Acceleration of Spiral Fourier velocity encoded MRI using 3D SPIRiT

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Introduction

Fourier velocity encoded (FVE) MRI [1] is useful in the assessment of vascular and valvular stenosis [2] and intravascular wall shear stress [3,4], as it eliminates partial volume effects that may cause loss of diagnostic information in more conventional phase-contrast MRI [5]. FVE MRI has not been adopted for any routine clinical applications, primarily because scan-time is prohibitively long.

Scan-time in FVE can be significantly reduced using temporal acceleration [6], and temporal resolution can be improved using parallel imaging [7-9]. Image-domain 2D SPIRiT [10] has been previously used for acceleration of spiral FVE, without temporal acceleration [7,8].

Experiments

Imaging: Data were acquired on a GE Signa 3T EXCITE HD system (40 mT/m, 150 T/m/s), using a 4-channel carotid coil. Scan parameters: $1.4 \times 1.4 \times 5$ mm^3 spatial resolution, 16 cm field of view (FOV), eight 4-ms variable-density spirals, 5 cm/s velocity resolution, 240 cm/s velocity FOV, 12 ms temporal resolution, and scan time 146 seconds (256 heartbeats at 105 bpm).

Evaluation: Parallel imaging acceleration was evaluated using 4-fold retrospective undersampling of the spiral FVE datasets. Temporal undersampling was performed using three different view-ordering schemes: (i) acquiring only the 1st and 5th spiral interleaves in each k_v-t coordinate [7,8]; (ii) alternating interleaves pairs between k_v levels and cardiac phases (Fig. 2a); and (iii) alternating between half of the interleaves or no interleaves, for each k_v-t coordinate (Fig. 2b) [6]. Undersampled data was reconstructed using three approaches: sum-of-squares (SoS) [11], image-domain 2D SPIRiT [7,8,10], and 3D image-domain SPIRiT [12]. The fully sampled SoS result was used as the reference.

Discussion & Future Work

We have demonstrated the potential for 4-fold acceleration of spiral FVE using retrospective undersampling and 3D SPIRiT reconstruction. Results may be further improved using a temporal implementation of SPIRiT (analogous to TGRAPPA [13]), and/or pseudo-random selection of spiral interleaves for each k_v-t coordinate, which would result in incoherent aliasing artifacts in v-t space; and a ℓ_1-norm regularization factor [10]. This general approach also needs to be evaluated prospectively.

References

[1] Moran PR. MRI 1:197, 1982. [2] Carvalho JLA et al. MRM 57:639, 2007. [3] Carvalho JLA et al. MRM 63:1537, 2010. [4] Frayne R et al. MRM 34:378, 1995. [5] Tang C et al. JMRI 3:377, 1993. [6] Carvalho JLA et al. ISMRM 15:588, 2007. [7] Lyra-Leite DM et al. ISMRM 20:1189, 2012. [8] Lyra-Leite DM et al. EMBC 34:416, 2012. [9] Steeden et al. MRM 67:1538, 2012. [10] Lustig M et al. MRM 64:457, 2010. [12] Roemer PB et al. MRM 16:192, 1990. [13] Shin T et al. JCMR 14:250, 2012. [13] Breuer FA et al. MRM 53:981, 2005.

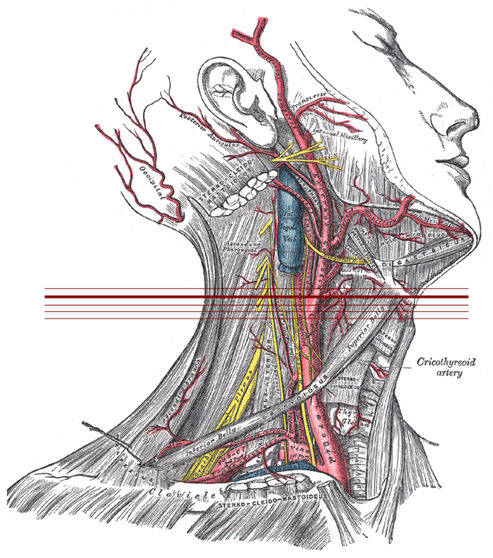

Fig.1: The strong line indicates the anatomical position of the reconstructed slice.

