Real-time cardiovascular PC imaging using undersampled radial FLASH and nonlinear inverse reconstruction

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Introduction: Velocity-encoded phase-contrast MRI is a well established method for quantitative mapping of flow velocities. Cardiac MRI studies commonly rely on ECG and respiration synchronized cine acquisitions of multiple heartbeats either in the state of free breathing or suspended respiration. This approach may be affected with temporal and/or spatial averaging of phase information obtained from multiple cycles and as a result might lead to underestimating of flow parameters when compared to other methods. Recently, significant advancements have been made for real time cardiovascular imaging with undersampled radial FLASH and nonlinear inverse reconstruction [1, 2]. In this study we combine this approach with velocity-encoded phase contrast (PC) to achieve real time flow MRI of the ascending and descending aorta.

Methods: Healthy volunteers (n = 7) of heterogeneous age group were included in the study after given informed consent before each MRI examination. Studies were conducted on a 3 T MRI system (TIM Trio, Siemens Healthcare, Erlangen, Germany) with MRI signals acquired in supine position using 32 channel cardiac coil with 16 anterior and posterior element arrays. A real time velocity encoded phase contrast sequence with highly undersampled RF-spoiled radial FLASH acquisition was employed for measuring through-plane flow. Velocity encoding gradients were overlapped with the slice refocusing gradient to shorten TE. Typical scan parameters were VENC 150 cms^{-1}, TR/TE/α 3.03ms/2.27ms/10°, in-plane resolution 1.8 mm, slice thickness 5 mm, FOV 256 × 256 mm^2, 7 spokes, 42.5 ms temporal resolution per phase contrast map. Typically, series of 650 images covering a time period of 30 s were recorded during free breathing. Phase contrast maps were obtained using regularized nonlinear inverse reconstruction [1]. Flow parameters such as peak velocity, stroke volume and flow rates of individual heart beats were analyzed using Argus Flow analysis tool (Siemens Healthcare, Erlangen, Germany).

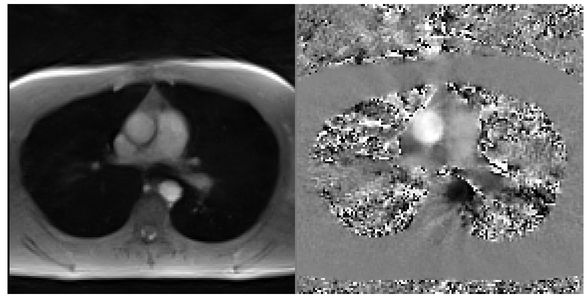

Figure 1: Real time PC MRI of through plane flow in aorta.(Right) Magnitude image, (Left) Phase contrast map.

Results: The magnitude images and phase contrast maps obtained from 7 spokes are shown in figure 1. The flow parameters obtained from real time PC imaging for ascending and descending aorta are shown in figure 2. The peak velocities (average of four neighboring pixels) and flow rates of ascending and descending aorta for individual heartbeats show variability with respect to cardiac and respiratory cycle. The variation of peak velocities was more than 10% during the expiration and inspiration phase of the respiratory cycle. Due to high temporal resolution a shift (two images of 85 ms) between the flow rate peak of the ascending and descending aorta in single cardiac cycle can be observed. The modulation in peak value of flow rates for multiple cardiac cycles indicates the influence of respiratory cycle on flow parameters.

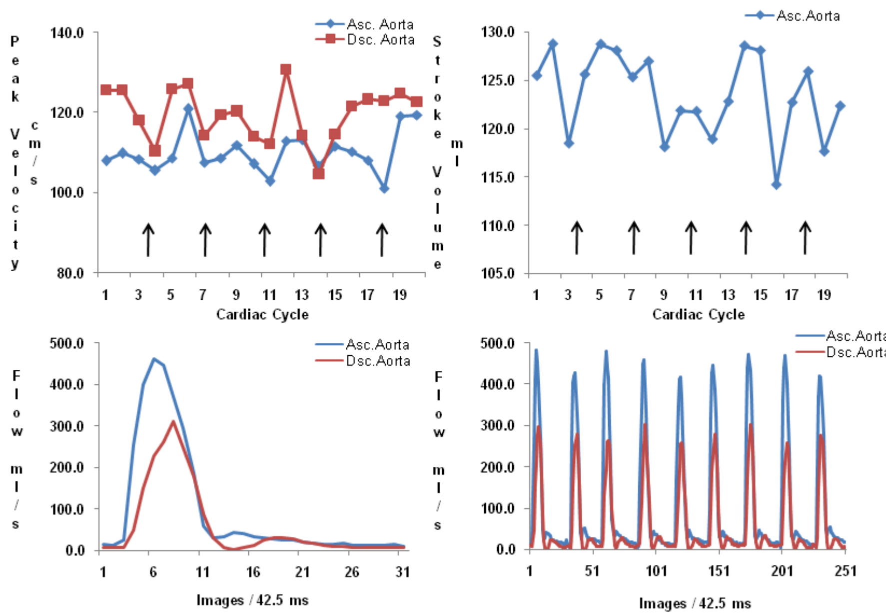

Figure 2: Flow Parameters obtained in ascending and descending aorta. (Top-left) Peak Velocities obtained for 20 cardiac cycles. (Top-right) Stroke Volume obtained from ascending aorta for 20 cardiac cycles. (Bottom-left) Flow rate obtained for single cardiac cycle. (Bottom-left) Variation in flow rate for 10 cardiac cycles. Arrows indicate inspiration.

Conclusion: We have successfully demonstrated the use of real time MRI with undersampled radial FLASH and nonlinear inverse reconstruction in the field of phase contrast imaging. Flow parameters of ascending and descending aorta were analyzed. The high temporal resolution aids in removing the averaging effect on phase values commonly noticed in Cine imaging and the underestimation of flow parameters in MRI in comparison to other methods. The difference or variability of flow parameters as observed for multiple heart beats and respiratory cycles indicate the importance of real time imaging in phase contrast flow studies. This method will aid in direct assessment of patients with physiological or pathological irregularities such as arrhythmia, stenosis.

Reference:

[1] M. Uecker et al. MRM. 2010, 63:1456-1462.
[2] S. Zhang et al. JCMR. 2010, 12-39.