
# Atherosclerosis - Plaque Burden Assessment and Classification using MRI

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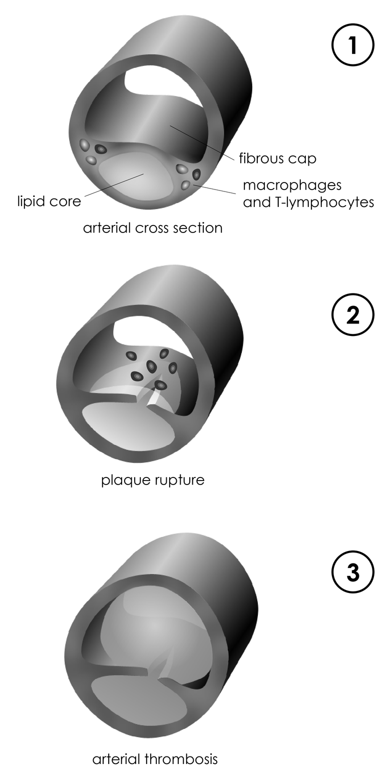
## Atherosclerosis

Atherosclerosis is a leading cause of death in the western world. It is a condition where arteries become narrowed or occluded with the effect that the flow of oxygenated blood to cells is reduced. When occlusion occurs in the coronary or carotid arteries, a heart attack or stroke can result.

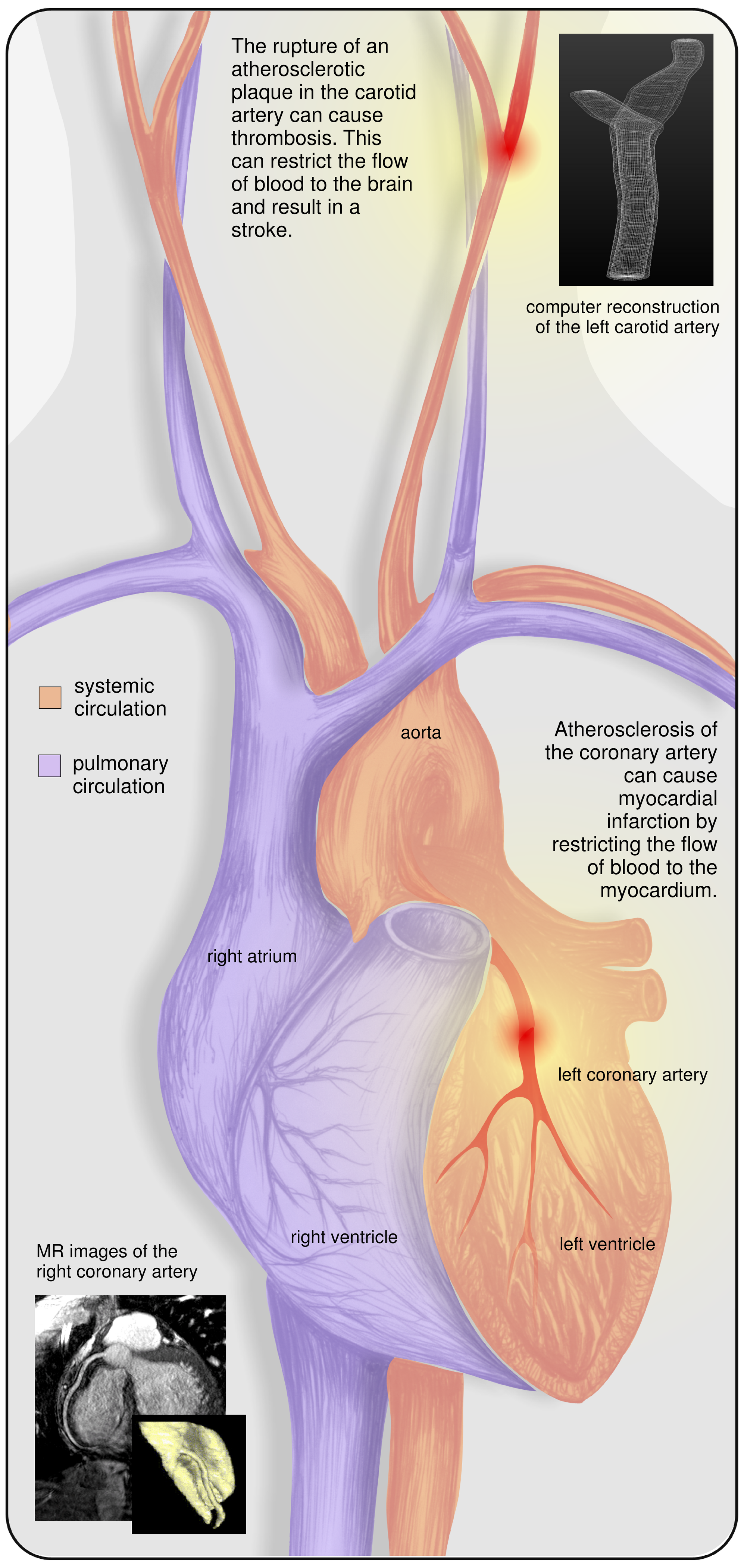
This work presents two techniques, *plaque burden assessment* and *plaque classification*, that enable the *in-vivo* monitoring of atherosclerosis.




