Accelerated spiral Fourier velocity encoded MRI using SPIRiT parallel imaging

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Introduction

Fourier velocity encoding (FVE) [1] is robust to partial volume effects that may cause loss of diagnostic information in phase-contrast imaging [2]. Scan time in FVE can be significantly reduced using spiral trajectories in $\mathbf{k_x}$-$\mathbf{k_y}$ for spatial encoding [3], and/or temporal acceleration [4,5]. The use of parallel imaging may reduce spatial aliasing due to temporal undersampling in temporally-accelerated FVE [6]. We investigate the use of the iterative self-consistent parallel imaging reconstruction (SPIRiT) method [7] to accelerate the acquisition of spiral FVE.

Theory

Spiral FVE: Acquisition is performed using spiral trajectories in $\mathbf{k_x}$-$\mathbf{k_y}$ for spatial encoding, and bipolar gradients for phase-encoding the velocity dimension ($\mathbf{k_v}$).

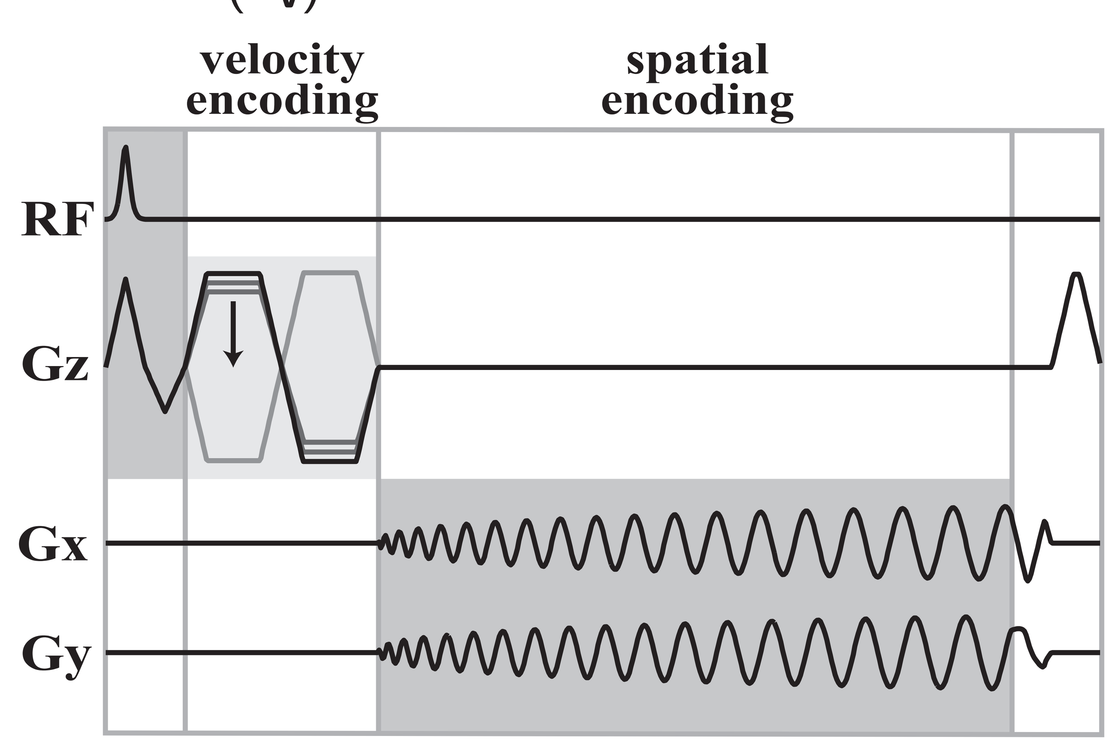

Figure: Spiral FVE pulse sequence [3].

