Arterial Spin Labeling Using 3D Spiral TSE with A Distributed Spiral-In/Out Trajectory

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Introduction Arterial Spin Labeling (ASL) has drawn increasing interest as a non-invasive quantitative tool to measure the cerebral blood flow (CBF). A segmented 3D readout is preferred to collect the data[1]. Various 3D techniques have been developed, including GRAdient- and Spin-Echo(GRASE)[2,3] and spiral Turbo-Spin-Echo (TSE)[4] sequences. In the conventional spiral TSE ASL method, a spiral-out readout is typically used (Fig. 1a), so the spin echo is not aligned with the center of k-space. The data are often collected on a stack of spirals trajectory (Fig. 1c), which requires the number of slices be equal to (or a multiple of) the echo train length (ETL). In this work, we propose a 3D spiral TSE sequence employing a distributed spirals trajectory[5] with a spiral-in/out readout[6] to overcome these drawbacks.

Methods The gradient waveform and k-space trajectory of the cylindrical distributed spiral-in/out method are shown in Fig. 1 (b) and (d). The spiral-in/out readout aligns the spin echo to the center of k-space and therefore produces higher SNR. With the cylindrical distributed spirals method, the uniform distribution of all spiral arms along the kz direction eliminates the constraint on the number of slices and ETL. A spherical distributed spirals trajectory[5] is also feasible (not shown here).

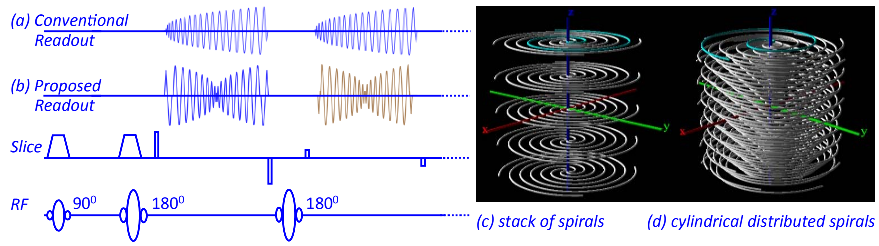

Fig. 1 Spiral TSE with a conventional spiral-out readout (a) and the proposed spiral-in/out readout (b). The blue and brown colors in b) indicate different spiral waveforms (i.e., different rotation angles). The corresponding k-space trajectories are illustrated for stack of spirals (c) and cylindrical distributed spirals (d).

Cardiac triggering is used to mitigate the shot-to-shot signal variation by synchronizing the ASL preparation with the cardiac cycle. Given that the TR is about 4.3 s, this has little impact on scan time.

The sequence was implemented on a Philips 3T Ingenia scanner. Volunteer data were acquired with a pseudo-continuous ASL preparation[4] (Labeling Duration = 1.8 s, Post Label Delay = 1.9 s) and the following imaging parameters: FOV = 240x240x120 mm^3, resolution = 3.5x3.5x4 mm^3, 5 arms/slice, ETL = 7, ADC = 16 ms, TR ~ 4.3 s (cardiac triggering). For comparison, data were also acquired using 3D Cartesian GRASE with ETL = 8, EPI factor = 25, TR = 4.3 s, number of signal averages = 6, SENSE reduction factor 3 and 1.2 in the phase and slice encoding directions, respectively. The scan time is 3:52 for both spiral TSE and Cartesian GRASE methods. In addition, proton density weighted images were also acquired with both methods for the calculation of CBF map. (A better reference is the conventional spiral TSE mentioned in the Introduction session, but it is neither available as a product from our vendor, nor implemented in house yet).

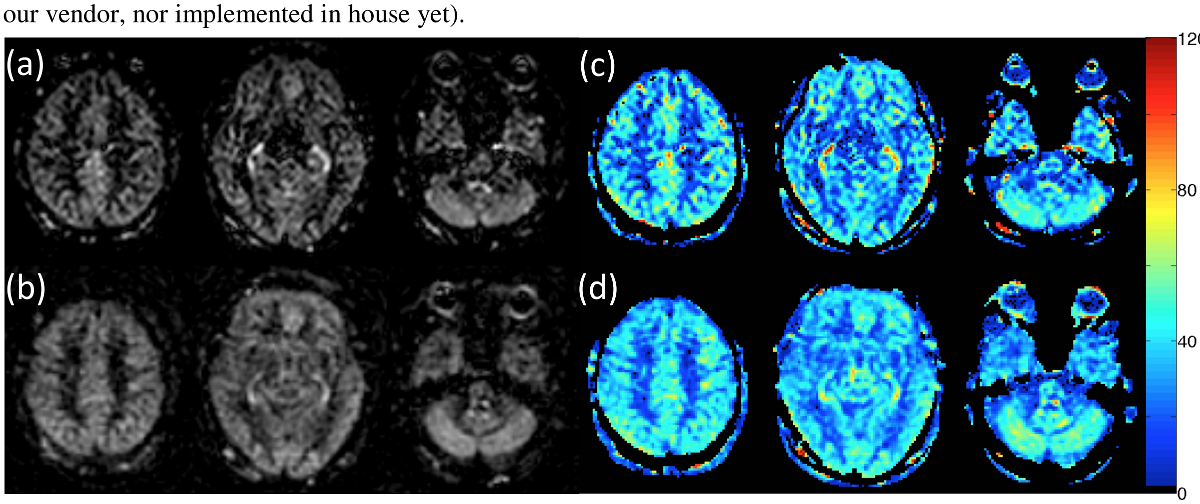

Fig. 2 Three out of 30 perfusion images acquired with 3D Cartesian GRASE (a) and the proposed 3D spiral TSE (b). (c) and (d) are the calculated CBF maps from the Cartesian GRASE and spiral TSE data, respectively. The unit of the CBF maps is ml/100 g/min.

Results Fig. 2 shows the perfusion images (3 out of 30 slices) obtained with 3D Cartesian GRASE (a) and the proposed 3D Spiral TSE (b). The residual distortion artifacts near the frontal lobe in the GRASE images are not present in the spiral images. Fig. 2c and 2d show the corresponding CBF maps calculated from the GRASE and spiral TSE data sets, respectively. These preliminary results demonstrate that the proposed technique can produce comparable or higher image quality when compared to 3D GRASE ASL.

Conclusion A new 3D spiral TSE data acquisition technique is developed for ASL perfusion imaging. By incorporating a spiral-in/out readout and a distributed spirals trajectory, the proposed technique achieves good SNR efficiency and flexibility in choosing the number of slices and ETL. Future work includes implementing the conventional TSE with a stack of spiral-out trajectory and performing a direct comparison.

References 1. Alsop DC, et al. Recommended Implementation of ASL perfusion MRI for clinical applications. ISMRM perfusion study group meeting 2013. 2. Gunther M, et al. MRM 2005;54:491. 3. Fernandez-Seara MA, et al. MRM 2005;54:1241. 4. Dai W, et al. MRM 2008;60:1488. 5. Turley DC, et al. MRM 2013;70:413. 6. Glover GH, et al. MRM 2001;46:515.

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