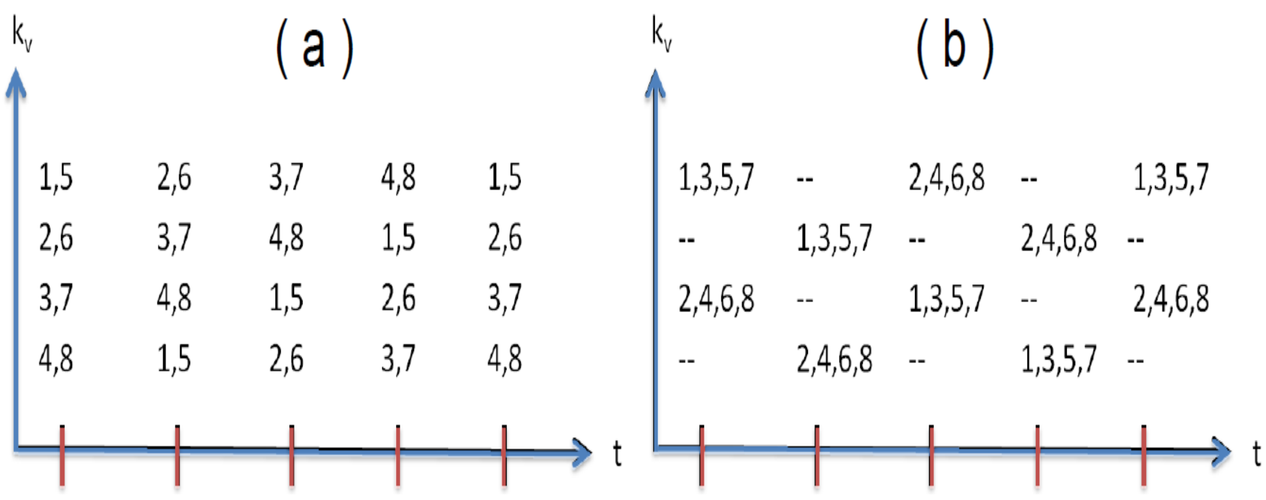

Fig.2: View-ordering schemes: (a) alternate interleaves pairs between k_v levels and cardiac phases (scheme ii); (b) alternating between half of the interleaves or no interleaves, for each k_v-t coordinate [6] (scheme iii).

Results

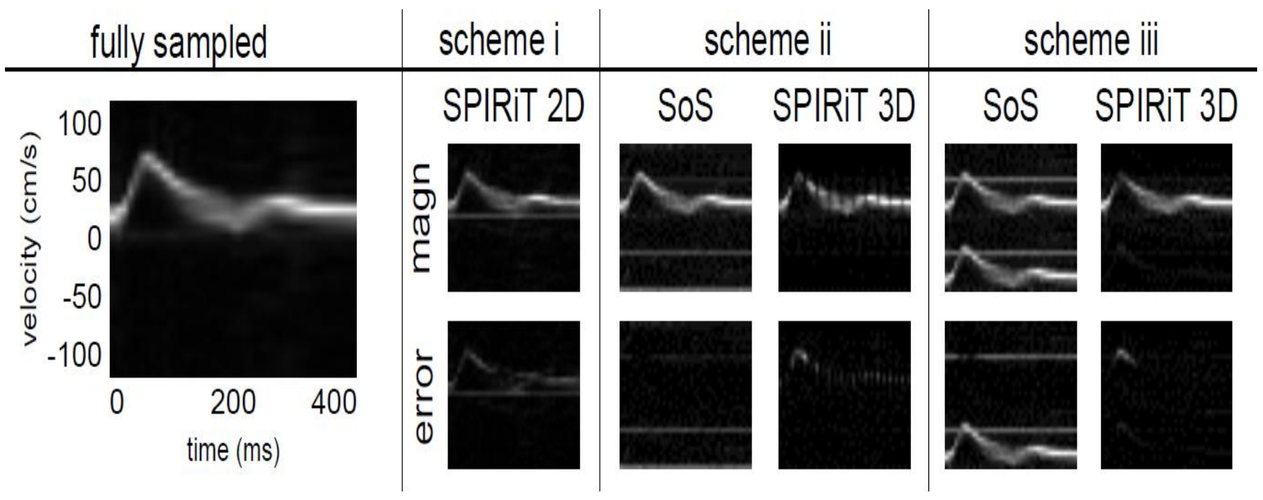

Fig.3: Time-velocity distributions from the left carotid bifurcation of a healthy volunteer, obtained from 4-fold temporally-undersampled data (right), and from the fully-sampled data (left). The undersampled data was obtained using three view-ordering schemes (i-iii) and reconstructed using sum-of-squares, and 2D and 3D SPIRiT (right, top row). The bottom row shows the residual error for each result.

Table 1: Signal-to-error ratio (in dB) for 4-fold undersampled results, with respect to the fully-sampled reference.

View Order	Recon	Right ECA	Right ICA	Left Bifurc.
i	2D SPIRiT	6.6	7.7	7.5
ii	sum-of-squares	−3.6	0.4	5.0
ii	3D SPIRiT	8.0	10.5	11.3
iii	sum-of-squares	−0.9	−0.5	−0.9
iii	3D SPIRiT	8.6	12.9	12.7

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