MEASUREMENT OF AORTIC PULSE WAVE VELOCITY IN VOLUNTEERS

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Introduction

The increased risk of cardiovascular disease with age is associated with both structural and functional changes of the aortic vessel wall. The pulse wave velocity (PWV) can be used as a measure of the increased risk since it changes with aortic wall stiffness. PWV data have been presented by a number of groups [1-5]; however we are unaware of any reported studies addressing the reproducibility of PWV measurement in normal volunteers and/or patients. In addition there is no single agreed best method for determining the transit time for the PWV calculation. In this work we performed PWV measurements in healthy volunteers and investigated several different algorithms for determining the transit time.

Method

Three volunteers (2 males, 1 female, age range 25 to 44 years) were positioned supine within a 1.5T MR system (HDx, GE Healthcare, Waukesha, WI) using an 8 channel abdo-torso coil. They were examined on five separate occasions, each at least a week apart. Black blood localisers were obtained to allow consistent positioning of the phase contrast images and to allow measurement of the luminal centreline distance between slices. Cine phase contrast (CPC) velocity mapping was performed at four locations as indicated on Figure 1: (AB) ascending/descending aorta at the level of the right pulmonary artery, (C) through the thoracic aorta at the level of the diaphragm, (E) thorough the abdominal aorta 3 cm above bifurcation and (D) midway between positions (C) and (E). The CPC sequence utilised a fast segmented *k*-space acquisition using 1 view per segment, with TE = 3.2ms; TR = 6.7ms; flip angle 30°; matrix 256 x 128; 2 signal averages; FOV 28cm x 28cm with 5mm slice thickness and velocity encoding (venc) of 150 m/s. 50 temporal phases were retrospectively calculated. Total scan time was approximately 30 minutes. The pulse wave velocity was calculated using distances obtained from the localiser images and the waveform time delay between slices ΔT. The PWV was obtained by dividing the distance ΔD travelled by the time ΔT: $PWV = \Delta D/\Delta T$. The following methods were used to determine ΔT: 1) minimum point, 2) fraction of the pulse height (point taken at 10% of the systolic upstroke), 3) peak of the second derivative of flow, associated with the foot of the pressure wave, 4) the intersection of the lines of fit during late diastole and early systole, 5) the deviation of a line of fit during early systole from the measured flow wave. The five different methods were applied to all fifteen studies and are illustrated in figure 2. For the final two visits, aortic PWV was also measured using ultrasound by a SphygmoCor PWV system (AtCor Medical, West Ryde, Australia), taking readings at the carotid and femoral arteries and measuring the distance between sites. Additionally for the final visit of subject 1, MRI CPC velocity maps were taken at the same carotid and femoral locations and the transit time was calculated.

Results

Method 1 was unable to consistently determine the foot of the flow waveform due to the variability in the flow during the diastolic phase. The PWV values derived from method 2 had a substantially increased standard deviation in the most distal location due to the large changes in the slope of the systolic upstroke between the different sites. Methods 4 and 5 showed the expected trend of increased PWV with increased distance from the heart but failed when measuring the PWV between locations D and E, again due to the change in the slope of the systolic upstroke. Method 3 was found to give the lowest standard deviation of pulse wave velocity across all measurements and also showed the expected trend of increased PWV with distance from the heart. Figure 4 demonstrates the mean and SD variation for each volunteer across the five examinations by location using method 3. Table 1 shows the aortic PWV measured using ultrasound for the final two visits for all volunteers. For subject 1 visit 5, MRI CPC data from the carotid and femoral arteries were used to find a transit time by method 2. A PWV of 7.7 ms^{-1} was calculated.

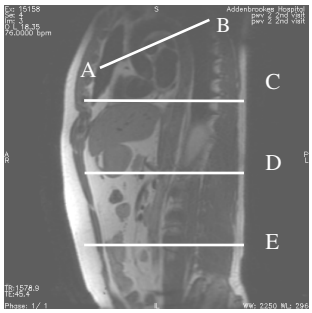

Fig.1: Slice prescription locations

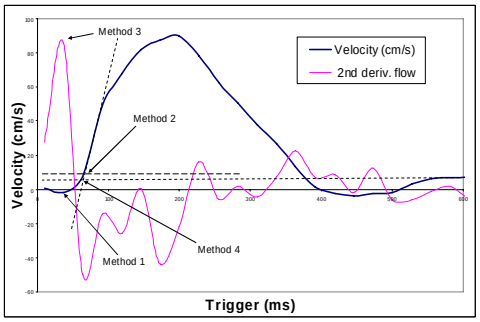

Fig.2: The various methods to find the waveform foot

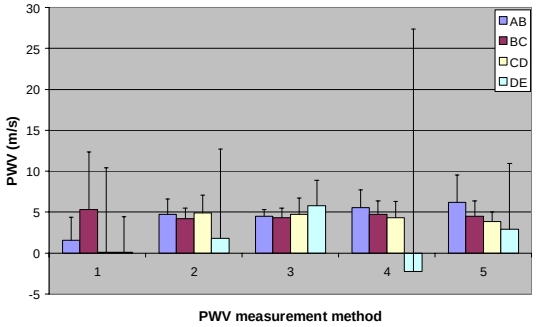

Fig.3: Comparison of PWV calculated by each method.

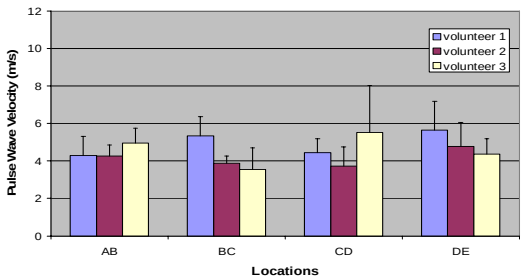

Fig.4: Mean PWV over 5 visits for each volunteer by location

Subject	Visit	Mean PWV (ms^{-1})
1	4	8.25
1	5	8.3
2	4	5.6
2	5	5.15
3	4	7.5
3	5	7.3

Table.1 PWV from carotid and femoral artery ultrasound measurements

Conclusion

Five foot finding methods have been applied to all fifteen studies. The least variability in PWV was found with method 3 using the peak of the second derivative of flow, since the other methods rely on the slope of the early systolic upstroke which changes greatly from the arch to the bifurcation. The variability of PWV measurements in normal volunteers will allow us to establish limits for the minimum detectable changes when applying these methods to patient studies.

We also note that the values for regional aortic PWV found using MRI as observed are lower than may be suggested by the common ultrasound technique, which requires measurements at the carotid and femoral arteries. Since the measurement by MRI at the same carotid and femoral locations yielded closer values, further investigation of this discrepancy is encouraged.

References : 1) Rogers WJ et al JACC 2001;38:1123-1129. 2) Wiesmann F et al. JACC 2004;44:2056-2064. 3) Vulliémoz S, et al. MRM 2002;47:649-654. 4) Shao X et al. MRM 2004;52:1351-1357. 5) Harle J et al MRM 2006 Poster 1915. 6) Oliver JJ, Webb DJ. ATVB 2003;23:554-556.