Quantitative Measurement of Arterial Remodeling In-vivo by High-Resolution MRI

N. Balu[1], W. Kerwin[2], C. Yuan[2]

[1]Bioengineering, University of Washington, Seattle, WA, United States, [2]Radiology, University of Washington, Seattle, WA, United States

Introduction

Evolution of carotid atherosclerotic disease, a leading cause of morbidity and mortality due to stroke, is not well understood. Arterial remodeling has been described as a pathway for developing high-risk plaques[1]. High-resolution MRI provides a unique opportunity to study arterial remodeling, the process of arterial shape and size change due to plaque deposition. Remodeling is classified into two types: positive and negative remodeling. The arterial lumen is preserved in the former and reduced in the latter with increased plaque deposition. Each type is distinct in clinical manifestations but their progression has not yet been studied thoroughly. Hence there is a need for quantitative indices to measure arterial remodeling.

Purpose

This study was aimed at developing a method to quantitatively measure and track shape and size changes of atherosclerotic arteries over time.

Materials

Black blood T1 weighted MR images of patients with moderate carotid stenosis (<50% stenosis by ultrasound) were taken at two different time points (18 months) on a 1.5T GE Signa scanner (TR/TE/FOV/NEX/Slice Thickness/matrix = 800/14/16/2/2/256x256).

Challenges

MR image data obtained by the above protocol poses two problems for our study. The images have high in-plane resolution but lower resolution (2.0mm) along the slice direction. It is also difficult to ensure patient positioning such that the same slice of the artery is imaged at the two time points. The proposed algorithm overcomes these challenges by casting the problem in a 3D domain.

Methods

Lumen and outerwall contours were drawn on axial MR slices using a cubic spline. The resulting contours were stacked in volumes and smooth 3D models of the carotid artery luminal surface and outerwall surface were obtained by fitting the contours with a thin plate spline[2]. The shape based interpolation provided by the thin plate spline solves the problem of reduced resolution in the slice direction. A 3D chamfer mask based Euclidean distance transform of the lumen model was used to obtain a skeleton of the artery passing through the center of the lumen. Corresponding points on the skeleton between the two time points were obtained by arc length parameterization of the skeletons from their respective carotid bifurcations. The two skeletons were then registered in 3D. This overcomes problems of slice-based registration. The 3D distance from the lumen to the skeleton was taken as a measure of shape for the lumen and the 3D wall thickness (distance between the lumen and outerwall) was taken as a measure of shape for plaque deposition. Thus a continuous quantitative index for shape change is available across the whole surface of the artery. The change in the above indices between the two time points was also color mapped onto a model of the artery at the first time point as shown in figures 1and 2

Results and Conclusions

The two indices as visualized by the method outlined above were compared with more traditional measures of remodeling, namely change in lumen area (fig 3) and change in plaque area (fig 4) as measured on a slice-by-slice basis. Figs 1 and 2 show that deposition of plaque is in a vertical band (fig 2) but impinges on the lumen only in the common carotid (fig 1) (negative remodeling). The lumen is maintained in the other regions (positive remodeling). The traditional lumen area and plaque area measures (figs 3 and 4) do not provide information about remodeling around the circumference of the artery while the indices developed in this study also portray information around the circumference that would be lost in traditional measures based on axial views. They also supplement the information provided by lumen area and plaque area measures. The current 3D based method enables a more accurate tracking of remodeling by improving registration. The method is also automatic and can be combined with automatic segmentation of the lumen and outerwall for efficient processing of data.

References

1. Burke, A.P., Kolodgie F.D., Farb A., Weber D., Virmani R., Morphological predictors of arterial remodeling in coronary atherosclerosis, Circulation, 2002; 105:297-303

2. Kerwin W.S, Yuan C, Three Dimensional Surface Models of Carotid Atherosclerosis, Proceedings Fourth IASTED Intl. Conference - SIP, 2002, 589-594

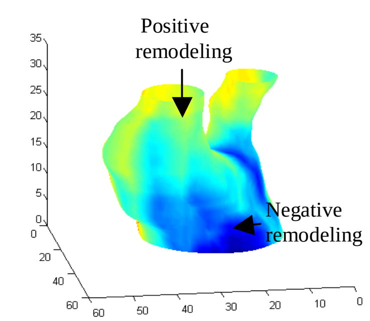

Fig 1. Distance between lumen boundary and center of lumen between two time points (distance units)

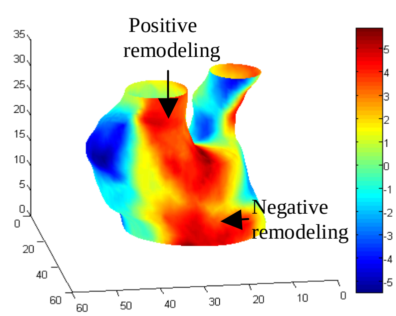

Fig 2. Distance between lumen and outerwall boundaries (plaque thickness) between two time points (distance units)

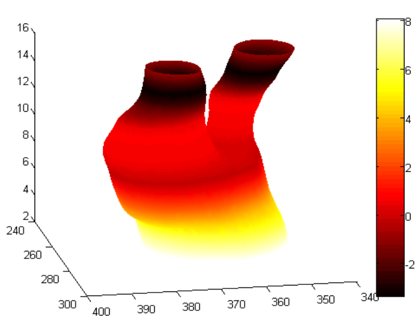

Fig 3. Change in lumen area (sq. mm.)

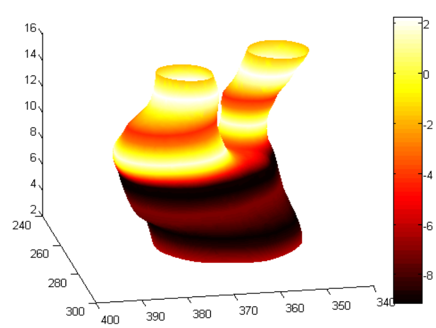

Fig 4. Change in plaque area (sq. mm.)

Proposed quantitative remodeling measures (figs 1 and 2) compared to traditional remodeling measures (figs 3 and 4) show remodeling status additionally along the circumference of the artery