” which should be used to mark out the mitral valve border.
- e. Ensure that you have removed the segmentation white line before clicking the points. (the aim being to click on the true mitral valve and not where the segmentation has delineated as the atrial wall).
- f. Click select landmarks
- g. ‘Add new point set’ and select the default name of ‘point set’
- h. Select the ‘+’ button at the bottom left of the point set viewer.
- i. Hold ‘Shift’ and click left mouse button to add points around the mitral annulus on the DICOM LGE image.

- j. 2 Points should be placed on the medial/Aortic side at 7 and 10 o'clock. A lateral point should be placed at 3 o'clock (endocardial side).
 - k. Click "Point set" in "data manager" window - selected in Blue.
-Display clipper at this point generates a visible sphere showing which area will be clipped for the mitral valve to review prior to clipping. To move a point, click the "+" button again and drag the point (the crosshair will change to red when it is ready to be moved to a new position on the valve).
 - l. Once happy, Hit 'Clip Mitral Valve'.
11. **'Scar Map'**
- a. Select the LGE DICOM in the Data Manager and hit 'Scar Map'
 - b. Use Max Intensity Projection with Min step -1 and Max step +3
12. **'Scar Quantification'**
- a. Click OK to "3" voxels in the dialogue box for the erosion to calculate the blood pool erosion
 - b. Suggested thresholds are in the table below, and a dialogue box will generate a "global fibrosis score" in %.
13. Finally, save your project using the save button at the top left – name it project.mitk in your project directory.

It is best to close the program once you've done this and reopen to start the next case as some dialogue boxes and labeling are different if you keep the program open which may create confusion.

LEARNING CURVE

The whole process from start to finish can be done in 12-15 minutes for most cases.

However, there is a learning curve to this and I would imagine needing to do 10-20 cases to get down to this level of efficiency. Expect the first few cases to take you an hour or so, with the majority of time spent ensuring that the segmentation is as accurate as possible, especially between the LUPV and appendage.

Standard Example Parameters

Step	Parameter	Meaning	Value
Step 5: Scar Map	Min step	The number of pixels interrogated going into the blood pool	-1
	Max step	The number of pixels interrogated going out of the blood pool	3
Step 6: Scar Quantification	Image Intensity Ratio	Threshold value for image intensity ratio for defining scar. Atrial wall values divided by mean intensity of blood pool	0.97, 1.61
	S.D.	Number of standard deviations above the blood pool mean	3.3