Age Dependent Aortic Pulse Wave Velocity Effects in Normal Volunteers Using a New Phase Contrast Technique

Y. Wang[1,2], K. Jayaraman[1,2], A. Bentow[2], S. T. Mathew[1,3], W. Schapiro[1], N. Reichek[1,3]

[1]Research and Education, St. Francis Hospital, Roslyn, NY, United States, [2]Biomedical Engineering, SUNY Stony Brook, Stony Brook, NY, United States, [3]Medicine, SUNY Stony Brook, Stony Brook, NY, United States

INTRODUCTION: Pulse wave velocity (PWV) can be determined from the distance (ΔD) between two aortic cross sections in phase contrast (PC) images divided by the time (Δt) to arterial blood arrival from one section to another. The conventional PC technique has limitations in evaluating PWV due to its low temporal resolution, about 50ms, which is insufficient to evaluate fast arterial waves. In addition, Δt is normally evaluated by first calculating the upslope of the arterial-flow curve. However, there are only 2-4 time points during that time interval in a prospective ECG gated PC acquisition. To accurately determine PWV, we evaluated a new Prospectively Triggered and Retrospectively Sorted (TRETRO) PC technique for improved temporal resolution.

METHODS: 23 healthy volunteers ages 20 to 76 (Mean and STD: 54.61±15.06) were enrolled with IRB approval and informed consent. Volunteers were screened to exclude hypertension, high cholesterol and cardiovascular disease. Based on the 'candy cane' view of aorta, an axial plane through the ascending and descending aorta at the pulmonary artery level was prescribed (**Fig. 1**) and a breath hold cine PC was acquired using the through-plane velocity encoded TRETRO PC imaging technique. TRETRO collects data with ECG triggering but retrospectively sorts the data according to the timestamp recorded with each line by k-space interpolation, so that the reconstructed images cover the entire cardiac cycle, as in asynchronous retrogating. A Siemens Sonata 1.5T scanner with a CP body array flex coil (Siemens Medical Solutions, Malvern, PA) was used. The parameters were: A VENC of 150 cm/s, TR/TE/FA = 98ms/2.9ms/15°, data matrix 125×256, field-of-view 25×34cm^2, number of segments 7, bandwidth per pixel 310Hz and voxel spatial resolution 1.3×2×6mm^3.

The signal intensities of the phase images within each aortic cross-section were averaged for each point in time using FLOW (Medis, Leiden, the Netherlands). All time intensity curves were then exported to an Excel spread sheet to determine the flow upslope using least squares fitting by linearly interpolating 5 of the first 6 points in the upslope of the normalized flow-time curve. A time delay of Δt between the ascending and descending aortic regions of interest was determined as the difference in time of arrival measured when each curve reached 40% of maximal velocity. The distance traveled by the aortic pulse wave, ΔD, is determined by superimposing the axial imaging plane on the 'candy cane' image and measuring the distance between ascending and descending aortic cross-sections along the center of aorta. We calculated PWV = ΔD/Δt and the aortic compliance as C = 1/(ρ*PWV^2), where blood density ρ = 1057 kg/m.

RESULTS: Illustrative magnitude and phase PC images are shown in **Fig. 2** with the ascending aorta contour in red and descending in green. The corresponding flow time curves are shown in **Fig. 3**, ascending in blue, descending in pink. The mean and standard deviation of PWV and C were 2.56±1.1m/s and (21.1±14.3)*10^{-5}/Pa, respectively. Linear regression of C vs. age had an r^2 of 0.65 and $p < 0.0001$ (**Fig. 4**).

CONCLUSIONS: PWV can be evaluated with a through-plane velocity encoded TRETRO PC technique in a single breath hold utilizing the axial plane through aortic root and descending aorta. Our results show that it is an easy and robust approach and it has the potential to be an efficient and accurate clinical tool for assessment of vascular stiffness.

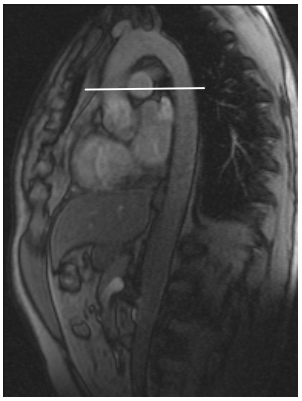

Fig. 1. (left) The 'candy cane' view of aorta. The bright line shows the position of the axial PC image plane.

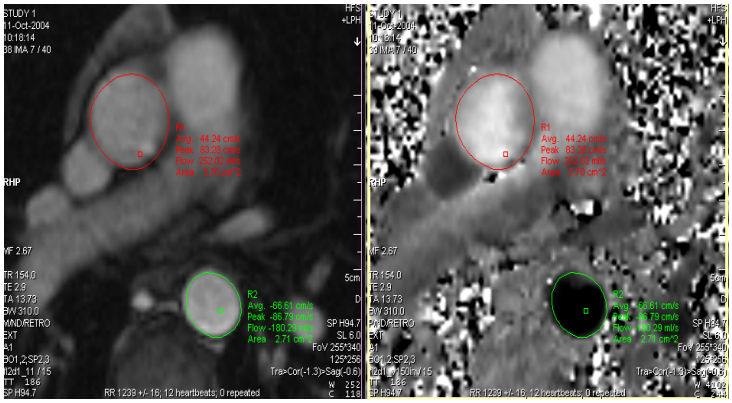

Fig. 2. (right) One frame of a pair of TRETRO PC magnitude (right) and phase images (far right) with ascending (red) and descending (green) aortic contours indicated

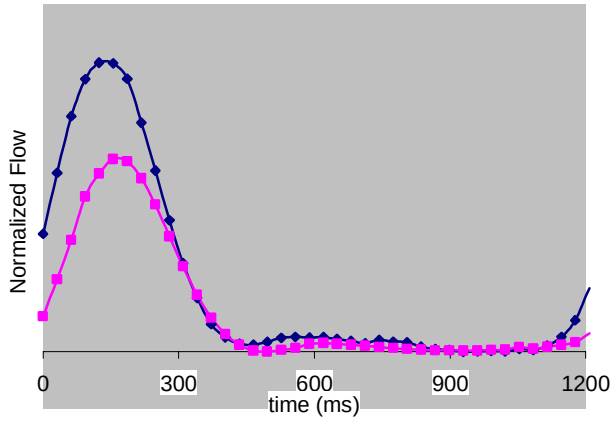

Fig. 3. Flow time curves from ascending (blue) and descending (pink) aorta.

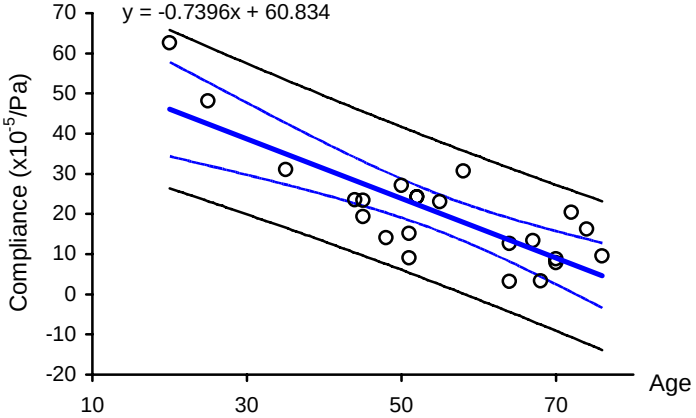

Fig. 4. Linear regression of compliance against age, r^2= 0.65.