Reproducibility Study of Wall Segmentation Approach in Evaluating PAD Patient with MRI

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Introduction

Peripheral arterial disease (PAD) is a common condition that is highly correlated with increased rates of functional impairment and decline and is associated with an increased risk of cardiovascular events. In recent years, high resolution MR imaging has been considered as the most promising imaging modality for assessing atherosclerotic plaque burden in many vascular beds [1]. However, there has been little research that uses MRI's ability to analyze atherosclerotic plaque burden in the lower extremity arteries. In this study, we use MRI cross sectional images to quantitatively analyze vessel wall morphology, in particular the following plaque characteristics: normalized total plaque volume, maximum arterial wall thickness, and mean arterial wall thickness – the three independent measures of plaque burden in PAD evaluation.

Methods

The images used in this study are obtained with a dedicated knee coil on a 1.5T MR scanner (Sonata, Siemens Medical Systems). For each subject, 10 consecutive cross-sectional MR images of the superficial femoral artery (SFA) are captured at the adductor canal, which is the most frequently affected site of atherosclerosis below the inguinal ligament. The imaging parameters selected in this study are: PDW (Regional Saturation Turbo Spin Echo, TR=2160ms, TE=5.6ms) and TOF (TR=28ms, TE=7.2ms), FOV=12x12cm, matrix=192x192. Time of Flight and PDW images were automatically registered using the native scan prescription software.

The femoral wall segmentation was performed by detecting lumen and outer wall boundaries. For outer wall, since PDW image has a high contrast signal along wall boundary, an automatic algorithm, Markov Shape Prediction, is used to find the outer wall contour with the assumption that the wall shape in neighboring locations are similar. Despite using regional saturation bands that are placed proximal and distal to the imaging region, removing the signal from flowing blood generally does not result in PDW images that provide a clear boundary signal, in many patients. It is hypothesized that the growth of the signal from slow flowing blood can mimic vessel wall. Therefore, we have incorporated 2D TOF images to improve inner wall boundary detection. This is because 2D TOF has higher sensitivity of blood flow. The algorithm proposed for lumen detection is called the Region Driven Snake, which automatically finds the lumen region based on a user input initialization point and then uses a B-Snake module to fine-tune its contour. These algorithms have been implemented into a computer program, CASCADE [2] (developed by Vascular Imaging Lab, University of Washington), which was used for data analysis in this study. Since the knee coil used in this study can keep the patient's leg position fixed, the images in both contrast weightings can be treated and registered. Therefore, the wall segment can be obtained by directly projecting lumen contour in the TOF image to the PDW image. An example is shown in Figure 1.

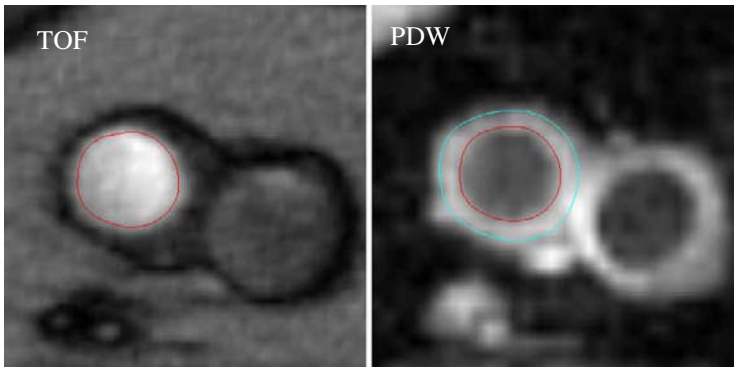

Figure 1. Wall segmentation based on registered multi-contrast images.

Once wall segmentation is completed, quantitative measurements, such as wall volume and thickness, can be computed. For patients with PAD, lumen and outer wall shapes are usually non-circular and a different optimized algorithm [3] is used for thickness measurement.

Performance Evaluation

To evaluate the performance of the proposed wall segmentation approach, a study was designed to measure the test re-test reproducibility for MRI measurements. Ten patients with known vascular disease underwent a baseline MRI scan and a follow up scan approximately 2-3 weeks apart. The two measurements of cross-sectional wall plaque were compared and the correlations are shown in Table 1. It demonstrates excellent reproducibility.

Table 1: Reproducibility results of proposed plaque analysis results

MRI-Measures (normalized values)	Pcc	P Value
Plaque volume	0.892	< 0.001
Max thickness	0.960	< 0.001
Mean thickness.	0.928	< 0.001

Summary

This study proposes a plaque burden measurement approach based on wall segmentation from black and bright blood techniques of the superficial femoral artery. Preliminary results show that all three MRI measurements of plaque morphology are highly reproducible with excellent correlation. MRI therefore provides effective and reliable quantitative measurements for peripheral arterial disease evaluation.

Reference:
1. Toussaint et al. Circulation 94:932-938, 1996.
2. Xu et al, ISMRM 2004.
3. Angiography and Plaque Imaging, ISBN 0-8493-1740-1, pp381-384.