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 x 1.4 x 5 mm³ spatial resolution, 16 cm field of view (FOV), eight 4-m 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 kₜ coordinate [7,8]; (ii) alternating interleaves pairs between kₜ levels and cardiac phases (Fig. 2a); and (iii) alternating between half of the interleaves or no interleaves, for each kₜ coordinate (Fig. 2b) [6].

Undersampled data was reconstructed using three approaches: sum-of-squares (SoS) [11], image-domain 2D SPIRiT [7,8], 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 kₜ coordinate, which would result in incoherent aliasing artifacts in k-t space; and a ℓ₁-norm regularization factor [10].

This general approach also needs to be evaluated prospectively.

Results

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

<table>
<thead>
<tr>
<th>View Order</th>
<th>Recon</th>
<th>Right ECA</th>
<th>Right ICA</th>
<th>Left Bifurc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>2D SPIRiT</td>
<td>-3.6</td>
<td>8.0</td>
<td>-0.9</td>
</tr>
<tr>
<td>ii</td>
<td>sum-of-squares</td>
<td>-3.6</td>
<td>7.7</td>
<td>10.5</td>
</tr>
<tr>
<td>iii</td>
<td>3D SPIRiT</td>
<td>8.0</td>
<td>10.5</td>
<td>11.3</td>
</tr>
</tbody>
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References