Single-Shot DENSE MRI of the Carotid Arteries

A. P. Lin[1,2], E. Bennett[2], Y. Le[2], S. Fraser[1], and H. Wen[2]

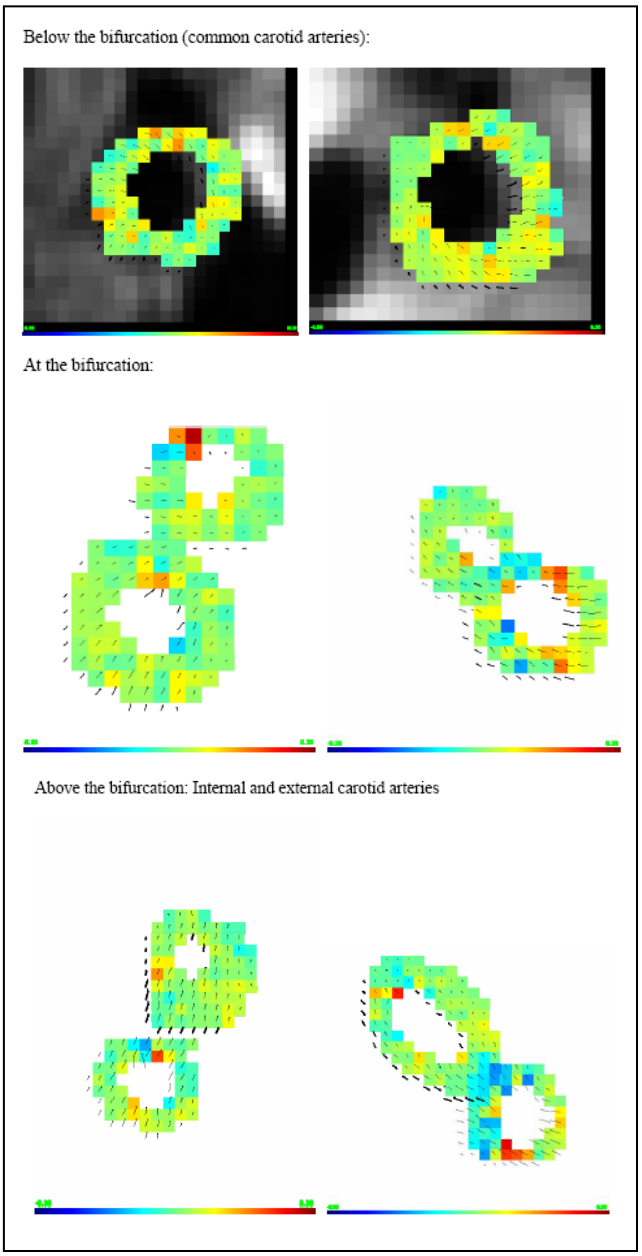
[1]Biochemistry and Molecular Biophysics, California Institute of Technology, Pasadena, CA, United States, [2]National Heart Lung and Blood Institute, National Institutes of Health, Bethesda, MD, United States

Introduction:

The DENSE (Displacement Encoding with Stimulated Echoes) method takes advantage of the stimulated echo which maintains phase information in the longitudinal direction that doesn't decay as quickly as in the transverse plane. The encoding and decoding gradient pulses are separated by the mixing time Tm, so that spin displacement during this time causes a phase shift in the acquired image which is proportional to the net displacement in the direction of the gradient. This method has been applied to the carotid arteries using a true-FISP segmented k-space readout and phase cycling signal averaging to improve SNR and remove unwanted FID and stimulated-anti-echo signals [1]. While it has been proven effective for validation of strain in the common carotid arteries [2], in-plane flow artifacts are pronounced at and above the bifurcation of the carotid arteries where blood flow is faster and more turbulent. Additional artifacts were seen with segmented k-space acquisition and signal averaging from misregistration caused by movement such as swallowing. We propose an alternate method using single shot data acquisition which will help to eliminate these artifacts.

Methods:

The single-shot DENSE sequence employs a true-FISP readout of 40 k-space lines per heartbeat at TR = 3.06 ms, resolution of 0.8x0.8x4.0 mm, matrix 64x256, restricted FOV excitation in the phase-encoding direction by the DENSE-encoding RF pulses equivalent to FOV of 104x205 mm and 128x256 matrix, trigger interval of 2 heartbeats. Three separate encoding directions are acquired in 3 separate heartbeats. 48 repetitions were acquired for a scan time of 5 minutes for each slice. Three slices were placed at 1 cm below the bifurcation of the carotid arteries in the common carotid, at just above the bifurcation and at 1 cm above the bifurcation to include the internal and external arteries. Data was acquired in phantoms and in five normal controls (n=9 exams) on a 1.5T Siemens Avanto TIM MR scanner using phased array surface coils (Machnet, Netherlands). To begin the analysis of the carotid lumen on either side, images were cropped to a rectangular window around the artery, and rigid-body registration of the windowed images were performed prior to strain analysis of each repetition, followed by calculating the average strain map over all repetitions. The adaptive spatial filter was applied by eliminating images that had the greatest motion artifact. In the regions above the carotid bifurcation strain maps were created around the internal and external carotid arteries independently and then overlaid.



Results:

Phantom studies using true-FISP readout showed a nearly 2x SNR increase over using a FLASH readout. Initial phantom and in vivo studies showed that a flip angle of 30° is optimal. Figure 1 to the right shows representative strain maps (color) overlaid the displacement vectors at the common carotid arteries (top, overlaid over anatomical images), at the bifurcation (middle) and above the bifurcation showing the internal and external carotid arteries (bottom). In all cases, in-plane flow artifacts above the bifurcation were eliminated and provided high SNR images with enough resolution to measure strain in the smaller lumen walls of the internal and external carotid arteries.

Conclusion:

Single-shot DENSE is an effective method to eliminate artifacts arising from head-neck motion and in-plane flow at and above the bifurcation of the carotid arteries. Future studies will quantify regional strain patterns and compare these patterns in healthy volunteers and patients with known carotid atherosclerosis. These data should show whether regional stiffness of the artery wall is correlated with and possibly an underlying cause of atherosclerosis.

References:

1. Wen H, et al.. Magn Reson Mater Phy 2005;18(S1):S60-S61. 2. Lin et al. J Cardiovasc Magn Reson 2006. 8(1):48

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