Accelerated Kinetic ASL using 3D Spiral TSE and Compressed Sensing

Li Zhao[1], Xiao Chen[1], Samuel W. Fielden[1], Frederick H. Epstein[1], John P. Mugler III[2], Josef Pfeuffer[3], Manal Nicolas-Jilwan[2], Max Wintermark[2], and Craig H. Meyer[1,2]
[1]*Biomedical Engineering, University of Virginia, Charlottesville, Virginia, United States,* [2]*Radiology, University of Virginia, Charlottesville, Virginia, United States,* [3]*Siemens, Erlangen, Germany*

Introduction: Kinetic ASL can yield maps of CBF, CBV, MTT and transit delay, which are useful in the setting of acute stroke. However, it is challenging to obtain sufficient SNR, accuracy, and coverage in the limited scan time available in this setting. 3D acquisition can improve the SNR significantly [1] and compressed sensing can exploit the underlying spatiotemporal sparsity efficiently [2], thus leading to a very rapid kinetic ASL acquisition. The goal of this study was to develop a kinetic ASL technique using multi-TI FAIR with a 3D spiral TSE readout [3] combined with acceleration using compressed sensing.

Methods: All experiments were performed on a Siemens Trio 3.0T scanner. The FAIR tagging used a FOCI pulse (1000mm slice thickness for control image, 80 mm slice thickness for label image). The signal was sampled using a 3DTSE stack of spirals with the phase encoding along the z direction. Each echo train repetitively sampled a particular spiral interleaf as the z phase encoding symmetrically sampled kz. Three spiral interleaves were required for full sampling, resulting in an in-plane resolution of 4.0x4.0 mm. The readouts were constant-density 6-ms spirals. Slab excitation and chopping were performed by alternating the phase of the refocusing pulses during signal averaging. BIR4 pulses and flow-sensitizing gradients were used to suppress blood flow before excitation. Crushers along all three axes were used to eliminate banding artifacts.

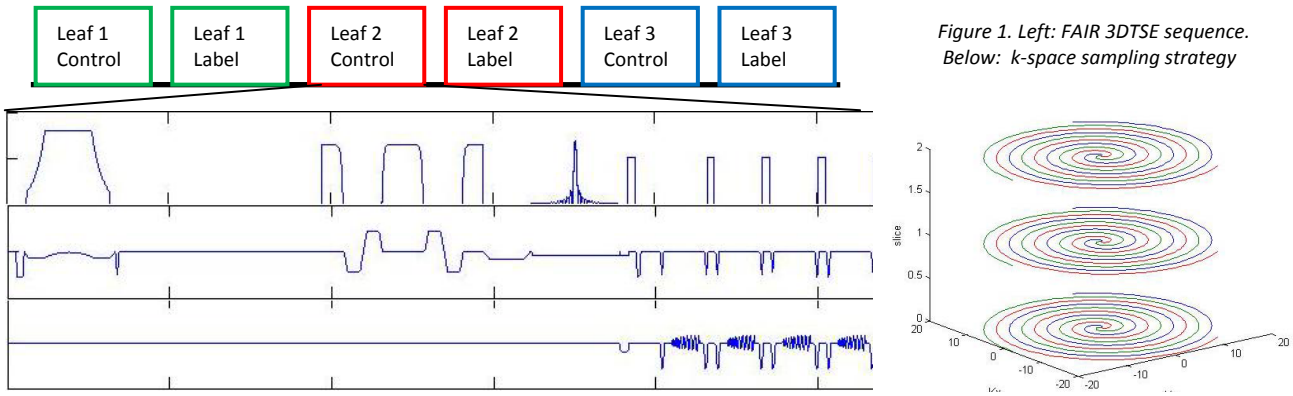

Figure 1. Left: FAIR 3DTSE sequence. Below: k-space sampling strategy

Other parameters in the experiments were TR = 5s, TE = 24 ms, FOV = 200 mm, slice thickness = 5mm, 12 slices, pulse triggering, 4 signal averages. Each fully-sampled frame was collected in about 2 minutes. 9 frames of images with different TIs (400, 700, 1000, 1300, 1600, 1900, 2200, 2500, 2800 ms) were collected.

The data was processed in MATLAB 2011b. Compressed sensing (CS) is tested on the 9th slice and data is undersampled off-line with an acceleration rate of 3. 1D FFT is done in the slice direction of each frame first. Then temporal constrained CS reconstruction [2] is performed on one of three interleaves in each frame. Non-Uniform Fast Fourier Transform (NUFFT) is used to transform data between k-space and image domain.

A classic single-compartment dynamic PASL model [4] was used for CBF and MTT estimation from fully-sampled data. Common assumptions were made: blood T_{1b}=1900ms, brain-blood partition coefficient λ=0.9. M0a was calculated from CSF recovery curve in control images and T2 decay was corrected with an assumption of T2_csf = 1000ms.

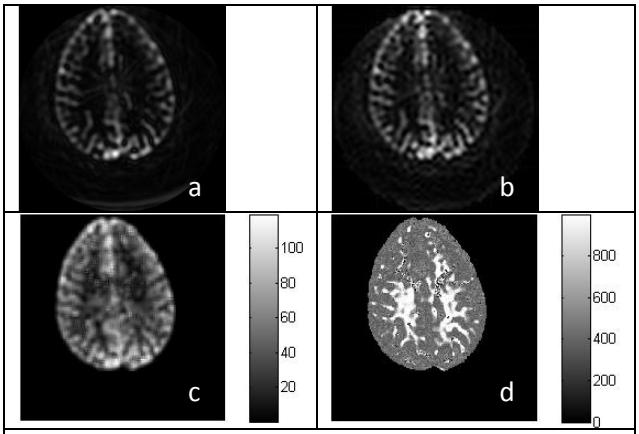

Figure 2. 3D spiral TSE- FAIR result.
a. Fully sampled (TI=1600 ms).
b. Compressed sensing (TI=1600 ms, R=3)
c. CBF (ml/100g/min). d. MTT (ms)

Result and Conclusion: As shown in Fig. 2, 3D TSE with constant density spiral readouts gives sufficient SNR in a short scan time. The mean CBF of selected GM ROI is about 66 ml/100g/min. The mean MTT was about 416 ms in grey matter and 983 ms in white matter. The compressed sensing reconstruction result was similar to the fully-sampled reconstruction, other than an expected reduction in SNR. Therefore, 3D kinetic spiral TSE spiral with compressed sensing acceleration shows promise for rapid kinetic ASL measurements. Future work will include kinetic perfusion modeling and higher acceleration factors by exploiting 4D sparsity and spatial parallel imaging.

Reference: 1. Gunther et al., *MRM*, 54:491-498 (2005). 2. Chen et al., ISMRM, 6349 (2011). 3. Fielden et al., *ISMRM*, 2820 (2011). 4. Buxton et al., *MRM*, 40:283-396 (1998).

Acknowledgements: This work was funded by the Coulter Foundation and Siemens Medical Solution.