Variable-Density Spiral Improves Quality of Multi-Shot Arterial Spin Labeling Perfusion Images

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Introduction. Spiral readouts offer a number of advantages for perfusion imaging, including shorter minimum TEs, greater immunity against bulk motion, and shorter acquisition times. Specifically, multi-shot spiral readouts offer the additional advantages of increased SNR and reduced sensitivity to off-resonance and susceptibility effects [1]. Furthermore, the reduced readout times in multi-shot spiral results in an increase in the ASL signal in distal slices by reducing tag decay between acquisition of the first and last slices in 2D acquisitions. Although single-shot conventional spiral samples the center of k-space beyond the Nyquist limit, multi-shot conventional spiral has limited self-navigation potential and, consequently, exhibits sensitivity to motion occurring between acquisition of each interleaf [1-3]. In contrast, by oversampling the center of k-space with each interleaf, variable-density spirals offer increased immunity against motion as well as facilitate self-navigated phase correction [2-4]. We demonstrate here that variable-density spiral readouts improve the quality of multi-shot ASL perfusion images in brain.

Methods. Three normal volunteers were used in this study. Acquisition was performed on a 3.0T GE Signa Excite whole-body scanner (GE Healthcare, Milwaukee, Wisconsin) equipped with 4 G/cm gradients. The body coil was used for RF transmission and a commercial 8-channel phased array coil was used for reception. Two runs of pulsed ASL were performed sequentially on each volunteer using a PICORE/QUIPSS II tagging scheme with multi-shot spin-echo spiral readouts. In the first run, ASL images were acquired using an 8-shot conventional spiral readout [5]. In the second run, ASL images were acquired using an 8-shot variable-density spiral readout [4]. Tagging and acquisition parameters consisted of the following: inversion time (TI,TI2)=1500msec, temporal tag width (tau, TI1)=700msec, tag thickness: 20cm, tag/imaging slab gap: 1cm, FOV=22cm^2, Matrix=96^2, TE=11msec, TR=3500msec, TH=5mm, Skip=1.5mm, number of samples (reps)=18 (17 averages), variable-density spiral pitch factor: 4. Images were reconstructed offline using custom software developed at our Institution. To evaluate the efficacy of phase correction on the ASL images, the variable-density spiral images were reconstructed without and with navigator correction [2]. Finally, mean difference images (i.e., ΔM) were calculated following nearest neighbor subtraction of tag from control images (excluding the first tag and control image).

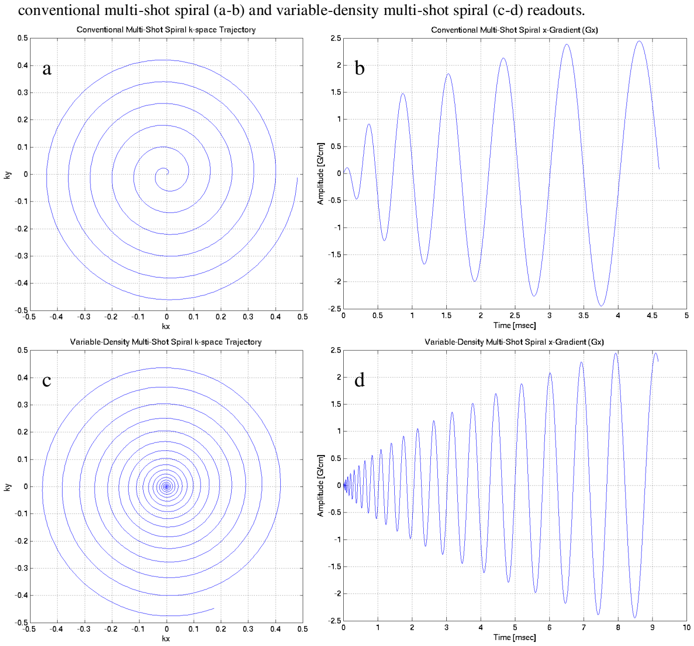

Figure 1: K-space trajectories and x-gradient (Gx) waveforms for one interleaf calculated for the conventional multi-shot spiral (a-b) and variable-density multi-shot spiral (c-d) readouts.

