Velocity-based cardiac self-gating in free-running radial 4D Flow MRI

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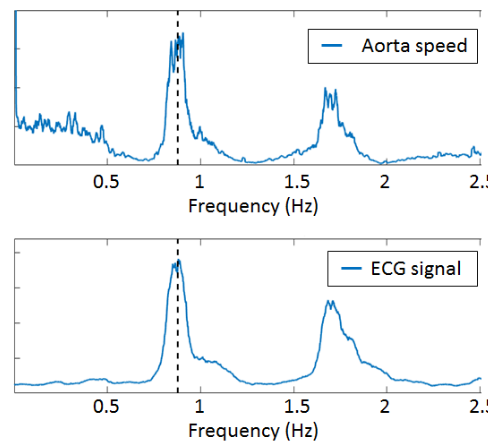
Introduction: Free-running whole-heart acquisitions with the capability of deriving cardiac self-gating (SG) signals present clear interest, particularly at 3T, where the ECG signal suffers from the magnetohydrodynamic effect and acquisition related noise. Our goal was to develop a novel velocity-based cardiac SG strategy for free-running radial 4D Flow imaging and to investigate the impact of cardiac SG on the velocity quantification in the thoracic aorta.

Methods: We implemented a free-running interleaved (8 spokes/interleaf) 3D radial velocity mapping sequence on a 1.5T Philips Ingenia (Philips, Best, The Netherlands), based on a spiral phyllotaxis pattern [1]. Imaging was performed on the thorax of 5 healthy subjects as follows: TE/TR 2.5/6 ms, FA=6◦, VENC=180-240 cm/s, 2.5 mm isotropic voxel, acquisition time: 8–12 minutes. First, a sliding-window reconstruction using 64 consecutive spokes and a step of 8 spokes yielded high temporal and low spatial resolution velocity resolved volumes. The average speed in the aorta was obtained for each volume, using a mask drawn on the fully sampled reconstruction. Then, to obtain the cardiac SG signal, the temporal evolution of the aorta average speed was filtered in the frequency domain and interpolated using multiscale kernel ridge regression [2].

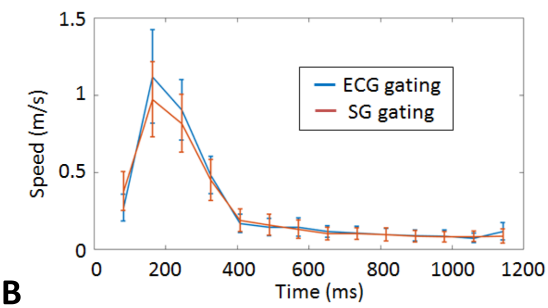
Finally, the cardiac SG signal and the ECG were used to bin the data in the same number of cardiac phases (N=12-18). Cardiac and velocity resolved images were then reconstructed offline using a compressed sensing algorithm implemented in Matlab (The Mathworks, Inc, Natick, MA). Velocity measurements in the thoracic aorta were then compared between SG and ECG based gating.



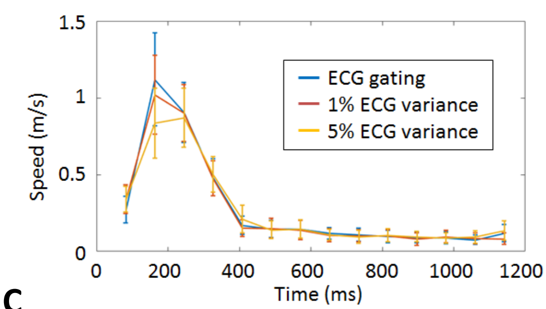
A

Results: A comparison of the frequency analysis of the temporal evolution of the aorta speed and the ECG signal is presented in Figure A for a representative case. The frequency peak corresponding to the heart rate and the first harmonic can be observed at the same location. Despite similar average RR intervals between SG and ECG, the R-peak detection precision for SG was 50ms on average.

Velocity quantification showed underestimation of peak systolic values for SG compared to ECG (Figure B). In order to confirm that the underestimation is due to the R-peak detection precision, we simulated 1% and 5% variability in the R-peak location in the ECG signal by random sampling according to a uniform distribution and used this simulated signal for cardiac binning. Similar to SG, an underestimation can be observed for the same case in the average speed (Figure C).



B



C

Discussion: We present here a novel approach to cardiac SG specifically dedicated to 4D Flow MRI. Our results are in agreement with previously reported results using a navigator spoke based method for cardiac SG in 3D radial [3]. While this precision does not affect the resulting anatomical images, we have shown an impact on the velocity quantification, particularly an underestimation of the peak systolic values. This underestimation was described previously for 3D radial 4D Flow [1], however its source was not completely identified. Improvement of the precision in the R-peak detection is expected with the use of more advanced methods in the sliding window reconstruction. In addition, a respiratory SG signal can be obtained in absolute values and enable respiratory motion correction (not shown). This is an advantage of our method, compared to other previous fully self-gated strategies.

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References:

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