MAPPING 2D STRAIN IN THE WALL OF THE CAROTID ARTERY USING DISPLACEMENT-ENCODED MRI

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Introduction: Atherosclerotic cardiovascular disease is the leading cause of death in the United States with over 19 million deaths worldwide where a large portion of these victims are asymptomatic [1]. Therefore there is a considerable demand for the early diagnosis of atherosclerosis, otherwise known as hardening or stiffening of the arterial walls. A number of large epidemiologic studies have demonstrated that carotid artery wall stiffness contributes to systolic hypertension, increased cardiovascular risk [2], and risk of ischemic stroke [3]. Furthermore, biomechanical models of the carotid artery have demonstrated increased atherogenesis in regions with high strain . We developed a displacement-encoded MRI (DENSE) sequence for imaging the motion of the carotid artery wall and mapping the 2D circumferential strain in wall [4]. With increased resolution and regional accuracy, this technique could potentially give more efficacious risk indicators of atherosclerotic cardiovascular disease. Carotid stiffness has been shown to increase with age [5], therefore our aim was to quantify strain using DENSE in two different age groups and characterize strain at the bifurcation of the carotid artery.

Methods: 25 normal, healthy subjects with no history of neurological or cardiovascular disease, were recruited for the study population. Young controls (n=15) were ages 19-35 years. Older controls (n=10) were ages 40-80 years. All subjects were scanned on a 3.0T whole-body clinical scanner (Trio, Siemens, Germany) using an 8cm surface coil (Nova Medical, MA). Initial three plane scout images were acquired to localize of the left and/or right carotid artery and optimize coil location. 2D TOF images were acquired and MIPs used for slice positioning. Three slices were centered 0.5 cm below the bifurcation of the carotid arteries (Figure 1). Time points of maximum and minimum vessel diameter were determined with an ECG gated cine scout scan. DENSE images of the carotid artery wall were acquired at 0.6x0.6x4.0 mm resolution, including displacement encoding in three oblique directions to produced a pixel-by-pixel 3D displacement map of the vessel wall and surrounding tissue. Image acquisition was consistently placed at the time of maximum lumen diameter, while in two separate scans the encoding portion was placed at 40 ms and 80 ms after the R-wave to capture the maximum wall strain and intermediate strain. Total scan time lasted approximately 45 minutes. DENSE raw data was processed to produce strain maps (DENSEView, Bethesda, MD) and compute average circumferential strain. For comparison, lumen vessel horizontal and vertical diameters were measured from the cine scans at the same time points as the DENSE images and the average circumferential strain was also calculated. The correlation between the two measurements provides a measure of accuracy.

Results: First, the comparison between cine displacement and DENSE strain measurements demonstrated good correlation, demonstrating the accuracy of DENSE measurements. Second, the older subject group showed significantly decreased strain when compared to the young subject strain measurements ($p<0.005$), confirming that DENSE could detect age-related changes (Figure 2). Furthermore, DENSE strain measurements increased in superior slices closer to the bifurcation which correlates with biomechanical models of the carotid bifurcation (Figure 3).

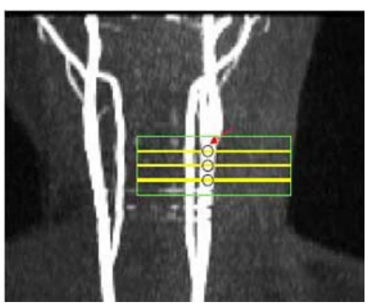

Figure 1. Slice locations for DENSE MRI scans. Red arrow indicates the bifurcation of the carotid arteries.

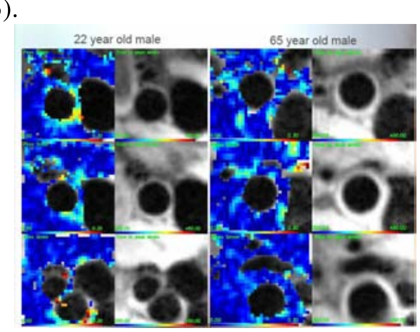

Figure 2. 2D strain maps in young (left) older (right) subjects. Note increased (yellow and red) strain in the young subject.

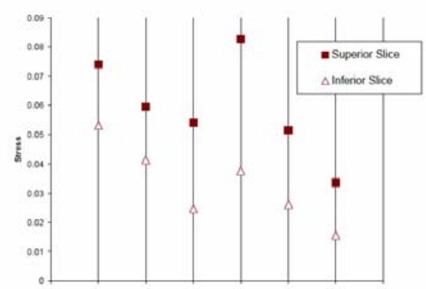

Figure 3. Strain measurements in superior and inferior slices in normal controls.

Conclusion: DENSE measurements of strain corroborate with both clinical and biomechanical views of strain in the carotid arteries in normal controls. Future studies will demonstrate the efficacy of this technique in patients with known atherosclerosis.

References: 1 .Myerburg, R.J., et al.,. Am J Cardiol, 1997. **80**(5B): p. 10F-19F. 2. Mitchell, G.F., et al., Circulation, 2005. **112**(2): p. 194-9. 3. Dijk, J.M., et al., Stroke, 2004. **35**(10): p. 2258-62. 4. Wen, H., A. Vignaud, and I. Rodriquez. *European Society of Magnetic Resonance in Medicine and Biology*. 2005. Basle, Switzerland. 5. McVeigh, G.E., et al., *e.* Hypertension, 1999. **33**(6): p. 1392-8.

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