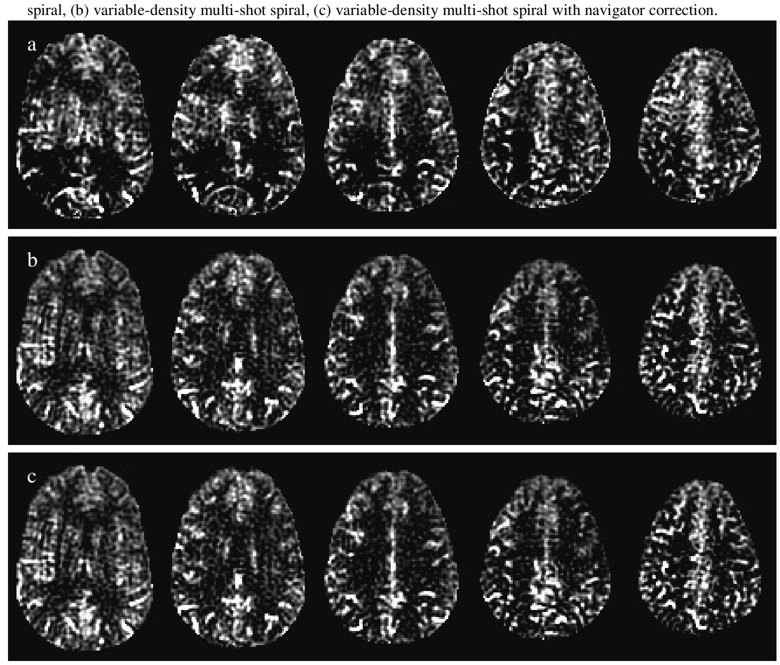

Figure 2: Mean difference images from one representative subject acquired using (a) conventional multi-shot spiral, (b) variable-density multi-shot spiral, (c) variable-density multi-shot spiral with navigator correction.

Results and Discussion. Figure 1 displays the corresponding k-space trajectories and x-gradient waveforms for one interleaf of the conventional multi-shot spiral (a-b) and variable-density multi-shot spiral (c-d) readouts. By oversampling the center of k-space, variable-density spiral offers more immunity to inter-shot motion and facilitates self-navigation, at the expense of a longer gradient waveform duration (i.e. longer readout). Figure 2 displays mean difference images, for one representative subject, acquired using the (a) conventional multi-shot spiral readout, (b) variable-density multi-shot spiral readout, and (c) variable-density multi-shot spiral readout with navigator correction. Similar results were obtained for each of the three volunteers used in the study. Notice the signal dropout and artifacts in the medial posterior regions of the difference images acquired with the conventional spiral readout. However, the difference images obtained with the variable-density spiral readout demonstrate considerable improvement, appearing more uniform. Although navigator correction was not found to make a substantial improvement in the quality of the variable-density spiral difference images with the experienced volunteers used in this study, it is expected to in improve results in patient studies. These results suggest that multi-shot arterial spin labeling perfusion estimates benefit from variable-density spiral readouts, an improvement we content will become even more important in patients. Future work will include application of multi-shot, variable-density spiral to high resolution ASL, and estimating water permeability via collection of multi-shot, diffusion-weighted ASL images [6,7].

References. 1. Glover et al., MRM 39:361-368 (1998), 2. Liu et al., MRM 52:1388-1396 (2004), 3. Li et al., JMRI 21:468-475 (2005), 4. Kim et al., MRM 50:214-219 (2003), 5. Glover, MRM 42:412-415 (1999), 6. Silva et al., MRM 38:232-237 (1997), 7. Wang et al., J CBF & Met 27:839-849 (2007).

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