# Abstract

Stroke is a leading cause of death and disability throughout the world. Clinicians recognize that carotid atherosclerotic plaque can be a contributing cause of stroke; however, clinical methods for characterizing carotid plaque with ultrasound are semi-quantitative, and tools are needed to assess plaque composition in asymptomatic individuals who have not yet suffered a stroke or other cerebrovascular event. To examine carotid plaque composition noninvasively and overcome some of these limitations, researchers have developed standardized quantitative ultrasound (QUS) methods based on brightness-mode (B-mode) images and radiofrequency (RF) echo signals. Our research group has been involved in this effort by developing signal processing approaches and evaluating QUS parameters. Some primary challenges of computing QUS parameters, particularly *in vivo*, are plaques' small sizes and heterogeneous composition. Algorithms developed in recent years reportedly minimize QUS estimation variance in simulation, phantom studies, and biological tissue. The primary goal of the research presented in this dissertation was to adapt some of these new signal processing approaches to carotid plaque assessment and develop and validate subsequent QUS parameters.

As part of this work, we applied an optimum power spectral shift estimation (OPSSE) method to RF echo signal data and computed attenuation coefficient and attenuation-corrected integrated backscatter parameters in plaque *in vivo* and *ex vivo*. Then, we compared our results to those from a reference phantom method (for *in vivo* attenuation coefficient estimation only) and to ground-truth assessments of plaque composition (whole plaque surgical scores, assessments of single representative sections of histopathology, and 3D reconstructions of histopathology whole slide images [for *ex vivo* only]). Our results demonstrated that the OPSSE method may provide QUS estimates with lower variance, fewer nonphysical estimates, and high spatial resolution. Further, attenuation coefficient and attenuation-corrected integrated backscatter

parameters correlated with cholesterol, calcium, thrombus, ulceration, hemorrhage, hemosiderin, and inflammation content in plaque and could discriminate among plaque scores.

Together, our results suggest that the applied signal processing approaches and developed QUS parameters may provide information about plaque composition that has not been revealed through other parameters and indices obtained as part of our study. This dissertation contributes to a growing body of QUS research that will guide future development of an accurate and reliable tool for assessing risk of plaque rupture or stroke by plaque echogenicity changes.