1. Atherosclerosis typically begins in childhood with the accumulation of lipid in the intima of the arterial wall. Later in life, these deposits can develop into atherosclerotic plaques that project into the vascular lumen.

2. Whilst the majority of plaques are stable and only slightly restrict blood flow, some are prone to rupture. Such plaques typically have a large lipid core covered by a thin fibrous cap that is unable to withstand the shear stress exerted by the blood flow.

3. Upon rupture, blood begins to clot around the plaque so as to seal the damaged region. Occasionally, this will lead to thrombosis where the artery becomes completely occluded thereby preventing the transportation of oxygen and nutrients.




## Plaque Burden Assessment

Plaque burden assessment involves measuring the volume of the arterial wall at different points in time. These measurements can be used to estimate changes in the volume of plaque present in an artery. Plaque burden assessment can be performed by acquiring a series of Magnetic Resonance (MR) images that bisect the artery. Conventionally, plaque burden is calculated by analysing manually delineated contours of the arterial structure. This is a time-intensive process that introduces inter- and intra-observer variability. In this work, we present a solution based on the Active Shape Model (ASM) with an outlier detection mechanism that does not involve human interaction.

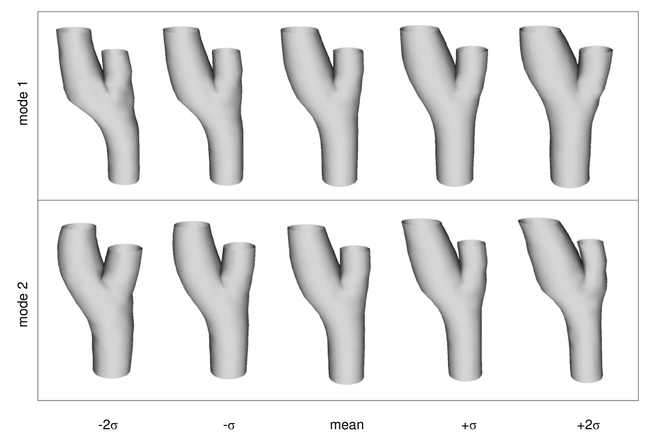



Figure 1. A statistical model of the carotid artery showing the mean shape and the principal modes of variation across 10 subjects.

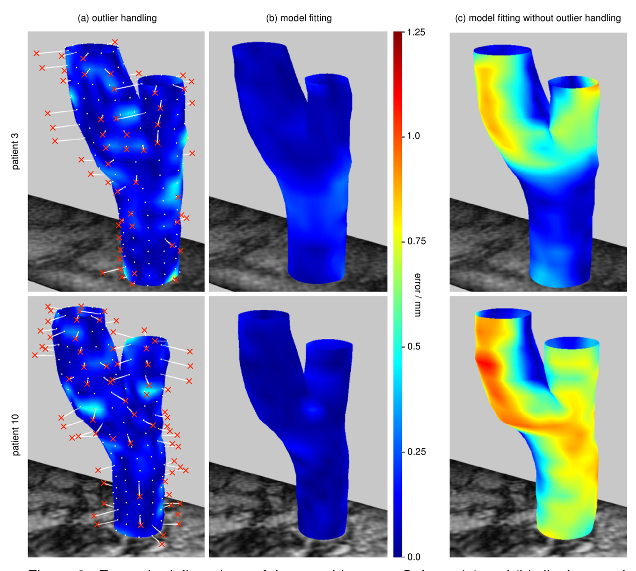



Figure 2. Example delineations of the carotid artery. Column (a) and (b) display results attained with the outlier handling mechanism whilst (c) is attained from the conventional ASM approach.

Images of the carotid artery were acquired from 10 normal subjects with a 1.5 tesla MR scanner. For each subject, a total of 20 2mm slices were acquired starting 20mm below the carotid bifurcation. In each image, the inner and outer boundaries of the arterial wall were delineated by an expert observer. These delineations were used to construct a statistical shape model of the carotid bifurcation shown in Figure 1. This modelled the mean shape of the artery and its principal modes of variation across subjects. The statistical model was fitted to image feature points that had been filtered by a new outlier detection mechanism that determines the probability that a feature represents the true border. The outlier detection procedure is based on an invariant shape representation using the ratios of inter-landmark distances which provides a measure for local shape dissimilarity analysis.

Figure 2 shows example models of the cartoid artery created from the *in-vivo* datasets. It can be seen that the proposed technique with outlier detection significatly reduces error when compared to the original ASM approach. Validation was performed using a leave-one-out testing mechanism. For each model, a statistical model was constructed from the remaining 9 datasets. The difference between the volume calculated from the automatic technique was compared to that derived using manual delineation and is presented in Figure 3. Whilst the average error for the standard ASM technique was 0.34mm, this error was reduced to 0.10mm when incorporating the proposed outlier detection mechanism.