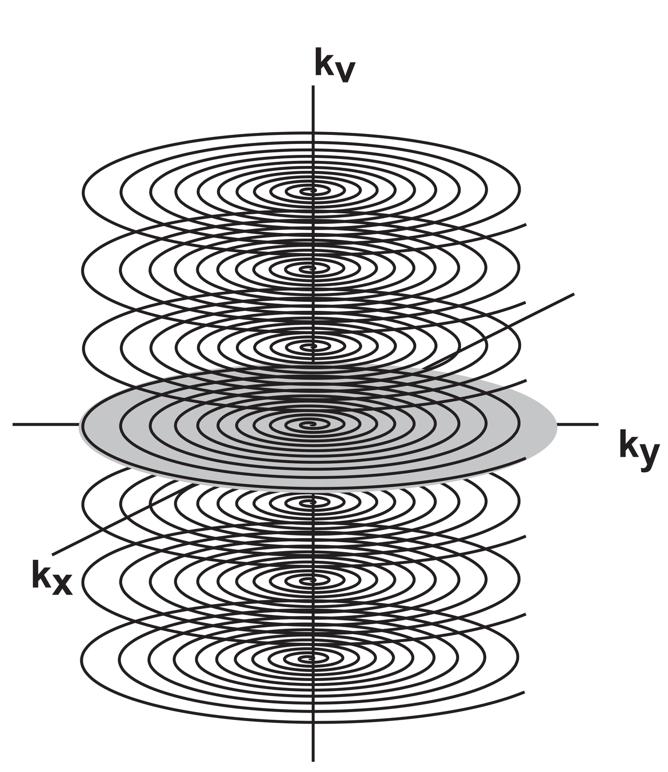

Figure: Spiral FVE's k-space trajectory is a temporally-resolved stack-of-spirals in $\mathbf{k_x}$-$\mathbf{k_y}$-$\mathbf{k_v}$ [3].

SPIRiT: The iterative self-consistent parallel imaging reconstruction (SPIRiT) approach [7] is an autocalibrated coil-by-coil parallel imaging reconstruction method, based on self-consistency.

Methods

Spiral FVE data was acquired on a GE Signa 3T EXCITE HD system (40 mT/m, 150 T/m/s), using a 4-channel carotid coil. Scan parameters: 1.4×1.4×5 mm^3 spatial resolution over a 16 cm FOV, 5 cm/s velocity resolution over a 240 cm/s FOV, 12 ms temporal resolution. Scan time was 146 seconds (256 heartbeats at 105 bpm).

Parallel imaging acceleration was evaluated using 2-fold and 4-fold spatially-undersampled datasets, obtained from a fully-sampled set. Data was reconstructed using sum-of-squares or SPIRiT.

Results (qualitative)

