Chapter 1 : Objectives

1.1 Research statement

Previous results indicate that local strain distributions in carotid plaques may have a direct relationship with the risk of plaque rupture. In this work, we develop and evaluate a completely noninvasive method for *in vivo* strain imaging of patients scheduled for carotid endarterectomy at the UW-Hospitals and Clinics. The purpose of this research is to develop a viable screening method to assess stroke risk. Transcranial Doppler examinations are also performed on these patients with the intent to detect the presence of micro-emboli, which identifies plaque involved in injurious ischemic processes. Plaques removed during carotid endarterectomy (CEA) undergo further evaluation *in vitro* with high-frequency ultrasound followed by comparison with gross pathology to better understand plaque composition. Successful completion of these carotid ultrasound characterization objectives will further the use of real-time ultrasound strain imaging as a screening tool to identify patients with atherosclerotic plaque prone to disruption and micro-embolization.

1.2 Outline of the dissertation

In Chapter 2, the physiology and pathological causes of stroke are covered, and the significance of carotid atherosclerosis is revealed. Next, the properties researchers have associated with high risk plaques are surveyed. And the invasive and non-invasive methods researchers have utilized to quantify these properties are reviewed. An in-depth review is applied to the history of plaque characterization with diagnostic ultrasound. The chapter concludes with a synopsis of the physiological and biomechanical mechanisms involved, and explains why strain is a quantity that may consistently identify vulnerable plaques. The potential limitations of external ultrasound to effectively quantify strain are discussed.

Chapters 3 and 4 describe new methods to improve the first step in the process of generating a strain image: tracking displacements between time frames. Chapter 3 details a regularization method that improves robustness and Chapter 4 examines a method to reduce errors related to image discretization. Chapter 5 develops the mathematical and geometrical concepts underlying the strain tensor, and covers methods to calculate strains from noisy displacement estimates. Quantities derived from the strain tensor that are potentially useful as a risk index are discussed. Finally, the means to effectively accumulate these quantities over the sequence of images encompassing the cardiac cycle are listed.

Chapter 6 and 7 transition focus towards high-frequency ultrasound. Chapter 6 discusses experimental methods to characterize the acoustic properties of a tissue-mimicking phantom at high frequencies. Chapter 7 presents initial 3D high-frequency parametric ultrasound images of excised plaques.

Chapter 8 studies transcranial Doppler monitoring of the middle cerebral artery to detect microembolic events. Peak flow velocities are examined from a number of subjects.

Chapter 9 returns to strain imaging with presentation of *in vivo* images made from subjects with the highest grade of carotid stenosis. First, the multi-resolution strain imaging algorithm applied is described. Next, a number of case studies that illustrate various pathological conditions are presented.

Chapter 10 provides a summary and conclusion, and provides direction for future work.