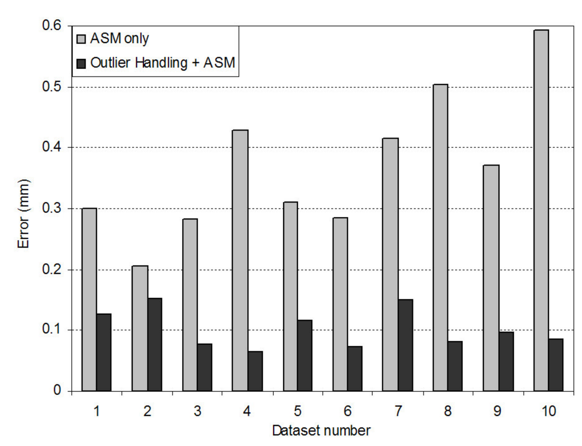


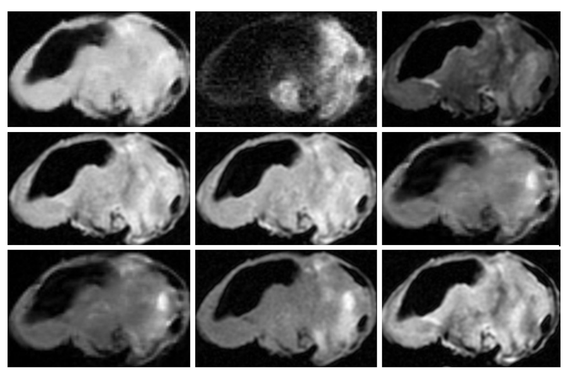

Figure 3. A comparison of the error between the ASM technique, with and without the outlier handling mechanism and the manual delineation.

## Conclusion

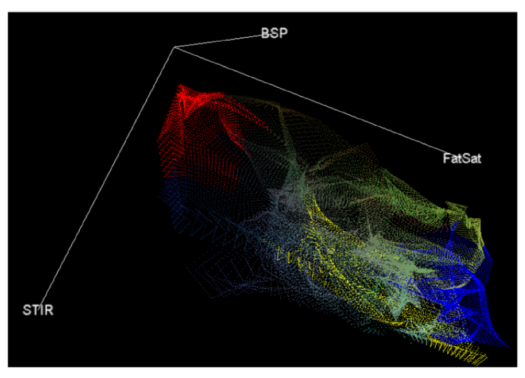
The availability of a reliable *in-vivo* technique for the quantitative assessment of atherosclerosis would have a profound impact on health in the western world. In this work, an automatic technique for calculating plaque burden is presented. This is a practical technique which, with an extensive validation program, could form the basis of an efficient clinical tool. Also presented is a plaque classification technique that aims to determine the constituents of Atherosclerotic plaques. Whilst this work has shown an ability to distinguish between different tissues, it remains difficult to reliably classify tissues across subjects.

## Plaque Classification

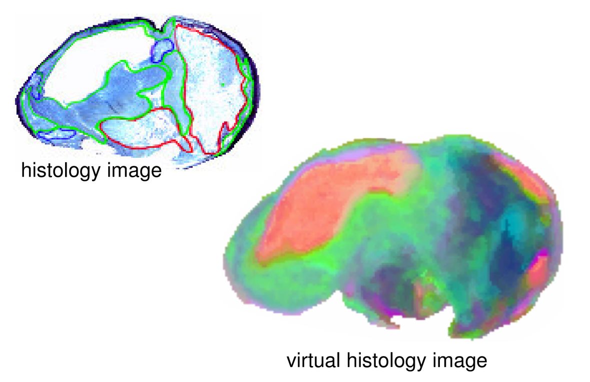
Whilst it is important to be able to track changes in the volume of an atherosclerotic plaque over time, it is also desirable to determine the constituents of the plaque *in-vivo*. This would allow clinicians to ascertain whether a plaque is stable or likely to rupture. Multispectral MR imaging provides a mechanism for distinguishing between different tissues. The technique involves acquiring a series of images of the same anatomical cross section using different imaging sequences that each have their own tissue contrast characteristics. For each voxel in the arterial dataset, it is then possible to classify which tissue type it represents. In this investigative work, we have applied a dimensionality reduction technique to reduce the number of dimensions required to represent the data. The advantages of doing this are two-fold. Firstly, it provides a mechanism for determining which imaging sequences are able to capture the important signal variations between tissues. Secondly, it enables complex multi-dimensional data to be presented in a fashion that is comprehensible to clinicians. In the image on the far right, we present a virtual histogoly image that has been created solely from MR images that displays distinct boundaries between the different plaque constituents.



Firstly, a set of MR images is acquired of a cross section of the arterial structure. Each image is acquired using a different sequence, flip angle or T1 / T2 weighting.




The data is converted into a multidimensional space where each voxel in the dataset is mapped to a specific location. It is assumed that different tissue types are consistently mapped to different regions in the multidimensional space.




Finally, a dimensionality reduction technique is applied to reduce the multi-dimensional space into its principle three dimensions that can easily be portrayed in an RGB colour image. The resulting image provides the clinician with a virtual histology that enables the distinction between different tissue types.