Atherosclerotic Carotid Plaque Characterization Using Ultrasound and Elastography

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In this dissertation, we explore the feasibility of utilizing clinical ultrasound systems to study both ultrasonic and elastographic parameters for carotid plaque characterization.

In in-vitro studies, we estimated the: (1) ultrasonic attenuation coefficient using a novel power difference method; (2) scattering parameter related to size using both Faran's scattering theory and the Gaussian correlation model for excised plaque specimens. For elastographic imaging, we utilized the strain ratio as a normalized indicator of relative stiffness. The combination of attenuation coefficient, scattering parameter related to size and strain ratio improves the ultrasound tissue characterization and classification ability.

A two-dimensional multi-level strain estimation method was developed for estimating displacement and strains in carotid artery plaque in-vivo. In-vivo ultrasonic tissue characterization analysis also demonstrate that attenuation and scattering parameter related to size are significantly different in soft and calcified plaques. The combination of the attenuation coefficient and scattering parameter related to size estimated using Faran's scattering theory illustrates that these two parameters can be utilized to distinguish between calcified and soft plaque under in-vivo imaging conditions. The maximum accumulated axial strain and the maximum relative lateral shift values computed from the strain images over the cardiac cycle also provide differentiation between soft and calcified plaques. ROC analysis and Support Vector Machine algorithms were also utilized to evaluate the performance of combinations of these parameters to classify plaque.

Finally, we presented a generalized analysis on catheter position correction in intravascular ultrasound elastography. This correction is necessary for accurate estimation of plaque strain values in intravascular elastography. A theoretical derivation of the general solution for an arbitrary catheter position in a vessel lumen was developed. The theoretical results were verified using simulations with the catheter placed in the vessel lumen at different positions.