Characterization of Carotid Plaque Vulnerability using Quantitative Ultrasound and Strain Imaging

Xiao Wang

Under the supervision of Tomy Varghese and Professor Robert J. Dempsey

At the University of Wisconsin-Madison

6/4/2015

Stroke is the leading cause of serious, long-term disability and the fourth leading cause of death in the United States. In addition to clinically recognized stroke, "silent" strokes may occur, and are five times more prevalent. Silent strokes are not detected based on classical transient ischemic attack (TIA) symptoms and therefore difficult to prevent. It is also likely that these "silent" strokes may cause accumulated cognitive decline, due to cerebral micro-emboli caused by instability in carotid vulnerable plaque. Thus it is important to characterize carotid plaque and assess its vulnerability.

Plaque instability may be characterized by increased strain variations over a cardiac cycle with arterial pulsation. Therefore, strain imaging to detect plaque vulnerability based on regions with large strain fluctuations, may be able to determine plaque regions at increased risk for rupture. In this dissertation, accumulated axial, lateral and shear strain indices were correlated with cognitive function assessed on human subjects. Significant correlation of these maximum strain indices and cognitive function was demonstrated, indicating the feasibility of using strain indices to predict cognitive decline. Carotid plaque along with adventitia layer was segmented to identify vulnerable regions. Ultrasound strain imaging may therefore be a useful surrogate in the clinic to detect vulnerability of plaque and assess potential risk of silent stroke.

Statistical distributions of strain indices in different groups of patients and volunteers were also evaluated, followed by comparison of strain indices to trans-cranial Doppler (TCD) results. In addition to strain estimation along longitudinal scanning planes, an algorithm was developed to estimate radial and circumferential strain in a cross-sectional view of *in vivo* carotid artery using noninvasive ultrasound.

Carotid plaque can also be characterized using quantitative ultrasound (QUS), to assess the acoustic properties of tissue. Differences in acoustic properties may reflect difference in tissue composition. A novel approach is proposed whereby localized calcified, fibrous and lipid regions within heterogeneous plaque using a region-to-region registration with 3D histology and 3D attenuation coefficient was performed. QUS may also provide improved characterization of vulnerable plaque composition using direct localization of plaque regions and structure to histology.