Analysis of Aortic Pulse Wave Velocities using Real-time PC MRI

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Target Audience: Cardiovascular magnetic resonance, MR flow and Flow quantitation.

Purpose: Aortic Pulse wave velocity (PWV) is a biomarker for indicating the vascular stiffness and the progression of atherosclerosis [1]. PWV analysis is usually performed by ECG-synchronized cine phase-contrast (PC) MR acquisitions at different regions of the aorta. However, Cine phase-contrast maps representing a single synthetic cardiac cycle can be a hindrance for the accurate measurement of PWV. Recent advancements in real-time PC MRI using undersampled radial FLASH and nonlinear inverse reconstruction provide the access to flow parameters over multiple cardiac cycles [2]. The aim of this study was to analyze the PWV values obtained from individual cardiac cycles using real-time PC MRI. Further, the Cine and real-time PC MRI acquisitions were compared with respect to PWV values.

Materials and Methods: All the experiments were performed on a 3T MRI system (TIM Trio, Siemens Healthcare). MRI signals were acquired in the supine position using 32 channel cardiac coil with 16 anterior and posterior element arrays. Normal healthy volunteers (n = 8) of a heterogeneous age (18-30) were chosen for this study and written consent were obtained according to the local ethics committee recommendations. Real-time phase contrast maps were obtained using highly undersampled radial FLASH sequence and regularized nonlinear inversion. The scan parameters for the real-time measurements were TR/TE/α 2.86ms/1.93ms/10°, FOV 192 mm, 2 × 7 spokes, 40 ms temporal resolution. Cine PC MRI was acquired with TR/TE/α 20.05ms/2.18ms/25°, FOV 256 mm. The measuring time for Cine PC MRI with free breathing was 3.3 minutes. The parameters of VENC 200 cms^{-1}, in-plane resolution 1.3 mm^2, slice thickness 6 mm were similar for both acquisitions. Real-time and Cine acquisitions were performed at 2, 3 and 4 positions of the aorta and the flow parameters such as spatial average velocity were analyzed using CAIPI Software (Fraunhofer MEVIS, Bremen, Germany). Two-Point PWV analysis consisted of measuring flow parameters of ascending and descending aorta calculated directly from a single perpendicular plane through the aorta. Pulse wave velocity (PWV) analysis was performed using Matlab (Mathworks, USA). Prior to PWV analysis, flow parameters obtained from real-time acquisitions were sorted into 10 consecutive individual cardiac cycles according to their ECG time stamps. Temporal shifts in the velocity waveforms between different planes were computed using time for upslope (TTS) and cross correlation (XCorr) methods [3].

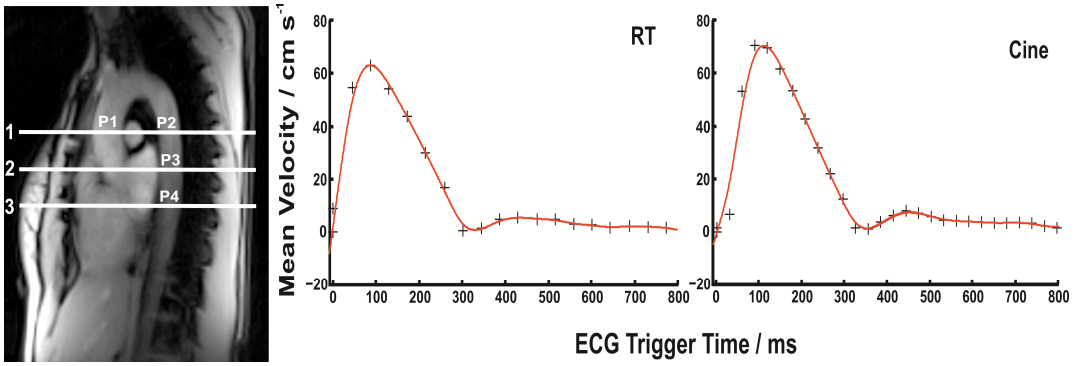

Figure 1: (Left) Slice positions (1, 2, 3) for PWV analysis using 2-Point (P1, P2), 3-Point (P1, P3, P4) and 4-Point (P1, P2, P3, P4) methods. Fitted of velocity curves of a single cardiac cycle for real-time PC MRI (center) and cine PC MRI (right).

Results and Discussion: The slice positions along the aorta used for the 2-Point, 3-Point and 4-Point PWV analysis are shown in figure 1. The velocity (spatial average over aorta) curves obtained by the fitting of single cardiac cycle real-time and cine acquisition data are also displayed. The comparison of PWV values obtained from Cine and real-time acquisitions for all methods are shown in table 1. The PWV values obtained using the real-time and cine PC MRI acquisitions were similar between different positions (2-Point, 3-Point, 4-Point) and analysis (TTS, XCorr) methods. However, a decrease in PWV values using XCorr method was observed for real-time acquisitions. In addition, the PWV values obtained from real-time PC MRI were found to vary according to respiration cycle.

	TTS			XCorr		
	2-Point	**3-Point**	**4-Point**	**2-Point**	**3-Point**	**4-Point**
Real-time	3.6±0.5	3.9±0.4	3.8±0.4	3.0±0.5	3.3±0.5	3.2±0.4
Cine	3.5±0.5	3.8±0.6	3.7±0.5	3.3±0.5	3.7±0.7	3.6±0.6

Table 1: Pulse wave velocity values in m s^{-1} (mean ± SD) for 8 subjects and 10 cardiac cycles obtained for real-time and cine PC MRI acquisitions.

Conclusion: Biomarkers such as pulse wave velocity are usually performed using the 2D or 4D Cine PC MRI. The use of real-time PC MRI with undersampled radial FLASH and nonlinear inverse reconstruction for pulse wave velocity analysis has been demonstrated. The flow parameters from individual cardiac cycles using real-time acquisitions provide consistent PWV values for different positions. Further, the acquisition time is drastically reduced by the use of real-time PC MRI thereby providing patient comfort. PWV analysis in combination with the real-time acquisitions can be used as a fast and robust tool to detect vascular stiffness and atherosclerosis.

References:

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