Measurement of Pulse Wave Velocity in the Aortic Arch by Tracking the Velocity Peak

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Introduction: The pulse wave velocity (PWV) is measured as the ratio of length along the aortic arch (D) to the time difference (ΔT) between the arrival of pulse wave between the ascending (aAo) and the descending (dAo) aorta. Conventionally, ΔT is measured by the time lag between the mean velocity time curves of aAo and dAo, measured at the half maximum velocity. The aortic velocity profile (figure 1) includes contributions from both ante-grade flow and flow reversals due to reflected pressure waves and runoff diastolic flow if present. Therefore the *mean* velocity of the lumen does not accurately characterize the ante-grade pressure wave dynamics. In this study, we developed an algorithm to map the ante-grade pressure wave in time and space using an automated, peak velocity tracking technique on phase contrast (PC) cine images.

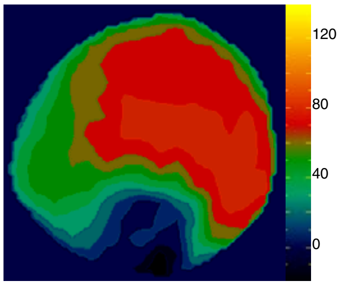

Figure 1. The spatial distribution of velocity (cm/sec) in the dAo at systole show asymmetric flow profile with flow in the opposite direction.

Method: We studied 24 healthy children of age between 5-10yrs (mean age=7.3yrs, 12F, 12M). PC cine MRI was performed in a plane depicting both the aAo and dAo. Imaging was performed on a 3T scanner (Siemens, Erlangen, Germany). Studies were done with no sedation. PC MRI parameters were: number of segments=3, TE/TR=4.8/7.5, slice=6mm, flip=15, in plane resolution=1.3x1.3mm. The average RR interval was 640ms. Twenty two phase images were reconstructed with prospective gating with an average temporal resolution of 29 ms. The aortic lumen was segmented using a semi automated snake algorithm on the magnitude PC MR images. The velocity peak was tracked as follows: For each time frame t, contours of velocities, $C_{v,i}(t)$ were defined within the lumen for levels $v=0,1,2..V_{enc}$ cm/sec. Where $C_{v,i}(t)$ is the i^{th} contour representing level v. Then for each level v, the contour region i, having the maximum number of pixels was chosen ($=C_v$). This step eliminates any pixel with erroneous phase. The number of pixels within each C_v when normalized by the total number of pixels within the lumen, represents a complementary cumulative distribution function of v; which we used to find the 90th percentile velocity, v'. The average velocity of the contour $C_{v'}$ was taken as the velocity peak at time t. Figure 2 shows the results of peak velocity tracking. The peak velocity-time curves were fitted with a 5th order polynomial to find the time lag ΔT. Both velocity peak-time curves and the mean velocity-time curves were used to calculate the aortic PWV for comparison.

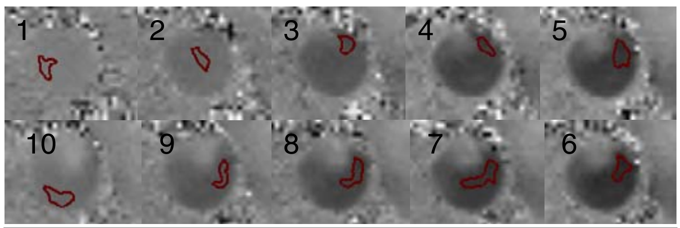

Figure 2. The contours of peak velocity in the dAo during systole depict the passing of the ante-grade pressure wave. The first 10 flow maps are shown as marked.

Method	Mean PWV ± Std Dev (m/s)	Range (m/s)	Coefficient of Variation
Mean Velocity Technique	2.9 ± 2.1	10.0	73
Peak Velocity Technique	2.4 ± 0.7	2.99	30

Results and discussion: A marked difference between the mean velocity-time and the peak velocity-time curves were seen in some subjects (figure 3). The PWV calculated using the mean velocity curves has a greater uncertainty as evident from the larger coefficient of variation. There was no significant correlation between age and PWV calculated by any method (Pearson's Coefficient= 0.1) as expected, given the limited age range in this study. Although no previous data of PWV in the aortic arch exist in this specific age group, extrapolated data from older subjects suggests that our values are within the expected range (Groenink M et al, Radiology 219(2) 535; 2001). The peak velocity tracking method introduced in this study can be used effectively to minimize errors in PWV measurements using PC MRI data. With improved sensitivity, MR based non invasive measurement of PWV can be a powerful tool in determining aortic compliance.

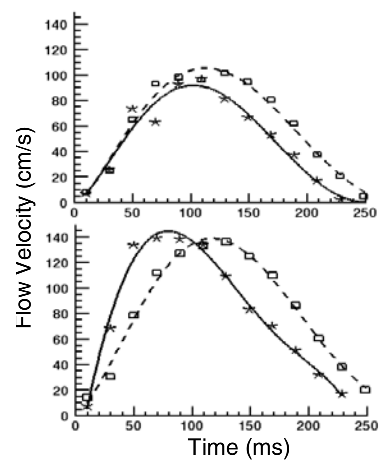

Figure 3. The flow velocity of aAo (—) and dAo (--) of the same subject using the mean value (upper) and the 95th % (lower).