Respiratory Self-Gated 4D Coronary MRA with UNFOLD

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Introduction:

Cardiac motion-resolved, or 4D MRA has been proposed for coronary artery imaging (1,2). Because of the need for high temporal and spatial resolution, the major challenge for 4D coronary MRA is to increase imaging speed. Parallel acquisition techniques were previously used to accelerate data acquisition for 4D MRA by permitting k-space undersampling. Temporal filtering of modulated undersampling artifacts may permit additional complimentary acceleration possibilities for 4D coronary MRA. The purpose of this work was to investigate the feasibility of using temporal filtering (UNFOLD Unaliasing acronym) (3) to permit accelerated undersampled data acquisition for 4D coronary MRA.

Methods:

Six healthy volunteers were scanned using a 1.5T Siemens Sonata system during free breathing. 4D coronary MRA data was acquired using the self-gating techniques to eliminate respiratory motion artifacts. The self-gating technique has been developed for respiratory gated cine imaging permitting continuous derivation of respiratory motion signals from the imaging data (4). A Cartesian k-space sampling steady-state free precession sequence was used for data acquisition with parameters: TR/TE 4.30/2.15 ms, 350×250 mm2 FOV, 256×154 matrix, 1.75mm partition thickness, 4 partitions, 60º flip angle, 11 lines/segment, 14 cardiac phases. Full k-space datasets were obtained for each cardiac phase. These 3D reference datasets were undersampled in the phase-encoding direction (factor of 2) to simulate a shorter scan time. Even numbered phase-code lines were retained for the even cardiac phases while odd lines were retained at odd numbered cardiac phases. The eliminated lines in each sub-sampled k-space dataset were zero-filled. After image reconstruction of using the undersampled k-space datasets at each cardiac phase, a Fourier transform of each voxel time series within the 4D image dataset was performed to observe the high-frequency peaks at +/- Nyquist frequencies (containing signals resulting from the phase modulated aliasing artifacts)(Fig. 1). A low-pass Fermi filter was used to suppress the aliasing artifact frequencies while maintaining relatively artifact-free signals contained within the low frequencies of the temporal spectrum. Finally, inverse Fourier transform of each voxel time series within the 3D image series was performed to return the dataset to 4D image space.

The reference images and the filtered images were qualitatively graded by a reviewer blinded to the image sets using a score of 1-4 (1: worse; 4: best) based on coronary delineation and the presence of image artifacts. A paired two-tailed t-test was used to determine significant differences between image quality scores for reference and temporally filtered datasets (α=0.05 level).

Results:

A full k-space reference image (a) and undersampled images without temporal filtering (b) and with filtering (c) from a volunteer during diastole are shown in Fig. 2. K-space undersampling caused obvious image fold-over (b) as compared to the reference image (a). However, after temporal filtering (c), the undersampled image appearance was indistinguishable to that of the reference image reconstructed from the full k-space dataset. The aliasing artifacts were completely removed. The mean quality score of the reference images was 2.75 with a standard deviation of 1.04, and the mean quality score of the temporally filtered undersampled image series was 2.68 with a standard deviation of 1.07. There was no significant difference in image quality between the two datasets.

Conclusion:

The UNFOLD temporal filtering strategy is a promising technique for increasing data acquisition speed during free-breathing 4D coronary MRA. Using this method, the acquisition time may be reduced by half while maintaining the image quality. Future work will combine this method with parallel acquisition techniques to further reduce imaging time.

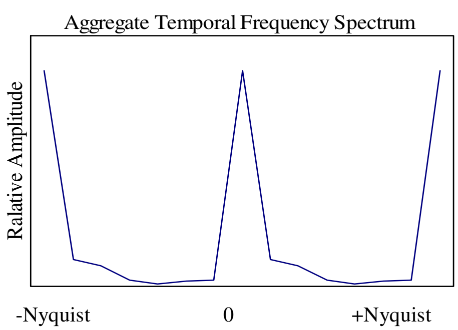
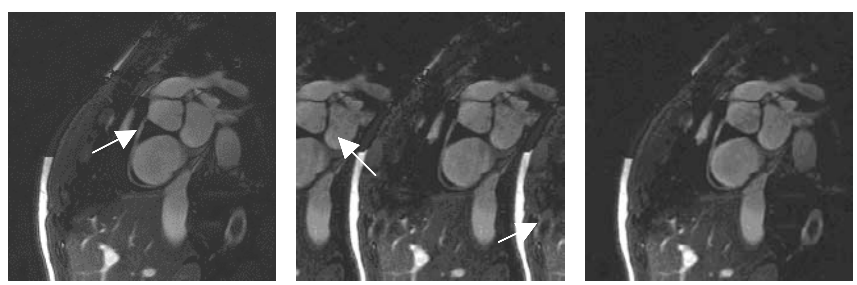


Figure 1. Aggregate Temporal Frequency Spectrum of a series of images in one cardiac cycle. Zero frequency peak contains the desired non-aliased object information, and the high frequency peaks at +/- Nyquist frequencies contains the aliased component information.



(a) (b)

Figure 2. Single-slice diastolic images acquired with 4D MRA method from a healthy volunteer. (a) Reference image based on full k-space, delineating the right coronary artery (arrow). (b) 'Folded' image based on undersampled k-space. Note the presence of aliasing artifacts (arrows). (c) Temporally filtered image based on the undersampled image. The

References:

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