3D Dual VENC PCMRA using Spiral Projection Imaging

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Purpose: This work focuses on the reduction of scan time required by the phase-contrast (PC) MRA technique. The presented work builds on earlier work [1] in the way of parameter optimization. The proposed method consists of a 3D variable density spiral projection imaging (SPI) trajectory [2] combined with a dual velocity encoding technique [3]. SPI is a rapid imaging technique that improves acquisition time through the intrinsic efficiency of spirals and through undersampling. Spatial aliasing due to undersampling is minimized using a known iterative sampling density algorithm [4]. The dual-VENC method improves SNR by allowing low-VENC (high SNR) data to be reconstructed without phase aliasing of the velocity measurements.

Methods: _SPI:_ Undersampling in each spiral plane is achieved through variable density spiral interleaves (Figure 1(a)) which are collected with a critical sampling radius of about 1/8 the extent in k-space. Past this radius, the distance between spiral interleaves diverges from the Nyquist sampling distance by a linear rate until an undersampling of 4 is reached at the edge of k-space. Undersampling is also achieved by omitting planes. Planes are collected at even azimuthal distances, rotated around the k_z axis (pole), providing a maximum undersampling of 4 at the edge (equator) of the sampled sphere (Figure 1(b)). The scan parameters for this sequence are as follows: 24cm FOV, 0.8mm^3 voxel, 300 dia. matrix, 20 interleaves, 120 planes, 19.5msec TR, and a 6min total scan time for 7 volumes. _Density Compensation:_ The MTF resulting from density compensation can be modulated to fit the density profile. Figure 1(c) is a plot of sample density along a radial projection in the equatorial plane. An MTF with this shape will lower the contribution (and therefore spatial aliasing) of undersampled spatial frequencies by the respective level of undersampling.
Dual VENC: The velocity encoded sets were collected with a 100cm/s VENC and 20cm/s VENC in three directions each. In areas of high velocity gradients, such as vessel walls, the low-VENC data show higher signal loss causing vessels to appear narrow. To address this, a weighted combination of the high and low VENC data is used.

Results and Discussion: Figure 1(d) and (e) are SPI PCMRA scans taken with a GE 3T Signa Excite system. There is susceptibility blurring near the sinus regions, which becomes problematic with even slightly longer sampling windows. Some smaller vessels appear spotted due aliasing caused by undersampling. Vessel diameter is regained by partial combination of high VENC data with the unaliased low VENC data.

Conclusion: This method provides short scan times that make the added time required by the dual VENC techniques less prohibitive. The addition of parallel imaging is currently being explored for further reduction in scan time.

References: 1: Koladia, ISMRM 06', abs. 336; 2: Irarrazabal, MRM, 33:656, 1995; 3: Lee, MRM, 33:122, 1995; 4: Johnson, MRM, 61:439, 2009;

Figure 1: Spiral Projection Imaging applied to Phase Contrast MRA. (a) A single plane of a linearly undersampled spiral trajectory. The inner radius is denser, providing critical sampling of low spatial frequencies. At the edge of the critical sampling radius, the distance between interleaves increases linearly until they are four times the Nyquist distance apart. (b) Spiral planes rotated around the k_z axis creating a more highly sampled cylinder about k_z. The highest level of undersampling (four times the Nyquist distance) occurs at the edge of the sphere furthest away from k_z in the rotation direction. (c) Plotted k-space support based on the level of undersampling on a radial line normal to k_z, centered at k_0. Low kspace radii fully support the 300mtx. (d,e) Axial and sagittal MIPs of the SPI PCMRA dual-VENC method. Collected resolution of 0.8mm^3, 24cm FOV, high venc of 100cm/s, low venc of 20cm/s, 6min total scan time.