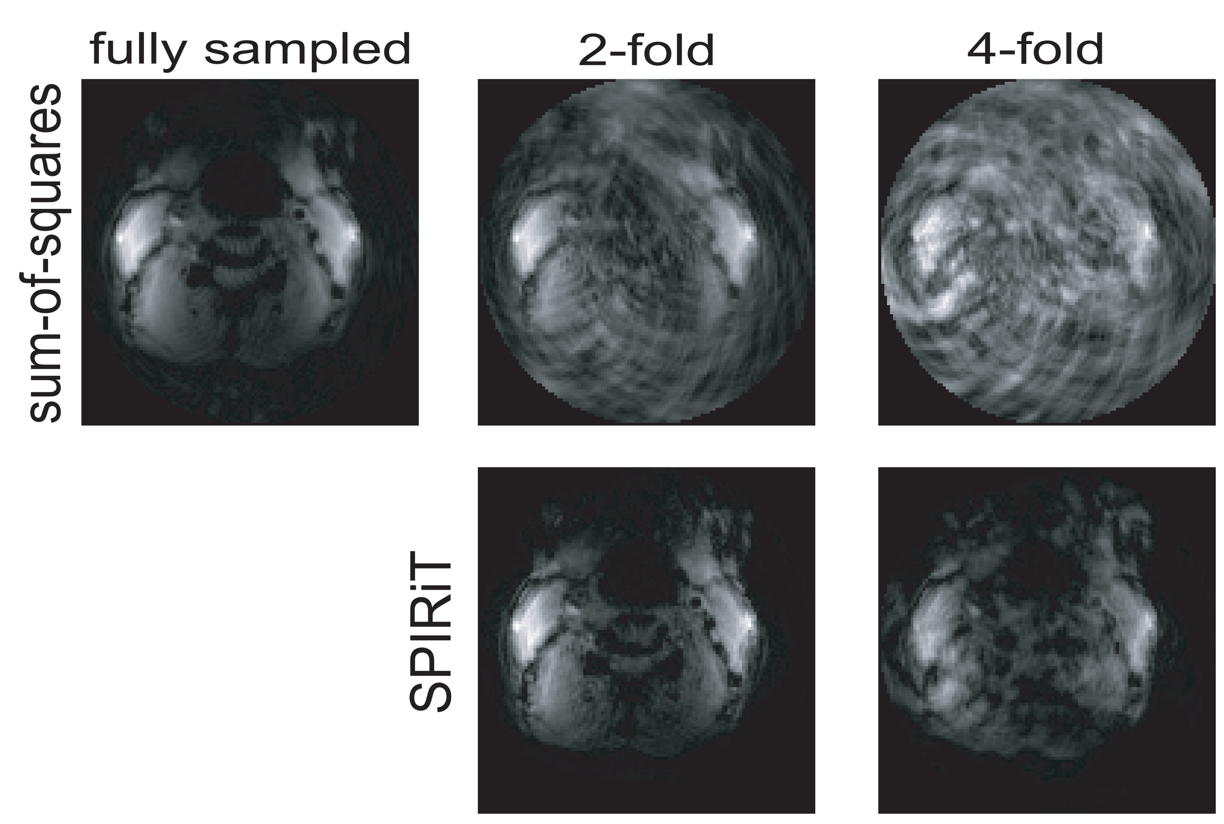

Figure: Axial magnitude images of the neck obtained using sum-of-squares (top row) and SPIRiT (bottom row), with different acceleration factors. These images correspond to $\mathbf{m(x, y, v, t)}$ for $\mathbf{v = 0}$ and $\mathbf{t = 0}$.

