

Multimodality Imaging for Investigation of Plaque Morphology and Blood Flow: Preliminary Results

F. T. Baluyot¹, V. Shandasani², H. Underhill¹, B. Chu³, W. S. Kerwin³, and C. Yuan³

¹Bioengineering, University of Washington, Seattle, WA, United States, ²Ultrasound Investigation, Philips Healthcare, Bothell, WA, United States, ³Radiology, University of Washington, Seattle, WA, United States

Introduction: Complications from atherosclerosis can lead to stroke, myocardial infarction, and death. As a result, not only is the detection of atherosclerotic plaques important, an understanding of the formation and progression of lesions is vital. Furthermore, since the artery lumen is exposed to blood, the effects of blood flow, particularly wall stress, should be considered. By using different contrast weightings, MRI has shown the capability to identify plaques and various components (e.g., calcium, lipid rich necrotic core) in the carotid artery [1]. Ultrasound can also identify plaques and, to a limited extent, can identify various components based on shadowing and tissue echogenicity [2]. Both imaging modalities have the capabilities to image blood flow. Despite these imaging abilities, both techniques have limitations. MRI slice thicknesses are generally thicker than ultrasound and are sensitive to motion. On the other hand, ultrasound is highly operator-dependant, and traditional color Doppler methods are limited to one direction. Although both methods have weaknesses, together they can provide complementary information in order to improve upon the detection and understanding of atherosclerotic plaques.

Purpose: In this pilot study, we develop techniques that can combine MRI imaging with Vector Doppler imaging of the carotid artery to assess flow patterns detected by ultrasound to appearances of vessel wall and lumen on MRI.

Methods: Five subjects with various types of plaques underwent both MRI and ultrasound. **MRI Imaging:** Using a 3.0-T scanner (Philips, Best, Netherlands), a 4-element surface coil, and standardized protocol [1], 16 slices (centered at the bifurcation) of 2mm thickness were acquired with a FOV of 140 mm × 140 mm and a matrix size of 256 × 256. Four contrast weightings were used: TOF, PDW, T1W, and T2W with the latter three weightings using black-blood imaging technique.

Ultrasound Imaging: A trained sonographer acquired color Doppler images at atherosclerotic plaque sites using a linear 7.5 MHz transducer (Philips, Best, Netherlands). At each site, the sonographer took two series of color Doppler images at 20° and -20°. A cross-sectional freehand sweep of the carotid was also obtained.

Plaque Identification: Plaque inner and outer walls in the MRI images were outlined by a trained reviewer using in-house software (CASCADE). **Vector Map Generation:** Velocities and flow direction were calculated from the two color Doppler angle data for an averaged cardiac cycle (i.e., over 6 cardiac cycles, the cycles were averaged frames matched with respect to peak systole) using methods similar to previously published methods [3]. In order to represent the data, the flow direction at a particular pixel is color coded (i.e., purple is to the left, red is up, white is right, blue is down, and any other direction is a blend of the closest two colors) and overlain on the corresponding B-mode image. A second image was generated with the calculated velocities and a seven-pixel square zone of averaged directional data. The center of the zone is depicted as a box and a line from the box shows the direction of flow similar to a weather-vane.

Data Analysis: Using the freehand ultrasound scan as a guide, the plaques were registered between the two imaging modalities. A trained reviewer identified MRI slices with flow artifacts, which was then compared against the presence of flow reversal in the Vector Doppler images.

Results: Our findings of 35 slices of matched MRI and ultrasound demonstrates a strong (i.e., a Fisher's Exact Test P-value of 0.001) relationship between presence of flow artifact in MRI against presence of flow reversal in Ultrasound with a sensitivity and specificity of 80% 90%, respectively. Two examples are shown in Figures 1 and 2. In Figure 1, six slices of TOF and T1W show no flow artifact along the plaque. The Vector Doppler image indicated that there is no flow reversal in four different frames of the cardiac cycle (there were actually no reversals in any frame for this plaque). In Figure 2, three slices are shown for TOF, T1W, PDW, and T2W. Inside the lumen, flow artifact mimicking plaque is seen for all contrast weightings. The corresponding Vector Doppler images indicate flow reversal. Both examples demonstrate cases of association of flow artifact and flow reversal that we had expected.

Conclusion: These findings suggest combining information from MRI and ultrasound can assist in MRI interpretation. Observing flow reversal in ultrasound can identify areas that may incorrectly be identified as a lesion by MRI. Ultrasound is already used for screening for plaques before acquiring MRI images, and therefore, minimal work is required to acquire

two additional color Doppler readings. This additional information can be used by image reviewers to discriminate between flow artifact and actual plaque. Additionally, this can be of particular interest in monitoring plaque progression and regression in which a change in plaque morphology alters blood flow. Further studies will explore additional information made available by using these two imaging modalities for detecting and following the progression and regression of plaques as well as investigating the effects of blood flow patterns.

References: 1. Yuan C, et al., *NMR Biomed.* 2006; 19:636-654. 2. Wilhelm JE, et al., *IEEE Trans Med Imaging.* 1998; 17:910-922. 3. Dunmire, B., et al., *Ultrasound Med Biol.* 2000; 26(8): 1213-35.

Table 1: Comparison of Vector Doppler Results and MRI Results

		MRI Results Flow Artifact	
		No	Yes
Vector Doppler Flow Reversal	No	20	1
	Yes	5	9

