Comparison of Segmented and Single-Shot DENSE MRI of the Carotid Arteries at 3T

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Introduction:

Strain mapping of the carotid artery wall using displacement encoded MRI with stimulated echoes (DENSE-MRI) provides regional stiffness measures [1]. However, the scan lasts several minutes, and segmented k-space acquisition suffers from artifacts due to head-neck motion and turbulent in-plane blood flow. This problem is solved with a single-shot imaging sequence and rigid body image registration in post-processing. The purpose of this study is to quantitatively compare segmented and single-shot DENSE strain measurements in phantoms and human subjects.

Methods:

Polyvinyl alcohol cryogel carotid phantoms were created and attached to a flow system with a pulsatile pump and imaged on a 3T Siemens Trio MR scanner using a 8cm surface coil (Nova Medical, Wilmington, MA). Segmented data was acquired as previously described. 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 acquired with both segmented and single shot DENSE in the same slice locations.

A series of 12 consecutive human subjects were also imaged using the same parameters described above. 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. All data was processed using DENSEview which provides SNR, circumferential mean strain and standard deviation [2]. Rigid body registration was used in single shot DENSE images to remove frames with the greatest motion artifact as determined by maximizing Pearson's correlation coefficient of the reference frame with the highest total correlation. To quantify the improvement of the image registration, SNR and strain were measured in the same data set using 10%, 30%, 45%, 60%, 75%, and 90% of the total frames.

Results:

In phantoms, in-plane flow artifacts were evident in segmented DENSE images but not single shot DENSE images as shown in Figure 1, insert. This improvement resulted in greater reproducibility and accuracy as reflected by the lower variability of repeated strain measurements and lower standard deviation of intravoxel strain measurements (Figure 1, graph). These results are also reflected in the *in vivo* studies where rigid body registration improved the quality of the DENSE images (Figure 2, left top: before registration, left below: after registration) such that morphology blurred by artifacts are now visible. The graph in Figure 2 illustrates in a representative case where image artifacts were so severe that when 40% of the frames were removed, SNR was optimal. The effect of this optimization is evident in Figure 3 which shows irregular displacement vectors in segmented DENSE that are likely the result of image artifacts whereas the single shot DENSE images reflects displacement in the expected directions.

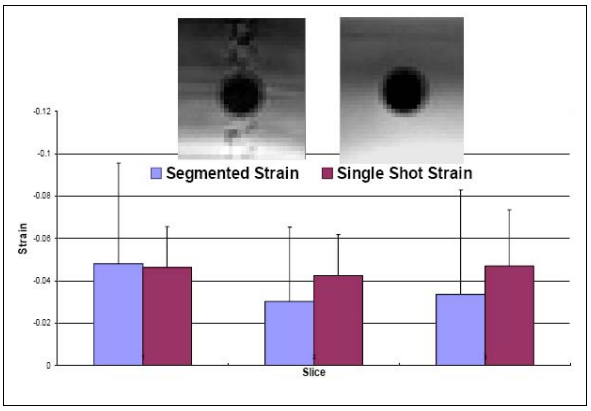

Figure 1. DENSE strain measurements and images in phantoms.

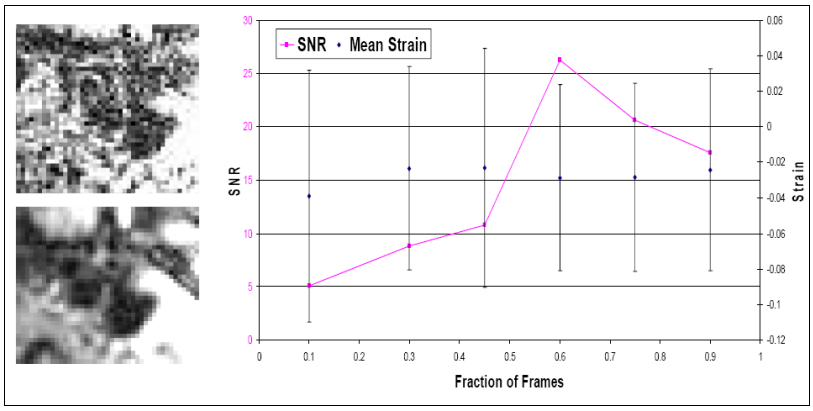

Figure 2. Impact of rigid body registration on DENSE images, SNR, and strain.

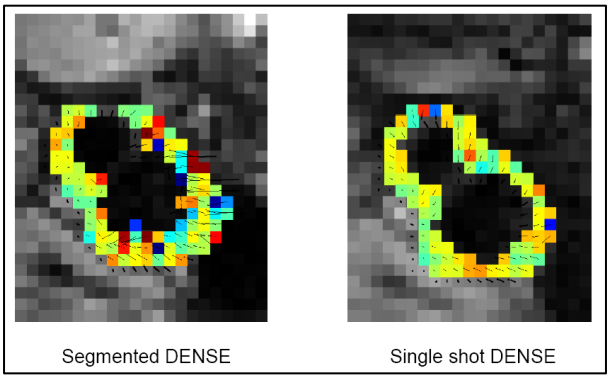

Figure 3 (left). In vivo segmented and single shot DENSE images in the same subject.

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. This improvement results in greater accuracy and reproducibility of the DENSE strain maps which will allow for better characterization of plaque in patients with atherosclerosis.

References: 1.Lin et al. MRM 2008;60(1):8-13 2. Wen et al. Radiology 2008;246(1):229-40