A new methodology for determining aortic pulse wave velocity using 2D PCMR velocity data

S. Fielden[1,2], B. Fornwalt[2], M. Jerosch-Herold[3], R. Eisner[1], A. Stillman[1], and J. Oshinski[1,2]

[1]Radiology, Emory University, Atlanta, Georgia, United States, [2]Biomedical Engineering, Georgia Institute of Technology/Emory University, Atlanta, Georgia, United States, [3]Medicine & Advanced Imaging Research Center, Oregon Health & Science University, Portland, Oregon, United States

Introduction: Pulse wave velocity (PWV) is a surrogate measurement of aortic stiffness. A major shortcoming of traditional ultrasound-based methods is that *central aortic* stiffness cannot be accurately and reproducibly measured. MRI can measure central aortic PWV. Previous MRI-based methods include the transit-time methodology (calculate arrival of flow waveform between two locations in the aorta), and the multi-site methodology (measure flow waveform arrival time at multiple locations in the descending aorta). Here we present a new MRI-based PWV method which uses velocity data from the ascending, transverse, and descending aorta by acquiring two-directional PCMR data in the aortic plane. The arrival of the flow waveform at multiple locations is estimated through a cross-correlation with the most proximal waveform. We refer to this new method as 2D-XC.

Purpose: Compare the intra-observer and inter-test reproducibility of the 2D-XC method to: 1) a transit-time method (TT) using slices in the ascending and descending aorta, and 2) a foot-identified multi-site method (FOOT) using descending aorta velocity data.

Methods: Thirteen healthy volunteers (11 male, mean age 29.4 ± 7.4 years were examined twice (mean time between examinations = 2.9 days) on a 1.5 Tesla MRI scanner (Philips Medical Systems, Intera CV).

To determine PWV based on the TT methodology, PCMR images were obtained in two slices perpendicular to the aorta (ascending aorta and abdominal descending aorta). Flow waveforms were then calculated at each location. The arrival time of the flow waveform was determined using the foot of the waveform. PWV was distance between slices divided by arrival time.

To determine PWV based on the FOOT methodology, an oblique sagittal PCMR slice through the descending aorta was acquired. Flow waveforms were computed at evenly spaced points along the length of the descending aorta. The foot of each waveform was again identified. The arrival time of the flow waveform at each location was plotted versus its distance from the first wave. PWV was defined as the inverse of the slope of a line fitted to this plot.

To determine PWV based on the 2D-XC methodology, foot-head and anterior-posterior velocity-encoded PCMR images were acquired in an oblique sagittal slice. Velocity magnitudes were calculated from temporally-paired PCMR images and the length of the velocity vector (velocity magnitude) was determined at each location. The flow waveform was computed at 30 evenly spaced points along the aorta and compared to the first waveform using a cross-correlation function to determine an arrival time for each location. PWV was again determined by plotting arrival time versus distance and taking the inverse of the slope. (Fig. 1)

Intra-observer repeatability was determined by having a single observer repeat the analysis five times and determining the coefficient of variation (CoV). Inter-test reproducibility was evaluated for each methodology by the absolute value of the experiments' difference between scans (as a percent), and these differences were compared using a repeated measures ANOVA with a Huynh-Feldt correction followed by a least significant difference post-hoc test. $p<0.05$ was considered statistically significant.

Results: No statistically significant difference was observed between the three estimates of PWV (FOOT: 4.18 ± 0.59 m/s, 2D-XC: 4.45 ± 0.47 m/s, TT: 4.07 ± 0.57 m/s, $p = 0.15$). The 2D-XC methodology yielded significantly better intra-observer repeatability as evaluated by the CoV than the FOOT methodology (FOOT: 9.2% ± 8.0%, 2D-XC: 2.8% ± 1.5%, $p = 0.01$) *The 2D-XC methodology had a superior inter-test reproducibility than either the FOOT or TT methods as shown by the lowest % difference between scans (Table1).*

Conclusions: A new PWV estimation methodology (2D-XC) that uses 2D PCMR data from the ascending, transverse, and descending aorta and a cross-correlation function to determine waveform arrival times has been developed. The 2D-XC method has better intra-observer and inter-test reproducibility than previously published methods. The improved reproducibility of 2D-XC suggests changes in PWV due to pharmacologic interventions could be seen in a fewer number of subjects.

Method	Mean PWV Scan 1	Mean PWV Scan 2	% Difference Between Scans	p-value
FOOT	*4.2 ± 0.6*	*4.6 ± 1.1*	*21 ± 17%*	*0.02*
TT	*4.1 ± 0.6*	*4.2 ± 0.9*	*16 ± 13%*	*0.02*
2D-XC	*4.5 ± 0.5*	*4.4 ± 0.5*	*8 ± 5%*	-

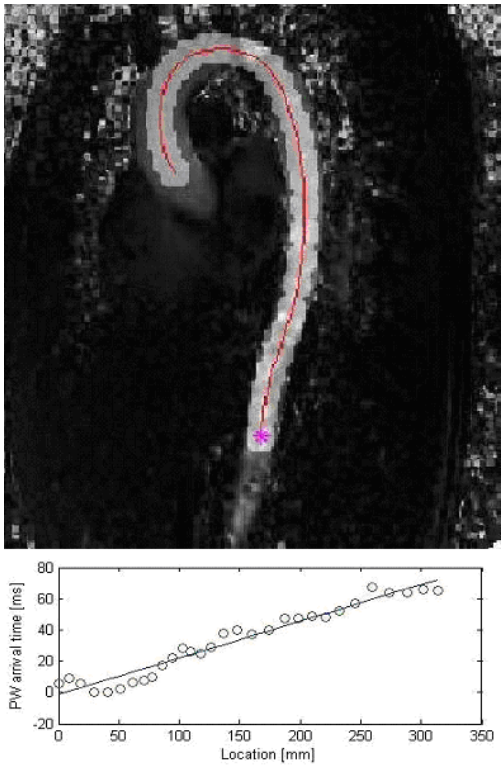

Figure 1. *Upper: aortic outline with centerline where velocity points were obtained. Lower: wave delay times plotted against location to determine PWV.*