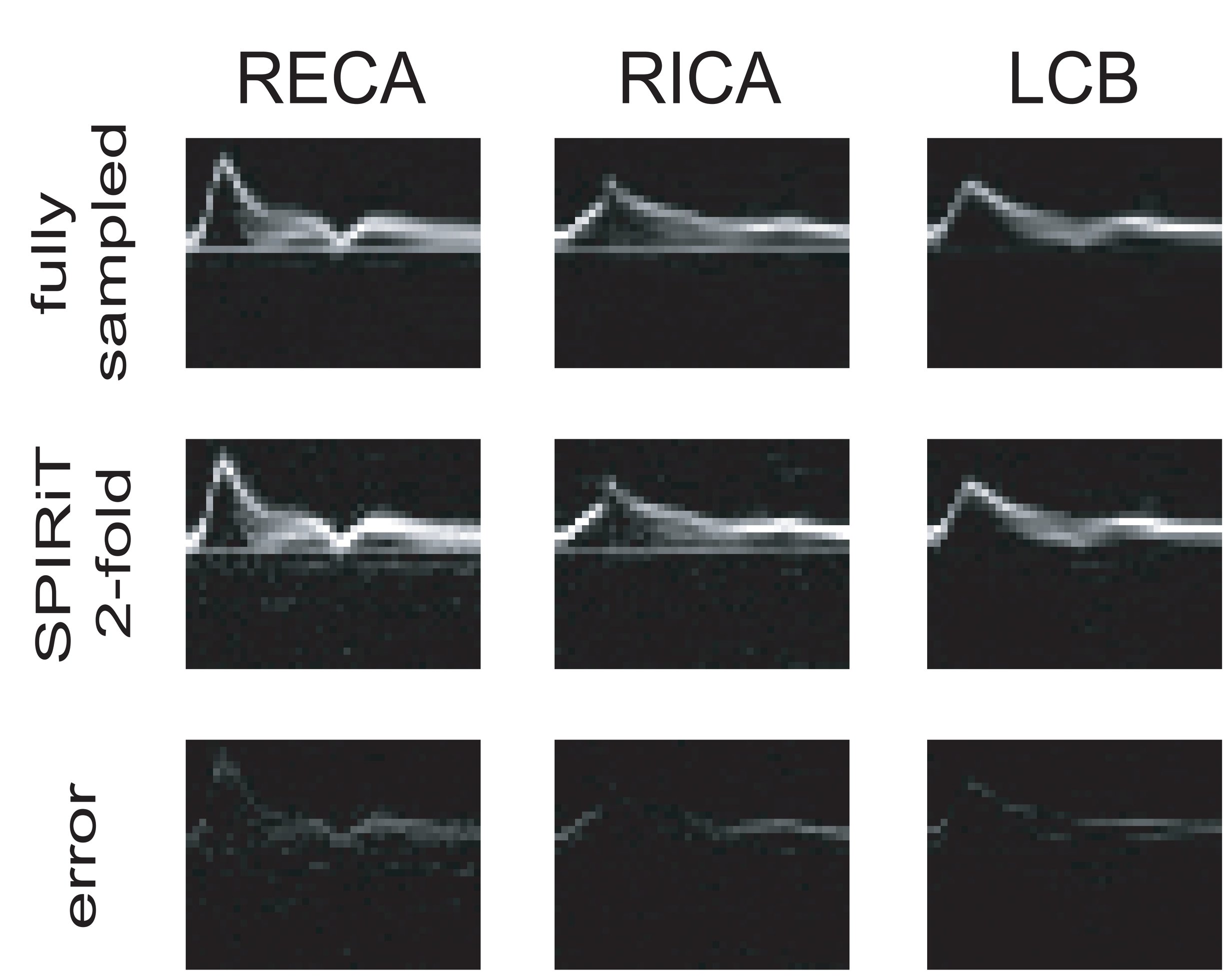

Figure: Time-velocity distributions from select voxels, reconstructed using 2-fold accelerated SPIRiT (center row), in comparison with the fully-sampled reference (top row): right external carotid artery (RECA); right internal carotid artery (RICA); and left carotid bifurcation (LCB).

Results (quantitative)

Table: Signal-to-error ratio (in dB) for 2-fold and 4-fold accelerated results, relative to the fully-sampled reference.

	spatial	RECA	RICA	LCB
sum-of-squares 2×	5.1	10.9	9.8	10.3
SPIRiT 2×	12.5	13.7	10.3	10.3
sum-of-squares 4×	−1.2	6.3	4.7	3.2
SPIRiT 4×	7.5	9.8	9.8	6.6

RECA: right external carotid artery;
RICA: right internal carotid artery;
LCB: left carotid bifurcation.

Discussion

Qualitatively, good results were obtained with 2-fold acceleration, in both spatial and time-velocity domains, but poor results were obtained with 4-fold acceleration. In time-velocity distributions, aliasing due to spatial undersampling typically results in increased signal at v = 0 cm/s, since the majority of the aliasing signal is associated with static material. Quantitatively, SPIRiT results are consistently better (higher signal-to-error ratio) than those obtained with sum-of-squares reconstruction.

Conclusion

We have demonstrated 2-fold acceleration of spiral FVE using SPIRiT parallel imaging. In future works, we will use SPIRiT to reduce spatial aliasing in temporally-accelerated spiral FVE [4]. This will enable the use of a less-selective UNFOLD filter, which will improve temporal resolution for high velocities.

References

[1] Moran PR. MRI 1:197, 1982. [2] Tang C et al. JMRI 3:377, 1993. [3] Carvalho JLA and Nayak KS. MRM 57:639, 2007. [4] Carvalho JLA and Nayak KS. ISMRM 15:588, 2007. [5] Hansen MS et al. MAGMA 17:86, 2004. [6] Baltes C et al. Radiol 246:249, 2008. [7] Lustig M and Pauly JM. MRM 64:457, 2010.

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