# Using the framework for Biomechanics based Prediction of Aneurysm Rupture Risk (BioPARR)

## 1. Installation

Install 3D Slicer (tested with version 4.4.0)

Install Paraview (tested with version 4.3.1)

Install Abaqus (tested with version 6.14)

Create a folder where all cases will be analysed (e.q. D:\AAA_Analysis)

Download the archive with the AAA analysis software and unzip it in the above folder.

## 2. Software configuration

Edit AAA_Configure.bat and set up the paths to 3D Slicer and Paraview based on your installation.

## 3. Analysis configuration

Edit AAA_AnalyseCase.bat to change the analysis configuration. By default, both variable (if data for the variable thickness exists) and constant thickness geometries are created and analysed using three scenarios.

For example, if you don't want variable thickness geometry, change

    SET AAA_ANALYSE_VAR_THICKNESS=0

at the start of the script. If you don't want the constant thickness scenario to be analysed, change

    SET AAA_ANALYSE_CONST_THICKNESS=0

at the start of the script.

The scenarios to be analysed are configured in .\Software\Scripts\AnalyseAllCases.bat. If you want to remove some of these scenarios from analysis, change the definition of the variable

    SET AAA_ANALYSIS_CASES=NoILT, ILTPressure, WallPressure

at the top of that file.

The actual configuration for each of these scenarios can be found in the Abaqus input file AAA.inp in the corresponding subfolder in .\Software\Scripts\Abaqus. You can modify these scenarios, or add additional scenarios that you want to analyse by creating additional subfolders and Abaqus input files.

The 3D Slicer modules used for analysis are found in .\Software\SlicerModules. You can run these with the "--help" parameters to find the different configuration options they have, and then change their command

line parameters. For example, the module for creating the Abaqus input files corresponding to the wall and ILT parts is called from AAA_AnalyseCase.bat with the options "--quad --hybrid", which means it creates hybrid tetrahedral elements having quadratic shape functions (10 nodes). This may lead to very long analysis time, so these options can be removed from the command line, leading to the use of linear tetrahedral elements.

## 4. Case analysis

- **Start**

Duplicate folder CaseID and rename it with the ID of the case you are going to analyse (e.g. D:\AAA_Analysis\Case11220).

- **Check the data**

Go to the shared data drive and copy the folders with the CT and MRI images you will use for this case. Open them in 3D Slicer and check if appropriate for analysis.

Change into the above folder and run AAA_AnalyseCase.bat from the command prompt – this will create the directory structure for you.

- **Cropping**

Open the CT image in 3D Slicer, define the region of interest (ROI) and crop the volume (Converters->Crop Volume) with isotropic output voxels. Save result in .\1_Segmentation_CT\ CT_cropped.nrrd

Open the MRI image in 3D Slicer, define the region of interest (ROI) and crop the volume (Converters->Crop Volume) with isotropic output voxels. Save result in .\2_Segmentation_MRI\ MRI_cropped.nrrd

**Note**: The ROI should start just under the renal arteries and end under the bifurcation of the iliac arteries (if visible in the images).

- **Segmentation**

*Lumen*

Open .\1_Segmentation_CT\ CT_cropped.nrrd in 3D Slicer. Go into Volumes and select the Window Level editor preset CT-abdomen. Go into Editor and use the Threshold Effect to create a rough segmentation of the blood channel. Use SaveIslandEffect to eliminate unconnected regions. Use the PaintEffect to make manual corrections (eliminate small veins, calcifications that may be in contact with the blood channel). These changes can be checked by using ModelMaker to create a surface representation of your segmentation. Once you are satisfied with your manual corrections use Surface Models-> Label Map Smoothing with a Gaussian Smoothing Parameter Sigma of 1 (set both input and output volumes as CT_cropped-label) to smooth out the segmentation. Save result to .\1_Segmentation_CT\ CT_blood_label.nrrd.

**Note:** Make sure the segmentation extends the entire height of the cropped CT image (check the first and last Red slices in 3D Slicer before saving the segmentation results).

*AAA*

Use the PaintEffect to extend the blood channel label to cover the entire AAA. Use a different label to mark the region around the AAA. Use the FastGrowCutEffect to segment the AAA. Once satisfied with the result, stop FastGrowCutEffect, use the ChangeLabelEffect to change the label used to mark the region around the

AAA to background color and use the PaintEffect to make manual corrections. Once you are satisfied with your manual corrections use Surface Models-> Label Map Smoothing with a Gaussian Smoothing Parameter Sigma of 2 (set both input and output volumes as the label you are working with) to smooth out the segmentation. Save result to .\1_Segmentation_CT\ CT_AAA_label.nrrd.

**Note:** Make sure the segmentation extends the entire height of the cropped CT image (check the first and last Red slices in 3D Slicer before saving the segmentation results).

**Tip:** Use a sphere in the PaintEffect to mark regions in several slices at once. Caution not to mark wrong regions in the slices you don't see.

### *AAA from MRI*

Use similar procedure as above to segment the AAA from MRI (the lumen does not need to be segmented separately in this case). Save result to .\2_Segmentation_MRI\ MRI_AAA_label.nrrd.

- **Wall extraction and MRI to CT registration**

Run AAA_AnalyseCase.bat from the command prompt – the script will do this automatically based on the segmentation data.

- **Wall Thickness extraction**

Open .\1_Segmentation_CT\ CT_cropped.nrrd and .\2_Segmentation_MRI\MRI_aligned_to_CT.nrrd (created by the script) in 3D Slicer. If you set them as Background and Foreground images you can blend them together and check they are aligned. Look for areas where the wall is visible in MRI (or calcifications in CT) and use the ruler to measure wall thickness. Save measurements in .\3_Thickness\M*.acsv.

- **Complete the analysis**

Run AAA_AnalyseCase.bat from the command prompt – the script will create the AAA and ILT surfaces, will mesh the AAA and ILT volumes, will create Abaqus input files, will run Abaqus analysis for three different loading configurations, will extract the stress in the wall and compute the rupture potential indexes (RPI).

- **Check the results**

If there are no errors during the script execution, open some of the result files and check the output.

If there are errors, you must solve them so the analysis can progress further (this may involve cleaning up the segmentations or using different parameters for meshing), then run again AAA_AnalyseCase.bat.

## 5. Tutorials

Tutorials describing the different steps of the analysis can be found at

http://staffhome.ecm.uwa.edu.au/~00058942/resources.html#Scripts