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Principal Strain Vascular Elastography for Imaging the Carotid Artery

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Abstract

Atheroscelrosis kill more Americans than all forms of cancer combined. The onset of the disease is characterized by thickening and stiffening of the arterial wall, and in advanced stages it leads to formation of life-threatening plaques. Rupture of these advanced plaques can lead to myocardial or cerebral infarction, and their rupture propensity is governed by its composition and structure. Vascular elastography can visualize the strain distribution in the carotid artery, and serve as a useful screening tool to assess the stiffness of the arterial wall – for early detection of major cardiovascular and cerebrovascular diseases, and to assess plaque composition.

Currently available vascular elastography techniques visualize polar strains across the transverse cross-section, and axial strain across the sagittal cross- section. It is difficult to produce reliable transverse polar strain elastograms (radial and circumferential) because the center of carotid artery is typically unknown. Further, axial strain estimated along the sagittal plane can only measure a component of the radial strain in the vessel. In this thesis, we hypothesized that principal strain imaging can overcome these limitations, provided reliable estimates of lateral displacements were available. To estimate high quality lateral displacements, multi-element synthetic aperture (MSA) vascular elastography was developed. The phantom and *in vivo* experiments demonstrated that MSA imaging can produce high quality axial and lateral strain estimates. Compared with synthetic aperture (SA) imaging and compounded plane wave (CPW) imaging, MSA imaging improved the elastographic contrast-to-noise ratio of the vascular elastograms by over 15 dB and 12 dB, respectively.

Subsequently, it was demonstrated that principal strains reduced artifacts incurred when polar strains were computed with imprecise estimates of the vessel center. The feasibility of using principal strain imaging in characterizing transversely isotropic mechanical behavior of the carotid artery was also established. Further, principal strain imaging addressed the issue of dependency of axial strain on the geometry of the vessel, when imaging across the sagittal cross-section. More specifically, principal strain imaging enabled estimation of arterial strain in the radial direction, independent of the angle between the transducer and the vessel, which is typically governed by the geometry and anatomy of the vessel, and varies across subjects.

The results obtained from this thesis suggest that principal strain imaging can be a very useful tool for translation of vascular elastography to the clinic. Future studies should involve the assessment of the mechanical properties of the carotid artery using principal strain elastography, and compare it conventional markers of subclinical atherosclerosis.